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Professor K.S.Krishnan FRS *

Professor K. S. Krishnan, distinguished physicist, philosopher and Acharya, will be sixty years old on 3 December 1958. On that auspicious occasion, we wish to convey to him our cordial felicitations and good wishes for his continued good health, activity and service to science, philosophy and international goodwill for many, many years to come.

Creative thinkers like Krishnan with understanding, critical judgement and tolerance, men who have a mind of their own and carry out their inner dharma unperturbed by changing fashions, men who "explore the explorable and quietly venerate the inexplorable" are not to be found in large numbers in any country. When we do find such persons, we do well to honour them.

Kariamanikkam Srinivasa Krishnan was born in the village of Watrap near Srivilliputtur in the Tirunelveli (now Ramnad) district in Tamilnad. His father was a scholar of the old school deeply versed in Tamil and Sanskrit religious literature. He spent a good part of his time in pilgrimages to South Indian temples, particularly to Srirangam and Tirupathi. Krishnan had his early schooling in Watrap and Srivilliputtur and was brought up ~~in~~ in a rural atmosphere. After matriculation, he had his collegiate education first in the American college, Madura, and later in the Christian College, Madras. After graduating in physics from the Christian College, he was for a few years a Demonstrator in Chemistry in the same college. He took his teaching seriously and was a very popular teacher. I have heard that

* By Professor K. R. Ramanathan, Director, Physical Research Institute, Ahmedabad

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In 1942, Krishnan was offered the post of Professor of Physics in the University of Allahabad which had been vacant for some years after the departure of Professor M.N.Saha to Calcutta. Krishnan always enjoyed teaching and discussion. The Professorship in Allahabad gave him an opportunity to review, in a systematic and comprehensive way, before senior students the various problems of classical scattering of light, X-rays and electrons, of statistical thermodynamics, and quantum theory and wave mechanics. Despite the difficult conditions created by the war, Krishnan and his associates were able to do a good amount of investigational work on these subjects. In particular may be mentioned his work with Dr A.B.Bhatia giving a critical review of Einstein's theory of light

scattering in homogeneous media as reflection from thermal elastic waves and a new and illuminating method of summing up the intensities of the elastic waves. They also treated on a unified basis the scattering of X-rays by fluids and of low velocity electrons by liquid metals and by alloys.

As an offshoot of the analysis of elastic waves in a homogeneous medium caused by fluctuations of density, Krishnan was led to the study of the mathematical problem of the summation of certain infinite series of a class of functions which are of special importance in physics. He showed that with functions whose Fourier transforms satisfy two simple conditions, the sum of the infinite series could be obtained just as well by rectangulation as by integration, and that this was not an approximate, but a rigorous result. Krishnan's paper "On the equivalence of certain infinite series and the corresponding integrals" in the Journal of the Indian Mathematical Society (Vol.12, 1948) shows the range and power of the method.

Even before the gaining of independence, it was felt by many Indian scientists and statesmen that there was a great need for national laboratories in different branches of science and technology in India. With the achievement of independence, the Government o India decided to start such laboratories and the laboratories for chemistry and physics were the first ones to be started. Professor Krishnan was offered the Directorship of the National Physical Laboratory. Although the acceptance of this meant getting away from teaching and research, at least temporarily Krishnan accepted the offer and took over the duties in 1947.

A good deal of Krishnan's time during the next few years was taken up in administrative duties and committee work, but still he was able to keep up active interest in scientific research. Evidence for this is found in his work with Dr S.K.Roy on the frequencies and anharmonicities of

alkali halide crystals and on a critical analysis of the difference between the characteristic frequencies which appear in the dispersion formulae of Drude and Lorentz. In the Drude formula, the frequencies are characteristic of the medium, and in the Lorentz formula, they are characteristic of the oscillators when unaffected by the polarisation field. At about the same time, there began to appear a series of four brilliant papers on thermionics with Dr S.C.Jain. Thermionics began to interest Krishnan when he was in Allahabad. He had suggested in 1944 a new method of determining the saturation pressure of electrons by effusion through a small aperture in a uniformly heated chamber of graphite whose inside could be coated with different materials. Like cavity radiation for the study of black body radiation, this method has several advantages. With the assistance of Dr Jain, he started experimental work at the National Physical Laboratory and, in a few years, they were able to determine with great accuracy the thermionic constants of graphite, the metals of the iron group and of the monovalent metals, copper, silver and gold. In their final paper they discussed the energy barrier at the surface of a monovalent metal, on the thermodynamic potential of the electrons and on the work function in metals. They showed that the observed variation of the work function was as though the electrons in the metal and in the vapour formed the two phases of a single component thermodynamic system. They showed further that the thermal expansion of the lattice and the thermal agitation of the atoms in the lattice both affected the work function of the metal, but that the effects of the two practically cancelled each other.

Another problem which is of an applied physical nature and has engaged Krishnan's attention in the National Physical Laboratory is the distribution of temperature along a thin rod (or wire) electrically heated

in vacuo. In modern electrical technology, electrically heated wires find extensive use in various devices, such as electric lamps valves of various kinds, cathodes of X-ray tubes, etc. The functioning and efficiency of these devices depend largely on the manner in which the temperature, and depending on it, other properties, are distributed along the wire. With the collaboration of Dr Jain, Krishnan attacked this problem both from a theoretical and an experimental point of view. On the theoretical side, the authors formulated the appropriate differential equation and solved it in a practically usable form both for long and short filaments. On the experimental side, they carried out measurements on thin rods of Acheson graphite and platinum filaments, and verified the theoretical results. Moreover, they compared these theoretical results with the empirical findings of many investigators who had studied the subject before and found very satisfactory agreement. They thus brought orderly thinking into a complex but very practical subject and made the way easier for further advances.

I have mentioned above only the major items of work in which Krishnan himself was personally engaged, for they bring out clearly his broad outlook, his carefulness in the choice of problems, the masterly combination of theoretical and experimental methods of approach the depth, thoroughness and maturity of his treatment and the elegance of his presentation of results. I do not propose to discuss the various other studies and projects, both in the National Physical Laboratory and elsewhere, in which he has taken interest and guided or helped. Scientists in India know how freely he gives of his knowledge and time. I should not, however, fail to mention his intimate, active and uninterrupted association with the Department of Atomic Energy

from its very beginning.

Believing as Krishnan does that science alone cannot solve all problems in life, he combines an earnest study of the classics of Indian religious literature with the study and practice of science, and endeavours to live a life of religious faith. The combination of Vinaya (humility) with Vignan (critical understanding) which has become natural to him, makes it easy for people of all stations in life to feel at ease in his company.

It is not surprising that Krishnan is much sought after for giving addresses and discourses not only on scientific but also on literary and philosophical subjects. He has great respect for Indian scholars of Sanskrit and other Indian languages who have been brought up in the traditional Indian way. Being himself a writer of distinction on philosophic and scientific subjects in Tamil, Tamil and Sanskrit scholars all over India and in Ceylong find him congenial and stimulating company, and take delight in inviting and honouring him at their conferences and assemblies.

Krishnan has been the recipient of many honours both in India and abroad. He is a past President of the Indian Science Congress, of the National Academy of Sciences and of the National Institute of Sciences. He is a Founder Member of the International Union of Crystallography. He has been Vice President of the International Union of Pure and Applied Physics and of the International Council of Scientific Unions. Krishnan's quick grasp of essentials and the brevity and lucidity of his exposition make him a respected member in international scientific meetings and assemblies.

In 1955, the U.S. National Academy of Sciences invited Krishnan to be their chief guest at their annual meeting as the representative of Indian Science. This is an honour which had been previously given to the President of the Royal Society, London, the President of the Royal Netherlands Academy and the President of the Swedish Academy. At the ceremonial dinner of the Academy, Krishnan spoke on India's forward outlook on science and technology and also explained how that outlook was tempered by her own basic philosophy and sense of values. After the meeting, President Bronk wrote to Krishnan, "You did much to emphasize and strengthen the friendly bonds between scientists of your country and ours, and thus fostered the traditional international unity of science."

Next year, in 1956, Krishnan was elected a Foreign Associate of the National Academy of Sciences. This is a high honour indeed as the total number of Foreign Associates today is only 60, of whom 9 are physicists. In the same year, at the request of the All India Radio, Krishnan gave in Delhi the second series of Sardar Vallabhbhai Patel Memorial Lectures, taking as his theme "The New Era in Science."

The Government of India recently honoured Krishnan by appointing him a National Professor — an honour which he shares with Professor C.V.Raman and Professor S.N.Bose. The whole country wishes Krishnan many years of active happy life, searching, learning and teaching in his own quiet and confident way.

- K. R. Ramanathan

WORK CARRIED OUT UNDER THE AUSPICES OF THE INDIAN NATIONAL COMMITTEE FOR THE IGY 1957-1958

ISSUED ON THE OCCASION OF
THE SIXTIETH BIRTHDAY OF

DR K. S. KRISHNAN, F.R.S.

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FOREWORD

THE International Geophysical Year 1957-58 has been a period of great importance for science. A successor to the two previous Polar years — one in 1882-83 and the other in 1932-33, the current IGY has followed a much bigger programme of observations. Thanks largely to the efforts of the Special Committee of the International Geophysical Year (CSAGI) set up in 1952 by the International Council of Scientific Unions (ICSU) of which Dr K. S. Krishnan has been a Vice-President for several years, the IGY programme is truly international in character with over seventy countries actively participating in it. The main objective of the IGY being the study of the earth sciences in all their aspects, the programme includes the study of (a) the interior and the surface of the earth, (b) the atmosphere around the earth and higher up, and (c) the sun and its activity, on which depend many natural phenomena on the earth's surface. The programme, extending over 13 major fields, ranges from subjects of general interest like meteorology, cosmic rays, seismology, ionosphere, and latitude and longitude determinations, to more specialized fields like glaciology, oceanography, rockets and satellites.

An Indian National Committee was set up in 1953 with Dr Krishnan as Chairman and was made responsible for the drawing up, and implementation of, the Indian programme. The plan of work adopted by this Committee has become quite extensive.

It is now exactly 17 months since the IGY programme began. During this period, India has maintained, in addition to the large network of meteorological stations, about sixty other stations distributed all over the country, some of which have been specifically established for the IGY. The geographical position and the vast area of the country render the Indian IGY work specially significant. There are observing stations as far north as Kashmir and as far south as Trivandrum. The geomagnetic equator passes through the southern part of India and it has been possible to establish stations like Kodaikanal, Trivandrum, Chidambaram and Tiruchirapalli, both north and south of it.

There is a network of stations concerned with investigations on geomagnetism, latitude and longitude, glaciology, oceanography, seismology and gravity. Five stations, three of which are in South India, near the geomagnetic equator, are studying magnetic storms, magnetic pulsations and the daily magnetic variations. At the National Physical Laboratory, New Delhi, work on standard frequency and time service has been organized. At Naini Tal, a Markowitz Moon Camera has been installed. Tides in the oceans are being measured by automatic tide gauges at 20 ports. Survey of tidal streams are being carried out

at 30 sites in the Gulf of Cambay. Seismograph observations are being made at 12 stations and in collaboration with the Columbia University, U.S.A., a long period electromagnetic seismograph loaned by the University has been installed at Agra. A seismography-cum-microseismography station was established at Port Blair in the Andamans, in April 1958.

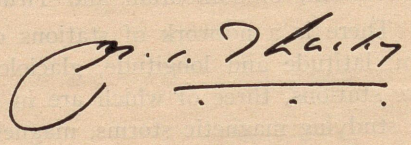
India is also maintaining a number of stations for investigations on geomagnetism, ionosphere, airglow and aurora. In the field of meteorology, routine observations are being continued. A long range medium power radar, Decca 41, which was functioning at Calcutta, has recently been replaced by a high power Japanese storm detector radar. Four other radar stations are functioning, two at Delhi, one at Bombay (Santa Cruz) and one at Poona. Radiation measurements have been in progress at Poona, Delhi, Calcutta and Madras. The ionosphere is being studied at 11 stations distributed over a wide geographic region, mostly near 75°E longitude zone, using transmitters which can sweep over a large frequency in a few minutes, and also by receiving radio emissions from the galaxies. A particularly significant feature is the installation of a new ionosphere station at Trivandrum. This station is as much south as Kodaikanal is north of the geomagnetic equator. Commenting on India's choice of this station, the CSAGI resolved "CSAGI warmly commends the plan of India to establish a new station at Trivandrum. This will provide a useful station doublet with Kodaikanal for studying the fine structure of equatorial ionosphere variations."

The period has been specially fruitful for the observation of sunspot activity. The present sunspot cycle is the largest on record, and there has been an abundance of severe solar flares with generally turbulent ionospheric conditions. These flares have been studied by the observatories at Hyderabad and Kodaikanal.

Through the courtesy of the Smithsonian Institution, U.S.A., a Baker-Nunn Camera has now been set up at Naini Tal.

In the papers that follow, Indian experts engaged in the implementation of the programme have given reports of their work.

I would like to record my appreciation and that of the scientists of India of the important work carried out by Dr Krishnan and his Committee. In this work, the lead and direction given by Dr Krishnan have been significant. I am confident that when the accumulated data are fully analysed and correlated, India's contribution will by no means be insignificant.



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When Professor Raman left Calcutta in 1933, Krishnan was invited to take up the post of Mahendralal Sircar Professor of Physics in the Indian Association for the Cultivation of Science. There were no regular teaching duties attached to the post and a return to the old familiar cosmopolitan surroundings of 210 Bowbazar was welcome to Krishnan. The magnetic and optical properties of crystals together with their structure analysis by X-rays, and the various ways in which the anisotropy of crystal units manifest themselves in the bulk properties of the crystals continued to occupy his attention. To the second Calcutta period belongs the work of Krishnan, Bose and Mookherjee on the magnetic properties of salts of the rare earth and iron groups including a detailed comparison of their extensive experimental measurements with the conclusions which follow from the theoretical work of Van Vleck and Penney and Schlapp on the crystalline electric fields of such crystals. In paper V in the series on magne-crystallic action published in the *Philosophical Transactions of the Royal Society*, there is detailed discussion of the susceptibilities and anisotropies of these crystals and of the conditions which determine to what extent the temperature variation of their susceptibilities will follow the Curie Law. To the same period also belongs a characteristically significant paper by Gangulee and Krishnan on "The magnetic and other properties of free electrons in graphite" (*Proc. roy. Soc.*, 1941). In this paper, the authors show that the diamagnetism of graphite is almost wholly along the hexagonal axis, that in a graphite crystal, one electron per carbon atom is free to move in the basal plane but not in a perpendicular direction, or in other words, the electrons in such a crystal form a two-dimensional electron gas, and that the theoretical properties of such an electron gas can be verified in detail from a study of the magnetic properties of graphite. From the measured values of the diamagnetism of graphite at different temperatures varying from $-90°$ to 1270°K., they conclude that the energy distribution of electrons in graphite conforms to Fermi-Dirac distribution.

Professor Krishnan's contributions to physics were recognized by the invitations he received from Lord Rutherford in Cambridge and Sir William Bragg in London to give a course of lectures in the Cavendish Laboratory and in the Royal Institution (1937). He later visited a number of universities in Europe and was awarded the University Medal by the University of Liége for his scientific achievements. In 1939, he was invited to participate in an International Symposium on Magnetism at Strasbourg. Krishnan was elected to the Fellowship of the Royal Society in 1940.

In 1942, Krishnan was offered the post of Professor of Physics in the University of Allahabad which had been vacant for some years after the departure of Professor M. N. Saha to Calcutta. Krishnan always enjoyed

teaching and discussion. The Professorship in Allahabad gave him an opportunity to review, in a systematic and comprehensive way, before senior students the various problems of classical scattering of light, X-rays and electrons, of statistical thermodynamics, and quantum theory and wave mechanics. Despite the difficult conditions created by the war, Krishnan and his associates were able to do a good amount of investigational work on these subjects. In particular may be mentioned his work with Dr A. B. Bhatia giving a critical review of Einstein's theory of light scattering in homogeneous media as reflection from thermal elastic waves and a new and illuminating method of summing up the intensities of the elastic waves. They also treated on a unified basis the scattering of X-rays by fluids and of low velocity electrons by liquid metals and by alloys.

As an offshoot of the analysis of elastic waves in a homogeneous medium caused by fluctuations of density, Krishnan was led to the study of the mathematical problem of the summation of certain infinite series of a class of functions which are of special importance in physics. He showed that with functions whose Fourier transforms satisfy two simple conditions, the sum of the infinite series could be obtained just as well by rectangulation as by integration, and that this was not an approximate, but a rigorous result. Krishnan's paper " On the equivalence of certain infinite series and the corresponding integrals " in the *Journal of the Indian Mathematical Society* (Vol. 12, 1948) shows the range and power of the method.

Even before the gaining of independence, it was felt by many Indian scientists and statesmen that there was a great need for national laboratories in different branches of science and technology in India. With the achievement of independence, the Government of India decided to start such laboratories, and the laboratories for chemistry and physics were the first ones to be started. Professor Krishnan was offered the Directorship of the National Physical Laboratory. Although the acceptance of this meant getting away from teaching and research, at least temporarily, Krishnan accepted the offer and took over the duties in 1947.

A good deal of Krishnan's time during the next few years was taken up in administrative duties and committee work, but still he was able to keep up active interest in scientific research. Evidence for this is found in his work with Dr S. K. Roy on the frequencies and anharmonicities of alkali halide crystals and on a critical analysis of the difference between the characteristic frequencies which appear in the dispersion formulae of Drude and Lorentz. In the Drude formula, the frequencies are characteristic of the medium, and in the Lorentz formula, they are characteristic of the oscillators when unaffected by the polarization field. At about the same time, there began to appear a series of four brilliant papers on thermionics with Dr S. C. Jain. Thermionics began to interest Krishnan when he was in Allahabad. He had suggested in 1944 a new method of determining the saturation pressure of electrons by effusion through a small aperture in a uniformly heated chamber of graphite whose inside could be coated with different materials. Like cavity radiation for the study of black body radiation, this method has several advantages. With the assistance of Dr Jain, he started experimental work at the National Physical Laboratory and, in a few years, they were able to determine with great accuracy the thermionic constants of graphite, the metals of the iron group and of the monovalent metals, copper, silver and gold. In their final paper they discussed the energy barrier at the surface of a monovalent metal, on the thermodynamic potential of the electrons and on the work function in metals. They showed that the observed variation of the work function was as though the electrons in the metal and in the vapour formed the two phases of a single component thermodynamic system. They showed further that the thermal expansion of the lattice and the thermal agitation of the atoms in the lattice both affected the work function of the metal, but that the effects of the two practically cancelled each other.

Another problem which is of an applied physical nature and has engaged Krishnan's attention in the National Physical Laboratory is the distribution of temperature along a thin rod (or wire) electrically heated *in vacuo*. In modern electrical technology, electrically heated wires find extensive use in various devices, such as electric lamps, valves of various kinds, cathodes of X-ray tubes, etc. The functioning and efficiency of these devices depend largely on the manner in which the temperature, and depending on it, other properties, are distributed along the wire.

With the collaboration of Dr Jain, Krishnan attacked this problem both from a theoretical and an experimental point of view. On the theoretical side, the authors formulated the appropriate differential equation and solved it in a practically usable form both for long and short filaments. On the experimental side, they carried out measurements on thin rods of Acheson graphite and platinum filaments, and verified the theoretical results. Moreover, they compared these theoretical results with the empirical findings of many investigators who had studied the subject before and found very satisfactory agreement. They thus brought orderly thinking into a complex but very practical subject and made the way easier for further advances.

I have mentioned above only the major items of work in which Krishnan himself was personally engaged, for they bring out clearly his broad outlook, his carefulness in the choice of problems, the masterly combination of theoretical and experimental methods of approach, the depth, thoroughness and maturity of his treatment and the elegance of his presentation of results. I do not propose to discuss the various other studies and projects, both in the National Physical Laboratory and elsewhere, in which he has taken interest and guided or helped. Scientists in India know how freely he gives of his knowledge and time. I should not, however, fail to mention his intimate, active and uninterrupted association with the Department of Atomic Energy from its very beginning.

Believing as Krishnan does that science alone cannot solve all problems in life, he combines an earnest study of the classics of Indian religious literature with the study and practice of science, and endeavours to *live* a life of religious faith. The combination of *Vinaya* (humility) with *Vignyan* (critical understanding), which has become natural to him, makes it easy for people of all stations in life to feel at ease in his company.

It is not surprising that Krishnan is much sought after for giving addresses and discourses not only on scientific but also on literary and philosophical subjects. He has great respect for Indian scholars of Sanskrit and other Indian languages who have been brought up in the traditional Indian way. Being himself a writer of distinction on philosophic and scientific subjects in Tamil, Tamil and Sanskrit scholars all over India and in Ceylon find him congenial and stimulating company, and take delight in inviting and honouring him at their conferences and assemblies.

Krishnan has been the recipient of many honours both in India and abroad. He is a past President of the Indian Science Congress, of the National Academy of Sciences and of the National Institute of Sciences. He is a Founder-Member of the International Union of Crystallography. He has been Vice-President of the International Union of Pure and Applied Physics and of the International Council of Scientific Unions. Krishnan's quick grasp of essentials and the brevity and lucidity of his exposition make him a respected member in international scientific meetings and assemblies.

In 1955, the U.S. National Academy of Sciences invited Krishnan to be their chief guest at their annual meeting as the representative of Indian Science. This is an honour which had been previously given to the President of the Royal Society, London, the President of the Royal Netherlands Academy and the President of the Swedish Academy. At the ceremonial dinner of the Academy, Krishnan spoke on India's forward outlook on science and technology and also explained how that outlook was tempered by her own basic philosophy and sense of values. After the meeting, President Bronk wrote to Krishnan, " You did much to emphasize and strengthen the friendly bonds between scientists of your country and ours, and thus fostered the traditional international unity of science ".

Next year, in 1956, Krishnan was elected a Foreign Associate of the National Academy of Sciences. This is a high honour indeed as the total number of Foreign Associates today is only 60, of whom 9 are physicists. In the same year, at the request of the All India Radio, Krishnan gave in Delhi the second series of Sardar Vallabhbhai Patel Memorial Lectures, taking as his theme " The New Era in Science ".

The Government of India recently honoured Krishnan by appointing him a National Professor — an honour which he shares with Professor C. V. Raman and Professor S. N. Bose. The whole country wishes Krishnan many years of active happy life, searching, learning and teaching, in his own quiet and confident way.

K. R. RAMANATHAN

Sir K. S. Krishnan & the International Geophysical Year

PROFESSOR SYDNEY CHAPMAN

President, Special Committee for the International Geophysical Year, Brussels

IT is a pleasure to take part in the celebration of the sixtieth birthday of my distinguished friend and colleague Sir K. S. Krishnan, F.R.S., by contributing to this special volume. Such a volume on this occasion is a fitting tribute to the high distinction he has won as a scientist and administrator, and to the many services he has rendered to science and to his country and to the community of nations. His personal scientific researches have been recognized by the conferment upon him of many high honours. As a teacher he has fostered the scientific spirit and enthusiasm of his country's youth. As Director of a great scientific institution he has furthered the scientific and economic advance of India.

Here, however, I would specially write of his association with that remarkable world-wide scientific enterprise — the International Geophysical Year (IGY) 1957-58. Only his colleagues on the National IGY Committee for India can fully know the leadership and the support he has given, as President of that Committee, in developing India's IGY participation and programme. But the scope and excellence of that programme redounds to his credit, which he will be the first to wish to share with his many distinguished fellow officers and colleagues on the Committee, and with the still greater number of his countrymen and countrywomen who are taking a direct personal part in the programme.

Sir K. S. Krishnan has not only led and supported the plans for India's share in the IGY, he has also given it valuable support on the international level, in his capacity as Vice-President of the International Council of Scientific Unions (ICSU) for the past six years. This eminent position has given him a voice in the formation and progress of the Special Committee for the International Geophysical Year (CSAGI) — Comité Spécial de l'Année Géophysique Internationale — over which I have had the honour to preside. As a leading member of the Bureau of ICSU he has shared the executive responsibility resting on that Bureau for the multitudinous scientific affairs associated with ICSU; and not least as regards the IGY and the reports by CSAGI to ICSU, his scientific knowledge and experience have fitted him to give counsel solidly based.

To turn now to the IGY programme of India, it is good to record that India took part in every one of the fourteen divisions of the international programme. The Meteorological Department of India, as one of its many valuable contributions to the programme, received the notices of Alerts and Special World Intervals, and relayed them to All India Radio to be broadcast at specific times of the day. These broadcasts included a daily report on the sun's activity, received from the Kodaikanal Observatory. This observatory was an important member of the chain of solar stations that girdle the earth, whose regular programmes of observation were extended and intensified during the IGY — so that the sun was then observed with a degree of completeness and detail never before approached. The Nizamiah Observatory, Hyderabad, also contributed to this achievement, by its observations of solar flares.

The India Meteorological Department played an active role in its own most distinctive sphere, as a member of the World Meteorological Organization (WMO) in the execution of India's part in the meteorological IGY programme drawn up jointly by CSAGI and WMO. It gave valuable support also to the IGY auroral programme, by directing ten of its stations to watch regularly for the aurora at specific times. Its exploration of the atmosphere by balloons included, besides the usual meteorological elements, the measurement of the electrical potential gradient and electrical conductivity of the air.

In geomagnetism the same Department extended its normal observatory recording by the maintenance of additional stations at Trivandrum and Chidambaram, supplementing the permanent magnetic station at Kodaikanal, to study the equatorial electrojet. Projects related to the World Magnetic Survey that is to form a deferred part of the IGY were carried out by the Survey of India and the Hydrographic Department of the Indian Navy.

The IGY airglow programme of observation was advanced by observations at four stations, Mt Abu, Gulmarg, Dharwar and Poona. The cosmic ray neutron programme was executed at four stations, Ahmedabad, Kodaikanal, Gulmarg and Darjeeling, and there were cubical meson telescopes at five stations, and ionization chamber studies at Howrah. The Physical Research Laboratory at Ahmedabad (Director, Professor K. R. Ramanathan) took an active part in the airglow and cosmic ray programmes, and also in the WMO scheme of ozone studies — in which India employed no less than six Dobson spectrophotometers.

The many-sided IGY ionospheric programme was very actively undertaken in India, with eight observatories for vertical incidence recording. The pre-IGY measurements of ionospheric drift were extended by an additional station, making four in all. Absorption measurements were also made at four stations.

The Survey of India and the National Physical Laboratory co-operated in the programme of Latitudes and Longitudes, including the use of a Danjon impersonal astrolabe and a Markowitz moon camera.

Three glaciers, at Gangotri, Shigri and Machhoi were re-visited and studied after 57 years, by the Geological Survey of India.

The Survey of India extended its oceanographic activities, among other ways by increasing the number of its normal tide-gauge stations from fifteen to twenty-one. The India Meteorological Department made associated observations at each tide station.

India took part in the IGY satellite tracking programme by means of a Schmidt precision camera installed at the Uttar Pradesh State Observatory at Naini Tal; the camera was a gift from the Smithsonian Astrophysical Observatory at Harvard.

India co-operated also in the IGY programmes for seismology, earth tides, gravity measurement and nuclear radiation.

In this connection I would like to recall a fine passage of the Presidential Address of Sir K. S. Krishnan's friend and colleague, Professor K. R. Ramanathan, given at the opening Assembly of the International Union of Geodesy and Geophysics at Toronto, on 3 September 1957.

"The ICSU and the CSAGI have done a great job. The greatest single achievement of organized science in history was perhaps the building of the first atom bomb. It required the bringing together of many top-ranking scientists, technologists and organizers on an unprecedented scale. But they were top-ranking men, and of a few countries only. The IGY is in my view an undertaking of greater magnitude and difficulty, because it has involved the bringing together of workers of many nations with differing ideologies and in very varying stages of scientific development. A keen, diligent observer with modest education in any corner of the world has a respected place in the IGY scheme. The approach is human and earthy, and the potentialities for the unification of mankind are infinitely greater."

Among Dr Krishnan's many other achievements that will be recalled in this birthday celebration, the part he has played in this great enterprise of the IGY must not be forgotten.

Space Exploration— An Achievement of the IGY

L. V. BERKNER

Vice-Président, Comité Spécial de l'Année Géophysique Internationale

RARELY in the history of man's rise to civilization is recorded an interval of real greatness — an interval when the members of some group or nation have interacted among one another in a manner that has stimulated outstanding advances to human thought. Certainly the rise of Greek philosophy and science was such an interval, for it provided both the foundations and the standards from which subsequent thought could grow and be measured. Again in the golden age of seventeenth century science, men created the brilliant standards of experimental investigation and objective analyses that have generated science as we know it today. Now, during the International Geophysical Year (IGY) scientists of the whole earth have interacted, almost spontaneously, to demonstrate how great problems involving the whole planet can be attacked and solved. The willingness of men of 66 nations to set aside their ordinary pursuits, and to join together their efforts on problems of our planet, is an extraordinary innovation in man's civilized development. This universal and simultaneous recognition by scientific leaders of every country of the immense power of joint voluntary action is a new procedure in the advance of human thought — a procedure that has come in our time.

The great programme of India in the IGY is typical of the response of nations from East to West to the need for joint worldwide programmes of scientific observation and study. This response, organized under the leadership and vision of Prof. K. S. Krishnan, Chairman of the Indian National Committee of the IGY, came at a time when India was immersed in a reconstruction that to her involved serious economic and social problems. Yet India's scientific leaders were quick to recognize that in the new framework of human thought, represented by the IGY, India must do its part in spite of great difficulties. This spirit of sacrifice of each participating nation, that it should do its part, is the spirit of the IGY.

But the contributions of India are not simply those of a mere participant, for its leaders have joined in the very inception of the ideas and plans for the international activity of the IGY. India has long lent its strong support to the International Council of Scientific Unions (ICSU) whose very existence provided the framework whereby the IGY could be constructed. As senior Vice-President of the ICSU during the critical years of IGY planning, Prof. Krishnan lent his great wisdom, philosophy and leadership towards the formation and guidance of the effort. His participation typifies the common thinking and enthusiasm of men of the whole earth in shaping the IGY enterprise.

The power of IGY co-operation in advancing man's knowledge of his environment can hardly be better illustrated than by its projection of science into space exploration. Situated under a blanket of relatively opaque atmosphere, man on the earth's surface is severely insulated from events of space that influence his environment. For centuries, man had developed observation of the stars and the planets, of geomagnetism and aurora, to find clues to the events that occur in space.

With the creation of radio at the turn of the century, new means were provided to examine the regions beyond the earth's surface. But the problems were too complex to permit more than the most elementary and sometimes misleading descriptions of major phenomena encompassing the earth, without actual experiments in the space involved.

The IGY provided the opportunity for man's 'break-through' to space exploration. Not only did IGY stimulate the initial launching of earth satellites instrumented for scientific observations in space — it also provided the co-operative framework for the international tracking and instantaneous location of space vehicles that was essential to interpretation of the data. India has joined enthusiastically in this effort. Located strategically in the earth's geography for important tracking observations, Indian scientists have undertaken responsibility for the operation of one of the 12 great Baker-Nunn cameras. They have supplemented this activity with collaboration on radio tracking and radio telemetry that has contributed significantly to the success of the space-exploration effort.

Man's conquest of space opens whole new horizons in the comprehension of our planet, its environment, and the universe about it. From a vantage point above the atmosphere, man can now see the universe in the full range of chromaticity — from the shortest to the longest wavelengths, from the softest to the most energetic particles traversing it. This access to observation of the sun and the planets, of the stars, and of the interstellar debris gives a new and most fundamental grasp to the study of the processes of nature. Moreover, actual landings on the moon and the nearest planets with scientific instruments, and even perhaps with man himself, cannot be very far in the future. Intimate examination of the processes of other worlds can only be viewed by science with the most intense excitement. Looking back with satellites, man's instruments circling the earth can scan the atmosphere and its phenomena in a way that permits description of their organization as a whole.

Already vast advances have been made, and even more important observations are immediately planned. Through measurements of ultraviolet and X-radiation of the sun by rockets and by satellites, the relative roles of these radiations in the photochemistry of the atmosphere are being determined. The discovery of the radiation belt of 40-mev. protons between the auroral zones and extending beyond 1000 km. above the earth's surface brings striking evidence of a cosmic ray albedo of charged particles contained and reflected in the geomagnetic field. It is but a step to the measurement of the force and orientation of the geomagnetic field in space to ascertain the nature of its coupling with the particles of surrounding space and the character of its distortions with impinging particle streams from the sun. This softer radiation emitted from the sun, and entering the atmosphere to generate aurorae and magnetic disturbances, is now under direct observation from rockets and satellites. For the first time man is measuring variation of cloud cover and albedo of the earth, and the relative energy received and retained by the meteorological system with its great weather disturbances.

The exploration of space stimulated by the IGY exemplifies man's great power in advancing human understanding through genuine and voluntary international co-operation. But in this process, the warm recognition of the part played by each individual and group, and the willingness of each to depend on the other, represent an advance in man's social values comparable to the scientific progress that has been achieved. For their part in each of these, we salute our Indian colleagues, and their great leader, Prof. Krishnan, and convey, on the occasion of his sixtieth birthday, the depth of our personal friendship that collaboration in science has made possible.

A Preliminary Report "On the Nature & Origin of Atmospherics"

M. W. CHIPLONKAR, R. N. KAREKAR, T. A. RAJU & M. S. HATTIANGADI

Department of Physics, Poona University, Poona

THE phenomenon of atmospherics is a very complicated one involving, as it does, such uncertain factors as its transient nature, energy distribution in the E.M. spectrum, propagation mechanism and its association with the weather. Further because of its special and temporal variations the phenomenon has become a major topic of geophysical investigation at many places over the globe. Although the frequencies of atmospherics are known to cover a very wide range of the electromagnetic spectrum, at present, the study of low (<300 kc/s.) and very low frequency (below 30 kc/s.) atmospherics has assumed both theoretical and practical significance and, therefore, has been included in the IGY programme.

For an all-round investigation of atmospherics in the low frequency region a comprehensive programme was already chalked out and commenced early in 1953, in the University Department of Physics at Ganeshkhind, Poona. So far, our attention has been concentrated on the following aspects of the phenomenon:

(1) Rate of occurrence of atmospherics,
(2) Intensity of atmospherics,
(3) Frequency distribution of atmospherics,
(4) Direction of approach of atmospherics, and
(5) Wave forms of atmospherics.

In this communication are discussed, in a general way, some of the results of our investigations carried out as part of the IGY programme. Each of these aspects will be dealt with individually and separately.*

SECTION I

Rate of occurrence of atmospherics

In this section we confine ourselves to the study of the number of atmospherics received per minute on the following four selected frequency bands: 85, 125, 175 and 455 kc/s.†

Equipment and method of observation

Fig. 1 shows a general view of the equipment used in this investigation. Four narrow band T.R.F. receivers tuned to the above frequencies were used to record the number of atmospherics. An outdoor inverted L-type of aerial having an effective height of only 4 metres is connected to the input terminals of all the receivers in common. The aerial is broadly tuned over a frequency range of 50-500 kc/s. The output of each receiver is given to an automatic relay type telephone counter.

The receiver units are periodically checked and maintained constant as regards their

*Three separate papers, two entitled "On the Nature and Origin of Atmospherics: Parts I and II[1]", and the third entitled "Simultaneous Recording of Intensities . . . Region: Part III[2]", giving full experimental details and discussion of some of the previous data, are under publication. Here they will be referred to as P I, P II and P III.

†This last band has been chosen beyond 300 kc/s. for the sake of comparison of conditions in the higher frequency region.

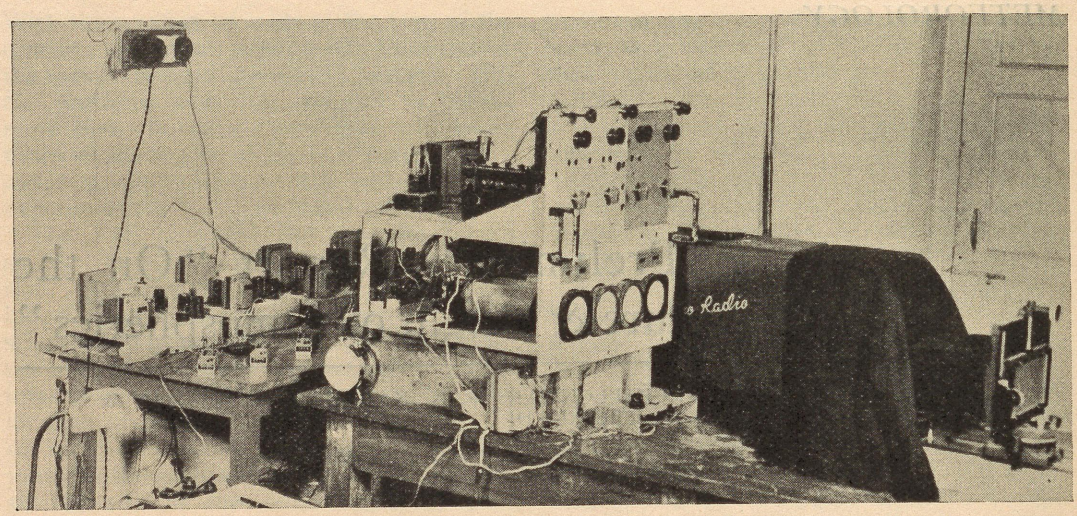

FIG. 1 — A GENERAL VIEW OF THE EQUIPMENT SET UP AT POONA FOR RECORDING THE RATE OF RECEPTION AND INTENSITY OF ATMOSPHERICS

operation, overall sensitivity, selectivity, response characteristics, etc. For this purpose a signal, 100 per cent modulated by 400 kc/s. sine wave, obtained from a standard signal generator (Marconi TF 144 G), was used through a dummy aerial of the same characteristic impedance as the aerial in use. The telephone counters were able to count at a maximum rate of 15 pulses per second.

The method of observation briefly consisted in noting down the total number of impulses received during the three minutes' interval at the end of every hour. This 'spot reading' is taken to represent the average number of atmospherics received per minute during that hour. At times, automatic photographic recording method was also adopted to give relief to the observer. In this, two instantaneous photographs of all the counters are taken automatically at an interval of three minutes at the end of each hour.

Results

The data consist of these spot readings of the number of atmospherics received on four bands during the 3 min. interval at the end of each hour, throughout the 24 hr and for all days of the month during the period June 1957 to May 1958. The data are complete except for occasional breakdown of the automatic recording device or the apparatus or due to heavy man-made noise at the time of observation and similar other unavoidable causes. It may be noted that such losses did not exceed even 10 per cent of the maximum obtainable data.

From these data the following tables were prepared and figures drawn to bring out their salient features:

(1) Tables showing the average diurnal variation of the rate of reception of atmospherics for each month and each band separately (Fig. 2, wherein curves for only two typical months, June and December 1957, are shown).

(2) Tables showing the monthly averages of the rate of reception of atmospherics during the night and the day hours separately and their corresponding ratios for each individual band (Fig. 3).

(3) Tables showing the daily average values (indicating the daily character) throughout the period for each band separately.

(4) (a) Tables showing the average monthly values (indicating the monthly character) for all the months in this period for each band separately (Fig. 4, which includes the results from August 1956 to July 1958).

(b) Similar tables as above for the following selected hours were prepared and figures drawn to indicate the hourly character for the selected hours, month by month. The

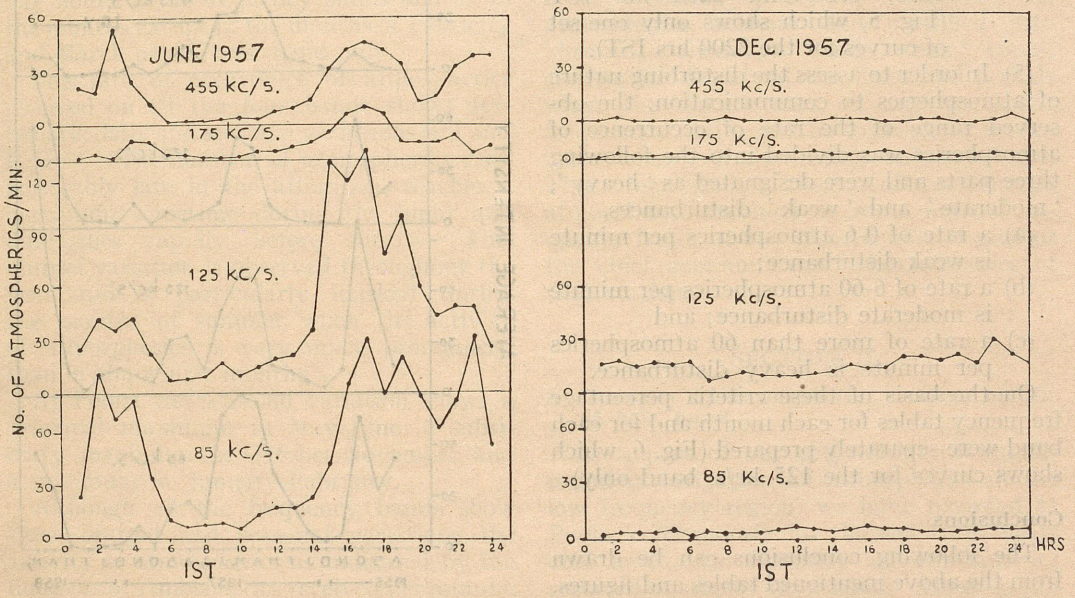

FIG. 2 — DIURNAL VARIATION OF AVERAGE NUMBER OF ATMOSPHERICS RECEIVED PER MINUTE DURING JUNE AND DECEMBER 1957

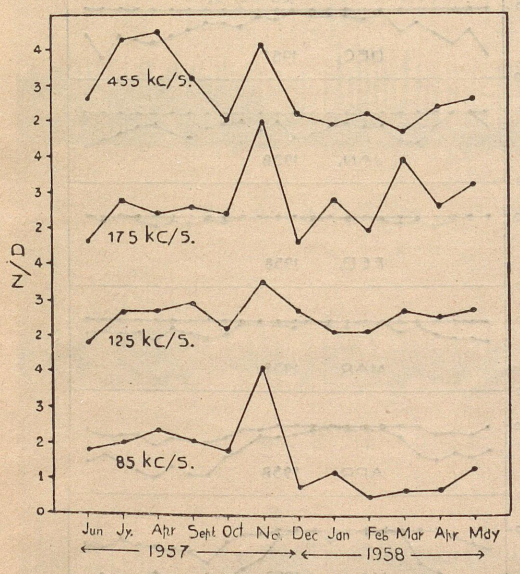

FIG. 3 — VARIATION OF THE RATIO N/D MONTH BY MONTH [N is the average number of atmospherics received per minute during the night hours and D, the corresponding number for the day hours]

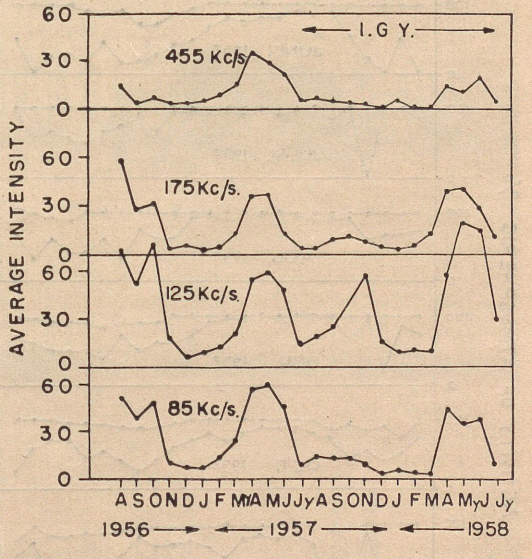

FIG. 4 — VARIATION OF THE MONTHLY AVERAGE VALUES OF ATMOSPHERICS

hours selected were 0300, 0700, 1200, 1700 and 2200 hrs IST (Fig. 5, which shows only one set of curves for the 2200 hrs IST).

(5) In order to assess the disturbing nature of atmospherics to communication, the observed range of the rate of occurrence of atmospherics was divided into the following three parts and were designated as ' heavy ', ' moderate ' and ' weak ' disturbances.

(a) a rate of 0-6 atmospherics per minute is weak disturbance;

(b) a rate of 6-60 atmospherics per minute is moderate disturbance; and

(c) a rate of more than 60 atmospherics per minute is heavy disturbance.

On the basis of these criteria percentage frequency tables for each month and for each band were separately prepared (Fig. 6, which shows curves for the 125 kc/s. band only).

Conclusions

The following conclusions can be drawn from the above-mentioned tables and figures.

On the average the number of atmospherics received per minute during the night hours is

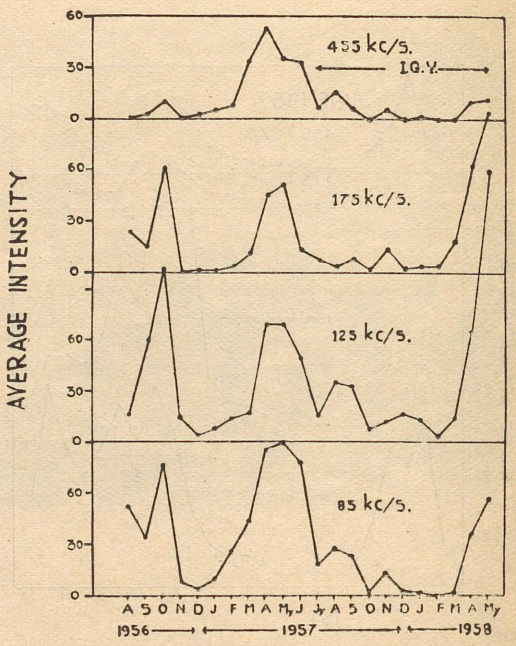

FIG. 5 — VARIATION OF THE MONTHLY AVERAGE VALUES OF ATMOSPHERICS AT 2200 HRS IST

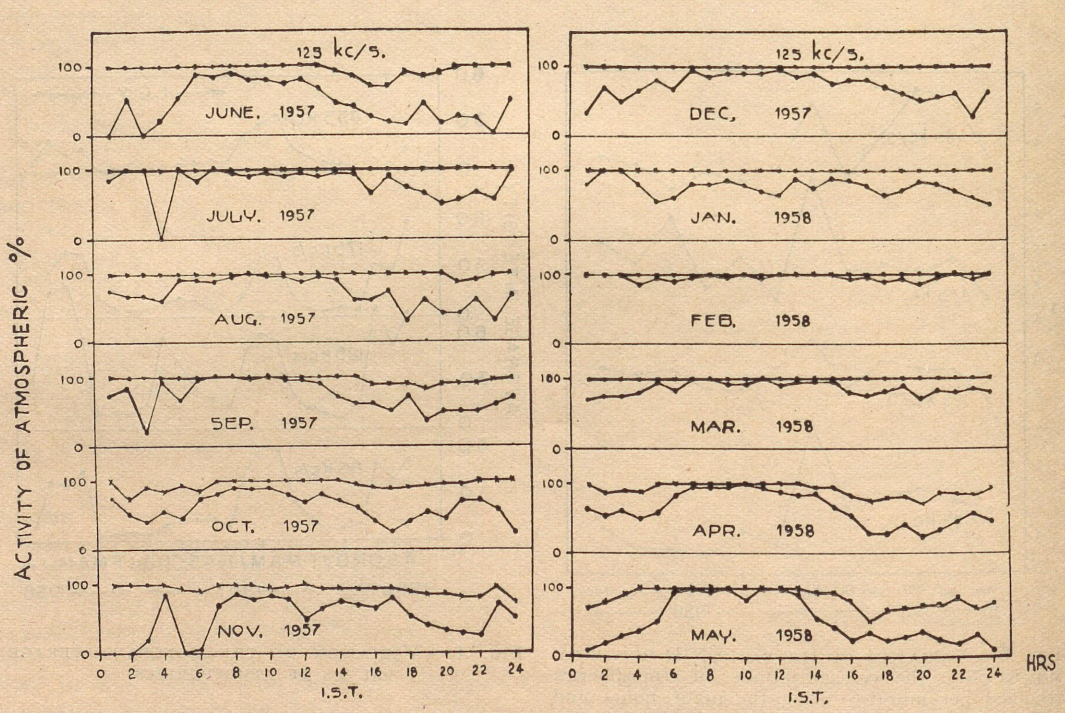

FIG. 6 — DIURNAL VARIATION OF THE WEAK, MODERATE AND HEAVY ACTIVITIES OF ATMOSPHERICS ON 125 KC/S. BAND [• — • — •, weak activity and × — × — ×, weak plus moderate activity]

much larger than that received during the day hours on all frequency bands and in all the months except in the months of February and March on 85 kc/s. band only.

The rate of occurrence of atmospherics received on all the four bands shows systematic daily and seasonal variations (P I and P II)[3,4]. The number of atmospherics rises noticeably late in the afternoon, reaches a maximum sometime during the night and diminishes rapidly before sunrise. This diurnal variation is observed throughout the year and is particularly marked during the months of summer when the activity of atmospherics is very much pronounced than in the winter months.

At Poona the seasonal variation shows a principal maximum in May-June, a subsidiary maximum in October-November and a minimum in January-February.

Although all the frequency bands show these diurnal and seasonal variations the activity of atmospherics as indicated by the numbers of atmospherics received per minute, it is remarkably high on the 125 kc/s. band (P III).

The diurnal and seasonal variations studied here by setting up certain criteria for the atmospherics activity and classified into 'heavy', 'moderate' and 'weak' types, give us an idea about the times and periods when the disturbances on any particular frequency band would be tolerable or intolerable while communicating on that band. Thus a mere study of the rate of occurrence of atmospherics received on some narrow frequency bands at any place is able to give us the chief communication characteristics of that station.

SECTION II

A. *Intensity of atmospherics received on the 85 kc/s. band*

As a part of our programme of an all-round investigation on atmospherics in the low frequency region, we have recorded at Poona continuously for the last three years and more, the intensity of atmospherics received on the 85 kc/s. band. However, in this section, only the results of the statistical analysis of the data obtained during the IGY

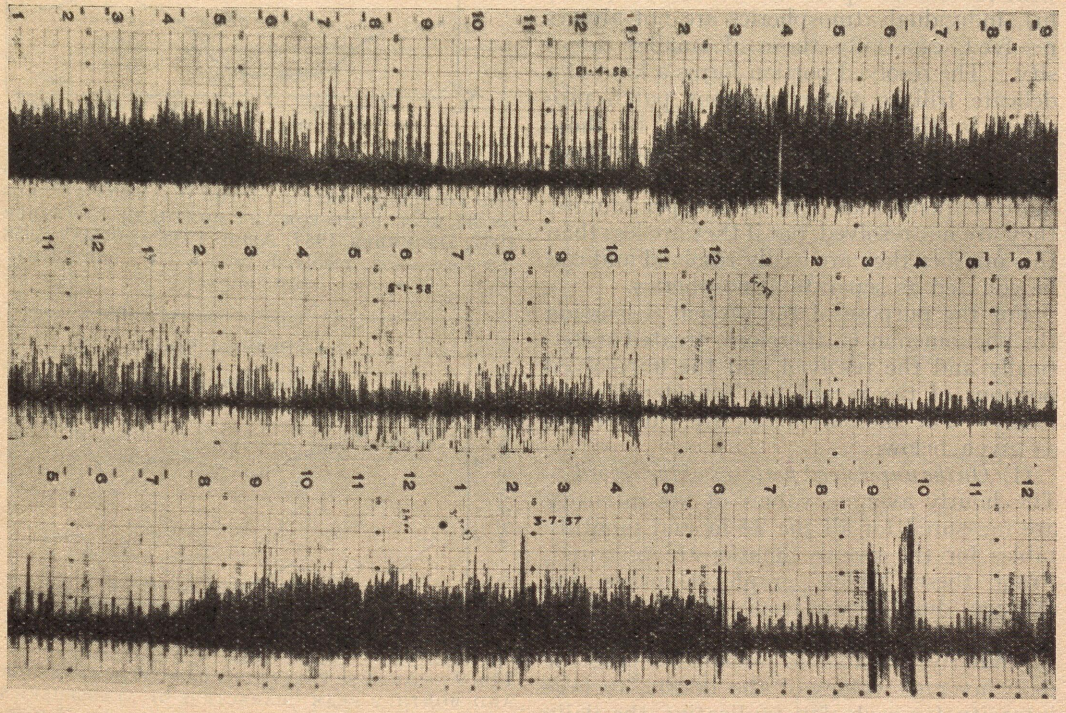

FIG. 7 — TYPICAL PORTIONS OF THE INTENSITY RECORDS ON 85 KC/S. BAND

period from 1 June 1957 to 30 April 1958 are presented and discussed.

Equipment and method of observation

The same set-up of the T.R.F. receiver tuned to 85 kc/s. band described in Section I is used to record the intensity of atmospherics received on this band. The output of the final stage of the receiver is given, through a condenser and a rectifier, to an Evershed and Vignols pen recorder.

Results

A continuous record of the intensity of atmospherics received on this band is thus available for the IGY period of June 1957 to May 1958 which is measured and statistically analysed here. It should be pointed out that from 16 January 1958 the recorder was alternately used on this band and on the 27 kc/s. band, especially when 'Alert' and 'SWI' warnings were received. Thus from this date onwards the data for 85 kc/s. band is not as continuous and profuse as before that date.

It will be seen from the three typical portions of the record reproduced in Fig. 7 that with the normal speed of the recorder (1 in./hr), individual atmospherics are not always resolved, especially those of smaller intensity. The resolved portion forms a kind of a delicate frill to the continuous patch produced by the unresolved ones, i.e. by those that are coming in too rapid a succession. Roughly we can say that if atmospherics are more frequent than four or five per minute, they are not resolved, but if they are less than this number they are easily resolved and can be counted as separate atmospherics.

For the purpose of the present discussion the phenomenon is, therefore, treated statistically and the resolved and the unresolved portions of the record are considered separately. The measurements are carried out as given below.

(1) *On the unresolved portions of the record* — The hourly average values of the intensity are measured for all the 24 hr and monthly tables for the twelve months are prepared. From these tables, graphs showing the average diurnal variation of the average intensity for each month are drawn (Fig. 8).

Similarly, a table is prepared giving the daily average values of the hourly average intensity for each day (indicating the daily average character) during the whole period.

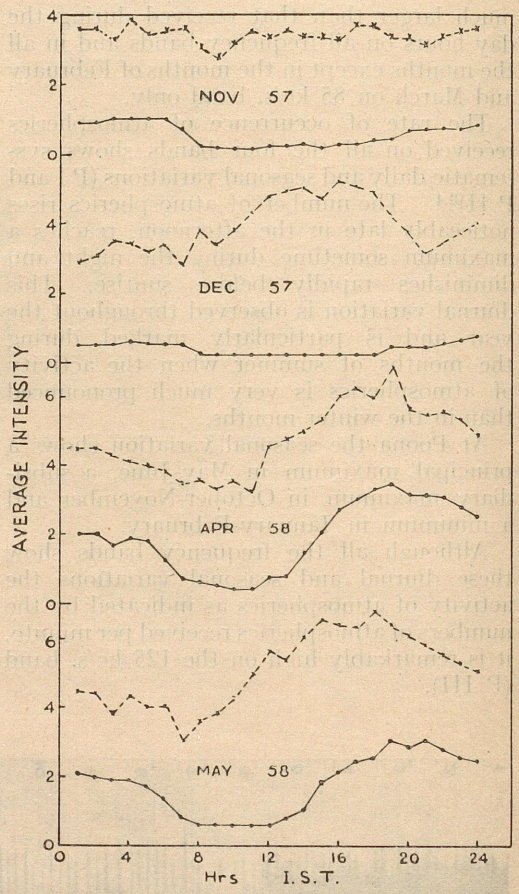

FIG. 8 — DIURNAL VARIATION OF THE UNRESOLVED AND RESOLVED PORTION OF THE INTENSITY RECORDS ON 85 KC/S. BAND FOR THE MONTHS OF NOVEMBER 1957, DECEMBER 1957, APRIL 1958 AND MAY 1958 [× - - × - - ×, resolved, • — • — •, unresolved]

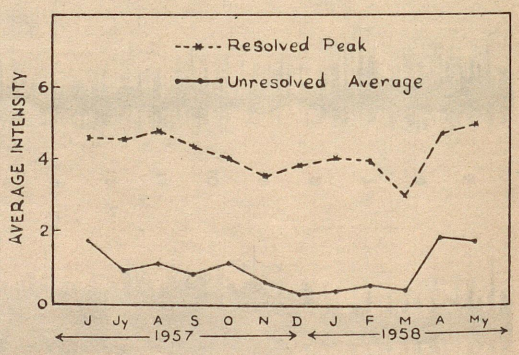

FIG. 9 — ANNUAL VARIATIONS OF MONTHLY AVERAGE AND MONTHLY PEAK CHARACTERS OF ATMOSPHERICS DERIVED FROM THE INTENSITY RECORDS ON 85 KC/S. BAND

Further, from these the monthly averages were tabulated and graph drawn to bring out the annual variation of this monthly character of the intensity records (Fig. 9).

(2) *On the resolved portions of the record* — The peak amplitude during each hour is measured and entered as the upper limit of intensity for that hour.

As in (1) monthly tables are prepared for these peak amplitude values and graphs are drawn to show the diurnal variations in each month (Fig. 8).

Similarly, a table is prepared showing the daily average values of the hourly peak intensity for each day (indicating the daily peak character) throughout the period. Further, from these the monthly averages were tabulated and graph drawn to bring out the annual variation of this monthly peak character of the intensity records (Fig. 9).

For the sake of assessing the results of measurements thus obtained, we adopted the idea of 'atmospherics activity' based on both the intensity and the rate of reception of atmospherics.

In the case of the unresolved portions it is obvious from the above remarks that the number of atmospherics received per minute is greater than four or five per minute and in spite of this high rate, therefore, for this portion of the record, if the average hourly intensity is less than 2·5 cm. (150 μV./metre), then the disturbance is taken to be ineffective or harmless for communication purposes on this frequency band. This value of the amplitude has been chosen for co-ordination of the results of the different investigations and actually corresponds to the minimum power necessary to actuate the telephone counters described in Section I.

Similarly, in the case of the resolved portions of the record the measured values of the peak amplitudes, which are equal to or greater than 5 cm. (350 μV./metre) in spite of their low rate, are taken to be decisive disturbances to communication on this frequency band. It may be noted that this limit is twice the former limit which was taken to represent the upper limit of the activity of harmless atmospherics.

On the basis of the above two criteria, two separate frequency tables were prepared showing the number of occasions during each month for each hour when the records show

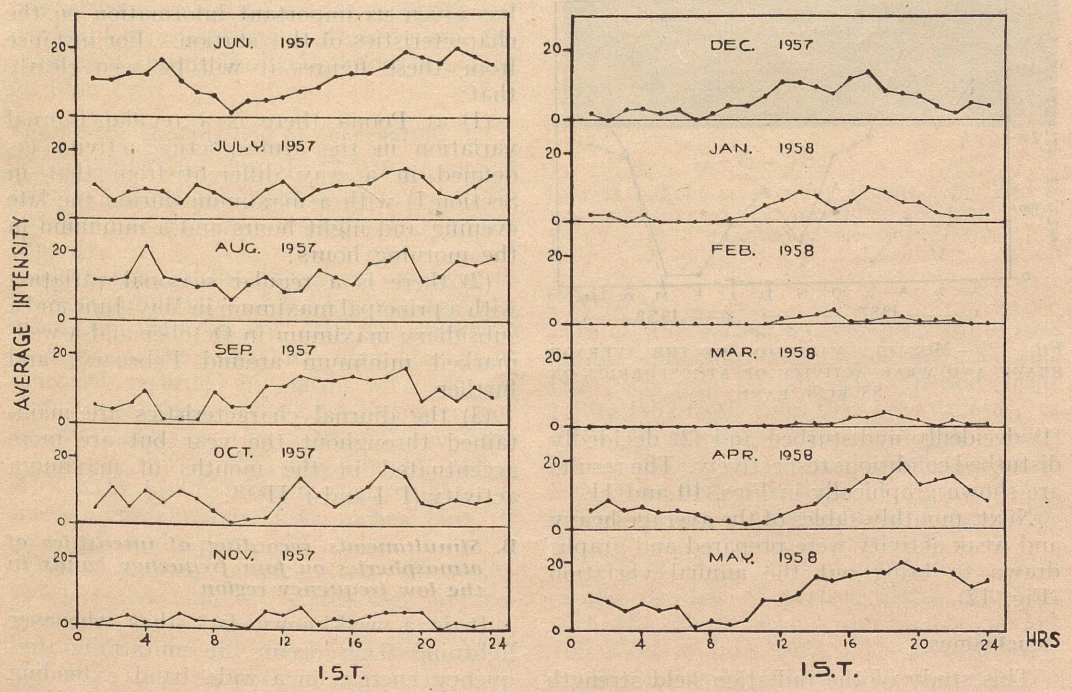

FIG. 10 — DIURNAL VARIATION OF THE HEAVY ACTIVITY OF ATMOSPHERICS ON 85 KC/S. BAND

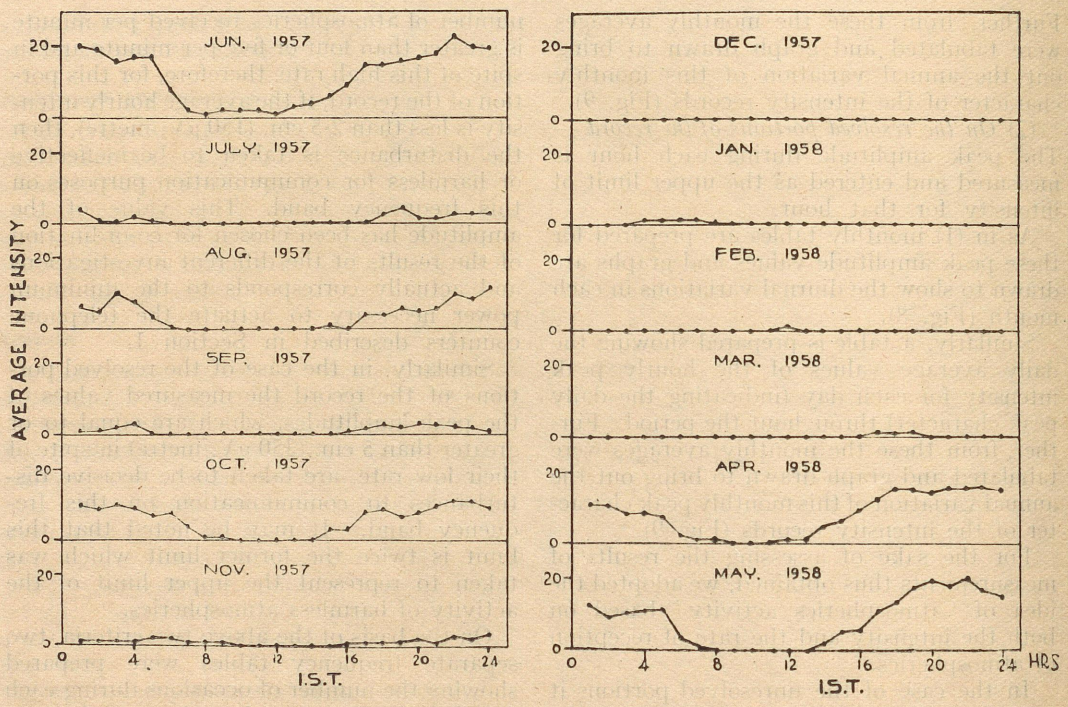

FIG. 11 — DIURNAL VARIATION OF THE WEAK ACTIVITY OF ATMOSPHERICS ON 85 KC/S. BAND

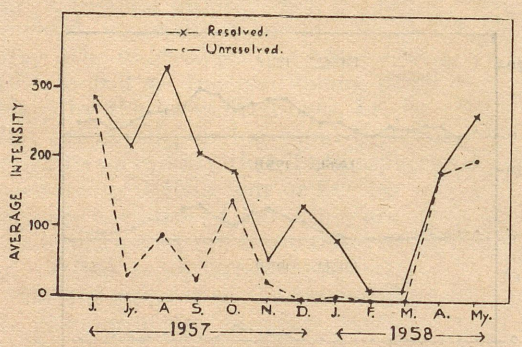

FIG. 12 — MONTHLY VARIATION OF THE AVERAGE HEAVY AND WEAK ACTIVITY OF ATMOSPHERICS ON 85 KC/S. BAND

(1) decidedly undisturbed and (2) decidedly disturbed conditions respectively. The results are shown graphically in Figs. 10 and 11.

Next, monthly tables of the average heavy and weak activity were prepared and graphs drawn to bring out the annual variation (Fig. 12).

Conclusions

This study of the radiation field strength of atmospherics on only one frequency band has given us important information on the characteristics of this station. For instance from these figures it will be seen clearly that:

(1) at Poona there is a regular diurnal variation in the atmospherics activity (as defined in a way different from that in Section I) with a maximum during the late evening and night hours and a minimum in the morning hours;

(2) there is a regular seasonal variation with a principal maximum in May-June and a subsidiary maximum in October and a well-marked minimum around February; and further

(3) the diurnal characteristics are maintained throughout the year but are more accentuated in the months of maximum activity (P I and P II)[3,4].

B. *Simultaneous recording of intensities of atmospherics on four frequency bands in the low frequency region*

It is a well-known fact that whenever lightning flash occurs, it emits radio frequency energy on a wide band extending right from a few hundred c/s. to a few Mc/s.

It is natural that the spectral distribution of energy in this wide band depends, at the source, on the several physical and geometrical factors such as the length and the height of the flash above the ground, the variation of the current in the flash with time and along the track of the flash, the distributed inductance and capacitance of the path and its branches, etc.

Further, the propagation mechanism responsible for carrying this energy over different distances considerably modifies this distribution of energy in the whole spectrum. The ground wave propagation and the sky wave propagation obviously will have different characteristics and any temporal changes in the properties of the medium along the two paths will be clearly indicated in the signals received over different distances.

In particular, these effects will be frequency dependent and hence a simultaneous study of intensity variation of the different components of an individual atmospherics will be of great significance. Accordingly in the larger scheme " On the Nature and Origin of Atmospherics " this aspect was also included and some preliminary results obtained earlier were reported (P III). In the present communication we are reporting the results of investigations continued along the same lines, during the IGY period July 1957 to June 1958.

Equipment and method of observation

The same four straight T.R.F. receivers (band widths of about 5-8 kc/s.) tuned to 85, 125, 175 and 455 kc/s. respectively are used (Fig. 1).

The outputs of these receivers are given to the horizontal plates of the four cathode ray tubes (Mullard ECR 35). The movements of spots on all the four C.R. tubes are simultaneously recorded by means of a moving plate camera (lens aperture, f/4·5) to give four separate traces on the plate. Observations are made during the pre-midnight period (2130-2330 hrs IST) once every night. A trace, approximately four inches long, is recorded on the plate in 1 min.

While making measurements of amplitudes recorded on the plates they are enlarged to the original size by a projector, thus giving directly the measurements of the deflections on the screen of the C.R. tubes.

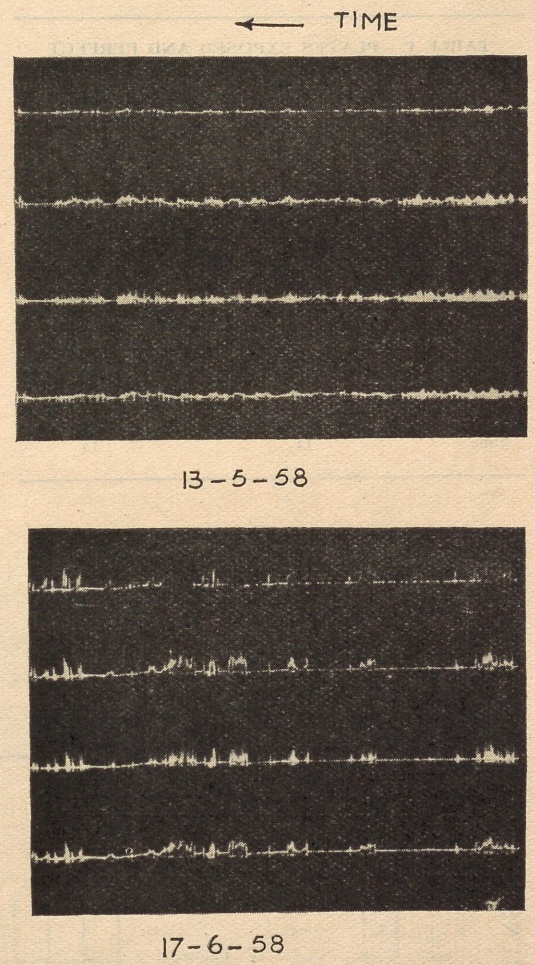

FIG. 13 — TYPICAL RECORDS SHOWING THE SIMULTANEOUS INTENSITY VARIATIONS ON THE FOUR FREQUENCY BANDS

Results

In all 157 perfect records (Fig. 13) of one minute duration taken at about 2200 hrs IST each day for the IGY period from 1 July 1957 to 30 June 1958 are available. It should be pointed out that although a number of records were spoiled by man-made noise, the non-availability of photographic materials was a more serious difficulty in maintaining a continuous record.

Table 1 gives the monthly distribution of the number of perfect plates obtained with the above set-up during the period July 1957 to June 1958. The results given in the following tables are based on the measurements of these plates.

TABLE 1 — PLATES EXPOSED AND PERFECT PLATES OBTAINED DURING JULY 1957 TO JUNE 1958

Month	Total No. of plates taken	No. of perfect plates
1957		
July	13	7
August	22	20
September	18	16
October	12	10
November	16	13
December	18	15
1958		
January	9	7
February	15	14
March	18	16
April	15	14
May	12	12
June	14	14

In order to analyse these results the following two procedures were adopted:

(1) *Intensity distribution on the different frequency bands* — For this purpose a scale of intensities with the following ranges of deflections was adopted: (a) 0-3 mm., (b) 3-6 mm., (c) 6-9 mm., and (d) 36-39 mm.

Monthly totals of the frequencies of occurrence are tabulated and histograms drawn. Typical histograms for the months of November 1957, February and June 1958 only are shown in Fig. 14.

(2) *Comparisons of amplitudes recorded simultaneously* — The maximum amplitude on one of the four frequency bands and the corresponding amplitudes on the remaining three frequency bands are measured; the process is repeated for all frequencies. The

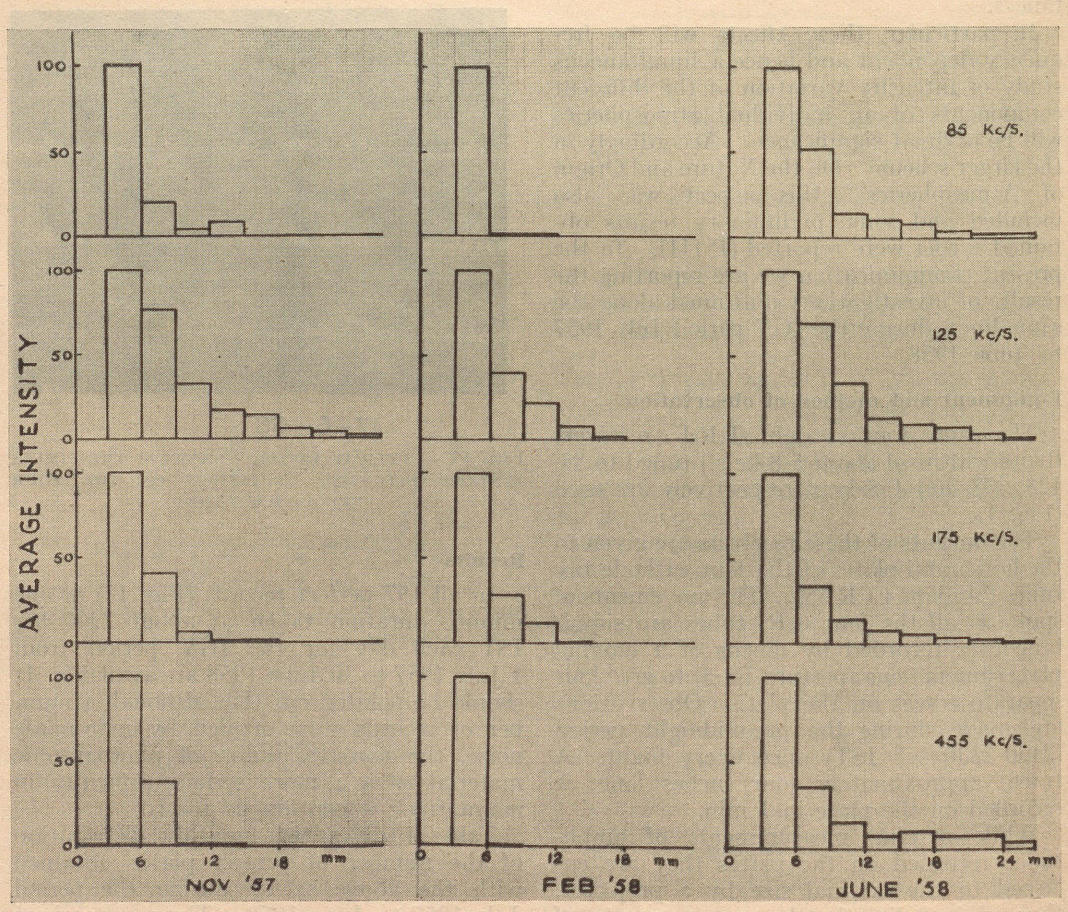

Fig. 14 — Typical histograms of frequency of occurrence of atmospherics for the months of November 1957, February 1958 and June 1958

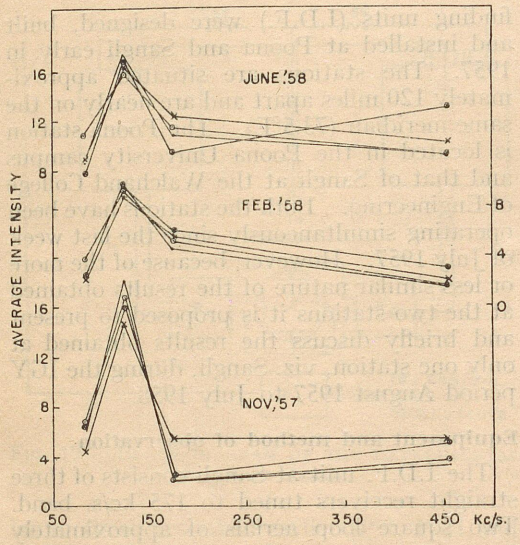

FIG. 15 — AVERAGE FREQUENCY VARIATION OF THE INTENSITY OF ATMOSPHERICS FOR THE MONTHS OF NOVEMBER 1957, FEBRUARY 1958 AND JUNE 1958 [⊙—⊙—⊙, 85 kc/s.; •—•—•, 125 kc/s.; ×—×—×, 175 kc/s.; and ⊗—⊗—⊗, 455 kc/s.]

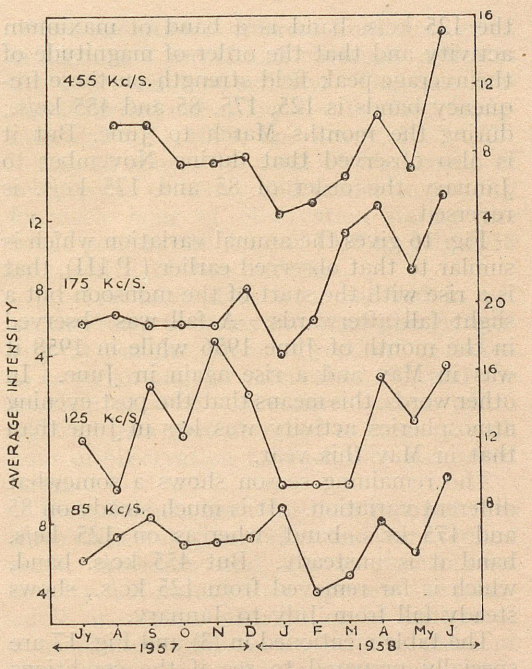

FIG. 16 — SEASONAL VARIATION OF THE AVERAGE PEAK AMPLITUDE ON THE FOUR BANDS

monthly averages of these values are tabulated and figures drawn. Only three typical graphs for the months of November 1957, February and June 1958 are shown in Fig. 15.

Fig. 16 shows the variations of monthly averages of peak amplitudes for all the four frequencies separately.

(3) With a view to studying the local storms by this method, records taken during such conditions were picked out and studied separately from the rest of the records. During the period of observation only four clearly defined cases of local storms were available. The results of measurements on these plates are tabulated and shown graphically in Fig. 17.

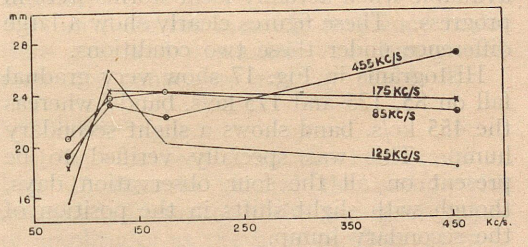

FIG. 17 — FREQUENCY VARIATION OF THE INTENSITY OF ATMOSPHERICS DURING STORM-TIME [⊙—⊙—⊙, 85 kc/s.; •—•—•, 125 kc/s.; ×—×—×, 175 kc/s.; and ⊗—⊗—⊗, 455 kc/s.]

Conclusions

From the table mentioned in (1) and histograms shown in Fig. 14, it will be observed that the spread of the histograms is larger during stormy seasons than during the quiet seasons. It is maximum in June and minimum in February. The other months show characteristics in between these two.

From round-the-clock observations on the number of atmospherics received on these four different bands, it is known that normally in the months of May and June, at Poona, the atmospherics activity continues from the afternoon to even beyond midnight, while during other months, such as October and November, the activity ceases practically within a few hours after the sunset. Thus at the time of these observations (2130-2330 hrs IST), i.e. during the pre-midnight period, the month of June showed the maximum activity while October, though otherwise stormy, did not show such a high value.

The characteristics of the histograms on all frequencies are nearly similar.

The table mentioned in (2) and Fig. 15 confirm the earlier observations (P III) that

the 125 kc/s. band is a band of maximum activity and that the order of magnitude of the average peak field strength on these frequency bands is 125, 175, 85 and 455 kc/s., during the months March to June. But it is also observed that during November to January the order of 85 and 175 kc/s. is reversed.

Fig. 16 gives the annual variation which is similar to that observed earlier (P III), that is a rise with the start of the monsoon but a slight fall afterwards. A fall was observed in the month of June 1956 while in 1958 it was in May and a rise again in June. In other words, this means that the post-evening atmospherics activity was less in June than that in May this year.

The remaining season shows a somewhat different variation. It is much steady on 85 and 175 kc/s. band, whereas on 125 kc/s. band it is unsteady. But 455 kc/s. band, which is far removed from 125 kc/s., shows steady fall from July to January.

The table mentioned in (3) and Fig. 17 are specially prepared to see if the conditions during storm are different from those observed otherwise. Four such plates were available when actually local storms were in progress. These figures clearly show a large difference under these two conditions.

Histograms in Fig. 17 show very gradual fall on 85, 125 and 175 kc/s. bands, whereas the 455 kc/s. band shows a slight secondary hump. This was specially verified to be present on all the four observation days, though with slight shifts in the position of the secondary hump.

It may be stated that even if the phenomenon under observation is very complicated and the available data comparatively meagre, a few general conclusions can be drawn, such as: (a) that at Poona, 125 kc/s. band shows a maximum of activity; (b) that the average distribution of energy in the different frequency bands varies from month to month; and (c) that the local storm-time variations are different from those of the fair weather.

SECTION III

Directional distribution of sources of atmospherics around Sangli

In order to investigate the distribution of the sources of atmospherics around the place of observation two instantaneous direction finding units (I.D.F.) were designed, built and installed at Poona and Sangli early in 1957. The stations are situated approximately 120 miles apart and are nearly on the same meridian (73·5°E). The Poona station is located in the Poona University campus and that of Sangli at the Walchand College of Engineering. Both the stations have been operating simultaneously since the last week of July 1957. However, because of the more or less similar nature of the results obtained at the two stations it is proposed to present and briefly discuss the results obtained at only one station, viz. Sangli, during the IGY period August 1957 to July 1958.

Equipment and method of observation

The I.D.F. unit at Sangli consists of three straight receivers tuned to 175 kc/s. band. Two square loop aerials of approximately two metres size each are placed at right angles to one another feeding into two of the receivers and one vertical aerial feeding into the third receiver used for the sense determination (Figs. 18 and 19). The directions of approach of atmospherics are displayed on the screen of the C.R.O. Observations are taken four times a day at 0800, 1200, 1700 and 2200 hrs IST, when a photographic record of two minutes' duration is taken on a continuously moving 35 mm. film (Fig. 20). The units were standardized and their conditions maintained constant by periodical checks and calibrations using methods simi-

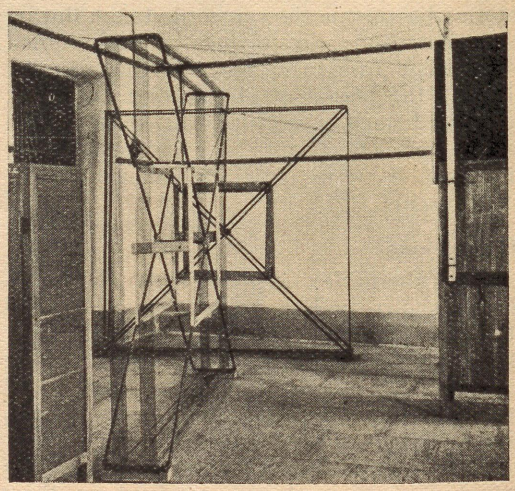

FIG. 18 — TWO SQUARE LOOP AERIALS INSTALLED AT SANGLI

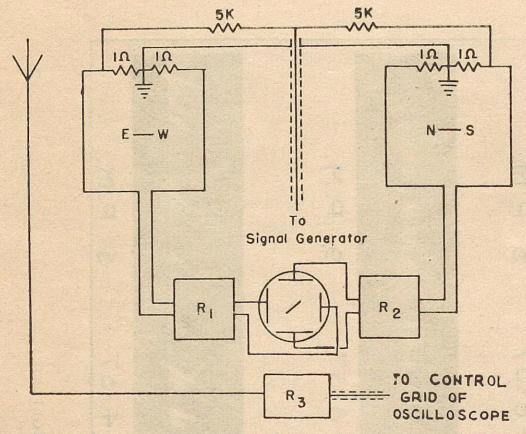

FIG. 19 — BLOCK DIAGRAM OF THE EXPERIMENTAL SET-UP AT SANGLI

lar to those described earlier (P I, P II and P III). For convenience and accuracy of measurements the films were projected on a large white screen with a ruled grid having radial and circular lines. The directions of approach of atmospherics and their amplitudes could thus be measured individually and quickly.

Results

The basic data thus collected consist of the number, amplitude (intensity) and direction of approach of each individual atmospherics recorded in the 2 min. interval at each hour of observation during the IGY period August 1957 to July 1958 (Table 2). These data were statistically handled and the following tables prepared and diagrams drawn to bring out the salient features.

(1) Frequency tables of intensity distribution of atmospherics for each time of observation are prepared for each month separately and histograms drawn.

(2) Tables are prepared and figures drawn showing the directional distribution of 'heavy' and 'moderate' atmospherics activity around the place of observation at Sangli (Fig. 21 in which those for December 1957 and June 1958 only are shown). For this purpose the activity of atmospherics in any direction was defined by the relation $X=N.A^2$, where X is the activity of atmospherics, N is the number of atmospherics recorded in the two minutes' interval in one direction, and A is the maximum amplitude of atmospherics recorded in that interval in that direction.

This definition is different from those given in Sections I and II and obviously indicates the upper limit of activity. The classification is carried out as low, $0<X<250$; moderate, $250<X<1000$; and heavy, $1000<X$.

Fig. 22 shows the total of frequencies of occurrences of heavy and moderate activity for each hour of observation during the whole period from August 1957 to July 1958 irrespective of the direction.

(3) The basic data were handled in yet another way to assess the atmospherics activity at Sangli. Here 'direction' is taken to cover an angular interval of 10°, and the number of such 'directions' from which atmospherics were observed to come at each hour of observation for each day was noted down.

These frequencies were then grouped into three classes as given below and were termed weak, moderate and heavy atmospherics activity. Naturally they represent the panoramic or angular distribution of centres of atmospherics activity around the place of observation: $0\leq n\leq 5$ is low panoramic activity; $6\leq n\leq 11$ is moderate panoramic activity; and $12\leq n\leq 36$ is heavy panoramic activity.

From these the monthly frequency tables were prepared separately for heavy and moderate panoramic activity (Table 3).

Conclusions

It will be seen from the histograms in Fig. 22 that in general the group with maximum frequency shifts to higher values of amplitudes as the hour of observation is

TABLE 2 — SUMMARY OF OBSERVATIONS TAKEN AT SANGLI

MONTH	NO. OF DAYS*	NO. OF TIMES			
		8 a.m.	12 p.m.	5 p.m.	9 p.m.
1957					
August	24	13	13	17	14
September	23	18	17	19	17
October	26	24	22	22	14
November	28	27	22	24	28
December	26	14	9	19	18
1958					
January	27	19	15	23	20
February	25	19	14	19	24
March	30	18	23	27	27
April	28	22	23	17	16
May	25	19	17	20	14
June	29	22	21	27	26
July	29	13	16	18	29

*The number of successful days of observation is shown along with the number of occasions at each hour of observation during a day.

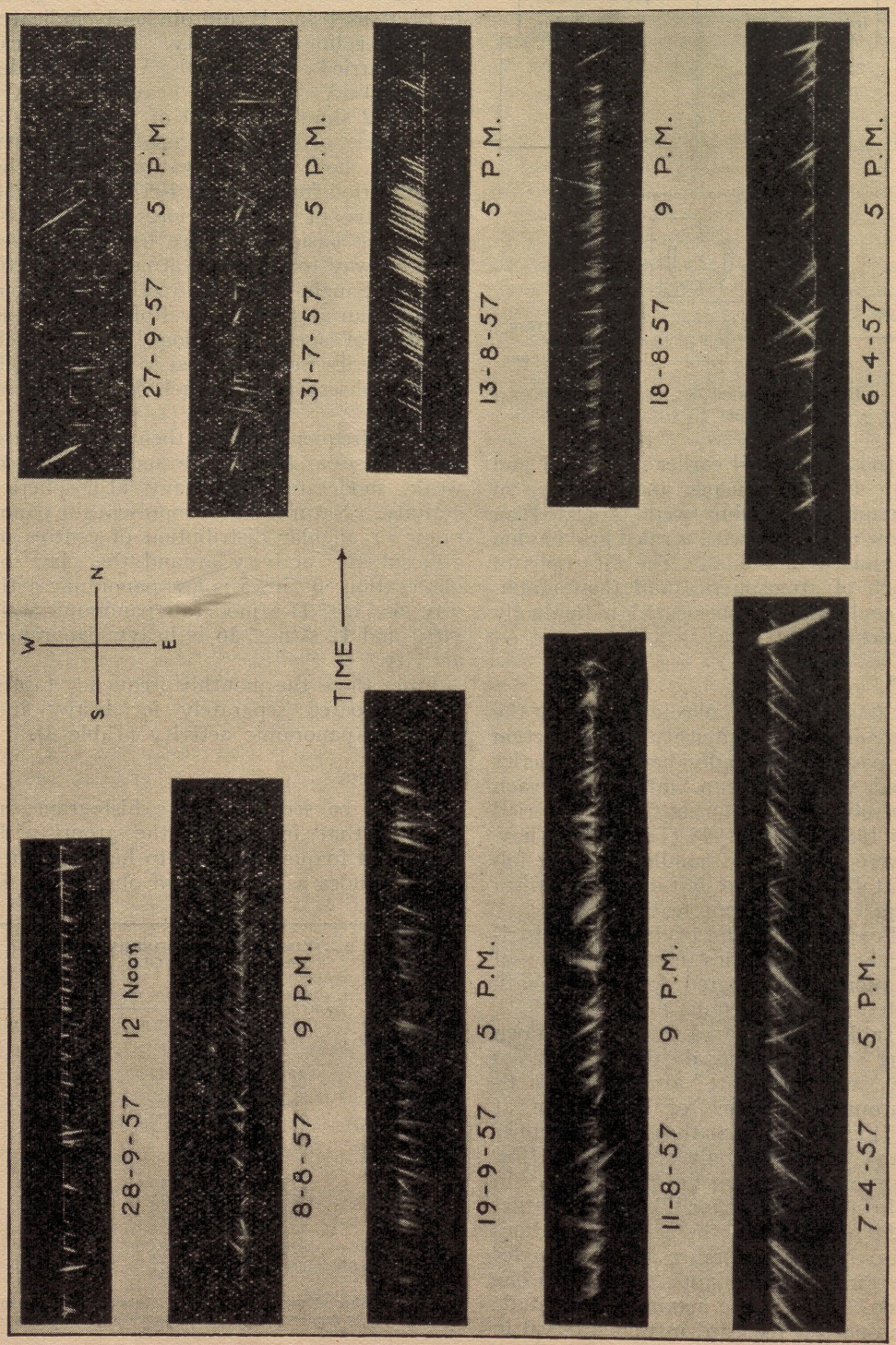

FIG. 20 — TYPICAL RECORDS TAKEN WITH THE I.D.F. UNIT AT SANGLI

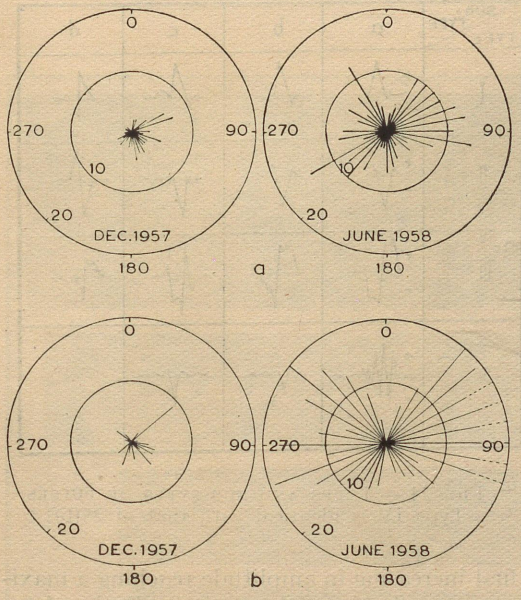

FIG. 21 — DIRECTIONAL DISTRIBUTION OF ATMOSPHERICS AROUND D.F. STATION AT SANGLI FOR THE MONTHS OF DECEMBER 1957 AND JUNE 1958 FOR (a) HEAVY ACTIVITY AND (b) MODERATE ACTIVITY

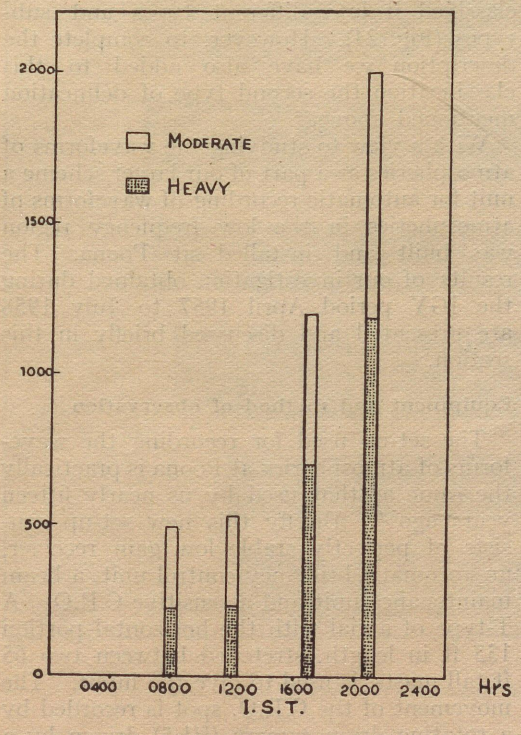

FIG. 22 — TOTAL FREQUENCY OF OCCURRENCES OF HEAVY AND MODERATE ACTIVITY

TABLE 3 — HEAVY AND MODERATE PANORAMIC ACTIVITY OBSERVED AT SANGLI

Month	Heavy				Moderate			
Hrs, IST	0800	1200	1700	2100	0800	1200	1700	2100
1957								
August	0	1	4	12	2	4	10	1
September	0	0	3	6	0	4	10	11
October	4	1	4	3	4	7	15	9
November	0	0	0	12	2	4	11	14
December	0	0	0	0	0	0	1	13
1958								
January	0	0	0	5	1	2	3	15
February	0	0	1	5	2	1	5	17
March	1	0	1	14	3	5	13	12
April	1	0	7	7	11	14	9	7
May	1	2	10	7	11	8	6	5
June	4	4	16	19	16	11	9	5
July	0	0	2	28	7	4	9	1
Total	11	8	48	118	59	64	101	110

increased, except in October 1957 in which month the highest group is at 0800 hrs.

Secondly, for the first two hours of observation the frequency is seen to fall with the increase in amplitude, while in the evening and night it is seen to rise with the increase in amplitude or a maximum is shown for one of the intermediate groups and frequency falls on both sides of this group.

In general the heavy as well as the moderate classes of activity are maximum during the months of April and June and minimum around December.

The heavy type of activity shows a directional distribution around the place of observation peculiar to its geographical position, viz. that during the period July 1957 to May 1958 on the whole the heavy activity was located within the range of angles 70° (E-NE) to 170° (S-SE) approximately which means that the land mass is more favourable than the ocean for the development of sources of atmospherics.

Further, our observations show a fairly good agreement with the corresponding daily weather reports over a region of about 2000 km. radius around Sangli.

Table 3 shows clearly that on the whole both the heavy and the moderate activity increase with the hour of observation. However, the heavy activity for the month of October and the moderate activity for the months of April to July show a decreasing activity with the advance of hour of observation. The activities taken together show the same annual variation, viz. a principal maximum in May-June, a subsidiary maximum in October and a minimum in December.

FIG. 20 — TYPICAL RECORDS TAKEN WITH THE I.D.F. UNIT AT SANGLI

SECTION IV

Wave forms of atmospherics

The transient nature of atmospherics is too well known to be commented upon here. However, at any given place the manner in which the field strength varies with time may be termed the form of disturbance or the waveform of atmospherics. It will be seen from the way in which this term has been used by different authors that there is no particular mention of the time-resolution that must be adopted while delineating this waveform. As new techniques were discovered and developed the time-resolution was increased more and more and accordingly the meaning of this term has undergone several stages of modification. For instance, with the slow-moving instruments like the galvanometers, electrometers, etc., naturally the time-resolution used was quite small, of the order of 1/100th sec. or more, with a C.R.O. type of indicator the time-resolution was increased gradually to 1/1000th and even to 1/10,000th sec. Naturally the forms traced out by these different indicators obviously showed different shapes of the same 'waveform'. At present the time-resolution used in several investigations is of the order of some tens of microseconds. Under this resolution, distinctly two different types of delineations are shown in the records. The first (Fig. 23a) consists of three distinct portions, namely in order of time sequence, the precursors, the ground pulse and a series of sky pulses which are repetitions of the ground pulse gradually dying down in amplitude; and second (Fig. 23b) is something like a group of waves

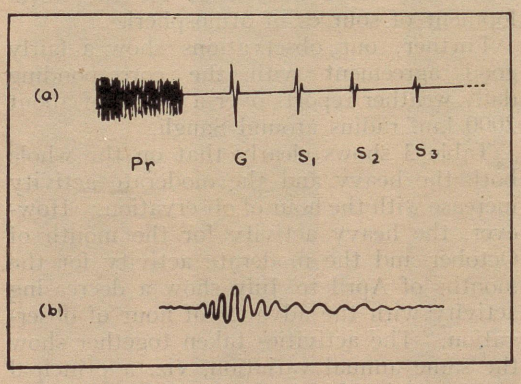

FIG. 23 — IDEALIZED WAVEFORMS OF ATMOSPHERICS
[(a) first type of delineation and (b) second type of delineation]

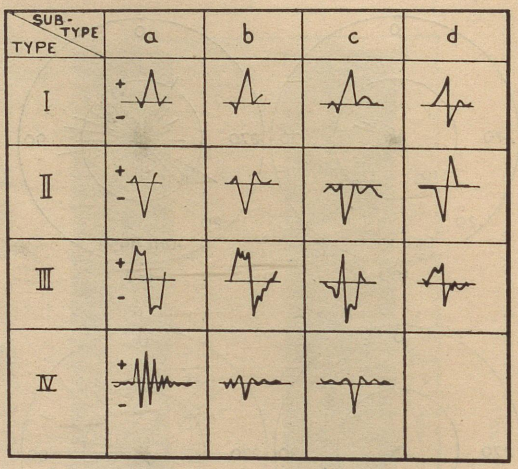

FIG. 24 — TYPES AND SUB-TYPES OF PULSES
[Type IV is identical with that of 25(b)]

first increasing in amplitude reaching a maximum and then decreasing. Both these have been explained in detail in the literature on this subject. In the present discussion we have laid stress on the shape of the ground pulse only of the first kind of delineation and classified it into different types and sub-types (Fig. 24). However, to complete the description we have also added to this classification the second type of delineation mentioned above.

With a view to studying the waveforms of atmospherics as a part of our larger scheme a unit for automatic recording of waveforms of atmospherics in the low frequency region was built and installed at Poona. The results of our investigation obtained during the IGY period April 1957 to July 1958 are presented and discussed briefly in this section.

Equipment and method of observation

The set-up used for recording the waveforms of atmospherics at Poona is practically the same as that used by us nearly fifteen years ago[5,6]. Briefly this new set-up consists of perfectly stable low gain receiver, an automatic brilliancy control unit, a beam maintenance unit and a sensitive C.R.O. A T-type of aerial with the horizontal portion 135 ft in length, stretched between two 65 ft tall masts, is used to give the input. The movement of the C.R.O. spot is recorded by a rotating drum camera (f/1·5) driven by a 1/8 h.p. synchronous motor.

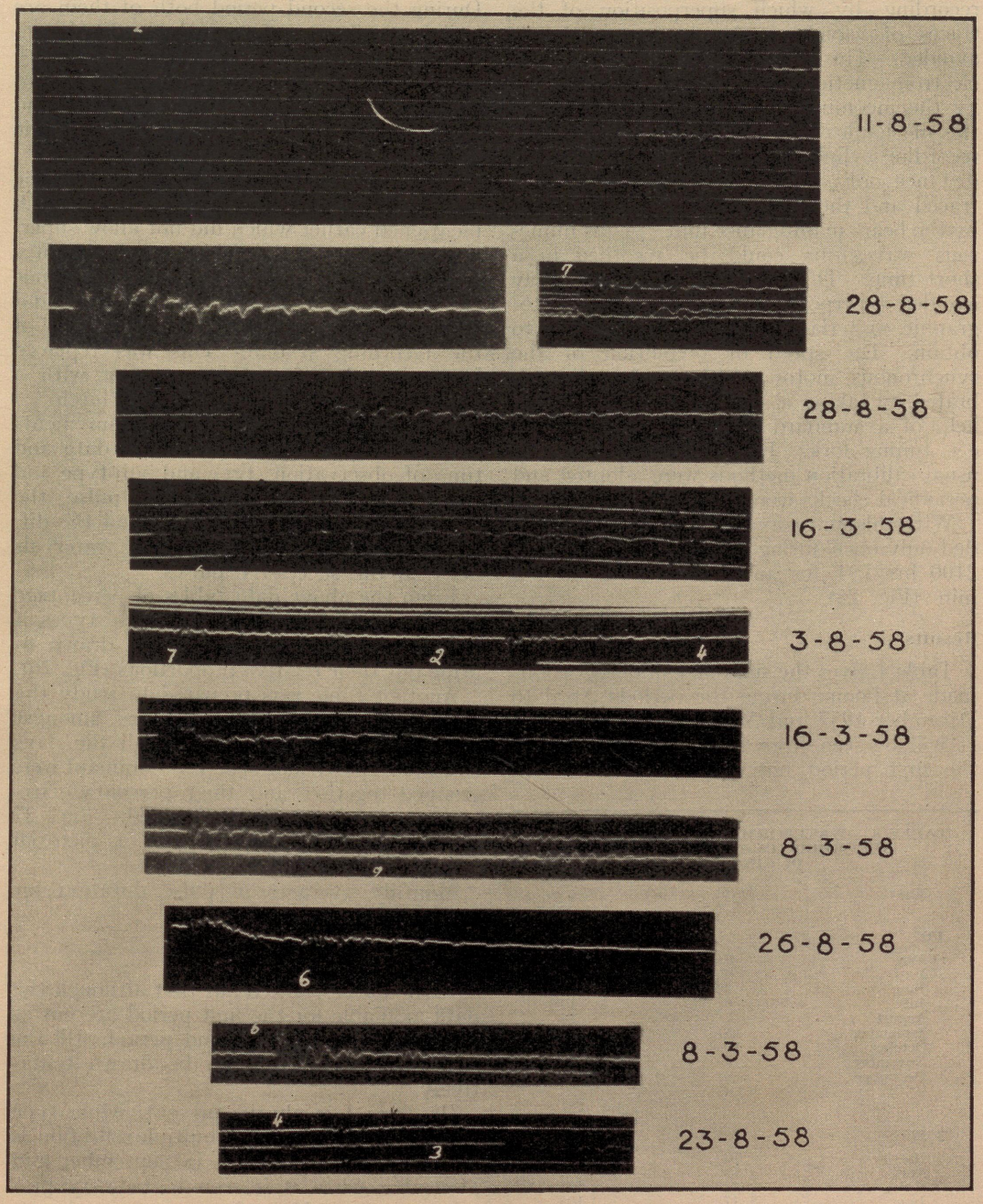

FIG. 25 — TYPICAL WAVEFORMS OF ATMOSPHERICS RECORDED AT POONA

In this new set-up we have carried out an important improvement in the method of recording by which superposition of the traces of waveforms is almost completely avoided. This consists of an automatic electromagnetic clutch which is energized by the incoming signal itself. But due to the mechanical inertia, the position of the recording cylinder is shifted through a small distance only after the whole waveform is traced and the C.R.O. spot is switched off by the beam maintenance unit. Thus numerous waveforms could be recorded in a short time. This has not only considerably avoided superposition but also saved photographic material which is very difficult to obtain. The speed of revolution of the synchronous motor was once for all calibrated by taking a sine wave trace with the help of a standard valve maintained 1000 c/s. tuning fork. For the other units the usual calibration methods were adopted and periodical checks were carried out.

With this unit waveforms have been recorded only once during the nighttime at about 2100 hrs IST for an interval of about 3-4 min. (Fig. 25).

Results

Table 4 gives the summary of observations made at Poona during the periods April to December 1957 and March to August 1958. It will be seen from this table that during the first period not only the numbers of days in each month are small but also the numbers of selected waveforms are very small. During the second period both of them are sufficiently large. This is because of two difficulties: (i) the waveform traces used to get superposed one over the other because of their incidence in very quick succession and (ii) difficulty of getting the photographic material.

TABLE 4 — WAVEFORMS OF ATMOSPHERICS RECORDED ON SELECTED DAYS DURING IGY

Month	Days	No. of waveforms
1957		
April	5	25
May	6	27
June	3	9
July	6	10
August	7	13
September	5	19
October	10	36
November	14	39
December	3	9
	Total	187
1958		
March	15	76
April	16	83
May	22	133
June	17	105
July	22	126
August	17	110
	Total	633
	Grand total	820

The first difficulty was overcome by the introduction of the electromagnetic clutch mentioned earlier which did not allow superposition of traces, but the second difficulty could not be overcome then. The absence of data during the months of January and February 1958 is due to the breakdown of the recording system. This was replaced by a second and a better system with a synchronous motor and the E.M. clutch.

The basic data obtained by measurements on these records consisted of the date and time of observation, type and sub-type and the duration of the elementary pulse, the amplitudes of the ground pulse and the different sky pulses and the time intervals between the successive pulses.

From the above data tables of percentage frequencies of occurrence of different types of pulses were prepared and figures drawn to bring out their relative proportions (Fig. 26).

Another table was prepared to study the association of these pulse types amongst themselves. For this purpose all the days on which a particular type was dominant were grouped together and their percentage frequency distributions determined. Fig. 27 shows the results obtained in a pictorial manner.

Monthly averages of pulse duration for each type are tabulated.

Conclusions

It should be pointed out that although the data available for the first period are not as numerous as for the second period, still the following conclusions can be drawn tentatively.

(1) Type I is always present, while type IV, which does not show multiple reflection, is very often absent except in September and December when it is seen to be very prominent. Type II is also sometimes absent, but when present, it is quite comparable to other types. Type III is perhaps the most prominent or nearly so in May, June, July, September and October. On the whole,

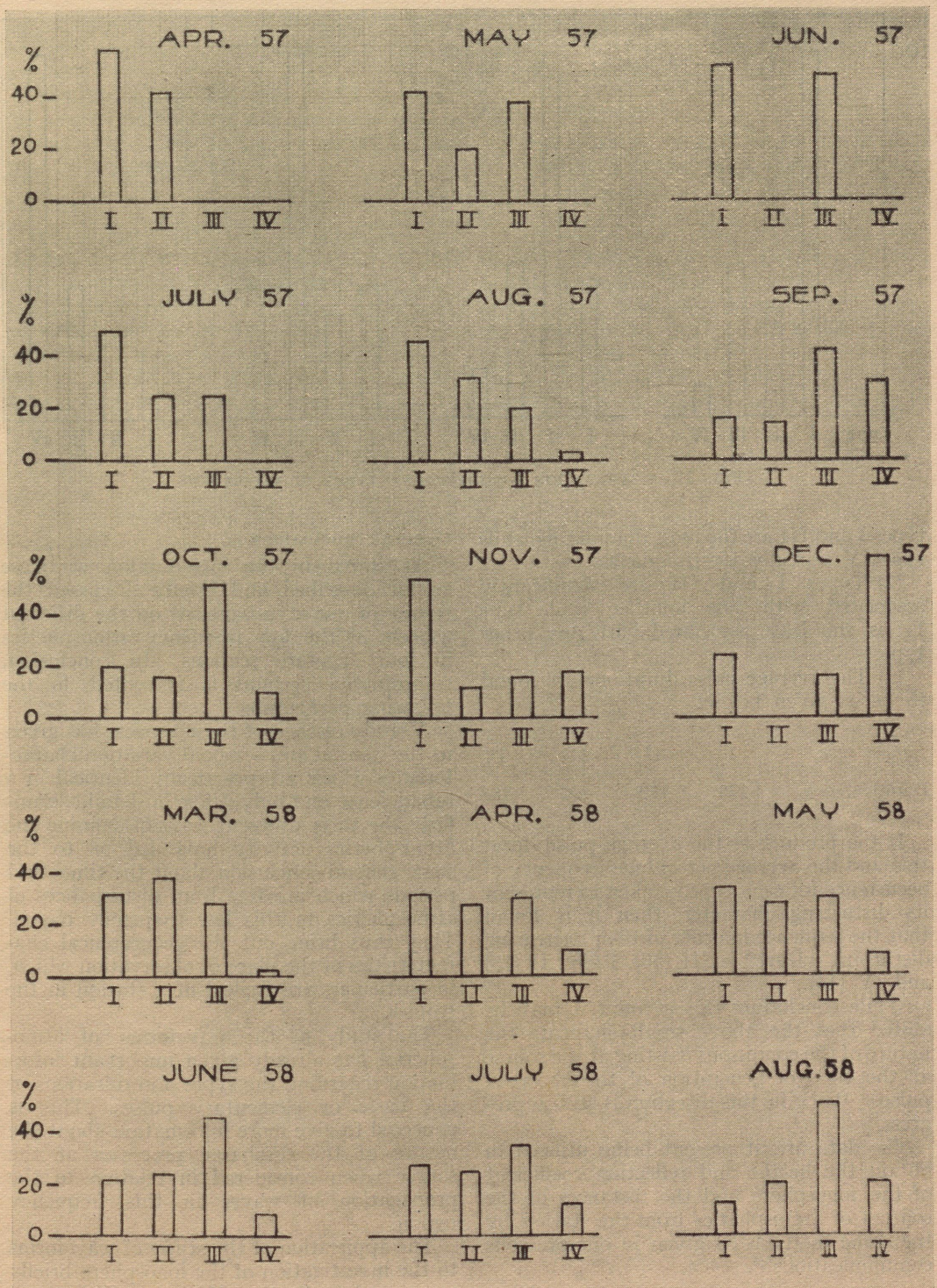

FIG. 26 — MONTHLY PERCENTAGE FREQUENCY DISTRIBUTION OF THE DIFFERENT TYPES OF WAVEFORMS OF ATMOSPHERICS RECORDED AT POONA

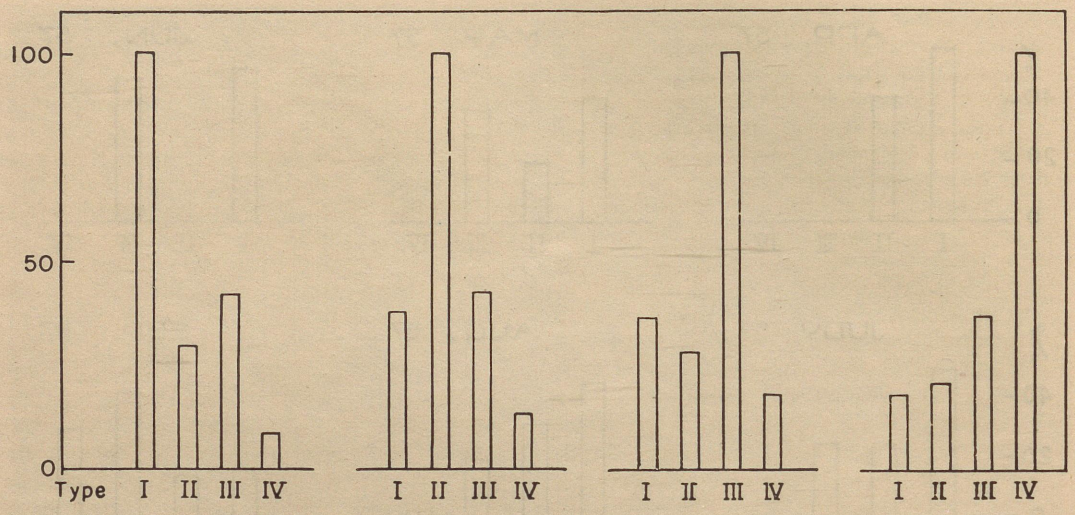

FIG. 27 — ASSOCIATION OF DIFFERENT TYPES OF WAVEFORMS

types I and III are the most dominating while type IV is really less frequent.

(2) Types I and III are significantly associated with one another while type IV is the least associated with any other type.

(3) The average pulse durations are found to be as given below:

Pulse type	I	II	III	IV
Duration, μsec.	126	130	192	188

If the product of the average pulse duration and the average percentage frequency of occurrence for each type is taken to represent its disturbing character, then it is found that the sequence in order of their decreasing disturbing nature* is III (40), I (28), II (18) and IV (14).

While concluding this account it may be stated that the above results indicate the nature of the conditions existing at the source at the time of generation of the observed pulse. Work in this direction is still in progress.

The data are at present being utilized to obtain the height and reflection coefficient of the ionosphere and the distances of the sources of atmospherics from the station by the same methods as given in our previous communications[5,6].

*The numbers in brackets indicate relative levels.

General conclusions

As stated in the introduction we have so far described and briefly discussed the results of our investigations on the different aspects of the low frequency atmospherics in four separate sections. In conclusion, co-ordinated account is presented in the following paragraphs.

A study of each of these aspects has given us the diurnal and seasonal variation characteristics which are practically identical in a broad sense and only differ in detail. Similarly the three different ways of defining the atmospherics activity have led us to the same general conclusion about the times and periods which are free from disturbances of atmospherics in this low frequency region. They thus bring out the geographical characteristics of the place of observation which, in particular, are typical of a station in the tropics.

The study of the waveforms of atmospherics has already given important information regarding the types and durations of the basic or elementary pulses. This is expected to give more information about the nature of the discharge processes at the source when considered in relation to the propagation of waves in this frequency region.

The application of the study of waveforms to the investigation of the ionosphere briefly mentioned in Section IV is no doubt very important but further work will be neces-

sary before it can be considered as a help to the ionospheric investigation as a routine measure.

We propose to go into greater details when the experimental work and our study of the propagation of low frequency waves in the tropics are completed.

Summary

Preliminary results of investigations on the low frequency atmospherics carried out as part of the IGY programme in the University Department of Physics at Poona are presented and briefly discussed.

Section I describes the results of observations on the rate of reception of atmospherics on four selected frequency bands (85, 125, 175 and 455 kc/s.) obtained during the period June 1957 to May 1958.

Section II(A) describes the results of recording of the intensity of atmospherics on 85 kc/s. band carried out during the period June 1957 to May 1958.

Section II(B) presents the results of simultaneous observations of intensity of atmospherics on the above four frequency bands obtained during the period July 1957 to June 1958.

Section III deals with the directional distribution of sources of atmospherics around the station for the period August 1957 to July 1958.

Section IV discusses the waveforms of atmospherics recorded at Poona during the period April 1957 to August 1958.

The results under each section are presented in the form of sample diagrams and tentative conclusions are drawn.

Acknowledgement

We are extremely grateful to the Council of Scientific & Industrial Research for sponsoring the scheme "On the Nature and Origin of Atmospherics", to the Poona University for instituting two special posts of IGY Assistants in this Department and to the Walchand College of Engineering for giving the necessary laboratory facilities at Sangli, which made these investigations possible. Our thanks are also due to Dr V. N. Athavale and Shri V. D. Pethe for their assistance and interest in this work.

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Atmospheric Electricity Observations in India during the IGY—Radiosonde Techniques for Measuring Potential Gradient & Conductivity

S. P. VENKITESHWARAN
Meteorological Office, Poona

THE meteorological programme of the International Geophysical Year (IGY) lays special emphasis on efforts being directed to low latitudes, much less being known in these areas than over the polar regions. The special committee of the IGY (CSAGI)* has been guided in its choice of problems by a desire to avoid dispersal of efforts and means, and it has, therefore, omitted local or regional questions of limited interest. They have recommended that the IGY investigations should be devoted to the large-scale synoptic and dynamic meteorology and physical meteorology. The problems suggested under physical meteorology are:

(i) Horizontal and vertical distribution of ozone, especially on each side of the sub-tropical jet stream.
(ii) Horizontal and vertical distribution of water vapour, especially at high levels.
(iii) Heat balance of the atmosphere, especially the radiation balance in relation to the general circulation.
(iv) Electric field in the atmosphere, on a planetary scale.

Regarding measurements of atmospheric electricity during the IGY, the CSAGI has recommended that participating countries (1) carry out soundings by radiosondes or aircraft, of the electric potential gradient and the conductivity of the air, at least during the World Days, at the largest possible number of stations and to compare the results of such soundings one with another; and (2) carry out surface measurements of the potential gradient and conductivity of the air at places not disturbed by accidental or local effects, compare such measurements one with another and compare them with data from soundings of the electric field.

*In French, AGI is l'Année Géophysique Internationale — hence the Special Committee is known by the letters CSAGI, the initials of its title in French. This committee is responsible for organizing the work of the IGY and for co-ordinating the projects of participating countries and the programmes drafted by international bodies.

Association between atmospheric electricity and meteorology

The subject of atmospheric electricity is concerned with (1) the nature and origin of the potential gradient and the equivalent topic, the origin and maintenance of the earth's negative charge; (2) the nature and origin of the atmospheric conductivity; and (3) the origin and nature of precipitation phenomena.

It is well known that the electrical properties of the atmosphere and every phase of weather process is closely interrelated. Precipitations, inversions, fogs, fronts, air masses, etc., are associated with atmospheric electric reactions. Atmospheric electrical processes, like meteorology, also show both global and local interactions, and a stage has been reached when extensive observations with regard to several elements at different places in a synoptic manner are necessary, as in meteorology, to get more insight into the atmospheric electrical processes. It is now accepted that the roots of the atmospheric electrical manifestations lie entirely in the field of meteorology. Both the regulating mechanisms in the electric field, those that vary from place to place and those that are the same over the globe, are of meteorological nature. This association between atmospheric electricity and meteorology opens the door to new methods and ideas in the work on these phenomena.

In a programme for studying atmospheric electricity, the aerological atmospheric electric

measurements will play an important part, because these will yield much better results than the measurements close to the ground, as they are free from local influences and thus permit easy comparison. Further, they offer the advantage that even in disturbed weather, when the results of ground measurements for large areas are not comparable, aerological measurements above the cloud level remain in general comparable for studying the conditions over large areas.

Techniques for measuring potential gradient and conductivity in the upper air

Measurements of the electrical potential gradient and conductivity of the air have been made near the ground for a long time in a few stations in the world and even over the sea. These observations were not feasible in the upper air for want of a suitable technique. However, with the development of the radiosonde for the measurement of pressure, temperature and humidity in the upper air, methods employing various principles were devised and used in different countries and it has been found that some of these techniques could be easily adapted for the measurement of the electrical properties of the air also. Idrac[1], Lejay[2] and Koenigsfeld[3] are among the earliest workers in this line. Venkiteshwaran *et al.*[4-6] adapted Koenigsfeld's principle of the valve electrometer to the U.S. type of radiosonde AN/AMQI, first for the measurement of the electrical potential gradient and later, for the first time, for the measurement of conductivity in the upper air. Since then, techniques have been developed by Rein *et al.*[7] in U.S.A., Lugeon[8] in Switzerland and Hatakeyama[9] in Japan.

This paper describes the techniques developed in India for the measurement of the electrical potential gradient and conductivity in the upper air by radiosondes and some of the results of the observations made in Poona.

Technique for measuring potential gradient

Radiosonde equipment of the type used by the U.S. Army during World War II was available at the Meteorological Office at Poona. The meteorological elements are measured with this type of instrument from the audio frequency modulation of a carrier wave on about 4 metres by varying the resistance in the meteorological control circuit. It was possible to adapt this type of radiosonde equipment to the valve electrometer devised by Koenigsfeld[3] to measure the electrical potential gradient of the atmosphere. In adapting this radiosonde for use with the valve electrometer, the resistances for measuring temperature and humidity were removed and replaced by the valve electrometer in the grid circuit of the modulator. The variations of the grid current of the electrometer which depend upon the negative bias on the plate change the audio frequency of the modulator[4] (Fig. 1). To measure both positive and negative potential gradients the valve electrometer is given a known negative bias voltage. The measurement of the negative potential gradient will be limited by the bias voltage. This equipment is used independently with any other radiosonde to obtain data relating to pressure, temperature and humidity. The F-type radiometeorograph was used at Poona for this purpose. In case no records are necessary and visual observations are enough, it will be feasible to rig up easily the necessary ground equipment for this purpose. However, at Poona, the ground equipment used by the U.S. Army had a recorder incorporated in it.

For the successful operation of the above technique, it is essential to have suitable collectors. These are now made in a simple manner by coating thin silver plates of size about 1×1 cm. with polonium by dipping them in a solution of radium D which lasts for a long time and is a source for polonium. However, one has to take some care

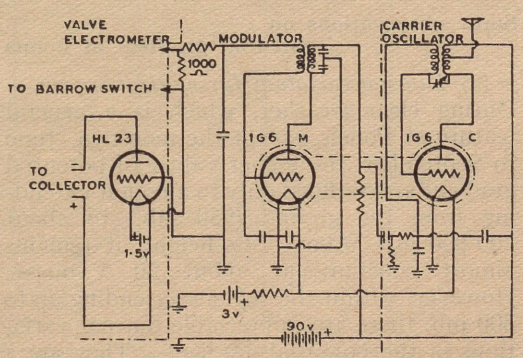

FIG. 1 — CIRCUIT DIAGRAM OF THE SET-UP FOR MEASURING THE ELECTRICAL POTENTIAL GRADIENT OF THE ATMOSPHERE

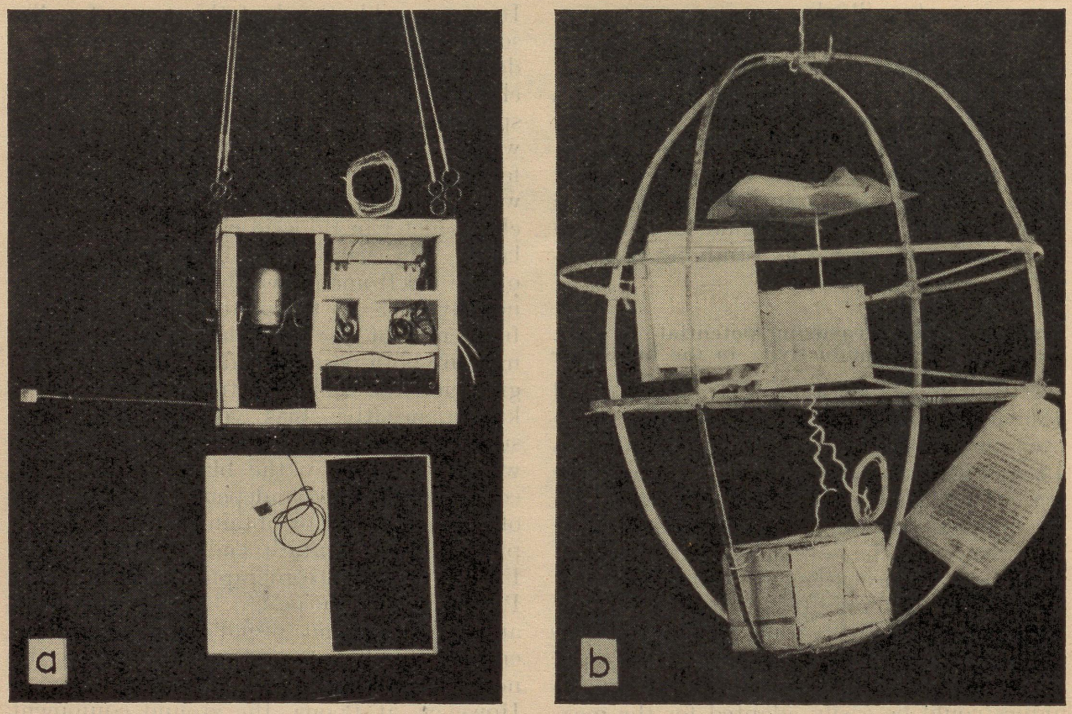

FIG. 2 — EQUIPMENT FOR MEASURING THE POTENTIAL GRADIENT OF THE ATMOSPHERE

in handling the solution and to see that it does not get scattered about.

Fig. 2 shows the arrangement for measuring potential gradient. It consists of two units—one consists of polonium collector with valve electrometer and its audio frequency modulated transmitter, and the second unit is the F-type radiosonde of the India Meteorological Department[10].

Some observations on potential gradient at Poona

(a) *Diurnal variation during clear season* — During clear weather, which is a general feature at Poona, except the monsoon, June to September, the higher values of potential gradient are confined only to a region extending from the ground (950 mb.) to about 700-600 mb. Above this height, it remains almost constant at about 20 V./metre. However, within the regions extending up to 600 mb. there are appreciable diurnal variations in the potential gradient. They are a minimum and almost constant during the hot parts of the day, and higher at other times. Figs. 3-5 show the type of variation of potential gradient and temperature at Poona during the clear winter season.

This appreciable diurnal variation is obviously due to local changes in the space charge and the conductivity of the air resulting from the changes in the meteorological factors. During the winter season, strong ground inversions prevail, particularly during the night and in the early morning, and, as a result, there is an increase in the condensation nuclei in the lower layers of the atmosphere, resulting in mist or even fog, which decreases the conductivity of the air by raising the proportion of slow ions, causing a corresponding increase in the potential gradient.

During the night and early morning there is a very sharp increase in the potential gradient from 20 to 30 V./metre near the ground to approximately 200-300 V./metre, at a height of only 500 metres above ground. This seems to be an important feature and it shows that the observations of potential gradient recorded on the ground do not represent the conditions in the free air even at such low heights.

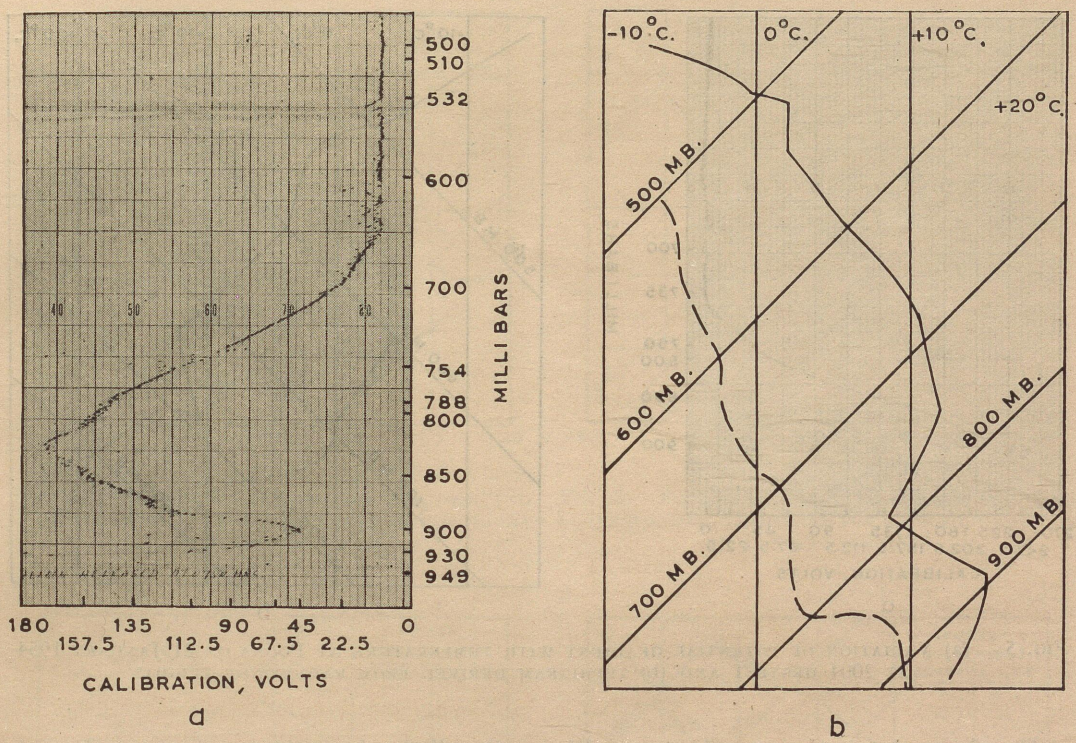

FIG. 3 — (a) VARIATION OF POTENTIAL GRADIENT WITH TEMPERATURE AT POONA ON 21 JANUARY 1954 AT 0750 HRS IST AND (b) TEPHIGRAM DERIVED FROM RADIOSONDE FLIGHTS

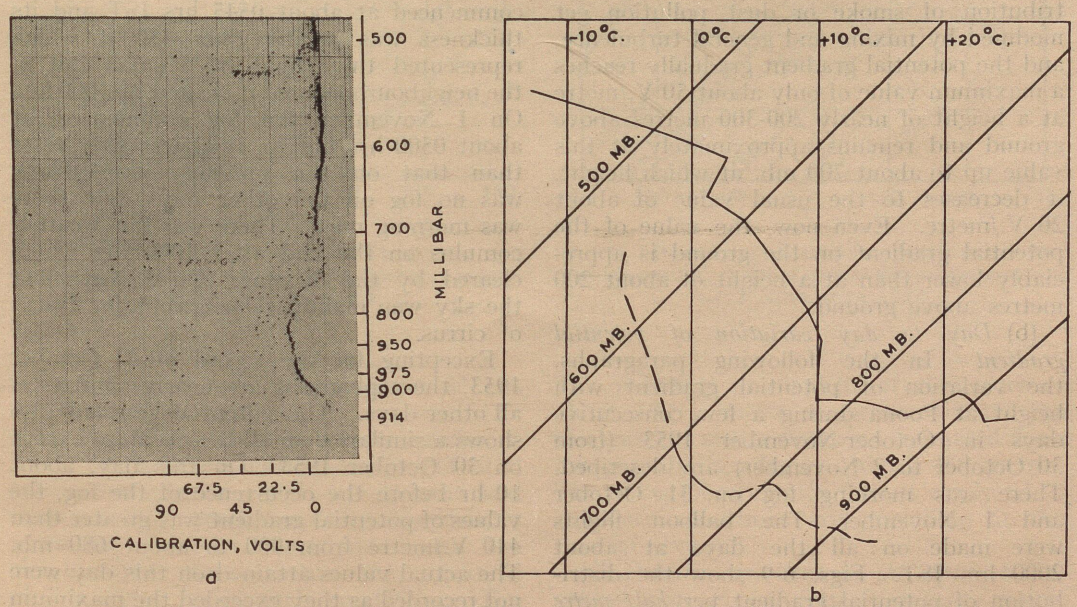

FIG. 4 — (a) VARIATION OF POTENTIAL GRADIENT WITH TEMPERATURE AT POONA ON 21 JANUARY 1954 AT 1453 HRS IST AND (b) TEPHIGRAM DERIVED FROM RADIOSONDE FLIGHTS

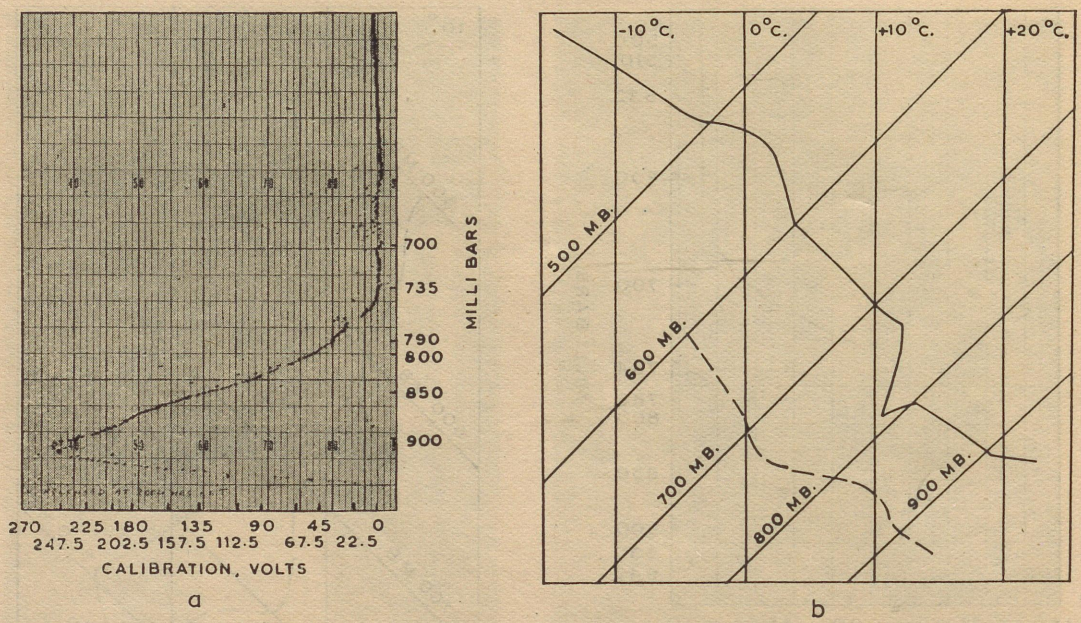

FIG. 5 — (a) VARIATION OF POTENTIAL GRADIENT WITH TEMPERATURE AT POONA ON 21 JANUARY 1954 AT 2004 HRS IST AND (b) TEPHIGRAM DERIVED FROM RADIOSONDE FLIGHTS

The above observations are, however, different in the afternoon or during maximum temperature epoch. Due to the ground heating and convection, the amount and distribution of smoke or dust pollution get modified by mixing and general turbulence, and the potential gradient gradually reaches a maximum value of only about 50 V./metre at a height of nearly 200-300 metres above ground and remains approximately at this value up to about 700 mb. at which height, it decreases to the usual value of about 20 V./metre. Even now, the value of the potential gradient on the ground is appreciably lower than at a height of about 200 metres above ground.

(b) *Day to day variation of potential gradient* — In the following paragraphs, the variation of potential gradient with height at Poona during a few consecutive days in October-November 1953 (from 30 October to 2 November) are described. There was morning fog on 31 October and 1 November. The balloon flights were made on all the days at about 2000 hrs IST. Figs. 6-9 show the distribution of potential gradient per *half metre* and the corresponding tephigram from the radiosonde flights.

On all the days, the weather was clear at the time of the balloon flight. There was, however, fog on the morning of 31 October and 1 November. On 31 October the fog commenced at about 0545 hrs IST and its thickness was greater than 350 ft which represented the height of a small hill in the neighbourhood and it cleared by 1000 hrs. On 1 November the fog commenced at about 0500 hrs but its thickness was lesser than that on the previous day. There was no fog on the other days, but there was morning mist. There was fair weather comulus on the 2nd after 1000 hrs which cleared by the evening. On 3 November the sky was mainly clear except for traces of cirrus.

Excepting for the record of 31 October 1953, the tephigrams are nearly similar on all other days. The potential gradient also shows a similarity on all the evenings except on 30 October 1953. On this day, about 10 hr before the occurrence of the fog, the values of potential gradient was greater than 440 V./metre from 900 to about 680 mb. The actual values attained on this day were not recorded as they exceeded the maximum of the scale. The occurrence of such high values of potential gradient on this day such

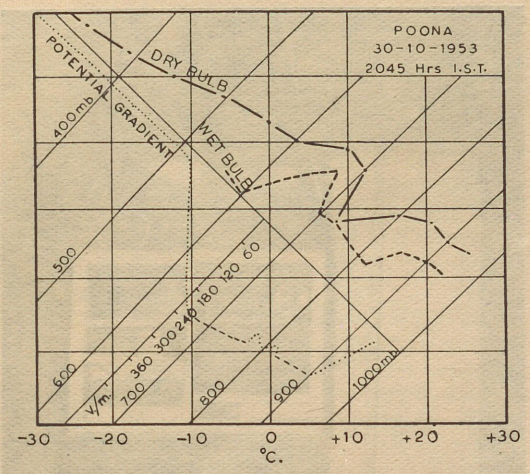

FIG. 6 — POTENTIAL GRADIENT DISTRIBUTION AND CORRESPONDING TEPHIGRAM FOR RADIOSONDE FLIGHT ON 30 OCTOBER 1953

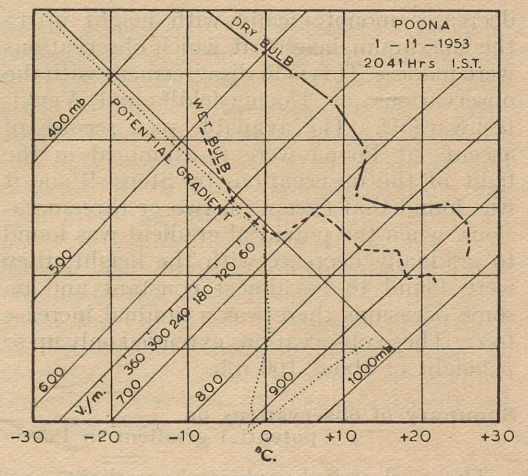

FIG. 8 — POTENTIAL GRADIENT DISTRIBUTION AND CORRESPONDING TEPHIGRAM FOR RADIOSONDE FLIGHT ON 1 NOVEMBER 1953

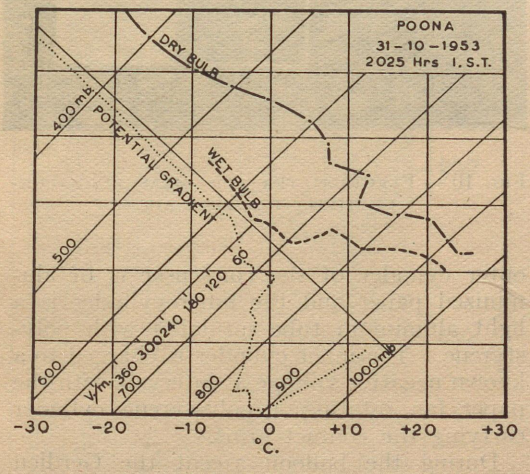

FIG. 7 — POTENTIAL GRADIENT DISTRIBUTION AND CORRESPONDING TEPHIGRAM FOR RADIOSONDE FLIGHT ON 31 OCTOBER 1953

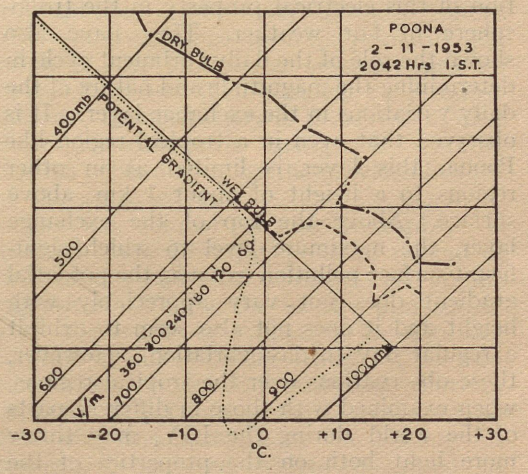

FIG. 9 — POTENTIAL GRADIENT DISTRIBUTION AND CORRESPONDING TEPHIGRAM FOR RADIOSONDE FLIGHT ON 2 NOVEMBER 1953

a long time before the formation of the fog is significant.

(c) *Potential gradient in cloudy weather* — There are large fluctuations in the potential gradient whenever clouds are present and they generally increase and decrease sharply when the balloon enters and leaves the clouds. One can estimate the thickness of the cloud under such conditions. The potential gradient in the low and medium clouds is of the order of about 500 V./metre. The potential gradient is of the order of about 100 V./metre in cirrus clouds. The thickness of cirrus clouds as estimated from the potential gradient is about 450 metres. The above observations do not apply when thundery conditions are prevailing at the time of ascent.

(d) *Potential gradient in the upper troposphere over Poona* — In a recent paper, Stergis *et al.*[11] have shown that above the exchange layer, the potential gradient

decreases monotonically with height up to the maximum height at which observations were made. This is in disagreement with the observations of Koenigsfeld[12] and Venkiteshwaran[13]. The available past records of ascents at Poona were re-examined in the light of the observations by Stergis[11] and it was found that except on two or three occasions, when the potential gradient was found to gradually decrease with the height, they were found to be almost constant and on some occasions there was a gradual increase too. These observations extended only up to a height of about 100 mb.

Summary of observations on potential gradient in Poona

These electrical potential gradient and meteorological measurements have thrown light on the altitude range to which local disturbances extend, the nature of atmospheric inhomogeneities and the diurnal variation of this electrical property in the troposphere in fair weather. They have also shown the role of the daily turbulent cycle in determining the magnitude and nature of the daily variations in the exchange layer. It is observed that even in a tropical region like Poona, this layer is limited as in other regions to a height of about 3 km. above surface. Above the top of the exchange layer, the maximum level to which significant surface pollution extends, the potential gradient does not vary appreciably with height and it does not also seem to exhibit a regular day to day variation. However, these observations over the tropical regions, when examined with those in different parts of the world during the IGY, may throw more light both on the properties of the exchange layer and on the universal aspect of atmospheric electricity. It is also being seriously considered by various workers in this field to arrange for soundings not only on the World Days, but also on consecutive days for a definite period during the IGY, at synoptic hours of 0400 GMT and 2000 GMT. These ascents would correspond to the minimum and maximum global time period of thunderstorm activity.

Measurement of conductivity by radiosonde

The valve electrometer of Koenigsfeld[3] was also adapted for measuring conductivity in the upper air[5]. In this case, the Gerdien condenser has been used (Fig. 10). The

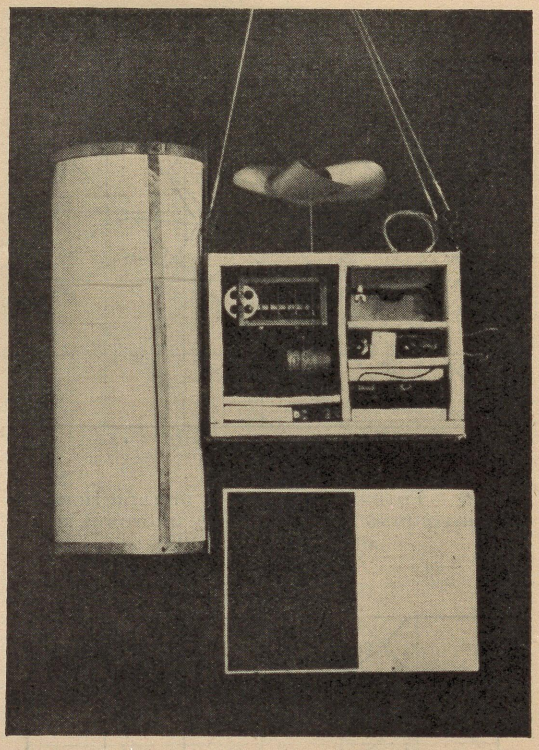

FIG. 10 — ELECTROMETER FOR MEASURING CONDUCTIVITY IN UPPER AIR

outer cylinder of the condenser is of aluminized paper and the inner cylinder is a light aluminium tube insulated with polystyrene. The inner cylinder is charged to a known negative voltage at intervals with the paper fan rotating a polystyrene cylinder carrying the contact arms.

During the balloon ascent the Gerdien condenser hangs vertically and is fully exposed to the vertical air current. The ground equipment for the reading of the potential gradient is used for measuring the conductivity also and it records the potential to which the central cylinder is charged and its variations due to leakage. One can calculate the conductivity of the air at different levels from the charging potential and the potential after discharge for a known interval of time. This technique refers only to the measurement of the conductivity due to the positive ions in the upper air. The method of adapting it to measure the conductivity due to the negative ions is still under examination.

From the soundings made so far, it is observed that though the general shape of the curve showing the variation of conductivity with height follows an exponential form, there are appreciable day to day variations, as in the case of the potential gradient, particularly in the exchange layer near the ground extending up to about 600 mb. Even above this height there are occasions when small variations in the sign of the conductivity are observed. Fig. 11 shows the record of a flight on 3 February 1958 in which such a fluctuation is observed in the region of the 250 mb. level (temperature, —40·6°C.). There were cirrus (5/8) at the time of ascent, and presumably the fluctuation is associated with this cloud. The cloud is probably charged with ions of opposite sign which strike the central electrode which tends to charge it with opposite sign. This observation supports those made by Lugeon[8].

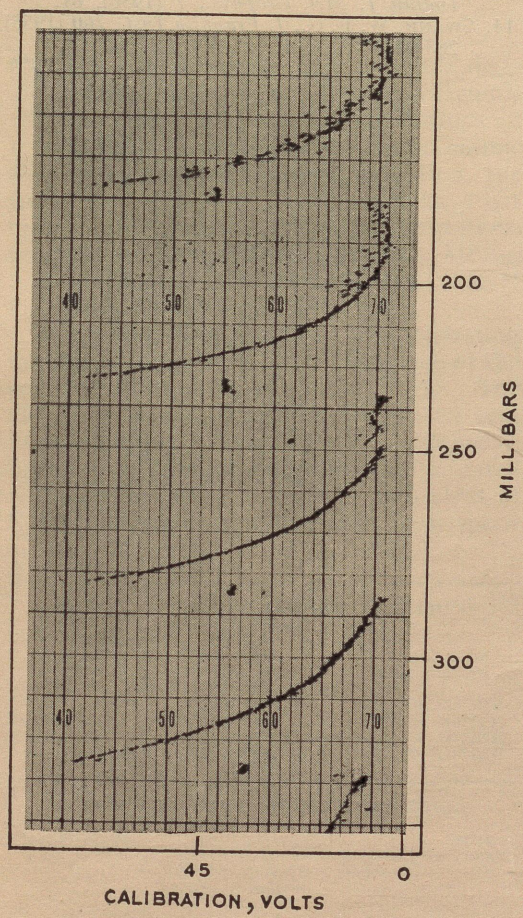

FIG. 11 — TYPICAL RECORD OF CONDUCTIVITY ASCENT AT POONA ON 3 FEBRUARY 1958 WHEN FLUCTUATION WAS OBSERVED IN THE REGION OF 250 MB. LEVEL

Observations of potential gradient and conductivity by the radiosonde using the techniques described in this paper are being made at Poona and Delhi during the IGY. Surface measurements of potential gradient are being made at Poona, Bombay, New Delhi and Calcutta. It is hoped that these observations will throw light on this subject of atmospheric electricity which is engaging increased attention of many scientists all over the world.

Atmospheric contamination by atomic explosions

The subject of atmospheric electricity is not only of interest to the meteorologists but also to the nuclear physicists since the atmospheric conductivity in the regions above the exchange layer is primarily the result of the production of small ions by cosmic rays and their removal by recombination. Detailed study in these regions may show non-systematic changes in varying degrees depending upon the previous history of the air mass, etc.

The ion content of the atmosphere is affected appreciably by the large amount of radioactive material released in atomic explosions. The whole of the atmosphere over the earth is estimated to normally contain about 6×10^7 curies of radium emanation. It is also estimated that an explosion of a bomb of the Hiroshima type puts into the atmosphere an amount of radioactive material which, measured in curies, is about three times this amount 24 hr after the explosion[14]. It is about one-fifth of this amount one week after the explosion, and 1/600th about a year after the explosion.

All this radioactive material is not immediately distributed uniformly, but it may go along in a concentrated form following the direction of the air currents. Thus even after travelling many miles, one might expect to find them fairly concentrated, and it will constitute a hazard, and particularly so if it is in the region of precipitation. If there is no precipitation, the rays from the radioactive material will be absorbed to a large extent before reaching the earth. There is,

however, the hazard of radioactive material getting deposited on the ground in due course.

The measurements of potential gradient and conductivity by radiosonde have been helpful to locate regions of artificial radioactivity in the atmosphere attributed to atomic explosions.

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Geomagnetic Work at Alibag, Annamalainagar & Trivandrum during the IGY

S. L. MALURKAR

Alibag & Colaba Observatories, India Meteorological Department

THE characteristics of the earth's magnetic field near the geomagnetic equator have special significance in several fields, especially in studies on cosmic rays and ionosphere. For this reason, the India Meteorological Department have set up a close network of geomagnetic stations near the geomagnetic equator, at Alibag, Annamalainagar and Trivandrum (Table 1) for operation during the IGY.

The station at Alibag had been operating uninterruptedly since 1904, and is one of the primary observatories of the world. The observatory at Kodaikanal commenced geomagnetic observations in 1949. Annamalainagar and Trivandrum (which are situated within a few degrees and on both sides of the geomagnetic equator) have been specifically established for the IGY, for intensive observations of the equatorial geomagnetic field. The ready co-operation extended by Travancore and Annamalainagar Universities is gratefully acknowledged.

TABLE 1 — IGY GEOMAGNETIC STATIONS IN INDIA

STATION	GEOGRAPHIC CO-ORDINATES	GEOMAGNETIC CO-ORDINATES
Alibag	18°38′N 72°52′E	09°38′N 143°53′E
Trivandrum	08°29′N 76°57′E	00°54′S 146°11′E
Kodaikanal	10°14′N 77°29′E	00°44′N 147°29′E
Annamalainagar	11°24′N 79°42′E	01°28′N 149°42′E

TABLE 2 — DATA SUPPLIED TO WDC

MAGNETOGRAMS	DATA			STORM ACCOUNT
	Hourly values	K and C indices	Index	
A	A	A	A	A
T	T	—	—	T
AN	AN	—	—	AN

Stations: A = Alibag; T = Trivandrum; AN = Annamalainagar.

Alibag Magnetic Observatory

The Magnetic Observatory at Alibag (29 km. SSE of Bombay) is located on the foreshore of the mainland and with few electric installations in the neighbourhood. The observation buildings have been constructed with non-magnetic materials.

Instrumental equipment and system of observations: (A) *Absolute instruments* — Absolute observation of the horizontal component of the earth's magnetic field (H) and declination (D) are made with the Kew pattern magnetometer as modified by the Survey of India. Absolute value of H is determined by the instrument at about 0500 hrs GMT every Wednesday and declination at about local noon every Thursday. Once every three months on Fridays, measurements are made using the new pair of magnets. Another instrument by Dover Charlton obtained in 1898 with its vibration magnet of nearly constant moment is used once in four weeks. Earth inductor by Schulze of Potsdam with galvanometer by Plath obtained in 1908 and another earth inductor by Otto Toepfer with galvanometer by the same maker obtained in 1914 are used for determination of the angle of inclination (I) regularly on alternate days, both being used on Saturdays for intercomparison purposes.

Additional instruments — A set of eye-reading instruments, Kew H, V and D magnetometers, which had been in use at the Colaba Observatory and installed at Alibag right from the beginning, is read five times a day. These observations serve as an indication of the magnetic character of the day and as check readings.

One set of quartz horizontal magnetometer (QHM) and balance magnetometric zero (BMZ) by La Cour received recently is kept periodically tested for issuing them to mobile magnetic observation parties and when required for intercomparison of the magnetic instruments at the field magnetic observatories.

A magnetic standard theodolite (Askania) is being installed and trial observations are being made. Two sets of Askania magnetic field balances for V and H (Gf-6 type) have been acquired for survey and other special work when required.

(B) *Variographs*—A complete set of Watson magnetographs — horizontal force (H), declination (D) and vertical force (V) — made by the Cambridge Scientific Instrument Co., has been in use since 1904. These variographs have a normal paper speed of 15 mm./hr. By change of gears, the paper speed can be changed to 180 mm./hr. The quick-run gear has been used for H and V variographs on selected occasions since 1949 and at present is being used also on all World Days and during Special World Intervals.

Another complete set of La Cour variographs is also used for continuous photo-registration of H, V and D and serves as a check on the readings of the Watson instruments and as standby instruments in case of breakdown of Watson instruments. H and V instruments have a common recorder and are in use since 1946. Since 1937 a declination magnetograph by La Cour with fourfold sensitivity than the corresponding Watson instrument installed on an isolated pillar a few feet away in the magnetograph room was in regular operation and its records are being tabulated since 1949. The La Cour H and V variographs running at the normal speed, paper speed 15 mm./hr can also be put to medium quick-run with speed 60 mm./hr and have been so used on special occasions since 1957.

Another set of La Cour magnetographs with quick-run recording arrangements, time scale 180 mm./hr and common recorder for all the three elements H, V and D is being used at Colaba pending final installation at Alibag.

It is to be noted that the main instruments for absolute and variation measurements have been in use at Alibag since the starting of the observatory and under identical conditions of exposure, etc., thus maintaining a continuity throughout the long series of the data recorded.

Once a fortnight the scale values of the magnetographs are determined photographically by effecting deflections with a magnet kept at definite distances.

A complete set of meteorological instruments together with some self-recording instruments are also maintained at the observatory and surface meteorological observations taken once a day.

Reduction of observations and supply of data — Scale values of the magnetographs and the base-line values of the H and V magnetograms are adopted, after taking running averages of several successive experimental values determined, to smooth out fluctuations.

The system of tabulation had undergone a few changes before but since 1924 averages of 60 min. centred at the full hours of GMT are being tabulated. The diurnal variations of H, V and D during each month for the five International Quiet (I.Q.) and Disturbed (I.D.) days notified by the International Association of Terrestrial Magnetism and Electricity of the International Union of Geodesy and Geophysics are calculated together with the correction ' allowance for means ' and ' non-cyclic changes ', etc.

The first four fourier coefficients and the phase angles are determined from the diurnal variation of H and V for the I.Q. and I.D. days, both monthly and annually.

The three-hourly international indices of geomagnetic activity (K indices varying from 0 to 9) and daily magnetic character figures according to (a) the old Bombay method of classification by assigning a letter, e.g. C, S, M, G, VG, etc., and (b) the international form of assigning figures, e.g. 0, 1, 2, are also tabulated.

The observations at Alibag Magnetic Observatory were intensified during the IGY period and arrangements were made to ensure a high standard of work. Besides the normal routine work, quick-run records of H and V on Watson magnetographs are being obtained on all World Days and during Special World

Intervals, as mentioned earlier. The La Cour H and V magnetographs are put on quick-run for certain other studies. Arrangements are also made to keep a watch at Alibag for the visual observations of aurorae, the watch being almost continuous during the Special World Intervals.

Field Magnetic Observatories during the IGY period

As part of the IGY programme two Field Magnetic Observatories were started at Trivandrum and Annamalainagar.

Field magnetic observatory buildings — The observatory structures at the Field Observatories consist of two units each. The variation room houses the magnetographs and the absolute room which houses the eye-reading instruments is used for absolute observations of H, V and D.

The variation room is of special construction in that it is so designed as to make the daily temperature fluctuations as small as possible. This is ensured by (1) providing a cubicle inside the room with a free passage all round and (2) providing a ceiling below the tiles and also a false ceiling between it and the top of the cubicle to minimize the effects due to heated tiles from above. The room has two air ventilators on each of the opposite walls, covered with strong and thick wire gauze of copper, so designed as to prevent rain water or dust entering the room. The room has two cement concrete pillars countersunk firmly into the ground, the tops having a level and smooth finish.

The room for absolute observations is constructed sufficiently away from the variation room. The room is well-lighted and is sufficiently big to make observations of H, V and D without hindrance.

In the construction of both the absolute and variation rooms, all materials used were tested to be free from magnetic impurities. The hooks, hinges, etc., are of copper or brass or other non-magnetic material. The non-magnetic materials are protected against corrosion by painting them with good non-magnetic resistant paint.

Instruments and system of observations at the Field Magnetic Observatories — A set of Askania earth magnetic variometer station after Eschenhagen for continuous photo-registration of H, V and D with a common recorder is used at each of the stations. The variometers are provided with Helmholtz coils and accessories required for scale value determination. The scale value observations are carried out twice a month.

For base-line determination absolute measurements of H, V and D are taken with a set of La Cour QHM and BMZ instruments. Absolute measurements of H and V are done thrice daily and that for D once a week. For observations with QHM all the three tubes and for observations with BMZ all the posible combinations of supplementary magnets are used. These observations also serve as check readings to ensure that loss of records due to fluctuations is minimized. Scale values and base-line values are adopted from running means of several successive determinations to smooth out the fluctuations. Hourly values of H, V and D are computed as for Alibag.

Other equipment like chronometers, radio receivers for reception of time signals to rate the chronometers and receiving IGY 'Alert' and 'SWI' warning messages are also provided at each of the field stations.

IGY work at Colaba

The magnetic data recorded at the above three observatories are analysed at Colaba. The observatory is also participating in the meteorological programme for the IGY including continuous photographic registration of atmospheric potential gradient at ground surface and evaporation of water.

Supply of IGY geomagnetic data — The data processed are supplied to World Data Centres and the National Archives of India (Table 2). Besides, the provisional hourly values of H at the above three stations are being supplied on request to Prof. J. Bartels in connection with the study of the earth ring currents. Information regarding magnetic conditions is also being supplied to All India Radio Research Station, New Delhi, when storms are recorded and occasionally to others interested as and when requested.

Atomic Nitrogen in the Thermosphere

M. NICOLET
Secretary-General of the Special Committee for the IGY, Brussels

IN the programme of the International Geophysical Year much emphasis was placed on the advantages of the world-wide dissemination of plans and observational data. An essential task of the Special Committee for the International Geophysical Year has been and is still to integrate the work done by the participating committees in the IGY to promote research by scientific organizations or by individual scientists.

It is important that scientific ideas can come from individuals as well as from large groups dealing with IGY results. I would like to call attention to the fact that an individual research can lead to progress in a general effort by taking an example.

It is not yet known whether atomic nitrogen is an important constituent of the thermosphere and, therefore, if it must be introduced in the analysis of data obtained from upper atmosphere measurements.

Atomic nitrogen cannot result from a direct dissociation of molecular nitrogen (above 100 km.) but from ionization and subsequent dissociation recombination.

The process is, therefore, as follows:

$$N_2 + h\nu \longrightarrow N_2^+ + e \quad \ldots\ldots\ldots (1)$$
$$N_2^+ + e \longrightarrow N + N \quad \ldots\ldots\ldots (2)$$

Atomic nitrogen reacts with molecular oxygen

$$N + O_2 \longrightarrow NO + O \quad \ldots\ldots\ldots (3)$$

and leads to nitric oxide. Since the activation energy of reaction (3) is of the order of 6 k.cal., atomic nitrogen is transformed into nitric oxide in the thermosphere where the temperature is high. However, the reaction between nitric oxide and atomic nitrogen is very rapid since the activation energy is certainly less than 1 k./cal.

Thus

$$NO + N \longrightarrow N_2 + O \quad \ldots\ldots\ldots (4)$$

leads to a simultaneous destruction of the new constituents.

Although the concentration of atomic nitrogen depends primarily on the solar energy available for the ionization of molecular nitrogen, the concentration of nitric oxide is only related to the ratio of reactions (3) and (4) depending on molecular oxygen concentration at a given temperature. Therefore, atomic nitrogen will be subject to variations following solar activity and will remain a minor constituent according to the ratio of processes (1) and (3). On the other hand, nitric oxide will be a small fraction of the concentration of molecular oxygen.

It can be added that the origin of nitric oxide ions (above 100 km.) does not come from a direct ionization of the neutral molecule, but from an ion interchange according to the following process:

$$O^+ + N_2 \longrightarrow NO^+ + N \quad \ldots\ldots (5)$$

competing with

$$O^+ + O_2 \longrightarrow O_2^+ + O \quad \ldots\ldots (6)$$

In order to achieve the work of the International Geophysical Year there is no doubt that all individual talents should be used. In this way the tremendous effort already made by the participating committees of the IGY and their observers will lead to an integration of all geophysicists towards the same goal.

Ionospheric Disturbances at Low Latitudes

A. P. MITRA

Radio Research Committee, National Physical Laboratory, New Delhi

A LARGE number of studies have been carried out on the ionospheric changes associated with magnetic disturbances. These studies, however, refer mostly to high and middle latitudes. For low latitudes, the studies have not been quite so comprehensive.

India has for some time been running a number of ionospheric stations in the geographical zone 28°35′N to 8°25′N latitudes and with magnetic dips ranging from 42·44°N to 0°. They, therefore, offer great scope for the examination of characteristics of the ionospheric storms at low latitudes.

In this paper are presented a few of the results of such analysis.

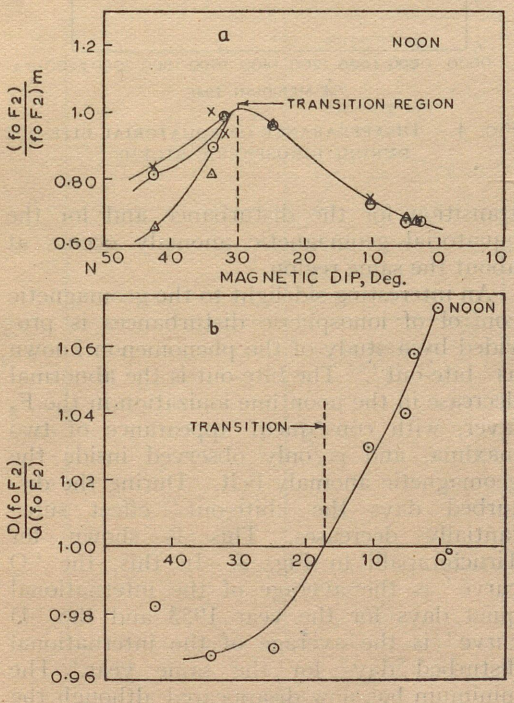

FIG. 1 — GEOMAGNETIC ANOMALY DURING (a) NORMAL AND (b) STORM CONDITIONS

Variations in the F_2 layer

It has now been established that while there is a depression in f_oF_2 at high latitudes at times of magnetic disturbances, at low latitudes there is an increase of f_oF_2 during these times. Appleton and Piggot[1] have shown that the quantity $D(f_oF_2)/Q(f_oF_2)$, when plotted against geomagnetic latitude, shows a systematic variation with this latitude: it is less than unity in the high latitudes in both hemispheres, but is greater than unity over a belt centred on the magnetic equator. They also showed that this belt is approximately the same as that of the F_2 layer geomagnetic anomaly, with some minor differences. Firstly, the former belt is a little wider than the latter. Secondly, the former appears to extend into slightly higher latitudes in the southern hemisphere.

The Indian stations, ranging from 18·75°N geomagnetic latitude to 0·9°S, form the major part of the northern side of this belt, and can, therefore, provide a more detailed picture of the belt. The results of analysis are shown in Fig. 1(b) in which $D(f_oF_2)/Q(f_oF_2)$ has been plotted against magnetic dip. The geographical and geomagnetic coordinates of the stations included in this analysis are given in Table 1.

These results appear to indicate a somewhat narrower belt in the northern hemisphere than indicated by Appleton and

TABLE 1 — LOCATION OF THE STATIONS

STATION	LATITUDE	LONGITUDE	LATITUDE (GEOMAGNETIC)	MAGNETIC DIP
Delhi	28°38′N	77°13′E	19°11′N	44·44°N
Ahmedabad	23°01′N	72°36′E	14°01′N	34·00°N
Haringhata (Calcutta)	22°58′N	88°34′E	12°15′N	32·00°N
Bombay	19°N	72°50′E	10°00′N	24·75°N
Madras	13°05′N	80°17′E	3°50′N	10·50°N
Tiruchirapalli	10°49′N	78°42′E	1°50′N	4·80°N
Kodaikanal	10°14′N	77°29′E	0°44′N	3·50°N
Trivandrum	8°29′N	76°57′E	0°54′S	0°

Piggot[1]. For comparison, the F_2 layer geomagnetic anomaly, as obtained from analysis of the Indian stations alone, is also shown [Fig. 1(a)] for noon conditions. This is shown separately for the summer, equinox and winter seasons, designated by J, E and D respectively. Instead of plotting f_oF_2, the ratio $(f_oF_2)/(f_oF_2)_m$ where $(f_oF_2)_m$ is the maximum value of f_oF_2 for the corresponding season, has been plotted. It will be observed that for all seasons the belt of low noontime values of f_oF_2 starts at a magnetic dip of 30°. This is somewhat different from the belt indicated in Fig. 1(b), which starts around 15°-20°. Thus, while Bombay (magnetic latitude 24·75°N) is within the belt of geomagnetic anomaly, it is outside the belt of stormtime enhancement.

However, we do not put much weight on this small difference. The transition region for the disturbance variation has been found to shift over a small zone of dip values. Examination of several selected ionospheric storms occurring in 1956 has shown that transition occurs sometimes at Calcutta and sometimes at Bombay, but rarely at Ahmedabad or Madras. In Fig. 2 are shown the results obtained from six selected ionospheric storms. It will be observed that in this case,

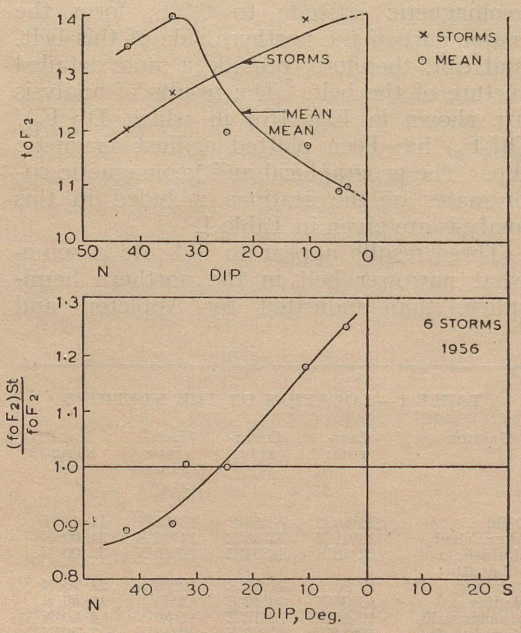

FIG. 2 — EFFECT OF IONOSPHERIC STORMS ON INDIAN STATIONS

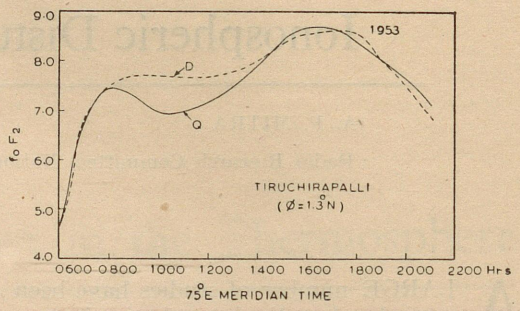

FIG. 3 — DECREASE OF 'BITE-OUT' EFFECT AT TIRUCHIRAPALLI DURING DISTURBED DAYS

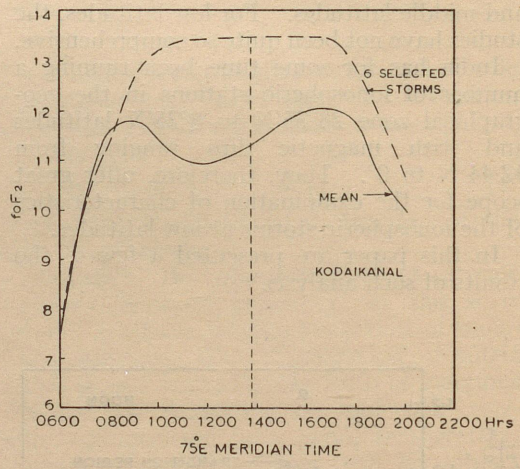

FIG. 4 — DISAPPEARANCE OF EQUATORIAL BITE-OUT DURING IONOSPHERIC STORMS

transition for the disturbance and for the equatorial geomagnetic anomaly occurs at about the same region.

An interesting sidelight to the geomagnetic control of ionospheric disturbances is provided by a study of the phenomenon known as 'bite-out'. The bite-out is the abnormal decrease in the noontime ionization in the F_2 layer, with consequent appearance of two maxima, and is only observed inside the geomagnetic anomaly belt. During the disturbed days the 'bite-out' effect substantially decreases. This is shown for Tiruchirapalli in Fig. 3. In this, the 'Q curve' is the average of the international quiet days for the year 1953 and the 'D curve' is the average of the international disturbed days for the same year. The minimum has now disappeared although the diurnal curve is still asymmetrical with the maximum in the afternoon.

The bite-out may completely disappear for several cases. In Fig. 4 are shown the resultant diurnal variations at Kodaikanal for six selected ionospheric storms of some severity. The bite-out here has completely disappeared. Another interesting feature of this variation is that it is now approximately symmetrical about 1345 hrs (75°E meridian time).

Variation in the E layer

In an attempt to explain the ionospheric variations associated with magnetic disturbances, Martyn[2] has suggested that such variations are due to the effect of an electrostatic field which is developed in the auroral zone, and spreads over the earth through the ionosphere in such a way as to produce a current responsible for the disturbance in daily magnetic variations. The interaction between these currents and the earth's magnetic field produces a drift in the ionization of the ionosphere. The observed ionospheric variations are the direct result of this drift.

If this hypothesis is correct, the resultant drift must substantially alter the ionospheric

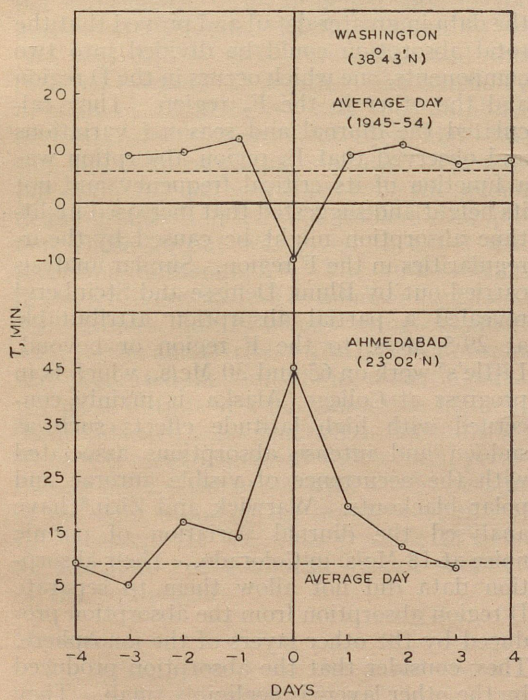

FIG. 5 — STORM DAY EFFECT ON THE SLUGGISHNESS OF THE E REGION

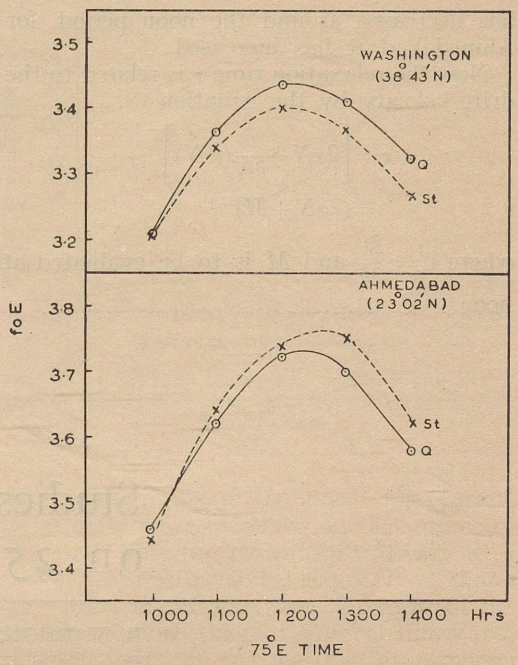

FIG. 6 — EFFECT OF STORMS ON f_0E AT HIGH AND LOW LATITUDES

'sluggishness' of the E region. To determine if such changes exist, the published values of f_0E for one medium latitude station and one low latitude station have been analysed by the superposed epoch method. The stations selected are Washington (38°43'N) and Ahmedabad (23°02'N). For Washington, this analysis covers all cases of severe and moderately severe magnetic storms occurring during 1946-54. For Ahmedabad the period covered is 1956-57. In both cases the zero day is taken to be the day of maximum (magnetic) activity following a sudden commencement, provided this covers the noon period of 09-15 local hours. Otherwise, the next day is taken as zero day. Diurnal variations for zero days and for days ± 1, ± 2, ± 3, etc., relative to the zero days, have been averaged and relaxation times obtained for these averages. The results are shown in Fig. 5. It will be observed that substantial changes occur in τ for both cases. However, the nature of the change is different in the two cases. For Washington τ drops from a value of 9 to —10 min. during storms. For Ahmedabad τ increases from 9 to 45 min. The corresponding changes in f_0E are shown in Fig. 6. While for Washington f_0E

has decreased around the noon period, for Ahmedabad it has increased.

Now the relaxation time τ is related to the drift velocity by the equation

$$\tau = \left[2\alpha N + \frac{\partial}{\partial N}(v'N)\right]^{-1}$$
$$= (2\alpha N + M)^{-1}$$

where $v' = \frac{\partial v}{\partial h}$ and M is to be evaluated at noon.

Thus it is concluded that the directions of flow of storm current are opposite at the two places. The change occurring in M, ΔM, must be comparable to M (and to $2\alpha N$) in both cases.

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Studies of Cosmic Radio Noise on 25 Mc/s. at Ahmedabad

R. V. BHONSLE & K. R. RAMANATHAN
Physical Research Laboratory, Ahmedabad

ATTENUATION of radio waves in the ionosphere is usually measured by comparing the amplitudes of repeated reflections of pulses transmitted upwards from the ground. This method is applicable only for frequencies lower than the critical frequency of the F_2 region at vertical incidence. For frequencies higher than f_0F_2, one would require a transmitter situated outside the earth's atmosphere. Extra-terrestrial radio noise sources in the galaxy provide convenient transmitters for the study of variations in the absorption and scattering of radio waves in the ionosphere.

Jansky[1] was the first to recognize that variations in the ionosphere affect the reception of cosmic radio noise. He attributed the reduction in the intensity of cosmic noise observed during the day to the ionosphere. Systematic observations were taken by Shain[2] using 18·3 Mc/s. in Australia. He concluded that useful information concerning the attenuation of cosmic noise passing through the whole of the ionosphere could be obtained by this means. He found that, so far as absorption was concerned, the F region was more effective than the E region. Mitra and Shain[3] undertook an analysis of the data in greater detail and proved that the total absorption could be divided into two components, one which occurs in the D region and the other in the F_2 region. They calculated the diurnal and seasonal variations and observed that F_2 region absorption was a function of its critical frequency and not its height and suggested that increased night-time absorption might be caused by the irregularities in the F region. Similar analysis carried out by Blum, Denisse and Steinberg[4] revealed a partial absorption attributable at 29·5 Mc/s. to the F region or beyond. Little's[5] work on 65 and 30 Mc/s., which is in progress at College, Alaska, is mainly concerned with high latitude effects such as sudden and intense absorptions associated with the occurrence of visible aurorae and polar blackouts. Warwick and Zirin[6] have analysed the diurnal variation of cosmic noise at 18 Mc/s. in Colorado. Their absorption data did not allow them to separate D region absorption from the absorption produced by the other layers of the ionosphere. They consider that the absorption produced by the other layers is negligibly small. They have derived the electron density as a function of height in the D region and of local

time and have inferred that the recombination coefficient, within the D region, is either constant or increases with height.

The results of experimental work on the ionospheric attenuation using extra-terrestrial noise have so far been mainly reported from stations located in middle and high latitudes. Since 1956, continuous recording of cosmic radio noise at 25 Mc/s. has been going on in the Physical Research Laboratory, Ahmedabad (India) (23°02'N: 72°38'E). This paper presents some of the results of the analysis of the records taken over a period of one year, from March 1957 to February 1958, with a brief description of the equipment and the method of analysis.

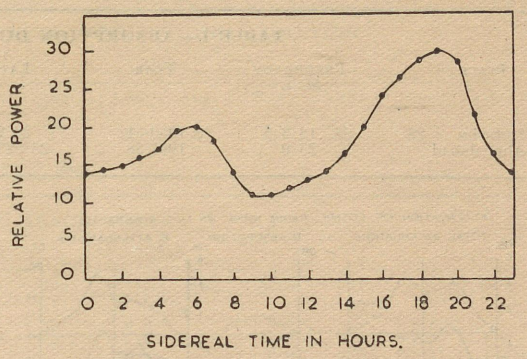

FIG. 1 — COSMIC NOISE POWER OUTSIDE THE ATMOSPHERE (ON 25 Mc/s.) WITH THE ANTENNA USED AT AHMEDABAD

Equipment

The equipment consisted of a directional aerial, a suitably modified communications type receiver, a differential type d.c. amplifier, a recording milliammeter and a noise generator. The aerial was a broadside-collinear array consisting of sixteen halfwave dipoles spread in E-W direction and backed by a parallel wire reflector at a distance of 0·2 wavelength. The principal lobe of the aerial had an angular width of about 40° in N-S and 30° in E-W directions, and was directed towards the zenith. The constancy of gain of the receiver and d.c. amplifier necessitated stabilization of their high tension and filament voltage supplies. The output of the receiver was taken from the second detector stage and fed to a stable d.c. amplifier whose output was given to a 0-1 ma. recording milliammeter. The audio-section of the receiver was used to monitor occasional disturbances, due to neighbouring channels, solar bursts and sferics. The receiver output was calibrated manually twice a day, against the noise output of a pure tungsten filament diode balanced noise generator. In addition, there was an arrangement which could periodically replace the aerial with a cold resistor of the same value as the input resistance of the receiver. It was thus possible to keep an adequate check on the overall stability of the equipment.

Method

The principal lobe of the aerial scans a portion of the sky about 40° wide in N-S and 30° in E-W planes centred around the zenith once every day owing to the diurnal rotation of the earth about its axis. The cosmic radio noise power received on the surface of the earth from the zenith sky will vary with its variation with sidereal time. It is, therefore, necessary to know the intensity of the cosmic noise at different sidereal times at a position outside the earth's atmosphere. Fig. 1 represents an extrapolated curve of intensity of cosmic noise at 25 Mc/s. against sidereal time. All the records taken during the year were utilized to develop this curve. It was necessary to average the power received from different portions of the sky at times when the ionospheric influence on the cosmic noise was at a minimum or negligible. Such conditions usually occurred between 03 and 06 hrs local time and when the critical frequency was less than 8 Mc/s. On this basis, records were chosen and the maximum intensity for each sidereal hour, which could be repeated with an accuracy of ± 5 per cent, was taken to be the 'standard' or 'unabsorbed' intensity of the cosmic noise at that sidereal hour. Now if one compares any day's record with this 'standard curve' then one can calculate the attenuation produced in the ionosphere. Our method of analysis consists in noting the intensity of cosmic noise at a local hour, finding the corresponding sidereal time, getting the extra-terrestrial intensity from the curve and then calculating the absorption. The total attenuation of the cosmic noise by the ionosphere is then given by the ratio, expressed in decibels, of the observed power Po, to the power Ps, that would have been observed, had there been no ionospheric attenuation.

TABLE 1 — ABSORPTION DURING DIFFERENT SEASONS

Place	Frequency *Mc/s.*	Year	Lat.	Long.	Maximum daytime attenuation, *db.*		
					Summer	Equinoxes	Winter
Hornsby	18·3	1950-51	34°S	151°E	1·3	0·8	0·9
Ahmedabad	25·0	1957-58	23°02'N	72°38'E	3·4	5·1	4·2

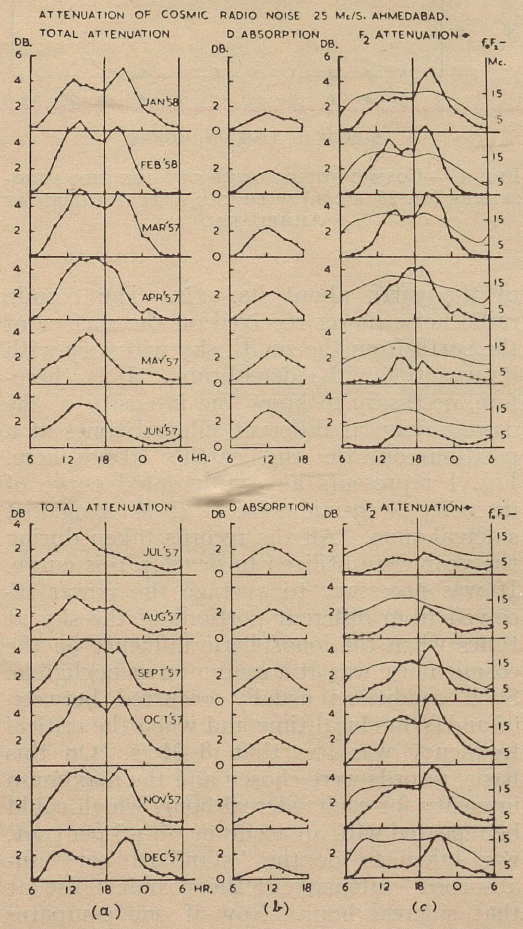

FIG. 2 — MONTHLY MEAN HOURLY VALUES OF (a) TOTAL ATTENUATION, (b) D ABSORPTION AND (c) F_2 ATTENUATION (ALSO MEDIAN VALUES OF f_0F_2)

Total attenuation

Fig. 2(a) represents the monthly mean hourly values of the total ionospheric attenuation in decibels produced in the different ionospheric regions and possibly also in the region laying beyond the level of maximum ionization of the F_2 region, which is normally inaccessible. Mitra and Shain[3] have shown that most of the absorption occurs in D and F_2 regions while E, E_s and F_1 contribute very little to the absorption. It is evident from the figure that the total attenuation exhibits a significant diurnal and seasonal variation. The general trend of variation in the absorption for each month is that, a minimum occurs sometime before sunrise and then it goes on increasing till a maximum is reached in the afternoon usually before 1400 hrs local time. December 1957 was an exceptional month in which the maximum daytime absorption occurred in the forenoon. Afterwards, the attenuation has a tendency to decrease till sunset. The total attenuation for different months after sunset shows two distinct types of trend, one in which the attenuation increases after sunset till a maximum is reached sometime between 20 and 22 hrs, followed by a continuous decrease for the rest of the night, and another which shows only a steady decrease throughout the night. The months of January, February, March, September, October, November and December belonged to the former group showing a pre-midnight maximum and April, May, June, July and August fell in the latter group which showed steady fall in absorption throughout the night. The pronounced pre-midnight peak in the total attenuation is thus peculiar to winter and equinoctial months, while it is suppressed during summer months. It is worthwhile to compare maximum daytime attenuations observed at Hornsby, Australia and at Ahmedabad, India.

Table 1 reveals that the absorptions observed during the corresponding seasons at these stations are quite different in magnitude. This difference in attenuations can be attributed to (1) the stations are situated at different latitudes and the F_2 critical frequencies are different, and (2) experiments were conducted at different epochs of the solar cycle.

Separation of contributions to absorption due to D and F regions

Our method of separating the attenuations into two components, one mainly due to the

TABLE 2 — LAG IN RESPONSE OF D REGION TO IONIZING RADIATION

	1958		1957									
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Delay in min.	22	17	24	31	36	41	31	30	28	29	32	15

Mean delay = 28 min.

TABLE 3 — NOON ABSORPTION

Place	1958		1957									
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Hornsby	—	—	—	—	—	—	0·6	—	0·6	—	1·1	—
Ahmedabad	1·5	1·8	2·2	2·2	2·6	2·7	2·2	2·3	2·6	2·3	1·7	1·2
Ahmedabad, extrapolated for $\cos \chi = 1$	2·1	2·2	2·6	2·1	?	?	2·1	?	2·6	2·5	2·1	1·3

TABLE 4 — VALUE OF n FOR DIFFERENT MONTHS

Place	1958		1957									
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Ahmedabad	1·5	1·9	2·3	1·8	2·0	2·3	1·9	2·1	2·3	2·2	1·8	1·1
Hornsby	—	—	—	—	—	—	0·5	—	0·9	—	—	1·1

D region and the other mainly due to the F region, is identical with that used by Mitra and Shain[3]. Briefly, the total attenuation is plotted against f_0F_2 for each solar hour. The attenuation decreases with decrease in f_0F_2, and the curve is extrapolated to low values of f_0F_2 and zero F_2 absorption. The residual absorption is found to depend on the solar hour and this is taken to be the contribution due to the D region. The extrapolation to low f_0F_2 values becomes less accurate at hours when low values of f_0F_2 are rare, as in the afternoons.

D region absorption

Fig. 2(b) represents the monthly mean hourly values of absorption which occurs mainly in the D region for each month. It is known that the D region absorption is non-deviative in character and is under strong solar control. The absorption is proportional to the product $N\nu$ where N is the electron density and ν the collisional frequency of an electron. Though N is small at the height of the D region, the large value of ν, which increases with the atmospheric pressure, maintains sufficiently high value of the product $N\nu$ resulting in heavy absorption. There are occasions when N also increases enormously, for example, at the time of solar flares, which then produce sudden large increases in cosmic noise absorption and shortwave fadeouts. These short-term effects will be reported in a separate communication. Otherwise, N depends on the solar zenith angle; its value increases as the solar zenith angle decreases. Therefore, a roughly symmetrical curve for D region absorption around the local noon is expected. But it has been found that the absorptions observed for the same solar zenith angle before and after the local noon are not equal. The maximum absorption in the D region occurs not at the local noon, but slightly *after* the local noon, and this has been consistently observed for each month. This observation gives supporting evidence to the view that there is a certain amount of 'lag or delay' in the response of the D region to the solar ionizing radiations. This lag in the response is a measure of the sluggishness of the ionosphere. An attempt has been made to measure the amount of delay for each month and is given in Table 2.

For some reason, there is no constancy in the observed lag in the response from month to month. The largest value for the lag was observed to be 41 min. in the month of June which is midsummer in Ahmedabad, and the smallest observed is 15 min. in December which is midwinter. The lag is thus a maximum in summer and a minimum in winter. It is interesting to note that the average lag taken over a year comes to about 28 min. which is in good agreement with the value of 27 min. obtained by Mitra and Shain[3].

Warwick and Zirin[6] have also reported an asymmetry in the maximum D region absorption, but it is in the opposite sense, and these authors feel that the delay found in this way is insignificant.

Table 3 gives the noon absorptions in decibels for different months. It is observed that the noon absorption in the D region undergoes considerable seasonal variation.

The maximum of nearly 2·7 db. was recorded in the month of June 1957 and a minimum of 1·2 db. in the month of December 1957. It is known that the diurnal variation of D region absorption is of the form $\cos^n \chi$. The values of n were determined for each month and are given in Table 4. The extrapolated values of absorption for $\cos \chi = 1$ for each month are given in the last row of Table 3. In some months, owing to the scatter of the points, no reliable extrapolation for $\cos \chi = 1$ could be made.

Averaging over different months, it was found that during summer and equinoctial months n was 2·1 and during winter it was 1·6.

F region absorption

Fig. 2(c) shows the monthly mean hourly values of the attenuation for the different months which mostly occurred in the F region. If the total attenuation is corrected for D absorption then the residual attenuation may be attributed to the F_2 region. The correction has to be applied only during the daytime since D absorption ceases soon after sunset. During the night, whatever attenuation is produced is in or beyond the F_2 region. It is known that the F_2 region absorption is mainly of the deviative type and, therefore, depends on the proximity of the exploring frequency (25 Mc/s.) to f_0F_2. It is also expected that the irregularities in the ionosphere, which cause scintillations of the radio stars, may have, at least, some effect on the intensity of cosmic noise.

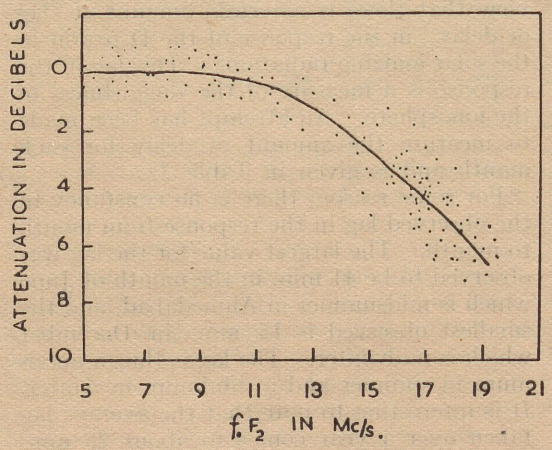

FIG. 3 — MASS PLOT OF ATTENUATION AGAINST f_0F_2 (NIGHT OBSERVATION)

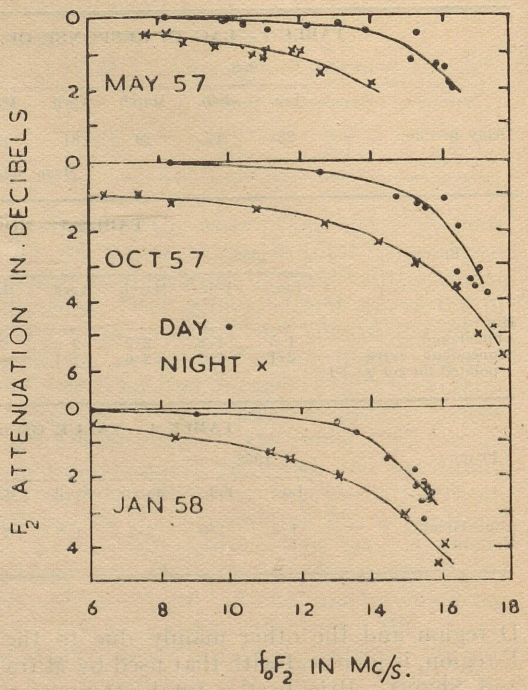

FIG. 4 — F_2 ATTENUATION VS f_0F_2, DAY AND NIGHT SEPARATELY, DURING DIFFERENT MONTHS

Fig. 3 shows a plot of f_0F_2 and F_2 absorption for the nighttime observations. It appears that below a particular value of f_0F_2, F_2 absorption is negligible. In general, for f_0F_2 less than 8 Mc/s., F_2 absorption is small. As f_0F_2 increases beyond 10 Mc/s., the absorption rapidly increases. It has been found by other workers that the major component of the total absorption arises in the D region, but that there is an appreciable contribution from the F_2 region. The absorption varies linearly with f_0F_2 according to Blum, while according to Mitra and Shain[3], a curvilinear relation holds over the range 4-8 Mc/s. (for 18·3 Mc/s.). Our observations show that F_2 absorption does not have a linear relation with f_0F_2 and F_2 absorption

is by no means less important than D absorption. While the D region absorption was never greater than 3 db. even in summer, high F_2 absorptions, exceeding 6 or 7 db., have frequently been observed. Another fact worth noting about F_2 absorption is that during equinoctial and winter months, the maximum nighttime F_2 attenuation exceeded the maximum daytime F_2 attenuation. In general, for a particular value of f_oF_2 it was observed that during all seasons, nighttime attenuation was greater than daytime attenuation (Fig. 4). Fig. 5 shows the excess (night minus day) attenuation at different hours of the night during different months. Such excess attenuation at night was also observed in Australia by Mitra and Shain[3] who have suggested that the ionospheric irregularities in the F region, which produce scattering of radio waves, might be responsible for the occurrence of excess attenuation. These irregularities appear as 'spread' or 'diffuse' echoes on the p'-f records taken by ionospheric pulse soundings.

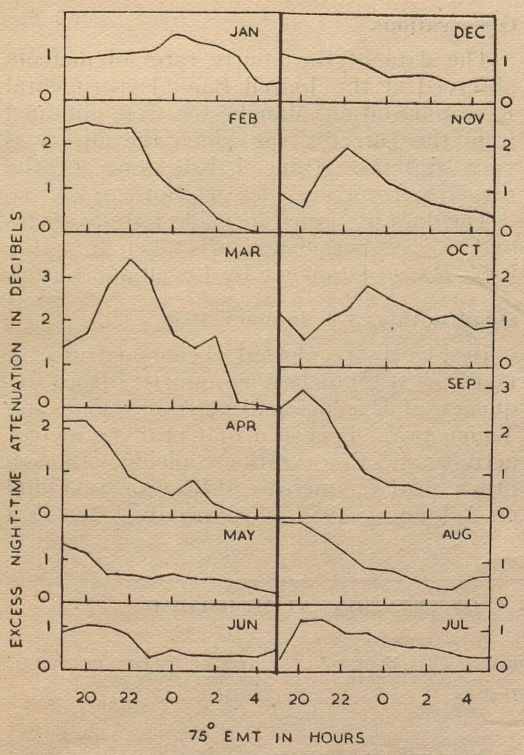

FIG. 5 — MONTHLY MEAN HOURLY EXCESS OF NIGHTTIME ATTENUATION OVER DAYTIME ATTENUATION FOR THE SAME f_oF_2

The data of the ionospheric station at Ahmedabad were analysed for the percentage occurrence of F-scatter echoes and it was found that, during summer and equinoxes when F-scatter echoes were most frequent, large excess attenuations were accompanied by the large frequency of occurrence of F-scatter echoes. The presence of an early night peak in the absorption curve during the winter and equinoxes is, however, difficult to explain solely on the basis of deviative absorption which depends on f_oF_2 and of scattering due to ionospheric irregularities. This will be discussed in a later paper.

Summary

Using cosmic radio noise at 25 Mc/s., the values of total ionospheric attenuation have been found for over a year at Ahmedabad. Since the D and F_2 regions of the ionosphere are the principal attenuating regions, an attempt has been made to separate their respective contributions to the total attenuation. The diurnal and seasonal variations in each case are discussed and it is observed that the F_2 attenuation for high values of f_oF_2 can exceed D absorption. The excess attenuation in the early part of the night are too high to be explained solely on the basis of the deviative absorption of F_2 and scattering due to ionospheric irregularities. This will be discussed in a later paper.

Acknowledgement

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Meteors & E_s Ionization

K. M. KOTADIA
Physical Research Laboratory, Ahmedabad

BESIDES the normal E layer in the ionosphere, layers of ionization, irregular in occurrence and with irregular variations of ion density, often form in the height range 95-135 km. Such layers, commonly known as the sporadic E layer or E_s, occur at different latitudes and their ionization has been attributed to various agencies. These include solar wave and particle radiation, meteors, thunderstorms and meteoric dust ionization.

It has now been well established that meteors are important agents for causing E_s ionization in temperate and high latitudes. Very little is, however, known about the influence of meteors on E_s in low latitudes. McNicol and Gipps[1] and later Thomas[2] at Brisbane (27·5°S: 153°E) and Rangarajan[3] at Kodaikanal (10·2°N: 77·5°E) did not find any changes in E_s intensity during meteor showers, nor did nighttime E_s show any effect due to sporadic meteors. The diurnal variation in the occurrence of sporadic E echoes at Japanese stations showed two maxima, one near sunrise and the other near sunset, but this does not agree with the diurnal variation of sporadic meteors. In a previous paper, Kotadia[4] showed that no relation could be established between meteors and E_s activity at Ahmedabad (23°02′N: 72°38′E) from a consideration of the occurrence of all types of E_s echoes in the first and second halves of the night. However, from a detailed analysis of different types of E_s occurring at Ahmedabad, it was shown that much of the sporadic E activity in the first half of the night was contributed by a downward drift of ionization from higher layers.

In this paper, a few definite cases of daytime and nighttime meteor showers are studied in relation to the E_s ionization observed over Ahmedabad, and it has been found that meteors do contribute significantly to the E_s ionization in low latitudes also, usually at a height of 95-105 km. The effect at Yamagawa (31·2°N: 130·6°E) is also described in two instances.

Observations

The data of the hourly rates of meteors observed at the Jodrell Bank Experimental Research Station, Manchester, were obtained from the Director, for which the author is very grateful. Table 1 lists some of the regularly recurring meteor showers.

The data presented in Table 1 are averages over a long period and are taken from the book *Radio Astronomy* by Lovell and Clegg[5].

Quadrantids, 3-4 January 1956

In Fig. 1 are plotted the hourly rate of meteors at Manchester and fE_s (top frequency of E_s reflection) at Ahmedabad and Yamagawa. It is seen that peaks in meteor activity and E_s ionization coincide with each other. A large increase of fE_s was also found on 3 January 1955 at Ahmedabad during a

TABLE 1 — METEOR SHOWERS DURING E_s OBSERVATIONS AT AHMEDABAD

Name of meteor shower	Day of maximum	Radiant co-ordinate R.A.	Radiant co-ordinate Decl.	Hourly rate	Time of transit *GMT hrs*	Time of marked increase in E_s at Ahmedabad *GMT hrs*
Quadrantids	January 3-4	230°	52°	35	08-09	08-09
Arietids	June 8	44·3°	22·6°	60	08-10	09
α-Orionids	July 12-13	87°	11°	50	04-08	04-08
ν-Geminids	July 12-13	98°	21°	60	04-08	04-08
λ-Geminids	July 12-13	111°	15°	32	04-08	04-08
Perseids	August 10-14	47°	58°	50	04-05	04
Geminids	December 13-14	113°	32°	60	00-00	Doubtful (22-00)

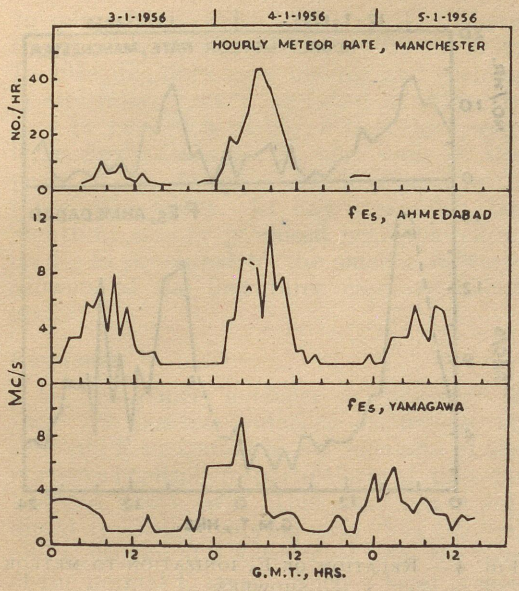

FIG. 1 — E_s IONIZATION AND RATE OF METEOR INCIDENCE

corresponding rise in meteor incidence. The height of the E_s echoes varied from 100 to 105 km. which is consistent with the idea of meteoric impact.

Arietids, 8 June 1956

Ionograms repeated at intervals of 15 min. are reproduced in Fig. 2 to illustrate the effect of the above meteor shower. It may be seen that fE_s shot up to more than 15 Mc/s. at 1400 hrs (75° EMT) which is also the time of peak meteoric activity. The frequency came down in the next 15 min., but the reflection was broad and diffused. At 1430 hrs, patchiness of the echo became pronounced and fE_s later continuously decreased, going down to less than 6 Mc/s. at 1515 hrs when the reflection became sharp and thin. So this high production of ionization was sustained only for a short duration of at the most half an hour and it took place at a height of 100 km. It should be noted that the intensity of ionization was so strong that frequencies up to 10 Mc/s. were blanketed

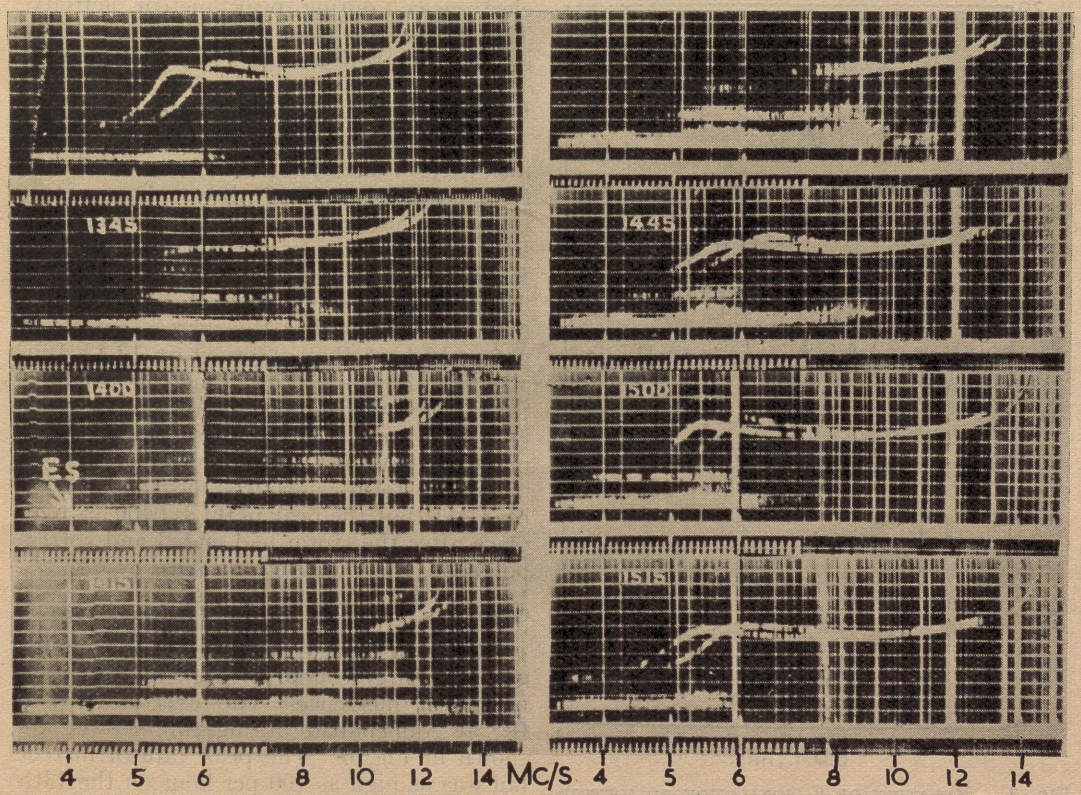

FIG. 2 — IONOGRAMS TAKEN AT AHMEDABAD ON 8 JUNE 1956

and the reappearance of echoes from higher layers began after the lower E_s ionization had diffused out. Rise in height at the end of the trace is possibly due to oblique reflection from the drifting cloud. We do not have the meteor data from Manchester for this day, but Table 1 provides sufficient information about the Arietids shower.

α-Orionids, ν-Geminids and λ-Geminids, 12-13 July 1953 and 1955

The effect of the above meteor showers of 12-13 July on fE_s is clearly seen from the plots of Figs. 3 and 4. The peaks in the hourly rates of meteors and fE_s agree very well in time with each other. The effect is also observed at Yamagawa as seen from Fig. 3. Increased E_s ionization produced blanketing of the higher regions, and the height remained at 100 km. during peak activity. It is interesting to find that although the hourly rate of meteor hardly reached 15, the increase in E_s ionization was

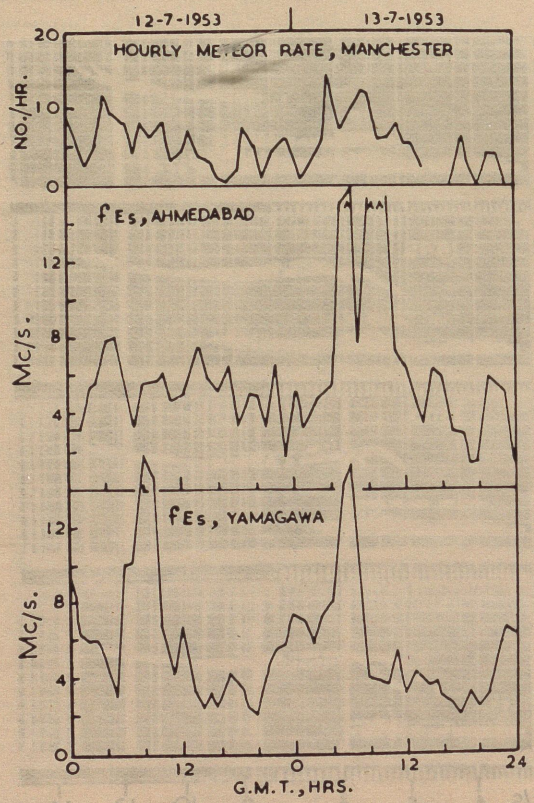

FIG. 3 — RELATION OF E_S IONIZATION TO METEOR SHOWERS

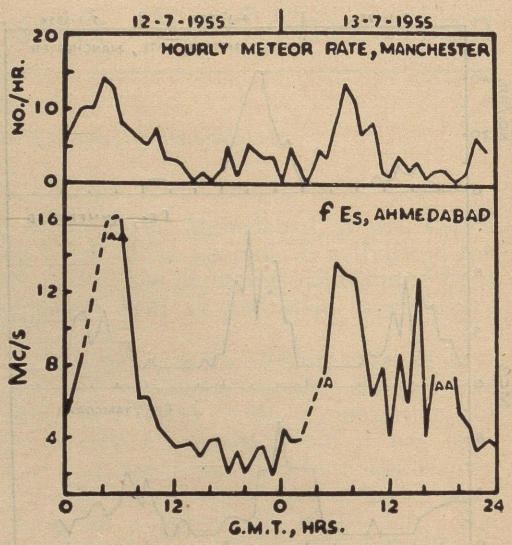

FIG. 4 — RELATION OF E_S IONIZATION TO METEOR SHOWERS

extremely large and in excess of $2{\cdot}5 \times 10^6$ electrons/cc. during peak meteor activity. This is found to be so almost in all cases of daytime meteor showers.

Perseids, 12-13 August 1956

It may be noted that the rate of meteor incidence of Perseids is larger than that of the showers on 12-13 July. The meteor rates at Manchester and fE_s at Ahmedabad for the above shower are plotted in Fig. 5. Here also the peaks in both the parameters at 0400 hrs GMT on 12 August 1956 coincide with each other, but the increase in fE_s is not so high as that observed on 12-13 July although the hourly rate of meteors is larger. On the next day, however, they do not agree exactly in time. The increase in fE_s on the night of 11 August 1956 followed an SC type magnetic storm which commenced at 0043 hrs GMT, but the peak in fE_s at 0400 hrs took place after the storm had ended and corresponds to the incidence of meteors.

Geminids, 13-14 December 1953 and 1956

Of all the meteor showers, the Geminids give the largest hourly rate and this is a nighttime incidence. The observations of fE_s at Ahmedabad during this shower are shown in Fig. 6. The peak rate of meteor fall was as high as 100 per hour on the 13th and 60 per hour on 14th at 00 hrs GMT.

In spite of this, there was no marked rise in fE_s at Ahmedabad either in 1953 or 1956. In 1954, fE_s data were missing and nothing of any interest could be found in 1955. It may be noticed from Fig. 6 that there were large fluctuations in fE_s and some of the peaks in fE_s, though small, do coincide with those of meteors. In any case, this big nighttime shower produced negligible effect on E_s as compared to the smaller daytime showers of the first three cases described above.

Summary

In this paper, evidence is presented to show the positive influence of meteors on sporadic E ionization in low latitudes of the northern hemisphere, particularly at Ahmedabad and Yamagawa. This ionization is produced at a height varying from 95 to 105 km. and is usually at a lower level than the base of the normal E layer. Such a layer is now called $E_s l$ or low type of E_s. The seasonal variation of occurrence of $E_s l$ at Ahmedabad has been found to agree well with that of meteors. It is also shown that the smaller daytime showers produce more pronounced effect on E_s than larger night time showers. The fact that the times of peak meteor activity and peak E_s ionization happen to be the same proves that the population of meteors in a beam is widely spread over the earth.

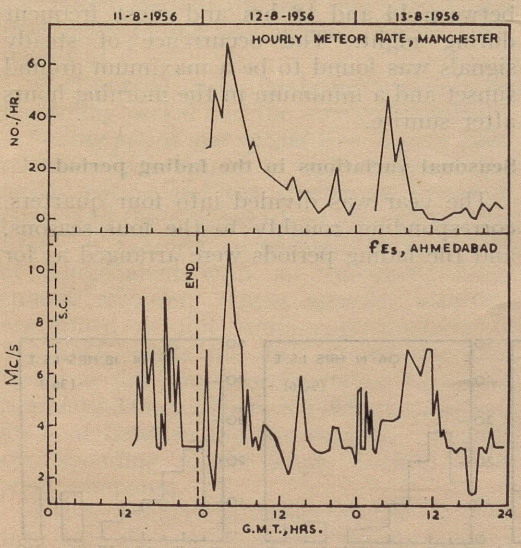

FIG. 5 — RELATION OF E_s IONIZATION TO METEOR SHOWERS

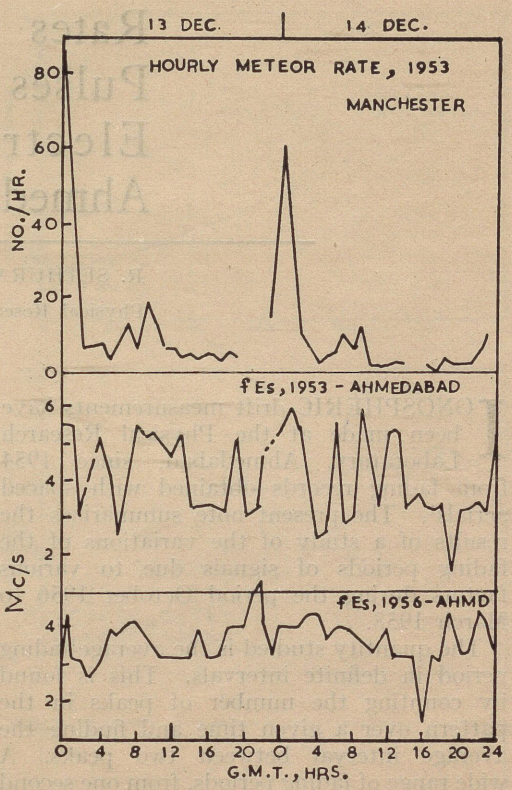

FIG. 6 — CHANGES IN fE_s COMPARED WITH HOURLY METEOR RATE

Acknowledgement

The author is greatly indebted to Prof. K. R. Ramanathan for suggesting the problem and for his help in preparing this paper. The Ionospheric Station at Ahmedabad is maintained with financial assistance from the Council of Scientific & Industrial Research.

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Rates of Fading of Reflected Pulses of Vertically Incident Electromagnetic Waves at Ahmedabad on 2·6 & 4·0 Mc/s.

R. SETHURAMAN
Physical Research Laboratory, Ahmedabad

IONOSPHERIC drift measurements have been made at the Physical Research Laboratory, Ahmedabad, since 1954 from fading records obtained with spaced aerials[1]. The present note summarizes the results of a study of the variations of the fading periods of signals due to various factors during the period October 1956 to March 1958.

The quantity studied is the average fading period in definite intervals. This is found by counting the number of peaks in the pattern over a given time and finding the average interval between two peaks. A wide range of fading periods, from one second to over a minute, has been found. In some instances, the peaks are so flat that no accurate estimate of the period could be obtained. Steady signals were treated as signals with infinite fading period.

Diurnal variation of the fading period

The daily observations during the entire period were grouped into four quarters of the day, 00-06 hrs representing the pre-dawn second half of the night, 06-12 hrs representing the first half of the day, 13-18 hrs representing the second half of the day and 19-23 hrs representing the first half of the night. The fading periods were grouped in the ranges 0-5 sec., 6-10 sec., 11-15 sec., etc. As it was difficult to determine periods greater than 30 sec. with any accuracy, they were broadly grouped as 31-90 sec., 90-200 sec., >200 sec., and steady signals. It was noticed that the normal fading periods for vertically incident signals were 5-15 sec. Fig. 1 gives the percentage occurrence of the various fading periods in the different quarters of the day. The fading periods were, in general, greater in the afternoon than in the morning hours. Very slow fading was sometimes observed in the nighttime. Quick fading (less than 5 sec.) was least frequent between 14 and 18 hrs and most frequent during night. The occurrence of steady signals was found to be a maximum around sunset and a minimum in the morning hours after sunrise.

Seasonal variations in the fading period

The year was divided into four quarters, corresponding roughly to the four seasons, and the fading periods were arranged as for

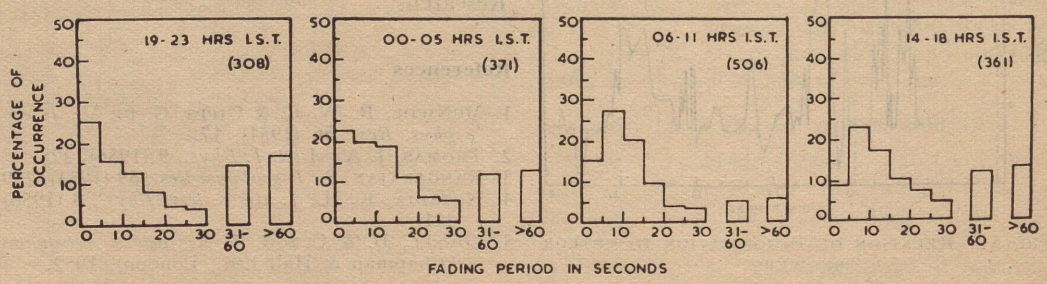

FIG. 1 — DIURNAL VARIATION OF THE FADING PERIODS OF 2·6 MC/S. REFLECTIONS
[Figures in parentheses indicate the total number of observations]

the study of the diurnal variations. No significant seasonal trends were observed in the fading periods.

Fading periods and geomagnetic activity

Many workers have reported a dependence of the fading period of F_2 reflections on geomagnetic activity. It was desired to find whether any relationship existed for reflections on 2·6 and 4·0 Mc/s. at Ahmedabad. In Fig. 2, the mean fading periods for day and night are plotted against the value of the index for geomagnetic activity, C_p, for the corresponding day. It will be seen that, in general, there is an increase of the fading period with geomagnetic activity. The sensitivity of the E and F layers to geomagnetic activity, as determined by the slope of the line joining the medians of fading periods for various values of C_p, shown by thick lines in Fig. 2, is not the same. The maximum effect is seen in the reflection of 2·6 Mc/s. signals during 19-05 hrs (nighttime F_2 layer), while reflections from the daytime E layer are least affected. The scatter of points is also larger for the F layer reflections than for the E layer reflections. Various workers[2,3] in the middle latitudes have reported a dependence of the fluctuation amplitude of scintillations of radio-star with geomagnetic activity. Millman[4], working on 75 kc/s., got fading periods up to 8 min. and found that rapid fading was associated with large values of C_p.

No clear relationship has been found between the fading period and the sunspot number.

Fading period and spread F — A very close relationship is found to exist between the fading period and the amount of spread F present in the p'-f records at about the same time. p'-f records are normally taken hourly at Ahmedabad with an automatic ionospheric recorder. These records, however, are timed at full hours corresponding to 75° EMT, while the drift observations are timed at full hours corresponding to Indian Standard Time. There is a difference of half an hour between the two records. Records corresponding to the same nominal hours were compared.

The ionospheric p'-f records are grouped into four classes, depending on the amount of spread present. Table 1 gives the classification adopted for the purpose.

This classification is similar to the one adopted by Wright *et al.*[5] and Briggs[6] and

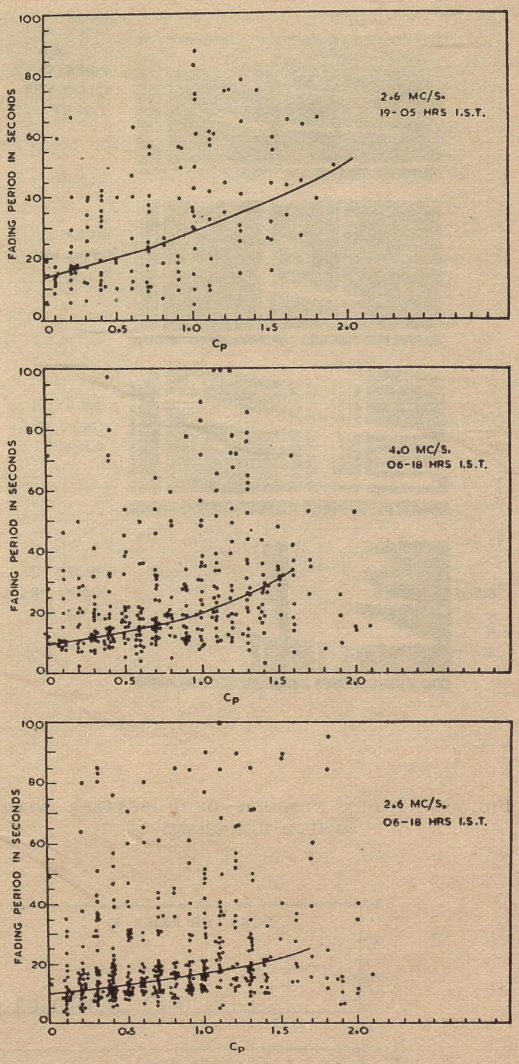

FIG. 2 — FADING PERIOD OF PULSE REFLECTIONS AND GEOMAGNETIC ACTIVITY

TABLE 1 — CLASSIFICATION OF p'-f RECORDS

F-SCATTER INDEX	NATURE OF F-SCATTER
0	No spread observed
I	A slight amount of spread is present, and the ordinary and extraordinary critical frequencies can be distinguished
II	The spread is so much that the ordinary and the extraordinary critical frequencies cannot be accurately estimated
III	Complete spread F_2

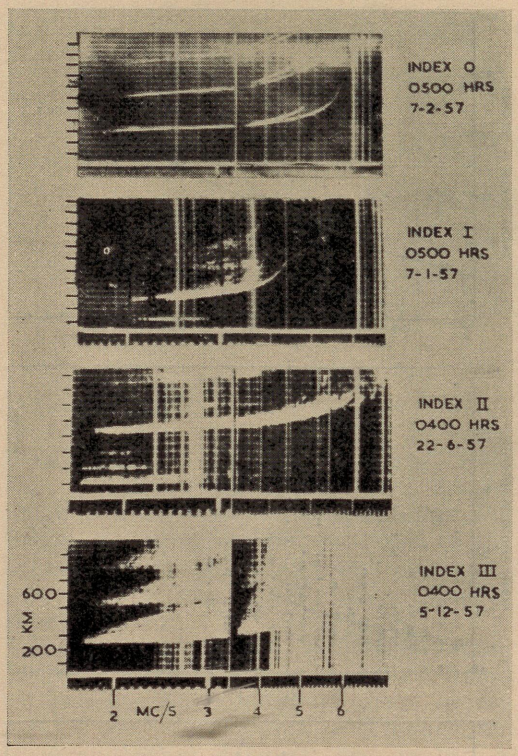

FIG. 3 — INDEX NUMBERS OF F_2-SCATTER WITH SAMPLE IONOGRAMS

others. Typical p'-f records to illustrate the classification are shown in Fig. 3. No doubt the amount of spread F present depends on the sensitivity of the receiver also, but the latter was maintained reasonably constant throughout the period.

The fading periods of pulse reflections, when each of these kinds of spread were present, were analysed. Fig. 4 gives the histograms of fading periods for the various indices of spread F_2. The mean values of the fading periods for each of these indices are also given in the diagrams. It will be seen that during periods of large spread (index III), the fading was most rapid (0-5 sec.). During periods of complete spread, the rapidity of fading was as much as 1 per sec. Under such conditions, it was difficult to select any particular echo for study with the finite resolution of the gate of the equipment. The records from the three spaced aerials under such conditions show no correlation among themselves and are useless for drift analysis. These indicate that under conditions represented by large spread F, intense short period turbulence is present in the ionosphere. In general, fading period decreases with the amount of spread present in the records.

An attempt was made to study the relationship between the speed of drift and the fading

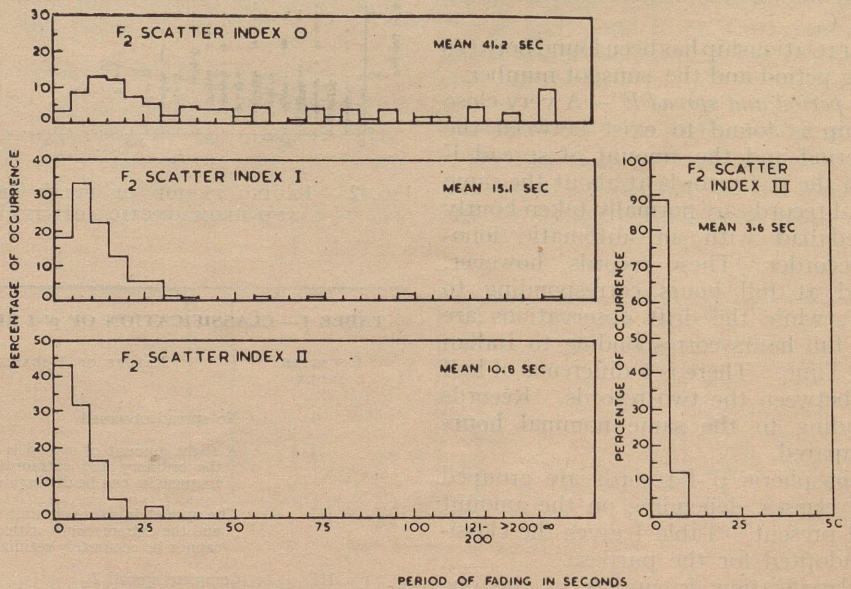

FIG. 4 — FREQUENCY OF OCCURRENCE OF FADING PERIOD VS F_2-SCATTER INDEX

period. Harang and Pederson[7] and others have reported decreased fading periods with increasing speeds. No such clear relationship could be found from the observations at Ahmedabad. There was also no relationship between the fading period and the height of reflection.

Summary

Some of the characteristics of the fading period of vertically incident pulse signals on 2·6 and 4·0 Mc/s. are reported. It is found that rapid fading, with periods below 5 sec., occurs mostly during the night hours. No clear seasonal changes are evident. The fading periods are found to show some dependence on magnetic activity, low values of C_p being generally associated with quicker fading. The nighttime F_2 layer is found to be sensitive to changes in magnetic activity; the daytime E layer does not show any marked effect. *The fading periods of night F_2 reflections have a marked correlation with the amount of spread F present in the p'-f records, large amounts of spread being associated with quicker fading.* No relationship between fading period and the speed of drift or the height of reflection was noticed.

Acknowledgement

The author is deeply grateful to Prof. K. R. Ramanathan for suggesting the analysis and guiding the work. He is thankful to Dr U. D. Desai for his interest in the work. The scheme is in receipt of financial assistance from the Council of Scientific & Industrial Research, New Delhi.

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Observations on Galactic Radiation at 30 Mc/s.

Y. V. SOMAYAJULU & N. NARAYANA RAO
Electronics Faculty, Madras Institute of Technology, Chromepet, Madras

SINCE the discovery in 1932 by Jansky[1] of the existence of galactic radiofrequency radiation, considerable amount of work has been done on galactic and solar radiations. Radiation from discrete sources, now termed 'radio stars', has also been detected[2]. Cosmic radio noise observations at frequencies around and below 30 Mc/s. are of importance (1) in relation to theories of origin of galactic radiation[3], (2) in relation to natural noise levels at receiving locations and (3) in the study of ionospheric absorption and movements in the ionosphere[4-7]. Observations on cosmic noise in this part of the globe and particularly in equatorial regions are meagre, and the present studies aim at obtaining cosmic noise data in this region (Madras, 13°N: 80°15'E), studying their diurnal and seasonal variations, and deducing data on ionospheric absorption. The present paper embodies the preliminary results obtained at a frequency of 30 Mc/s. These investigations are also part of the International Geophysical Year programme undertaken at the Madras Institute of Technology.

Equipment and experimental details

The observations have been carried out in the Institute campus at Chromepet, a suburb of Madras. The antenna system has been erected on the top of a building; the country around is flat and is surrounded by hills at a distance of 3-5 km. which subtend an angle less than 5° at the antenna. The antenna system consists of a 3-element collinear array with its axis in the East-West plane and is matched through a quarter-wave transformer to a 300-ohm transmission line which in turn has been matched to the receiver preamplifier through a balanced-to-unbalanced network. This antenna system provides a practical gain of 3 db. over a half-wave horizontal dipole at the same height at all vertical angles regardless of the height above ground. The beam width of the antenna at half power points is approximately 40 in the East-West plane; in the North-South plane, however, the antenna directivity is the same as that of a half-wave dipole and hence it is more sensitive to radiation from sources at low angles in the North-South plane than in the East-West plane. Thus, the observed

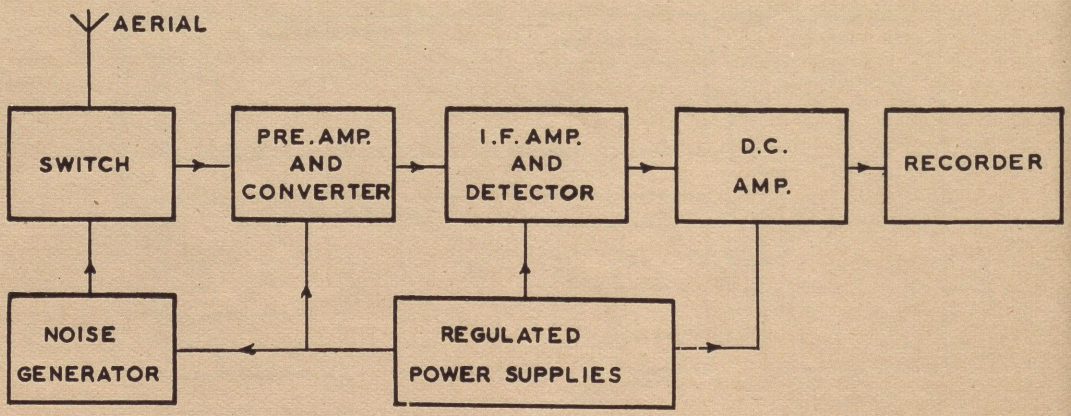

FIG. 1 — BLOCK DIAGRAM OF COSMIC RAY NOISE RECEIVING EQUIPMENT

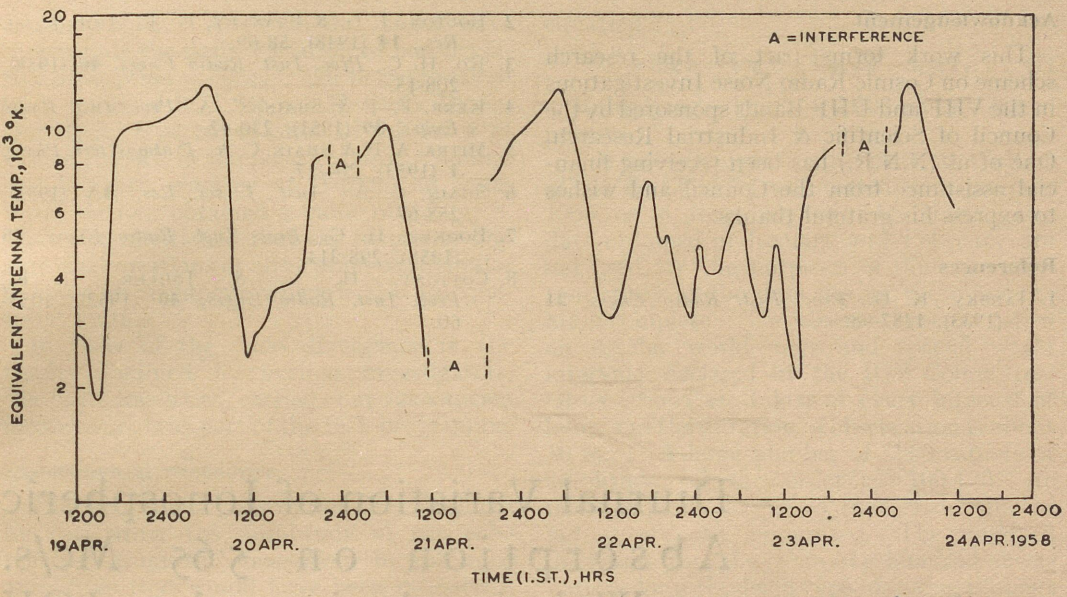

FIG. 2 — PLOT OF DIURNAL VARIATION OF RECEIVED COSMIC NOISE INTENSITY ON 30 MC/S.

cosmic noise at any time is the integrated noise in a strip 40° wide around declination 13 in the East-West plane and throughout the 'visible sky' in the North-South plane.

The receiving equipment consists of a stable, high-gain receiver preceded by a low noise amplifier. A block schematic diagram of the receiving equipment is shown in Fig. 1. The output of the second detector of the receiver is d.c. amplified and recorded continuously by a pen recorder. The receiver employed is a Philips Communications receiver type BX925A, with a bandwidth of 2·6 kc/s. The time constant of the recording circuit is 1 sec. The receiver has been calibrated regularly by a noise generator using Sylvania 5722 noise diode, in terms of equivalent antenna temperature.

Observations and discussion

Although the receiving equipment has been in continuous operation since October 1957, reliable records were available from April 1958 onwards, owing partly to change of frequency to avoid interference, and partly to power and equipment failures. The daytime records have been subject to considerable interference; some reliable daytime records could still be obtained when interference was less severe.

In Fig. 2 is shown a plot of typical diurnal variation of the received cosmic noise intensity. No allowance has been made for absorption and refraction in the ionosphere. From Fig. 2 it may be seen that the received cosmic noise shows a maximum at 0500 hrs IST corresponding to right ascension 1900 hrs and a minimum around 1300 hrs IST corresponding to right ascension 0500 hrs. The occurrence of the maximum at 1900 hrs right ascension corresponds to the positions of Sagittarius west of the meridian and Cygnus approximately the same distance to the east. Since the receiving antenna beam is directed overhead (13° declination), the antenna is in a position to receive maximum energy from the two sources. At the sidereal time 0300 hrs (1300 hrs IST) the sky is relatively free of intense sources and the ionospheric absorption is maximum, and hence the received cosmic noise will be minimum.

It may also be noticed from Fig. 2 that the received cosmic noise rapidly increases after sunset and decreases rapidly after sunrise. This is due to considerable changes in ionospheric absorption after sunset and sunrise.

Cottony and Johler[8] made similar observations and the results obtained and presented here are in good agreement with theirs.

Acknowledgement

This work forms part of the research scheme on Cosmic Radio Noise Investigations in the VHF and UHF Bands sponsored by the Council of Scientific & Industrial Research. One of us (N.N.R.) has been receiving financial assistance from the Council and wishes to express his grateful thanks.

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Diurnal Variation of Ionospheric Absorption on 5·65 Mc/s. at Waltair during the IGY

B. RAMACHANDRA RAO & K. V. V. RAMANA

Ionospheric Research Laboratory, Andhra University, Visakhapatnam

VERY little work has been done on absorption studies in the low latitude regions. Ever since Appleton developed the theory of non-deviative absorption in a simple region of the Chapman type for reflection from F_2 region, many workers have tried to verify this by conducting absorption measurements at different places. Appleton[1] has shown that in the case of reflections from F, the non-deviative absorption due to a simple Chapman type E layer is given by the relation

$$-ln\rho = 4{\cdot}13H\left(\frac{4\pi e^2}{mc}\right)\frac{N_\circ \nu_\circ}{(p+|p_L|)^2}\cos^{3/2}\chi \quad . \quad (1)$$

where the different terms have their usual significance.

At low latitude stations, such as ours, the propagation in E region is quasi-transverse, in which case the above expression gets modified to

$$-ln\rho = 4{\cdot}13H\left(\frac{4\pi e^2}{mc}\right)\frac{N_\circ \nu_\circ}{p^2}\cos^{3/2}\chi \quad . \quad . \quad (2)$$

The results of many workers indicate that the experimental value of n in the above equation varies between 0·5 and 2 and that it is seldom equal to 1·5. Hence, equation (2) can be written in the form

$$-ln\rho = A\cos^n\chi \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

The value of n in the above equation can be evaluated from experimental data of $-ln\rho$ variation with χ, the zenith angle.

Jaeger[2] gives an equation of the form

$$-ln\rho = \frac{\nu_\circ H}{c}F\left(\frac{f_c}{f}\right)\cos\chi \quad . \quad . \quad (4)$$

in the case of absorption in a layer for which f, the operating frequency, is greater than the critical frequency and when the wave is propagated vertically upwards from a level at which μ is effectively unity. The values of $F(f_c/f)$ are given by Jaeger for various values of f_c/f.

Best and Ratcliffe[3] obtained 1·5 for the value of n, quite in agreement with the theory of Appleton. White and Straker[4], working on F layer reflections, obtained widely varying day to day values of n ranging from 0·83 to 3·84 in winter season. Taylor[5], using CW automatic field intensity measurements, found that the law is different for different frequencies but a mean value of n

is nearly unity. Appleton and Piggot[6] have shown that the daily variation of non-deviative absorption at Slough can be represented by a value of 0·75 for n. Kenneth Davies and Hagg[7] reported a value of 0·5 for n at Prince Rupert, in the polar regions. Skinner and Wright[8], working at Ibadan, an equatorial station, obtained a value of 0·7 for n. They also mentioned that the frequency and seasonal variations of absorption were similar to those at Singapore, which is also an equatorial station.

In view of the wide divergence in the results obtained by various investigators, the authors have carried out absorption measurements as part of the IGY programme.

Experimental procedure

The ionospheric absorption is calculated by comparing the amplitude of the echo reflected from the ionosphere to the echo amplitude that would have been received if the ionosphere were a perfect reflector. The relevant equations are given below.

If I_n be the amplitude of the nth order echo and ρ, the apparent ionospheric reflections coefficient, and if the ground reflectivity is assumed to be very nearly unity as it is actually the case, the following relation is obtained:

$$I_n = \frac{G}{2nh'} \cdot \rho^n \quad \ldots\ldots\ldots (5)$$

where G is the calibration constant, and h' is the equivalent height of reflection. Measurement of h' and I_n enables us to calculate ρ, if the calibration constant is estimated by a separate experiment. The value of $-ln\rho$ gives absorption coefficient in nepers. The calibration constant G is obtained by taking measurements of amplitudes of multiple reflections using the relation

$$G = \frac{I_1^2}{I_2} \cdot h' \quad \ldots\ldots\ldots (6)$$

Hence the measurements of amplitudes of the first and second order echoes at the same time, or over a period of time, when ρ and h' do not change substantially, can be used to yield the calibration constant G. Obtaining G when second and first order echoes are together present, at nighttime and in the early morning hours, the apparent absorption coefficient can be calculated at any time when the first order echo is only present by making use of the following relation obtained from equation (5):

$$-\log \rho = \log G - \log 2h' - \log I_1 \quad \ldots (7)$$

Multiplying $-\log \rho$ by 2·303 gives $-ln\rho$ in nepers.

The measurement of absorption at Waltair (83°18′E: 17°43′N) was started from January 1958 on a frequency of 5·65 Mc/s. The data obtained in January and February are not used for the purposes of diurnal variation study as the data during these months are incomplete. The observations are taken on regular world days and special world intervals, declared by the IGY Committee. Observations are taken at every interval of hour, and the duration of observation is about 10 min. A large number of observations of amplitude, of the order of 100-120, are made in each sample so that errors due to fading, etc., are minimized. The standard deviation from the mean of a hundred observations for a Rayleigh type of fading is about 50 to 0. The absorption measurements are made during nighttime also, but they are not utilized here for the purposes of presentation and discussion.

The equipment used in this investigation consists of a pulse transmitter of 1 kW. peak power output, radiating pulses of 100 μsec. width at a repetition frequency of 50 c/s., a BC 348Q communication receiver modified for pulse reception, a video amplifier incorporated in the receiver itself, an oscillograph constructed for the measurement of absorption specially and dipole aerials for transmission and reception, tuned to the frequency of 5·65 Mc/s. An attenuator, which is matched to the aerial impedance, is incorporated between the aerial output and the receiver input. The gain of the receiver is kept constant. The attenuator provides a total attenuation of 90 db. at an impedance of 75 ohms to which the aerials are matched.

Results and discussion

Observations for about 23 days, evenly distributed in each month, are available between March and August 1958. Plots of $1+\log(-ln\rho)$ versus $1+\log\cos\chi$ are drawn for the daytime hours for each of the days under consideration. A straight line is fitted into the points obtained for each day. The gradient obtained in each case gives the value of n. The values of n thus obtained are presented in Table 1 along with corresponding dates of observation.

TABLE 1 — VALUES OF COS χ INDEX n

DATE	n VALUE
20 March 1958	1·40
21 March 1958	1·00
24 March 1958*	1·24
25 March 1958*	0·88
28 March 1958	1·43
18 April 1958	0·90
19 April 1958	1·58
20 April 1958	1·14
21 April 1958	1·14
5 May 1958	1·54
18 May 1958	1·10
19 May 1958	1·31
17 June 1958	1·60
18 June 1958	1·55
21 June 1958*	1·30
22 June 1958*	0·90
24 June 1958	1·75
9 July 1958	0·91
16 July 1958	1·35
17 July 1958	1·33
27 July 1958	1·30
30 July 1958*	0·90
7 August 1958*	1·36

*SWI days.

From the table it can be clearly seen that n varies from 0·88 to 1·75. An average value for all the observations comes out to be 1·25 as against the theoretical value of 1·5. Assuming that the absorption at noontime takes place in the E region, as the E region critical frequency during these months is close to the operating frequency, the absorption is calculated theoretically from Jaeger's formula given elsewhere. Taking ν_o to be $4{\cdot}5 \times 10^4$ c/s. at a height of 105 km. and the scale height H to be 8 km. at 105 km. level, the theoretical value of noontime summer absorption comes out to be 4·05 nepers which is close to the average summer noontime absorption of 4·4 nepers obtained by the authors. It is found that the contribution of F_1 region to absorption is considerably low. The authors have not observed any appreciable change of absorption as the operating frequency is increased gradually from a value below f_oF_1 to a value above this except when the operating frequency is close to f_oF_1. The F_1 critical frequency is sufficiently below the operating frequency, the collisional frequency in F_1 being much smaller than in E, at noontime so that its contribution to absorption can be neglected.

The contribution due to deviative absorption in F_2 layer is calculated and found to be about 0·2 nepers. The disagreement with regard to the value of the index of cos χ may be due to the fact that the assumption that the E region is of the simple Chapman type may not be correct.

As has been already said in the introduction, many workers report values of n widely differing from the one obtained by theory. It was found by Taylor that n also differs with frequency. Benner[9] reports a value of 0·7 for n, working on a frequency of 0·150 Mc/s.

It appears that the whole problem must be approached in a theoretical way to explain the variation of n with frequency and latitude. More data are also required to make any definite theoretical investigation of the experimentally observed facts.

Noontime absorption data that are available for most of the days from the beginning of this year gave a value of 2·2 on an average for the ratio of absorption value of summer to winter noon. The average summer noon absorption obtained is 4·4 nepers and winter noon absorption is 2·2 nepers. The summer absorption is in very good agreement with the theoretical value obtained on the basis of Jaeger's expression, but the winter value is not agreeing. This may be due to the fact that the available winter absorption data are not exhaustive.

Summary

Ionospheric absorption measurements on 5·65 Mc/s. were made at Waltair during the IGY period with a view to study absorption variation with zenith angle. The values of n, the cos χ index are found to vary from 0·88 to 1·75, the average being 1·25. A value of 2·2 is obtained for the average ratio of summer to winter noontime absorption coefficients.

Acknowledgement

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Effect of Enhanced Solar Activity on the F_2 Region Drifts at Waltair

B. RAMACHANDRA RAO & E. BHAGIRATHA RAO
Ionospheric Research Laboratory, Andhra University, Visakhapatnam

A SYSTEMATIC study of ionospheric drifts, particularly at low latitudes, is of importance in the current IGY programme as comparatively very little work has been done on the behaviour of the drifts in this region. It is expected that the wealth of new data available from such studies will help in the greater understanding of the worldwide distribution of drifts in the ionosphere, when examined in the light of the current theories of origin of drifts. Measurements of drifts in the E and F_2 regions of the ionosphere were first started at Waltair in 1953, using the spaced receiver method. The first observations were confined to a few specified daylight hours. Preliminary results of this investigation covering the period 1953-54 have already been published[1,2]. Since 1956, however, this programme of study has been intensified by taking continuous observations at hourly intervals for three consecutive days in each month with a view to study the diurnal or semi-diurnal variations as well as the seasonal changes, if any, in the F_2 region drifts. During the International Geophysical Year, hourly observations were taken on almost all the world days and the SWI days. The data obtained on some of the magnetically quiet days during the period of two years, February 1956 to January 1958, have been analysed and the main results of this investigation, which are in some respects different from those observed at high latitudes, have been reported in recent communications[3,4]. A result of this investigation, which is in agreement with that at high latitudes, is the predominance of the 24 hourly components in the diurnal variation curves of the NS and EW components of F_2 drifts, with a phase difference nearly equal to 90° in such sense that it indicates a continuous clockwise rotation of the drift vector. The drift directions at this latitude, however, are found to be nearly oppositely directed when compared to those observed at higher latitude at the same local time. This phase reversal of F_2 drifts at our low latitude is found to be in agreement with the prediction of phase reversal at 35° latitude expected on the basis of Martyn's theory[5].

The main object of the present investigation is to analyse the F_2 drift data obtained on several SWI days during the IGY and to examine the effect of enhanced solar activity on the trend of diurnal variation of drifts in F_2 region. Such an investigation has not been carried out so far systematically.

Experimental procedure

The method employed for the measurement of drifts is the spaced receiver method which has been suitably modified by using a triple-beam oscillograph for recording the fading patterns. Details of the equipment and the method of analysis have already been described elsewhere[1,2].

Almost all the F_2 layer drift records were taken on a frequency of 6·0 Mc/s. during most part of the daytime. With a view to see that the drift measurements refer to the same level in the F_2 region, the nighttime operating frequencies are reduced to a suitable value to give reflections from the same virtual height as during daytime. Fading records taken on a frequency less than or slightly higher than fE_s are discarded as the authors found that under these conditions F_2 drift measurements are generally influenced by the drifts in the E_s region[6].

SWI was declared on a good number of days during the period June 1957 to June 1958 but records could not be taken on all these SWI days due to occasional equipment failures and scarcity of recording films. Sufficient number of good records were not obtained on some SWI days due to heavy absorption. On the whole, records obtained on 21 SWI days are found to be suitable for analysis. The NS and EW components of

drifts obtained from observations on each of these days are first plotted separately and mean curves are drawn. A careful examination of these curves has shown that the variation exhibited by the NS and EW components on most of the successive SWI days in each month is more or less similar except on those days on or before the onset of an intense solar flare. Hence the data obtained on all the days other than intense solar flare days in each month are plotted in a single graph and a mean curve is drawn. Data obtained on the days when the drift behaviour is markedly different are plotted separately and mean curves representing the trend of variation on these days are obtained. The resulting daily variation curves thus obtained are shown in Fig. 1. The dates of the SWI days corresponding to each set of curves are given in the first column in Table 1. The results of harmonic analysis of all the curves are also presented in the same table along with the harmonic analysis data for the quiet days in the same months for the purpose of comparison. Even though drift data were available for one SWI day in August 1957 the number of observations were so few and widely scattered that no mean curve could be drawn. Data for the one SWI day declared in the month of November 1957 had to be dropped out for a similar reason.

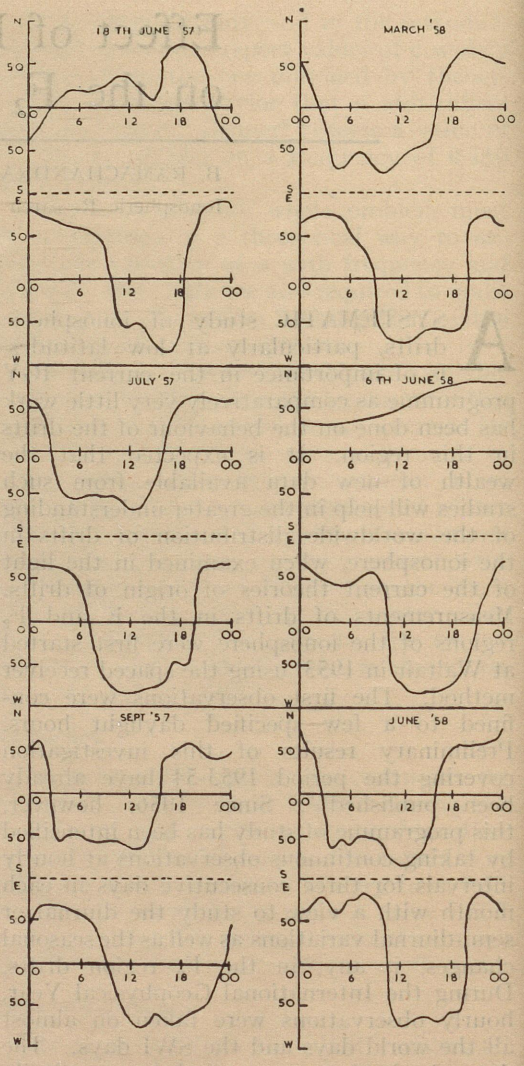

FIG. 1 — DAILY VARIATION OF NS AND EW COMPONENTS OF IONOSPHERIC DRIFTS

Results and discussion

It will be seen from the curves in Fig. 1, showing the variation of the NS and EW components of drifts on SWI days, that the 24 hourly component is predominant in all the curves except the NS curve on 18 June 1957 and 6 June 1958. This feature is in agreement with the variation of NS and EW curves on quiet days which also show a predominant 24 hourly component. The behaviour of the NS component on 18 June 1957 and 6 June 1958 is so unusual and entirely different from that observed on quiet days during the same month that the results from these records will be discussed separately.

The general trend of variation of the NS and EW components is more or less similar to that on a quiet day except for minor differences. Comparison of the harmonic analysis data on these days with the corresponding values of the quiet days in the same month shows that the differences are not significant. It will be noticed that the amplitude of the study component on SWI days is, in general, more than that on quiet days. The amplitude of the 24 hourly EW component is invariably higher than that in the NS curves, an observation which is in agreement with the conclusion from quiet day data. There is no significant difference in the 24 hourly components in the data taken on SWI and quiet days. From an analysis of drift data taken on quiet days over a period of two years the authors have already reported[3,4] that the phase angle of

TABLE 1 — HARMONIC ANALYSIS DATA OF F_2 DRIFTS ON SWI AND QUIET DAYS

(t, *local solar hour angle*)

June 1957	Q	NS	$-6{\cdot}6 + 78{\cdot}7 \sin(t + 127°) + 20{\cdot}5 \sin(2t + 339°)$
	Q	EW	$+1{\cdot}3 + 79{\cdot}6 \sin(t + 39°) + 18{\cdot}0 \sin(2t + 337°)$
18	SWI	NS	$+20{\cdot}1 + 18{\cdot}5 \sin(t + 210°) + 32{\cdot}7 \sin(2t + 230°)$
	SWI	EW	$+0{\cdot}8 + 88{\cdot}4 \sin(t + 56°) + 30{\cdot}3 \sin(2t + 174°)$
July 1957	Q	NS	$+6{\cdot}4 + 77{\cdot}6 \sin(t + 136° + 10{\cdot}0 \sin(2t + 158°)$
	Q	EW	$+1{\cdot}4 + 83{\cdot}6 \sin(t + 57°) + 10{\cdot}0 \sin(2t + 222°)$
1, 2, 3	SWI	NS	$-4{\cdot}2 + 73{\cdot}1 \sin(t + 130°) + 15{\cdot}6 \sin(2t + 225°)$
	SWI	EW	$-7{\cdot}1 + 89{\cdot}3 \sin(t + 73°) + 10{\cdot}5 \sin(2t + 22°)$
September 1957	Q	NS	$-9{\cdot}8 + 69{\cdot}0 \sin(t + 142°) + 21{\cdot}0 \sin(2t + 201°)$
	Q	EW	$-8{\cdot}2 + 78{\cdot}5 \sin(t + 45°) + 12{\cdot}8 \sin(2t + 352°)$
1, 2, 3, 4,	SWI	NS	$-6{\cdot}2 + 64{\cdot}4 \sin(t + 131°) + 7{\cdot}6 \sin(2t + 46°)$
12, 13	SWI	EW	$-10{\cdot}2 + 79{\cdot}0 \sin(t + 33°) + 14{\cdot}4 \sin(2t + 32°)$
March 1958	Q	NS	$-5{\cdot}1 + 73{\cdot}7 \sin(t + 140°) + 10{\cdot}7 \sin(2t + 46°)$
	Q	EW	$-4{\cdot}7 + 85{\cdot}8 \sin(t + 57°) + 14{\cdot}0 \sin(2t + 94°)$
5, 22, 24,	SWI	NS	$-9{\cdot}9 + 77{\cdot}2 \sin(t + 135°) + 10{\cdot}1 \sin(2t + 187°)$
25, 30, 31	SWI	EW	$+7{\cdot}4 + 81{\cdot}4 \sin(t + 63°) + 5{\cdot}1 \sin(2t + 243°)$
June 1958	Q	NS	$-9{\cdot}3 + 76{\cdot}3 \sin(t + 117°) + 15{\cdot}2 \sin(2t + 143°)$
	Q	EW	$+2{\cdot}1 + 84{\cdot}1 \sin(t + 39°) + 15{\cdot}2 \sin(2t + 331°)$
6	SWI	NS	$+ 62{\cdot}3$ (mean value)
	SWI	EW	$-5{\cdot}0 + 64{\cdot}0 \sin(t + 45°) + 17{\cdot}7 \sin(2t + 332°)$
7, 21, 22	SWI	NS	$-10{\cdot}0 + 74{\cdot}6 \sin(t + 145°) + 23{\cdot}6 \sin(2t + 265°)$
	SWI	EW	$-21{\cdot}5 + 82{\cdot}4 \sin(t + 42°) + 35{\cdot}7 \sin(2t + 266°)$

Q refers to quiet day variation.

the 24 hourly component for the NS curves is always higher than that for the EW curves by about 70°-80°, indicating a continuous clockwise rotation of the drift vector which completes a cycle in every 24 hr. This conclusion was found to be in agreement with a similar behaviour reported from higher latitude stations. The sense of phase difference between the 24. hourly components of the NS and EW curves is the same but the magnitude of the phase difference is found to be in general different from that on quiet days during the same month. For instance, this phase difference is higher than the value for the quiet days in the month of June 1958, while it is lower for the month of July and September 1957. The differences between the phase differences on quiet and SWI days are not significantly large, and hence they are possibly due to the uncertainty in drawing the mean curves through the observed points. The amplitudes of the 12 hourly component of drifts seem to be higher on the SWI days as compared to the corresponding values on quiet days in the same months.

Fig. 1 shows that the diurnal variation of the NS component on 18 June 1957 and 6 June 1958 was quite unusual, being different from that on quiet or other SWI days in the same month. It may be noted here that prominent solar flares were reported on 19 June 1957 and 6 June 1958 although the associated magnetic effects were not noticed. The effect of solar flare seems to be particularly prominent on the NS component on 6 June 1958 as the NS component was only towards north all through the day and only a gradual increase of the magnitude of the northerly component was noticed, the average value being 62 m./sec. The effect of solar flare is comparatively less on the NS component of drift on 18 June 1958. However, it is evident that there is more or less reversal of the drift directions of the NS component on this day, the drift being towards north during most part of the day, while it is usually directed towards south during daylight hours on quiet days. Around midnight, the drift is found to be directed towards south for a short duration, while it is normally towards north on all quiet days at this time of the year. The steady component on this day is of considerable magnitude and is directed towards north. The 12 hourly component has an amplitude which is larger than the 24 hourly component, the amplitudes of the 24 hourly component being considerably smaller than the corresponding values for the EW component. It is interesting to note that the solar flare effect is noticeable only on the NS component and not on EW component, as the diurnal variation of the EW component is more or less similar to that on quiet days.

It is generally believed that the various ionospheric disturbances accompanying solar flares are due to sudden enhancement of electron concentration at or below the level of E region. Several investigators have studied the effects of solar flares from the measurement of group path, phase path and

absorption on low frequencies. However, so far there is no evidence of effect of solar flares on F_2 region drifts. From a study of geomagnetic effects over a whole hemisphere produced by three solar flares, McNish[7] concluded that the main effect is an augmentation of the S field of the sunlit hemisphere due to increased strength of the current system in the lower E region. Further it is believed that the excess current is in the same direction as the normal diurnal variation current. As has been reported in earlier communications[3,4], the results of drift measurements at this latitude on quiet days revealed the interesting fact that they are in phase opposition to those at high latitudes confirming in a way the theory of the origin of F_2 drifts proposed by Martyn. If the predominant northerly movement of the F_2 drifts on prominent solar flare days is to be interpreted on the basis of Martyn theory, it is necessary to assume the presence of S field of opposite sense in the lower dynamo region during daytime. If the normal S field in the lower dynamo region is reversed on solar flare days during the daytime, then the combined effect of this field with vertical component of the earths field gives rise to a northerly drift. The predominantly northerly drift direction can thus be explained. But as yet there is no evidence to show that the S field in the dynamo region is reversed during a solar flare of class 2 prominence. We are handicapped in this study due to lack of a p'-f recorder, which would have enabled us to study the related effects of solar flares on other ionospheric parameters. It may, however, be said that this result will be useful in the development of the origin of F_2 drifts. Further work extended over a considerable period is necessary before the full significance of this result can be understood.

Summary

The results of harmonic analysis of drift data taken on a number of SWI days during the first one year of the IGY period are analysed with a view to studying the effect of solar activity on F_2 drifts. Comparison of these results with those obtained on quiet days revealed that the variation of the NS component is considerably affected on the SWI days on which prominent solar flares were reported. No significant effects were noticed on other days.

Acknowledgement

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A New Continuous Wave Radio Method for the Study of Ionospheric Drifts

B. RAMACHANDRA RAO & D. SATYANARAYANA MURTY
Ionospheric Research Laboratory, Andhra University, Visakhapatnam

AMONG the various methods available for the study of ionospheric drifts, the spaced receiver method of Mitra[1] has been widely used by several investigators as it is comparatively simpler in technique and convenient for this type of study. In a recent communication[2] from this laboratory, we have reported a new and simple method of studying ionosphere drifts, which has some advantages over other methods. In this method short-wave transmissions from a distant All India Radio (A.I.R.) transmitter are received by three simple vertical aerials situated at the corners of a right-angled triangle and the signal strengths of radio waves received at these points are recorded side by side on a photographic paper. Under conditions when ground wave is completely attenuated and only a single hop reflection from one region of the ionosphere is prominent, records were taken and analysed for evaluating the time displacements between identical fades in the three signal strength curves. The ionospheric drift velocities and directions are then calculated in the same way as for Mitra's method. This method is thus similar in principle to Mitra's method but it has the definite advantage of being much simpler in technique as it dispenses away with most of the elaborate electronic equipment required for the latter method. In later experiments, the technique involved was further simplified by using only a single communication receiver for amplifying the signals from all the three aerials in succession by using a high speed two-pole three-way rotary switch connected at the input and output ends of the receiver so that each recording galvanometer receives the amplified and rectified voltage due to signals from only one corresponding aerial during one-third of the rotation of the switch.

Experimental procedure

The equipment used for this investigation consists of a system of three vertical aerials, a specially designed two-pole three-way high speed rotary switch, one National H.R.O.-7 communication receiver, and a simple recording arrangement consisting of three Pye type galvanometers and a recording drum camera. Three pieces of 9 ft length of brass tubing supported vertically on insulated stands are used as vertical aerials and these are placed at the corners of a right-angled triangular plot on the ground such that aerials A_1 and A_3 are along north-south direction, and aerials A_1 and A_2 are along east-west direction, the separations being 64 and 60 metres respectively. The signals picked up by these aerials are brought through shielded coaxial cables to the recording station and fed to the receiver through the rotary switch.

The main purpose of the mechanical rotary switch (Fig. 1) is to dispense with the use of three different communication receivers for amplifying the signals from the three aerials. The high speed rotary mechanical switch consists of two independent identical sections each of which is a single-pole three-way device.

Each section of the switch consists of a brass annular ring divided equally into three segments which are insulated from each other by leaving a gap between the ends and mounting them on an ebonite base plate. Two of these sections are mounted on the opposite sides of a wooden box in identical fashion such that corresponding segments in each section have the same orientation. An ebonite rod passing axially through the two sections and mounted on ball bearings carries two adjustable phosphor-bronze contacting strips at each end such that the strips make effective contact with the brass segments. The rod is driven at a high speed of 1400 r.p.m. by connecting a $\frac{1}{8}$ h.p. motor to a pulley fixed at the centre of the rod. Two fixed phosphor-bronze strips mounted on insulators on the box press against the rotating contacts thus enabling electrical connection.

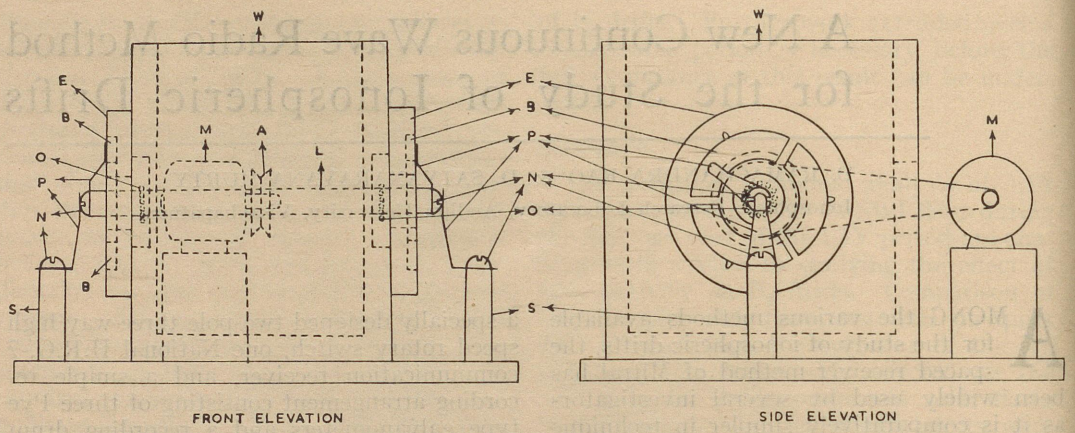

FIG. 1 — SECTIONAL VIEW OF THE TWO-POLE, THREE-WAY MECHANICAL ROTARY SWITCH [A, aluminium pulley; B, brass segments; E, ebonite annular disc; L, ebonite rod; M, motor; N, brass screw; O, ball bearing; P, phosphor-bronze strip; S, stand-off insulator; and W, wooden box]

One section of this switch is used at the input end of the receiver by connecting the three feeders to the fixed brass segments and the variable contact terminal to the input of the receiver so that the receiver amplifies the signals from the three aerials in succession as the variable contact rotates at a high speed. The other section of the switch is used at the output end for connecting the A.V.C. voltages due to the signals from the three aerials to the corresponding galvanometers. All the three fixed brass segments are connected to the three galvanometers and the variable contacting terminal is connected to A.V.C. lead of the receiver. The positions of the variable contacts on each section of the switch are so adjusted that at any position of the switch each galvanometer is fed by A.V.C. voltage due to signal picked by only one corresponding aerial. Thus the deflection in each galvanometer is proportional to the signal received by the corresponding aerial. The rate of the rotation of the movable contact of the switch being quite high a smooth fading record showing the variation of the signal strength at each point of the aerial is obtained though it is an interrupted signal that is fed to each galvanometer. The recording camera consists of a light-proof box in which a cylindrical drum of length 15 in. and circumference 12 in. is supported by two ball bearings and rotates about the horizontal axis. An opening provided at one end of the box contains a cylindrical lens of 4 in. focal length and 15 in. length and is provided with a light-proof cover. The axle of the drum, which projects outside the box, is coupled directly to a $\frac{1}{16}$ h.p. Everett Edgecumb 1 r.p.m. synchronous motor so that the photographic paper on the drum moves at the rate of 12 in. per minute. Light from a lamp housing, mounted rigidly on the wall and vertically above the galvanometer, was allowed to fall on the galvanometer mirrors after reflection by right-angled prisms and gets focussed as a fine spot on the photographic paper rolled on the drum of the camera after reflection. A typical record taken on 30 October 1955 using transmissions on 9·5 Mc/s. from Ceylon is reproduced in Fig. 2. It can be clearly seen that the fading patterns for all the three aerials are almost identical and that there are regular and systematic time differences in the occurrence of maxima or minima in each record. The ionospheric drift velocities and directions are then calculated from these time displacements in the same manner as for Mitra's method.

Results

Drift measurements for F_2 region — Records were taken on a frequency of transmission of 9·59 Mc/s. for Madras station situated at a distance of 600 km. during the month of November 1955 between 1300 and 1430 hrs. From the available ionospheric data, it is estimated that the maximum usable frequencies for transmission from Madras to Waltair by single hop reflections from E, F_1 and F_2 are 7·8, 7·5 and 11·5 Mc/s. respectively.

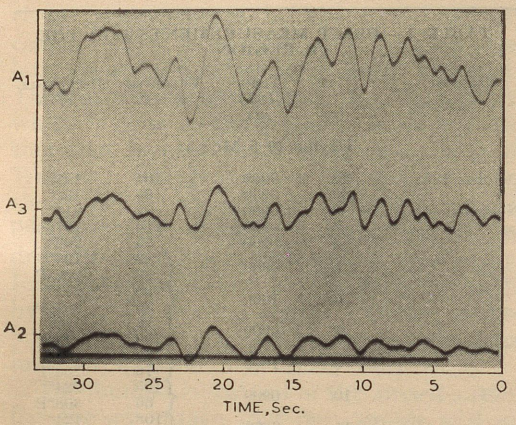

FIG. 2 — SIMULTANEOUS SPACED RECEIVER SIGNAL STRENGTH RECORD OF C.W. TRANSMISSIONS FROM CEYLON (9·5 Mc/s.) [Date, 30 October 1955; time, 0900 hrs IST; A_1, A_2 and A_3 represent the three aerials]

These values are only approximate and hold good for the time duration of the records. It is, therefore, inferred that no reflection is possible from E and F_1 regions while F_2 region gives a prominent single hop reflection. During the earlier part of the recording, when the ionization density is a little higher, there is a possibility of second hop reflection from F_2 region which may give rise to periodic fading due to $1F_2$ and $2F_2$ interference. But this effect is not observed prominently presumably due to the high absorption of the second hop reflection which is close to the M.U.F. for that angle. Such portions of those records which show occasionally significant periodic fading due to this effect are discarded. Thus by carefully examining the record visually for any prominent periodic fading before taking it up for analysis, possible errors due to this effect were avoided.

Transmissions on a frequency of 11·89 Mc/s. from Delhi station of A.I.R. situated at a distance of 1500 km. were also used for taking wind records in the early morning sunrise hours. Using the approximately known critical frequencies for the midpoint at the time of observations, maximum usable frequencies for single hop transmission by E and F_2 regions are found to be 8 and 11 Mc/s. respectively. Reflection from both the layers is, therefore, ruled out, but single hop reflection from F_2 layer is possible for the extraordinary ray as the maximum usable frequencies given above are for the ordinary ray only. The ordinary ray will penetrate all the ionospheric regions and no reflection is possible for this component. It will be noted that this condition is highly suited for wind measurements as all possible causes of periodic fading are eliminated. Transmissions on this frequency are usually available from Delhi from 0600 hrs but no reception is observed at Waltair until about 0620 hrs when the extraordinary ray is found to be returned by way of single reflection. Immediately after reception of signals with appreciable strength, all the Delhi records were taken to avoid magneto-ionic fading which is observed subsequently when the F_2 ionization rises high enough to return the ordinary ray.

The results for the F_2 region drift velocities and directions thus obtained during the month of November by using both these transmissions from Madras and Delhi are presented in Table 1. It will be noticed that the wind velocities are in a range of 40 to 120 m./sec. while most of the observations show a predominant wind direction which is towards south-west. These observations are in good agreement with the results obtained in this laboratory[3] by the pulse technique for the same season.

Drift measurements for E region — This method has also been extended for the study of drifts in the E region by choosing suitable wavelengths such that single hop reflection from E is predominant. Transmissions from

TABLE 1 — DRIFT MEASUREMENTS FOR THE F_2 REGION

MONTH	DATE	TIME (*IST*) *hrs*	VELOCITY *m./sec.*	DIRECTION *E of N*
		Madras (9·59 Mc/s.)		
November 1955	5	1330	73	243°
			73	233°P
	6	1430	60	38°
			75	69°P
	15	1320	40	261°
			91	225°P
	17	1330	46	254°
			101	227°P
	19	1400	62	222°
			110	231°P
		Delhi (11·89 Mc/s.)		
	24	0630	56	310°
	25	0620	53	61°
	25	0630	52	59°
	27	0630	70	224°
	29	0620	120	202°
	30	0630	85	218°
December 1955	1	0630	55	219°

P = pulse method.

Radio Ceylon station at a distance of 1540 km. on a frequency of 9·5 Mc/s. were used for taking drift records during the forenoon between 0900 and 1000 hrs. From the available ionospheric data, the maximum usable frequencies calculated for single hop reflection from E, F_1 and F_2 layers are found to be about 14·4, 12·6 and 16·0 Mc/s. respectively. This implies that single hop reflection is possible from all the three layers but it can be easily shown that the radio waves cannot penetrate the E and F_1 layers to get single reflected waves from the F_1 and F_2 layers respectively. The heights of F_1 and F_2 layers at this time during the month of December are found to be 225 and 250 km. Calculation has shown that to get reflection from F_1 layer the radio waves have to proceed at the appropriate angle for which the M.U.F. for E layer is as high as 9·8 Mc/s. and as such the transmissions on 9·5 Mc/s. cannot penetrate the E layer. In a similar manner it is observed that rays proceeding towards F_2 region for single reflection cannot penetrate the F_1 layer which has a M.U.F. of 10·8 Mc/s. though they can penetrate the E region having an M.U.F. of about 8·2 Mc/s. for this angle of incidence. The only other possibility is the single hop reflection from the E region as the second hop will be reduced in intensity considerably due to heavier absorption in the D region which is the main absorbing layer. Further the deviative absorption also will be considerable for the second reflection as the wave frequency will be very near the M.U.F. The drift velocities and directions thus determined for the E region are given in Table 2. The velocities are found to be in the range of 60 to 120 m./sec., while the directions are equally distributed between the south-east and south-west.

With a view to make a comparative study of drift measurements by the C.W. method employed by the authors with the results obtained by the spaced receiver pulse method of Mitra, simultaneous measurements of drift velocities and directions were made on 5·9 Mc/s. for the F_2 layer and 2·8 Mc/s. for the E layer. These simultaneous measurements were made when Madras and Ceylon transmissions were used for the C.W. method. The drift velocities and directions thus determined by the pulse method indicated by letter P are presented side by side with the results by C.W. method in Tables 1 and 2.

TABLE 2 — DRIFT MEASUREMENTS FOR THE E REGION

Month	Date	Time (*IST*) *hrs*	Velocity *m./sec.*	Direction *E of N*
		Ceylon (9·5 Mc/s.)		
October 1955	30	0900	104	155°
	30	0930	86	152°
November 1955	2	0900	87	211°
	3	0900	118	137°
	4	0900	75	202°
	5	0900	83	196°
			80	222°P
	6	1000	88	212°
			89	204°P
	7	0900	78	140°
			100	245°P
	9	1000	82	158°
			76	230°P
	10	0900	105	224°
			66	308°P
	11	0900	108	124°
			92	237°P
	12	0900	62	239°
	13	0900	89	149°
	14	0900	96	214°

P = pulse method.

Discussion

A comparison of the results of simultaneous drift measurements for F_2 layer by the C.W. and pulse methods presented in Table 1 reveals the interesting fact that the agreement is quite good particularly for the drift directions. On the other hand, the drift velocities by the pulse method are in some cases quite high compared to those by the C.W. method. This may possibly be due to the fact that the actual velocities obtained by both the methods genuinely differ occasionally as they correspond to different points of reflection in the ionosphere. The results obtained by the C.W. method using Madras transmissions give drift data in the F_2 region at a point midway between Madras and Waltair, while the pulse method gives data for the ionosphere above Waltair.

Simultaneous drift data obtained by the C.W. and pulse methods for the E region (Table 2) agree well in respect of velocities, though the drift directions are differing in some cases. The drift directions obtained by the pulse method show a consistent south-west wind direction not only from the simultaneous studies undertaken here but also from the regular drift measurements made by the pulse method over a large number of days during this season[3]. The direction of ionospheric drift obtained by the C.W. method shows a fluctuation from south-west to south-east directions, both being equally prominent. It must be noted that

these measurements by the C.W. method correspond to a point in the E region at a latitude midway between Ceylon and Waltair. These drift measurements for this point, which is close to the magnetic equator, may, therefore, be expected to differ from those of Waltair. It appears from this study that at the time of observation, which is around 0900 hrs IST, there is a transition of the drift direction from south-west to south-east. Ionospheric drift data for the E region made by the pulse method at this latitude, corresponding to the mid-point, are not available in order to make a detailed comparison.

The method employed in this investigation has the advantage that it is simple and inexpensive compared to some of the previous radio methods. Though, in principle, it is similar to Mitra's three-station method, it has the advantage that there is no need to use pulse transmitter, associated trigger circuits and oscillographs, which are essential in Mitra's method. The method also gives reliable results for drift data for the E and F_2 regions as the data obtained by this method are in reasonably good agreement with the values obtained by the pulse method.

The main disadvantage of this method is the ambiguity introduced in the results if multiple hops are received with sufficient signal strength to produce periodic fading. This has been largely eliminated in the present investigation by choice of operating frequency and time of recording. As for instance, though we have used the beamed transmissions from Delhi in the A.I.R. external services which should have normally skipped Waltair, signals of sufficient strength received by single hop reflection must be off-the-beam radiations. In this case both multiple hop interference and magneto-ionic fading were eliminated completely by choice of the time of recording. In the case of Madras and Ceylon transmissions there is a possibility of periodic fading due to magneto-ionic components but this fading is usually quite slow when the operating frequency is sufficiently below the M.U.F. that it can be easily distinguished from quick fading due to irregularities in the region which is used for taking time displacements in drift measurements. The usual uncertainty about the location of drifts measured by the spaced receiver pulse method applied to F_2 region is also present in this C.W. method, but recent measurements in our laboratory by simultaneous study of drifts by pulse method from E and F regions have shown conclusively that the drift measurements for the upper F_2 layer are not influenced by the drifts in the lower E region unless the operating frequency is very close to the critical frequency of the lower region.

Another unique advantage of this method is that it is possible to determine simultaneously the drift velocities and directions for any ionospheric region over different latitudes by choosing different transmitting stations for this study, as the measurements give values of drift data of the ionosphere midway between the transmitting and receiving centres.

Summary

A simple method for measuring the ionospheric drifts using transmissions from distant broadcasting stations is described, and the method has been utilized for measuring drifts in the E and F_2 regions. Comparison of the results obtained by this method with those obtained by using the standard spaced receiver pulse method showed that this method gives reliable and consistent results. By choosing proper operating frequencies, it is shown that the method has an important advantage and can be used for measuring drifts at different positions in the ionosphere by taking observations from the same receiving centre.

Acknowledgement

Our thanks are due to the Council of Scientific & Industrial Research for a research grant.

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Programme of IGY Solar Observations in India

THE sun occupies an important place in the programme of the International Geophysical Year. In India the sun is being watched by both optical and radio methods. The optical observations are carried out at Kodaikanal and Hyderabad, and the radio observations at the National Physical Laboratory (NPL), New Delhi, and Hyderabad. The latter are reported separately by A. P. Mitra and his colleagues (NPL) and by M. Krishnamurthi and others (Hyderabad).

The optical programme, which forms the major portion of the Indian programme on solar activity, is outlined below.

Kodaikanal Observatory

During the IGY, the normal routine programme of observations at Kodaikanal was intensified and extended in order to obtain as complete a coverage as possible. The extended programme is described below.

Photoheliograms — A photoheliogram in the blue-violet region was taken on 25 × 25 cm. plates every day in the morning using a 15 cm. photoheliograph with a suitable enlarging system giving a solar image of 20 cm. diameter. Weather permitting, two more photoheliograms were also taken daily, one at about 0500 hrs UT and the other at 0830 hrs UT on smaller plates, but covering the sunspot belts. In addition, visual sketching of spots and faculae was done once every day projecting, with the help of a 7·5 cm. telescope attached to the photoheliograph, an image of the sun on the same scale as for the photoheliogram, on an appropriate sun-chart.

Prominence spectroscope observations — Visual observations of fairly tall prominences in H-alpha, D_3 and H-beta lines were made with the prominence spectroscope once every day. Flares, dark-markings, sunspots, etc., were also studied. During the progress of special solar events, however, these observations were made continuously as long as the concerned phenomena lasted and were observable.

Spectroheliograms — Two complete sets of spectroheliograms of the disc in H-alpha and K and the prominences in K were taken daily at about 0200 hrs UT. In addition, two more sets of spectroheliograms were taken, one at about 0600 hrs UT and the other at 0830 hrs UT. Photometric standards were impressed on all these spectroheliograms.

Spectrohelioscope — Prominences, flares, dark-markings, etc., were visually observed in the H-alpha line with the spectrohelioscope. The hours of watch were 0200-0300, 0400-0430, 0500-0530, 0600-0630, 0830-0900 and 1000-1030 hrs UT. All observed features were sketched on a sun-chart on a scale of 20 cm. to the sun's diameter. A series of measurements of the effective line width, intensity, area, etc., were made at frequent intervals according to instructions contained in the *Instruction Manual of Solar Activity*.

To the spectrohelioscope of the Kodaikanal Observatory is attached a camera which permits the photographing of spectra of prominences, flares, etc., along with the visual observations. The third order spectrum covering almost the entire region from the H and K lines to a little beyond the F line can be photographed with this camera on a scale of about 3A./mm.; simultaneously the H-alpha line of the second order can also be photographed on a strip of plate sensitive to the H-alpha line. Spectra of flares, eruptive prominences, etc., were photographed with this camera at frequent intervals during the

progress of the phenomena. Special arrangements also exist for impressing photometric standards on the spectrum plates.

Lyot heliograph and coronagraph — The major optical components for the construction of a Lyot monochromatic heliograph have been received from France. The assembly of the instrument has been completed and it will be installed for regular observations as soon as the dome (for housing this instrument as well as the coronagraph), which is under construction, is completed. The coronagraph is expected shortly, and will be installed on an equatorial mount which has been kept ready; regular observations of the corona will begin only after the completion of the dome.

Nizamiah Observatory

This observatory has been participating in the observations of (i) solar flares, (ii) bright and dark surges and active prominence regions and (iii) sudden disappearances of filaments and prominences. These are observed by means of a spectrohelioscope in H-alpha light in accordance with the *Instruction Manual of Solar Activity*. The patrol hours of this observatory are 0300-0400, 0430-0500, 0530-0600, 0900-1000 and 1030-1100 hrs UT. During the period 1 July 1957 to 31 July 1958, the sun's disc was under observation for 594 hr and 105 flares, 99 surges and active prominence regions and 5 sudden disappearances were observed. Radial velocity observations of surges and active prominences were also communicated to the world data centres.

As in other fields, these data are being regularly despatched to the world data centres. In addition, daily summaries are regularly broadcast from All India Meteorological Broadcasting Centre; and data on solar flare and sunspot maximum are regularly published in the Radio Research Committee's publication on ionospheric data.

Solar Control of Some Unusually Remarkable Geophysical Events

S. L. MALURKAR
Colaba Observatory, Bombay

IT is well known that 24-48 hr after a solar active region has crossed its central meridian (C.M.) worldwide geomagnetic disturbances are often observed. These are accompanied by ionospheric disturbances, and occasionally by changes (generally a decrease) of the cosmic ray intensity, the latter showing close parallelism with the changes in the geomagnetic field[1,2]. These effects are assumed to be caused by emission of corpuscles from the sun, having velocities of the order of 800-1600 km./sec.

The second type of cosmic ray effect, associated with solar flares, occurs a little after the chromospheric eruption (thus needing a very high speed of the corpuscular emission, usually a large fraction of that of light), and occurs at stations away from the geomagnetic equator[3,4]. Forbush, Stinchcomb and Schein[5] brought together the following four very large solar flares which had given rise to cosmic ray bursts:

(1) The solar flare of 28 February 1942 was followed on March 1 by a geomagnetic storm with simultaneous cosmic ray change everywhere including Huancayo (near geomagnetic equator).

(2) The solar event of 7 March 1942 was not followed by a geomagnetic storm with corresponding cosmic ray changes. (The crochet recorded on the Alibag H magnetograms at 0440 hrs GMT shows a large steep rise of

TABLE 1 — MAJOR SOLAR ACTIVE REGIONS AND ASSOCIATED PHENOMENA

Solar active regions					Solar flares			Cosmic ray burst date	Magnetic storm date	Interval between magnetic storm and solar flare†	Interval between magnetic storm and C.M. passage	Simultaneous occurrence of cosmic ray and magnetic storm
Year	No.	Co-ordinates	C.M. passage date	Age	No. of distinct flares observed	Date	C.M. distance*	Age*					
1941	7	15N 35R	Feb. 27·5	2	7	—	—	—		Mar. 1·15	—	1·85	Magnetic storm not affected by cosmic ray
1942	12	7N 197	Feb. 28·8	+26?	17	Feb. 28·5	4E	+26?	Feb. 28·5	Mar. 1·31	0·81	0·51	
1942	—	7N 197	—	—	—	Mar. 7·20	91W	+32?	Mar. 7·18	—	—	—	
1946	15	23N 10	Mar. 26·9	>6	3	Mar. 27·2	4W	>6	—	Mar. 28·1	1·10	1·41	Magnetic storm affected by cosmic rays
1946	51	21N 198	July 26·8	>6	37	July 25·67	16E	>5	July 25·67	July 26·8	1·13	0·00	
1949/4	23‡	2S 116	Nov. 14·1	3	17	Nov. 19·40	75W	8	Nov. 19·44	—	—	—	Electron density in F_2 layer§ increased
1956/1	17	22N 176	Feb. 17·8	>6	32	Feb. 23·13	80W	11	Feb. 23·13	—	—	—	

*C.M. distance and age refer to those of the solar active region numbered in each row; C.M. distances approximate to within a few degrees only due to inherent observational approximations.

†Solar flare deduced from R.F. for the daylight side of the hemisphere.

‡The age at C.M. passage for this period is given as −1 in *Q. Bull. Solar Activity* (Int. astronom. Union, Zürich), No. 113 (1956), 264. It was also observed at Mitaka on 11 November 1949, 13 November 1949 and again on 14 November 1949. The age has been changed accordingly. It is also mentioned that this active region was a fresh formation on the return of active region No. 13 of 1949/4.

§No data of F_2 region behaviour available for other dates.

about 40 γ but its fall is much slower than usual.)

(3) The solar flare of 25 February 1946 was followed by a geomagnetic storm next day with corresponding cosmic ray changes at all observatories (even near the geomagnetic equator).

(4) The solar flare of 19 November 1949 had a phenomenal cosmic ray burst of 206 per cent above normal at Boulder. No geomagnetic storm with corresponding changes in cosmic ray followed.

In none of these events did the cosmic ray burst occur near the geomagnetic equator.

During the period of ten years covered above, there were only these four events of any appreciable changes in cosmic rays, although during this period a large number of big solar flares was observed. Examination of these four events reveal the following facts:

(1) The solar active regions corresponding to these events were all outstanding for their previous history.

(2) Of the four events, two (28 February 1942 and 25 July 1946) occurred when the corresponding solar active regions were near the C.M. These were followed by a geomagnetic storm *and* cosmic ray changes. In the two other instances (7 March 1942 and 19 November 1949), the solar flares were observed at or near the western limb of the sun. These were *not* followed by geomagnetic storms with cosmic ray changes. It appears that a cosmic ray burst and a subsequent geomagnetic storm with corresponding contemporaneous cosmic ray changes could be considered as eliminating criteria.

Now, there occurred on 23 February 1956 at 0330 hrs GMT, a remarkably severe solar flare which was accompanied by a large cosmic ray increase at all places, even at low latitudes. The flare belonged to a very active region at the western limb of the sun. The region was very active even when first sighted at McMath on 10 February 1956 near the eastern limb of the sun. A geomagnetic storm was recorded on 25 February 1954, but no change in cosmic ray could be observed during this storm[6]. This solar flare may, therefore, be considered as analogous to those of 7 March 1942 and 19 November 1949.

The data corresponding to these five events are given in Table 1.

From the results presented above, the following conclusions may be drawn:

(1) The position of the active region in the sun appears to be important in causing major geophysical events. Two small longitudinal sectors, one near the western limb and the other near the C.M. of the sun, are the areas where solar flares have been observed.

(2) Only those solar flares which arise from active regions of long and active history, give rise to big cosmic ray bursts.

(3) Cosmic ray bursts occur for severe solar flares occurring near the western limb of the sun. Apart from the usual fadeouts, such events are also associated frequently with an increase in electron density in the F_2 region of the ionosphere.

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Radio Emission from the Sun at 30 Mc/s.*

M. KRISHNAMURTHI†, G. SIVARAMA SASTRY & T. SESHAGIRI RAO

Physical Laboratories, Osmania University, Hyderabad

THE study of the sun and various solar phenomena forms an important part of the IGY programme. The work that is being reported in this communication has not been specifically undertaken as part of the IGY programme, but it is hoped that the results will be of interest to the other groups engaged in this programme. For the last eight months, the authors have been continuously recording the cosmic radio radiation at a frequency of 30 Mc/s. using a transit type instrument to be described more fully in the following paragraphs. In the months of May, June, July and August 1958, the sun has been in the beam of our radio telescope and the present paper is based on the observations made during this period.

Extensive observations on the sun have been made in the frequency region of 80-15,000 Mc/s. at various wavelengths. Recently, dynamic spectra of solar radiation in the range of 40-240 Mc/s. have been studied by Wild *et al.*[1-3]. Only few solar records are available at frequencies below 40 Mc/s. The present work should, therefore, be useful in extending the range of frequencies on the lower side.

Equipment

The receiving aerial consists of 30 full-wave dipole elements located about $\lambda/6$ above a flat ground. The 30 dipoles are distributed in five rows in the E-W direction and six columns in the N-S direction, the individual dipole being oriented in the E-W direction. The six elements in the N-S row were located at intervals of half a wavelength and are all connected in phase to a matching transmission line. The five transmission lines from the five columns are brought together in phase to the primary of a mutually coupled pair of tuned circuits.

*Communicated by Dr Akbar Ali, Director, Nizamiah Observatory, Begumpet, Hyderabad.

†Present address: Nizamiah Observatory, Hyderabad.

The secondary is connected to the receiver input by means of a low loss coaxial cable. The tuned transformer acts as a matching device. The beam width of the array between half power points in the E-W direction is 8° and in the N-S direction, 18°.

The receiving equipment consists of a Marconi type CR 150/3 receiver, the i.f. output of which is further amplified and rectified. The d.c. output is fed to an Esterline Angus recording milliammeter through a G.R. type 715-AS2 d.c. amplifier. The receiver alignment was specially altered to give maximum sensitivity at and near 30 Mc/s. The bandwidth of the receiver is 13 kc/s. and the time constant of the detector output is 4 sec. The gain of the receiving system is checked at regular intervals during the day with a local noise generator using a noise diode type CV 2171. The power supply to the whole unit consists of a constant voltage transformer followed by a voltage stabilized d.c. supply. Thus the regulation is carried out both at the a.c. mains and after rectification. This ensures constant voltage not only to the various electrodes of the valves but also to the filaments. The constancy of the output of the receiving equipment in the absence of the aerial was also checked occasionally for a full period of 24 hr.

Results

The results presented here cover a period of four months from 1 May 1958 to 31 August 1958. The usual types of solar radiation observed at higher frequencies may be classified into the following categories:

(1) Thermal radiation from the quiet sun;
(2) (a) noise outbursts of short duration of the order of less than a minute;
(b) noise outbursts of long duration of the order of a few minutes; and
(3) enhanced radiation.

While the first one is associated with the undisturbed sun, the other two are supposed to be due to some disturbing events in the sun. Our observations on the sun also have been classified as above and the results will be presented in these three categories.

Quiet sun radiation — This should be observable every day when the sun is in the beam of the aerial. But no such daily emission has been detected at noontime. This means that if there is any radiation from the quiet sun at this frequency of 30 Mc/s. it is less than the minimum detectable noise level of the receiving system. In order to calculate the minimum detectable noise level, it is assumed that the minimum background temperature of the sky at this frequency is 12,000°K. at noon during this part of the year. This assumption is based on our own survey of the sky as well as those of other workers. For our aerial system, and for a source of the sun's angular size, the minimum

TABLE 1 — ENHANCED RADIO EMISSION FROM THE SUN

Date	Duration		Max. flux density 10^{-22} *watts* m^{-2} $(CPS)^{-1}$	Remarks
	Beginning *IST hrs*	End *IST hrs*		
May 1958				
1	1105	1205	2	—
2	1200	1300	4	—
3	1100	1300	<1	—
5	1135	1340	1	—
19	1030	1150	5	—
June 1958				
5	1045	1300	16	—
6	1015	1030	Out of scale	Solar flare of importance 2 reported
26	1030	1315	16	Solar flare of importance 3 reported
July 1958				
3	1100	1330	2	—
10	1125	1330	1	—
11	1110	1400	8	—
12	1030	1430	Out of scale	—
13	1000	1415	do	Estimated from minor lobe, 40 units
14	1145	1300	2	—
15	1200	1300	⩽1	—
19	1200	1315	2	—
22	1145	1315	4	—
23	—	—	⩽1	—
24	1115	1400	14	—
25	1045	1400	Out of scale	Estimated from minor lobe, 70 units
26	0930	1400	8	Solar flare of importance 1 reported
27	1145	1400	10	—
28	1115	1300	4	—
29	0900	1315	Out of scale	Radio fadeout reported
30	1145	1245	2	—
31	1130	1200	9	—
Aug. 1958				
1	1110	1410	7	—
2	1200	1245	3	—
9	1150	1205	Out of scale	—
10	1150	1210	5	—
10	1215	1330	Out of scale	—
11	1100	1315	10	—
12	1105	1315	15	—
13	1145	1300	7	—
14	1115	1225	8	—
14	1230	1300	4	—
16	1015	1500*	Out of scale	Estimated from minor lobe, 100 units
31	1145	1310	14	—

*Instrument failed at 1500 hrs IST and put back into operation on 29 August 1958.

detectable difference in temperature between source and background is calculated to be 40,000°K. The fact that no radiation from the quiet sun is recorded, therefore, means that the quiet sun temperature at this frequency is less than 52,000°K.

Noise outbursts of short as well as long duration were observed quite frequently during the four-month period. The number of days on which both types of outbursts are absent was very few. The intensities and duration of these outbursts were very varied, ranging in flux densities from 10^{-23} to more than 10^{-21} watts m.$^{-2}$ (c/s.)$^{-1}$ and in time from a few seconds to a few minutes. Available data on daily relative sunspot numbers were compared with the occurrence of these events but no correlation was found between the two phenomena.

Enhanced radiation, sometimes lasting several hours, has been observed on nearly 40 days during this period. The dates on which enhanced radiation was observed are listed in Table 1, along with duration and the maximum observed flux density. On a number of occasions, the flux density could not be measured as the recorder went out of scale. In such cases the flux density is much higher than 20×10^{-22} units. In some instances, where the radiation was observed in the minor lobes, the intensity was estimated from the known radiation pattern of the aerial array. The duration of the radiation, as given in Table 1, will have to be taken with some reserve as the sensitivity of the aerial to solar radiation is not the same throughout the day.

Most of the events were confined to July and August whereas in the months of May and June enhanced radiation was detected only on eight different occasions. Only three of all these events could be associated with solar flares observed at Hyderabad and Kodaikanal, namely those occurring on 6 and 26 June and 26 July. On 29 July, optical observations could not be made due to cloudy conditions but worldwide reports of a radio fadeout indicate that a solar flare might have occurred on that day. Therefore, the enhanced radiation observed on that day also might be associated with a solar flare. The other occurrences of enhanced radiation could not be correlated with any solar flare or with the observed relative sunspot numbers. This is in accordance with the earlier results of Allen[4] and Owren[5].

It might be of interest to note that while almost all the occurrences of enhanced radio emission were accompanied by noise outbursts of short duration, the one on 16 August was almost completely devoid of any short duration outburst.

Information on the area of the largest sunspot each day and also of calcium plates is being obtained from other observatories. Further analysis of the above data will be taken up later.

Summary

The results of observations on solar radio emission at a frequency of 30 Mc/s. during the period May-August 1958 are presented. No radiation from the quiet sun was observed. Noise outbursts of short duration of the order of a few seconds and also of long duration of the order of a few minutes have been recorded almost everyday during this period. On nearly 40 occasions, enhanced radiation lasting several hours at times was also observed. Only on four occasions these events could be associated with solar flares.

Acknowledgement

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Radio Patrol of Solar Flares

A. P. MITRA, K. A. SARADA, N. V. G. SARMA & M. N. JOSHI
National Physical Laboratory, New Delhi

IONOSPHERIC effects associated with solar flares have, in recent years, been successfully used to provide continuous radio patrol of solar flares at a number of observatories. There are several such effects: (a) sudden enhancement of intensity of atmospherics at VLF (SEA)[1,2]; (b) sudden increase in absorption of medium and short radio waves[3,4]; and (c) sudden change in phase at VLF (SPA)[5]. Changes in absorption referred to under (b) have been measured by using terrestrial transmission and also by receiving radiofrequency radiation from our galaxy; the latter is known as sudden cosmic noise absorption (SCA).

At the Radio Propagation Unit of the National Physical Laboratory, methods (a) and (b) have been used during the IGY to study solar flares, using the following frequencies: (1) SEA at 27 and 100 kc/s., (2) SCA at 22·4 and 30 Mc/s. and (3) $f_{min.}$ by P'-f panoramic recorder sweeping over 1-25 Mc/s.

During the first year of the IGY, for which results are presented in this article, several outstanding flare effects were observed; in a few cases simultaneously at different frequencies. In this article we report the effects observed during the period July 1957 to August 1958, and also discuss some of the implications of these observations.

Ionospheric flare effects are known to occur over a very wide frequency range (from about 10 kc/s. to 100 Mc/s.) with a distinctive frequency characteristic (Fig. 1). At low and very low frequencies, the effect is one of enhancement; above 500 kc/s. and up to MUF, the effect is one of fadeout, the size of which progressively decreases with increasing frequency. At still higher frequencies — in the UHF range — where propagation is achieved by scatter from lower ionosphere irregularities, the effect is again one of enhancement. This frequency variation of amplitude is of great interest to ionosphere physicists, but no observation exists *over the entire frequency range for any one flare.* It was for this reason that in choosing radio methods for flare patrol in this unit, we chose those which give us maximum frequency coverage. The frequency coverage that we have achieved so far is from 27 kc/s. to 25 Mc/s.

VLF observations — sudden enhancement of atmospherics

Bureau[1] was the first to notice the fact that atmospherics in the VLF region increase in intensity simultaneously with a flare. He found maximum enhancement at 27 kc/s., a result later verified by Ellison[2] and others. The enhancement, however, disappears somewhere around 10 kc/s., below which there is fadeout, and in the higher frequency side there is a similar transition somewhere between 100 and 500 kc/s. The latter transition region is still unidentified.

Continuous recording of atmospheric radio noise was initiated in this unit sometime before the beginning of the IGY. The frequencies chosen are 27 kc/s. and 100 kc/s., the former, because existing knowledge

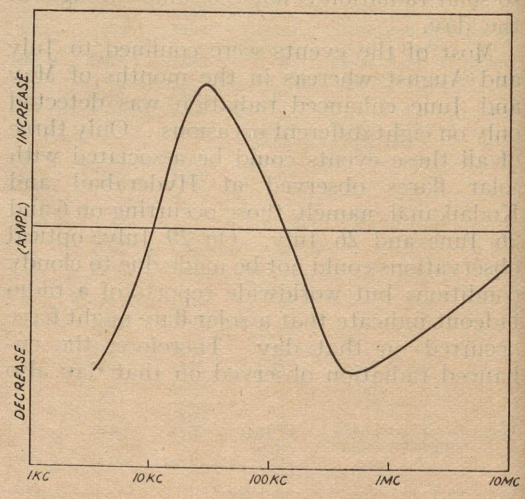

FIG. 1 — FREQUENCY DEPENDENCE OF ABSORPTION DURING FLARES

indicates maximum SEA effect at this frequency, and the latter because somewhere near this frequency the SEA effect is expected to vanish.

Equipment characteristics — The 27 kc/s. receivers consist of two tuned amplifier stages followed by cathode follower before feeding into the detector[2]. The detector output of the receiver is not by itself sufficient to drive the pen recorder. A differential amplifier followed by cathode follower is used. The time constant of output stage is one minute.

A HRO 60 National type receiver is used for 100 kc/s. atmospherics. Here also a differential amplifier followed by a cathode follower is used to drive the pen recorder. The time constant in this case is 40 sec.

Aerials for both the frequencies are of the normal inverted L type. The 100 kc/s. aerial is 122 ft long and 37 ft high. The 27 kc/s. aerial is 126 ft long and 57 ft high.

Results — A preliminary account of observations of SEA in this station has been given by Sachdev[6]. A typical flare record is shown in Fig. 2. This particular case occurred on 1 July 1957, coinciding with the beginning of the IGY, and is one of the most severe cases ever recorded in this laboratory. In Table 2 of Appendix III of this volume a list of all the definite SEA cases observed for the period July 1957-August 1958 have been given.

Flare patrol by an automatic ionospheric recorder

Automatic ionospheric sounding can also serve as a radio patrol of solar flares. The parameter $f_{min.}$, which denotes the minimum frequency that is being reflected from the ionosphere for a particular transmitted power and receiver gain, is proportional to the absorption suffered during the journey. During a solar flare one observes an increase in the value of $f_{min.}$, the variation of which follows roughly the time variation of $H\alpha$.

In this laboratory we have used a C4 ionospheric recorder designed by the National Bureau of Standards, U.S.A., and procured by this laboratory under the U.S. Technical

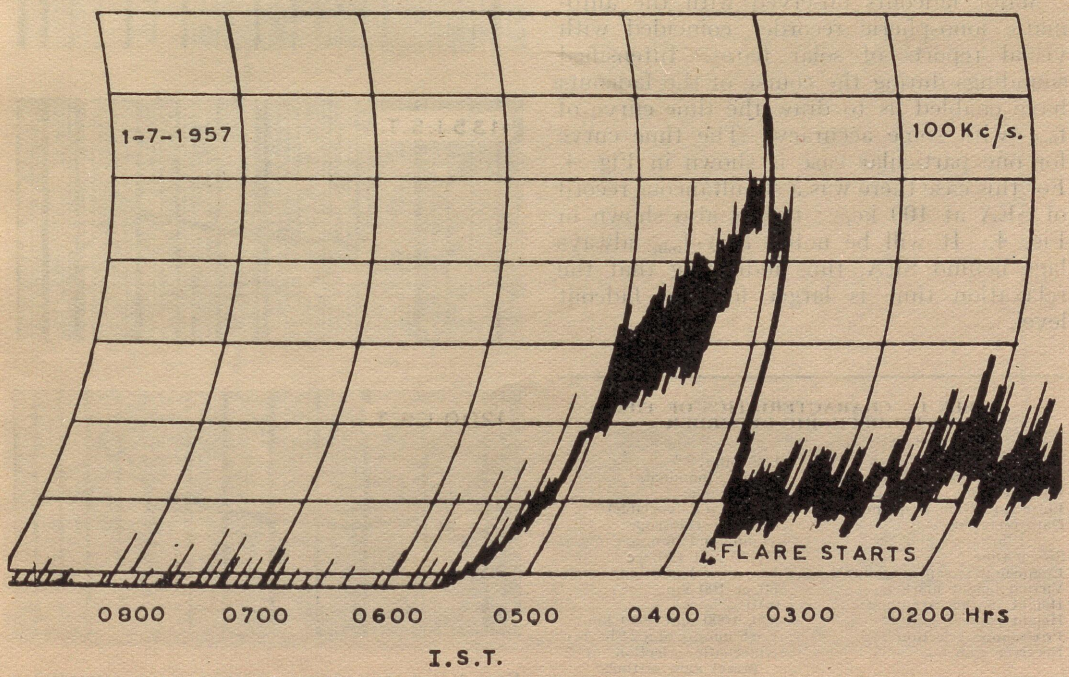

FIG. 2 — A SEVERE CASE OF SEA OCCURRING ON 100 KC/S. ON 1 JULY 1957, COINCIDING WITH THE BEGINNING OF THE IGY

Co-operation Mission. The recorder was installed in the National Physical Laboratory premises in the middle of April 1958. The main features of the equipment are given in Table 1.

Method of analysis — The relationship connecting $f_{min.}$ with absorption log ρ is

$$\log \rho = K(f_{min.} + f_L)^2 \ldots\ldots (1)$$

where K is a constant of proportionality.

Let (log ρ) be the absorption under quiet conditions at the time when a solar flare occurred, and ($f_{min.}$) the corresponding value of the observed minimum frequency. Then, the excess absorption produced during a flare is given by:

$$\Delta \log \rho = K[(f_{min.} + f_L)^2 - \{(f_{min.})_o + f_L\}^2] \ldots (2)$$

Results — Since the recorder started operating, five severe cases of fadeout have been observed. For four of these, the sounding schedules could be intensified so that observations were taken every 5 min. during the decay portion of the flare and every 2 min. during the maximum. The growth and decay of a typical fadeout observed on 16 August 1958 are shown in Fig. 3.

Major fadeouts observed with the automatic ionospheric recorder coincided with visual reports of solar flares. Intensified soundings during the course of the fadeouts have enabled us to draw the time curve of $f_{min.}$ with some accuracy. The time curve for one particular case is shown in Fig. 4. For this case there was a simultaneous record of SEA at 100 kc/s.: this is also shown in Fig. 4. It will be noted that $f_{min.}$ always lags behind SEA, thus indicating that the relaxation time is larger for the fadeout level.

TABLE 1 — CHARACTERISTICS OF THE C4 IONOSPHERIC RECORDER

Frequency range	1-25 Mc/s.
Peak pulse output power	10 kW. (nominal)
Pulse length	50 microsec.
Pulse repetition frequency	10-70 p.p.s. (variable)
Data recording	2-5 in. oscilloscopes
do	35 mm. and 16 mm. cameras
Sweep time	15, 30 and 120 sec.
Frequency sweep configuration	Linear or logarithmic
Virtual height markers	50 or 100 km.
Height marker accuracy	0·01%
Height ranges	500, 1000 and 4000 km.
Programme selection	Each minute of a 24 hr day
Receiver gain	Automatic selection of 3 preset gain settings
Transmitter output impedance	600 ohms balanced
Receiver input impedance	do

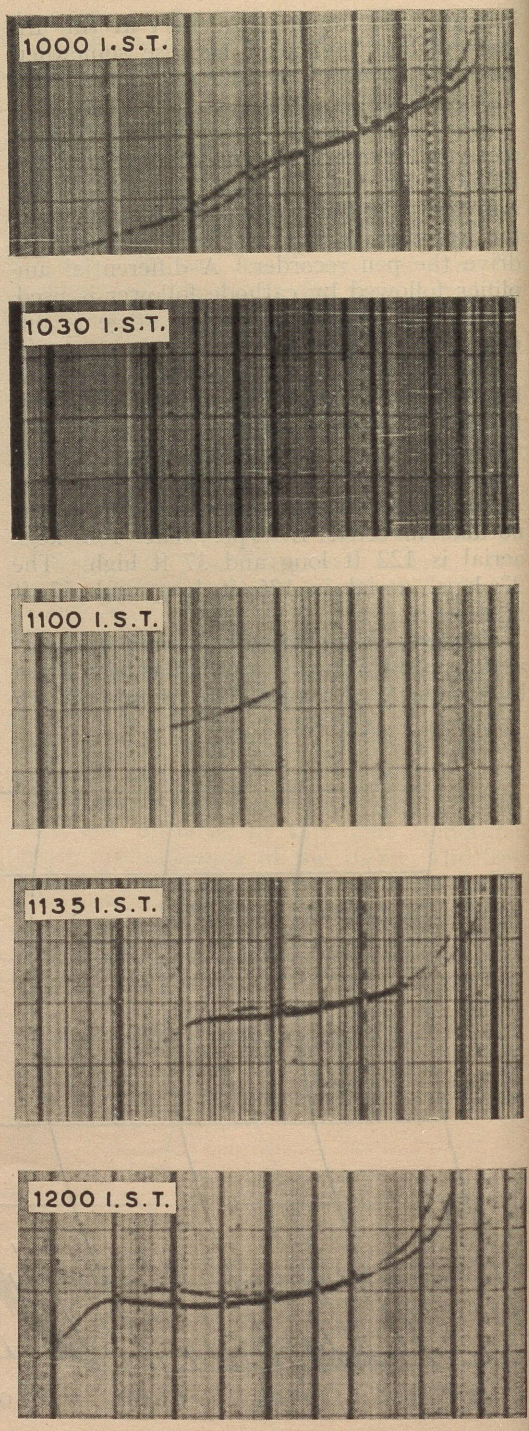

FIG. 3 — A SEQUENCE OF IONOGRAMS SHOWING A SEVERE FADEOUT OCCURRING ON 16 AUGUST 1958, FOLLOWING A MAJOR SOLAR FLARE

Flare patrol by cosmic radio noise

This method, originally developed by Shain and Mitra[4], utilizes the extraterrestrial radiation that is emitted by our galaxy at frequencies slightly above the critical frequency of the F_2 region. This method has been found to be one of the most sensitive available so far, and is also capable of providing information about the outer ionosphere, which is normally inaccessible to the terrestrial techniques.

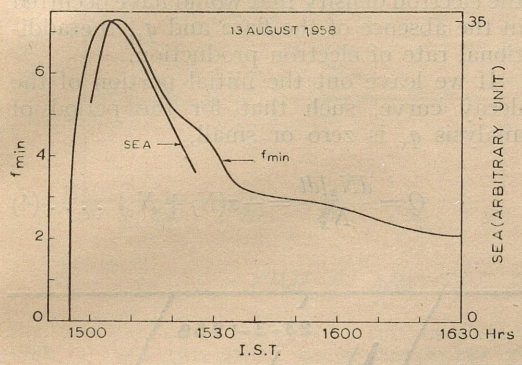

FIG. 4 — TIME VARIATION OF $f_{min.}$ AND OF THE INTENSITY OF ATMOSPHERICS DURING A MAJOR SID

In this laboratory radio flare patrol with this method was initiated on a frequency of 22·4 Mc/s. Observations at this frequency continued till November 1957, after which a new equipment was set up at Mussourie at a higher frequency (30 Mc/s.).

Characteristics of the cosmic noise equipment at 22·4 *Mc/s.* — The aerial consisted of four half-wave dipoles with corner reflectors. The calculated aerial beam width is $\pm 12°$ (Fig. 5).

The receiver used was an Eddystone communication receiver which was provided with a three-stage R.F. amplifier and a differential amplifier at the detector output. The overall gain was 120 db. The output for the differential amplifier was fed to an Esterline Angus recording milliammeter.

Calibration was performed by a noise generator which used 801A triode connected as a diode.

Characteristics of the cosmic noise equipment at 30 *Mc/s.* — It has been our experience with the 22·4 Mc/s. equipment that

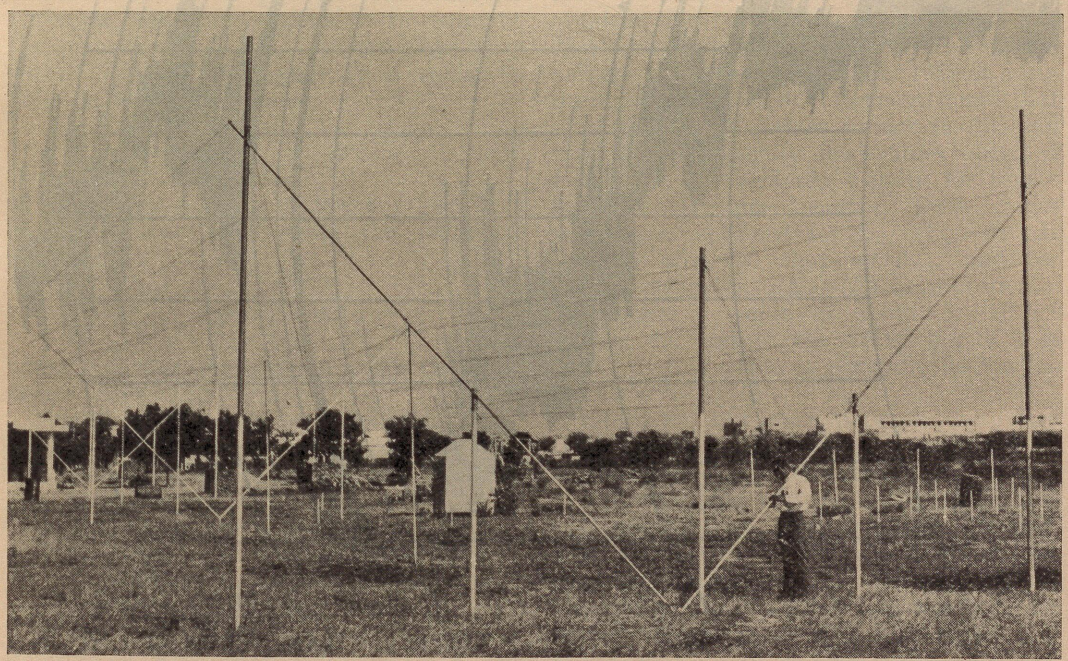

FIG. 5 — ANTENNA ARRANGEMENTS AT NPL FOR THE MEASUREMENT OF COSMIC RADIO NOISE ON 22·4 Mc/s.

much of the records cannot be used due to machinery and station interference. In our new equipment for 30 Mc/s. the carrier type of interference was reduced by building an electronic swept frequency receiver incorporating a 'fire back' loop. The receiver sweeps over a band of 130 kc/s. in the 30 Mc/s. region at a rate of 125 cycles/sec.[7].

Results — In Fig. 6 we have reproduced a very severe SCA[8] occurring on 23 March 1958, one of the largest recorded in this laboratory. In Table 3 of Appendix III of this volume we have given a list of the major SCA's obtained during the first year of the IGY.

Some implications of the results

It has been shown that useful information about the physical characteristics of the fadeout region can be obtained from an analysis of the decay portion of the SID[3] (Mitra, A. P., unpublished data).

The equation for the variation of electron density during a flare is given by:

$$\frac{dN_x}{dt} = q_x - \alpha N_x^2 - 2\alpha N_x N_\circ \quad \ldots . \quad (3)$$

where N_x is the excess electron density, $N_\circ$ the electron density that would have occurred in the absence of the flare and q_x, the additional rate of electron production.

If we leave out the initial portion of the decay curve, such that for the period of analysis q_x is zero or small,

$$Q = \frac{dN_x/dt}{N_x} = -\alpha(N_f + N_\circ) \quad \ldots . \quad (4)$$

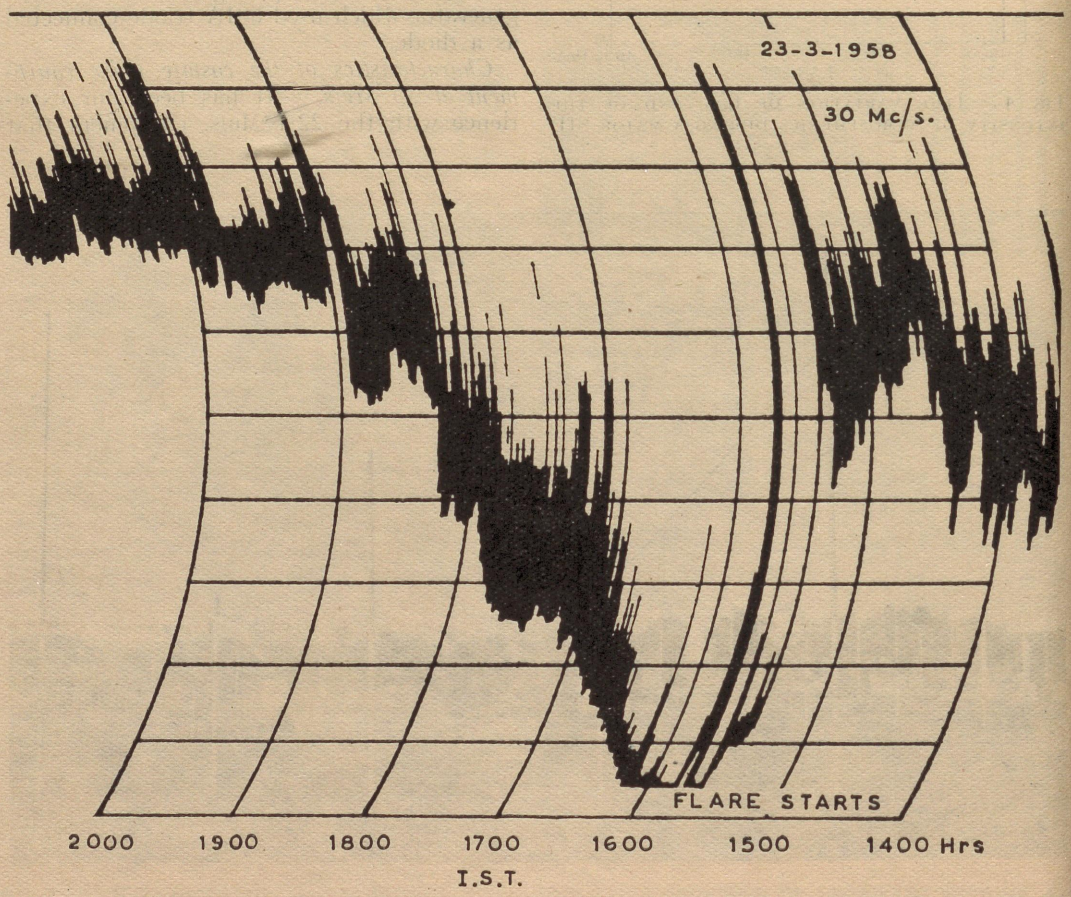

FIG. 6 — A SEVERE CASE OF SCA OCCURRING ON 23 MARCH 1958, FOLLOWING A MAJOR SOLAR FLARE. THE EFFECT WAS OBSERVED FIRST AT 0300 UT

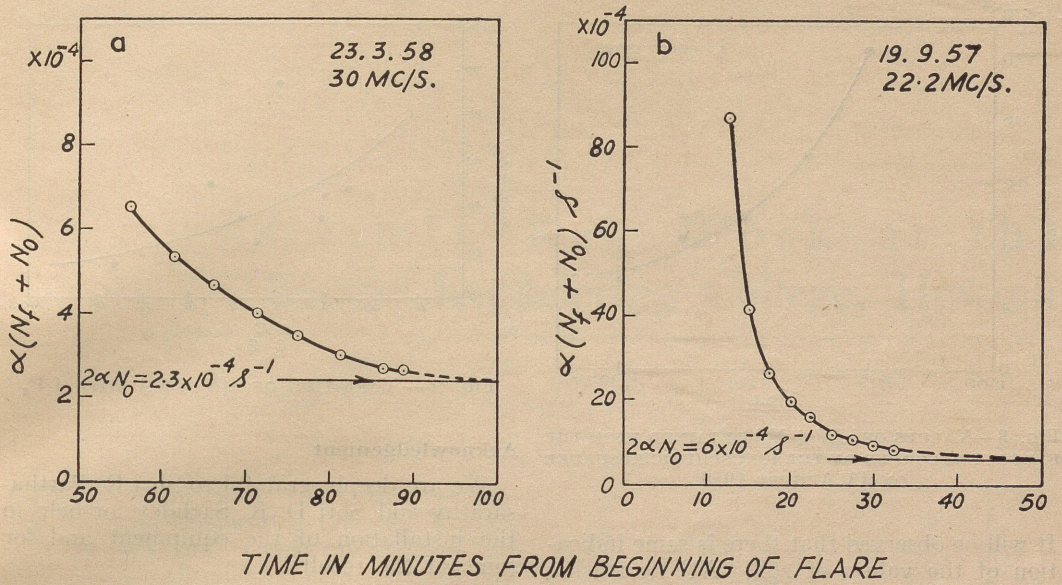

FIG. 7 — VALUES OF $\alpha(N_f+N_0)$ DEDUCED FROM TWO TYPES OF SCA'S, ONE OCCURRING ON 23 MARCH 1958 (a) AND THE OTHER ON 19 SEPTEMBER 1957 (b). SCA'S OF TYPE (b) GIVE ABNORMALLY LOW VALUES OF $\alpha(N_f+N_0)$

Determination of Q from the observed variation, therefore, enables us to estimate the quantity $\alpha(N_f+N_0)$. For those cases for which $N_f \gg N_0$, this quantity is equal to αN_x. Also for such cases

$$\frac{1}{N_x} = \frac{1}{N_{x_0}} + \alpha t \quad \ldots\ldots\ldots (5)$$

It is also possible to follow any variation in the fadeout level using the following expression:

$$\tau_0 = t \Big/ \left[\log_e \left(\frac{N_{x_0}}{N_x} + \frac{N_{x_0}}{2N_0} \right) - \log_e \left(1 + \frac{N_{x_0}}{2N_0} \right) \right] \quad (6)$$

where τ_0 is the relaxation time for the level under quiet conditions.

Equations (3) to (6) are applicable to all parameters which are proportional to N and can, therefore, be used for the flare curves of $f_{min.}$ and of SCA.

We have used the above methods of analysis in several cases of fadeout and of SCA. In the following paragraphs the results of such analysis are discussed.

Firstly, we find that values of $\alpha(N_f+N_0)$ determined from both $f_{min.}$ and SCA are somewhat similar, and also have similar time variation, excepting that, on several occasions, these values for SCA were abnormally low. In Fig. 7 we have given the results obtained for two SCA's, one occurring on 23 March 1958 at a frequency of 30 Mc/s. (a) and the other on 19 September 1957 at a frequency of 22 Mc/s. (b). We have found that most SCA's give values similar to (b), and that the abnormally low values obtained for (a) are encountered usually for severe fadeouts. We may compare these values with those obtained for $f_{min.}$ (Fig. 8). It will be observed that for $f_{min.}$ and for SCA of type (b), $\alpha(N_f+N_0)$ asymptotically approaches a value of about $5 \times 10^{-4} s^{-1}$ during the end of the SID. For SCA of type (a), this value is normally as low as $1 \times 10^{-4} s^{-1}$.

While the difference between these two types of SCA is not very clear at this stage, it appears that one of the causes contributing to this difference may lie in the production of a second absorption region at F region heights. Shain and Mitra[4] have shown that F region absorption of cosmic noise depends principally on f_0F_2. If this is also the case during fadeout, then such abnormally low values may occur if, on these occasions, values of f_0F_2 were larger than average. We find some confirmation of this in Fig. 9 in which we have plotted $\alpha(N_f+N_0)$ against f_0F_2.

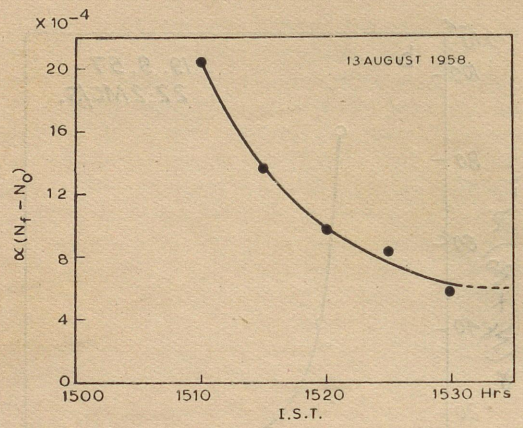

FIG. 8—VALUES OF $\alpha(N_f+N_\circ)$ OBTAINED FROM THE FADEOUT RECORDED BY THE IONOSPHERIC RECORDER ON 13 AUGUST 1958

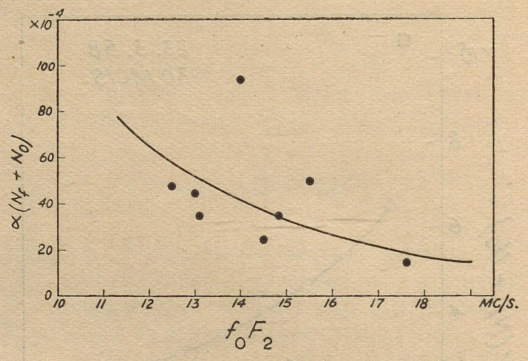

FIG. 9 — VARIATION OF $\alpha(N_f+N_\circ)$ WITH $f_\circ F_2$

It will be observed that there is some indication of the values of $\alpha(N_f+N_\circ)$ decreasing with increasing values of $f_\circ F_2$. However, more observations are needed before a specific conclusion can be made. If this conclusion is proved correct, one will have to explain how such a large amount of absorption can arise from the F region during a fadeout. We believe that more light can be thrown on this problem if observations of SCA are undertaken simultaneously at a number of frequencies, and for this reason a cosmic noise equipment at a different frequency is now being constructed in this laboratory.

Acknowledgement

We are deeply grateful to Shri R. Parthasarathy and Shri D. K. Sachdev for help in the installation of the equipment and for some of the results.

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Cosmic Ray Work at the Bengal Engineering College, Howrah

S. K. CHAKRABARTY
Bengal Engineering College, Howrah

THE Geophysical Laboratory of the Bengal Engineering College, Howrah, is supplying cosmic ray data to the IGY data collection centre through the Indian National Committee and to the WDCA, the University of Minnesota, Minnesota, U.S.A., at their request. Continuous records of the total cosmic ray intensity under 5 cm. thickness of lead and 1 cm. thickness of steel are being taken with a spherical ionization chamber. Hourly values of the intensity are being tabulated and the departures from balance are given in units of 0·1 per cent of the normal value of the cosmic ray intensity, after correcting for bursts and pressure variations. A continuous record of the fluctuations of the cosmic ray intensity is very useful in finding their correlations with other disturbances, particularly on the sun. An indication of a very short period fluctuation can be obtained easily only through the records of the ionization chambers. A comparison of similar fluctuations recorded at different stations will give information about their nature, particularly whether they are only local or of worldwide occurrence, and thus give important information about the origin of such cosmic ray fluctuations and their changes with latitude, longitude and altitude. Records of such short period fluctuations were available on 29 August 1957[1]. In Fig. 1 is shown the typical record of a sudden rise in

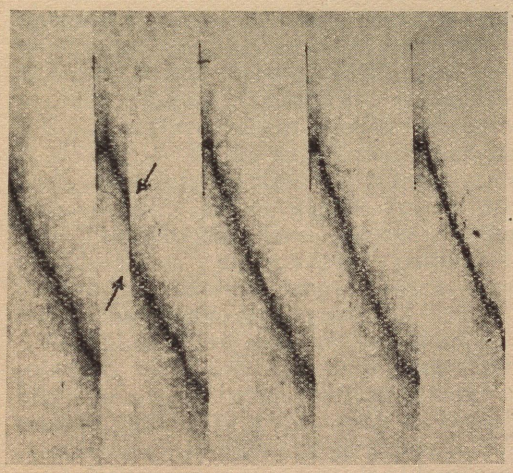

FIG. 1 — RECORD OF THE HOURLY RATES OF INCIDENCE OF COSMIC RAYS TAKEN BY IONIZATION CHAMBER IN TERMS OF DEPARTURE FROM 'BALANCE' SHOWING A SUDDEN RISE IN INCIDENCE BY ABOUT 1·5 PER CENT OF THE NORMAL VALUE

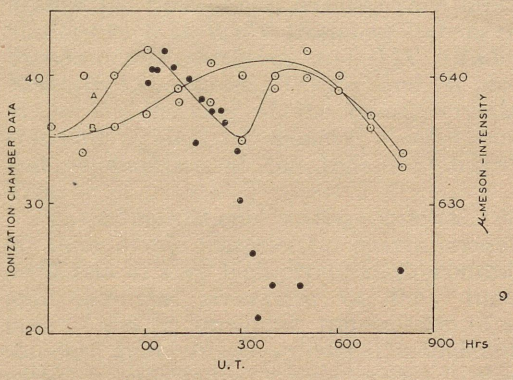

FIG. 2 — VARIATION OF COSMIC RAY INTENSITY BETWEEN 2100 HRS AND 0900 HRS UT ON 10-11 FEBRUARY 1958, RECORDED BY IONIZATION CHAMBER [A, from 2100 hrs, 10 February 1958; B, from 2100 hrs, 11 February 1958; • refer to μ-meson intensity recorded by a meson monitor at M.I.T.]

to run a rotary converter which supplies the current during the breakdown periods.

A schematic block diagram showing the installation of the equipment at the transmission centre is shown in Fig. 1.

It will be seen from the figure that the 100 kc/s. constant frequency signal obtained from the crystal is on one side stepped up to 10 Mc/s. through a suitable system of frequency multipliers and on the other side it is subdivided to obtain an audio frequency of 1000 c/s. This A.F. signal further goes through a process of subdivision and mixing to produce pulses of 5-millisecond duration which are repeated every second and also pulses of 100-millisecond duration repeated every minute.

The second and the third crystal oscillators are also similarly provided with divider units and this facilitates the intercomparison of the performance of the crystals as well as providing a standby unit.

Normally the performance of any two crystals is not exactly the same and allowance has to be made for variations caused through aging, mechanical vibrations or variations in associated components. It is essential to intercompare the stability of the crystals to a high degree of precision and to normally use, as a basic standard, the particular crystal which is found to be most satisfactory. The frequency of any one of the crystals will not be accurate enough over a long period of time and hence correlation with astronomical measurements becomes necessary. Suitable provision has, therefore, been made to change the crystal frequency by parts in 10^{-10} and to change the precise start of the seconds pulse by millisecond steps.

The performance of each crystal is checked continuously by taking the intercomparison of the frequency and the time signals generated from each one of them. The frequency stability is interpolated by using a 100 kc/s. phase comparator and a 10 Mc/s. frequency comparator; and time pulses are checked with an electronic counter chronograph.

Proposed characteristics of the frequency and time signals

Primary standards to be used — Three Essen Ring type crystals. The time signals will be checked with astronomical observations.

Location of the station — Kalkaji (28°33′36″N: 77°18′48″E), New Delhi, India.

Call sign — A.T.A.

Type of service — Experimental.

Carrier power — 300 watts.

Type of antenna — Horizontal dipole.

Number of simultaneous transmissions — One.

Number of frequencies to be used — One.

Emissions (hours per day) — Two (will be increased to 22 hr later).

Emissions (days per week) — Seven.

Standard frequency to be used as a carrier — 10 Mc/s.

Standard modulation frequency — 1000 c/s.

Duration of tone modulation in minutes — Four; repeated every 15 min.

Duration of the time signals in the transmission cycle — Continuous.

Method of adjusting the time signals — By steps of 50 milliseconds.

Transmission cycle per hour — (a) 1000 c/s. modulation with carrier for the periods 0-4, 15-19 and 45-49 min.; (b) pure unmodulated R.F. for 4-14, 19-29 and 49-59 min.; (c) voice code announcements of 30 sec. duration during the periods 14-15, 29-30, 44-45 and 59-60 min.; and (d) no transmission during the period 30-45 min. every hour.

Details of the seconds pulse signal (time signals) — (a) The seconds pulse, emitted for the identification of time, will consist of a group of 5 cycles of 1000 c/s. signals; (b) the minute (60th second) is identified by a lengthened pulse of 100-millisecond duration; (c) the seconds pulse will be transmitted throughout the transmission cycle; and (d) during the tone period, the seconds pulse will be transmitted, preceded and followed by short interruptions of the modulated transmission. During the unmodulated R.F. period, the pulse will be transmitted as a modulating wave.

The International Scientific Radio Union has recommended that the broadcast transmission of the standard frequency and time signals should be maintained to an accuracy of ± 2 parts in 100 million over a long period and that they should be in synchronism with the signals transmitted by other similar establishments in the world. This high precision could be achieved only through a proper link of the crystal standards with the time signals of other stations and with the astronomical measurements of stars; this has to be done because of the inherent variation of the frequency of the piezoelectric quartz crystal units. A monitoring station is, thus,

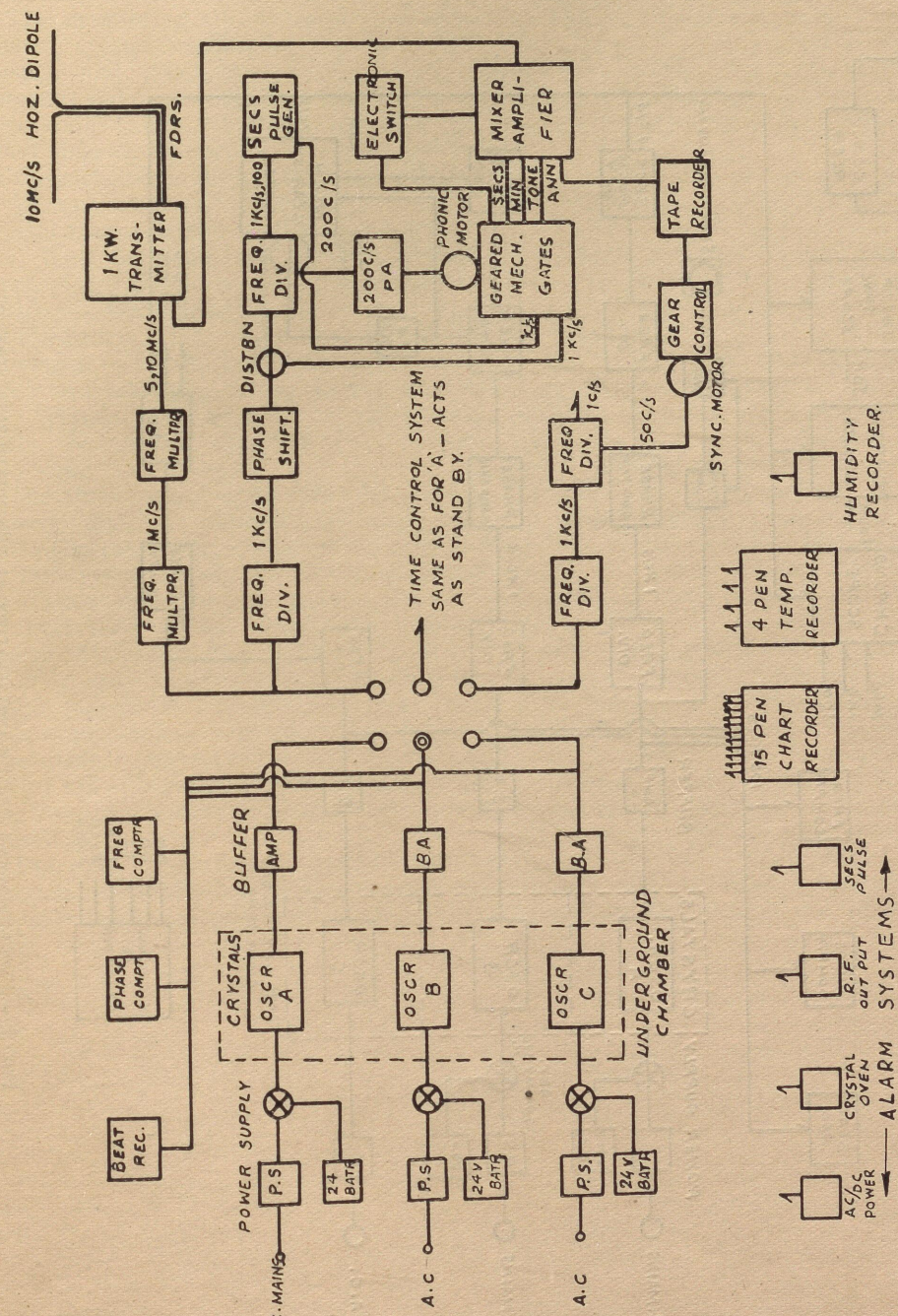

FIG. 1 — BLOCK DIAGRAM OF THE INSTALLATION AT THE TRANSMISSION CENTRE

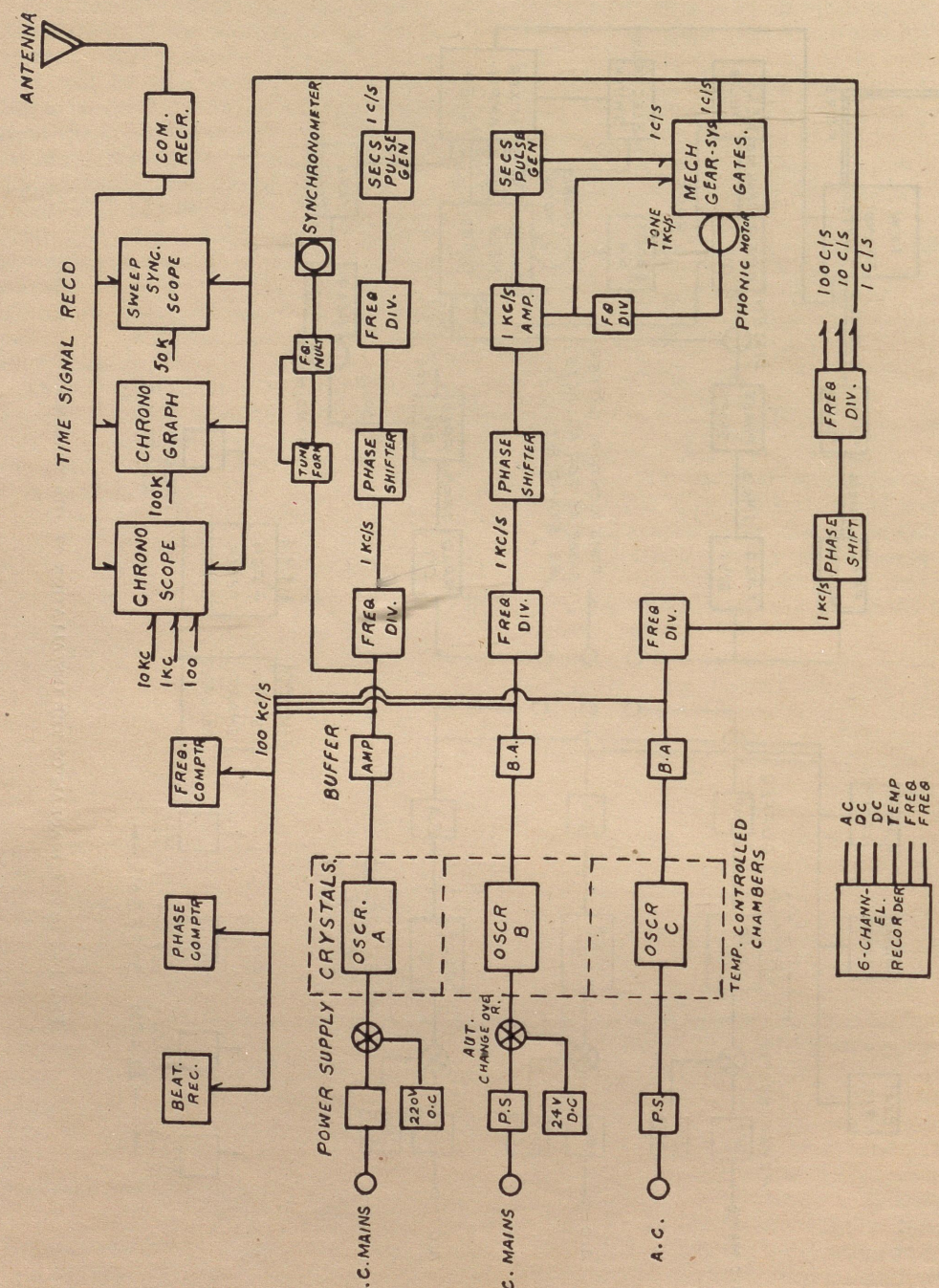

FIG. 2 — BLOCK DIAGRAM OF THE INSTALLATION AT THE MONITORING STATION

an essential feature for the maintenance of the primary standards of time and frequency.

The monitoring station consists of three quartz crystal oscillators, associated frequency and time signal control units, a complete radio receiving station and precision time comparators. A schematic block diagram showing the set-up of the equipment at the monitoring station is shown in Fig. 2. A primary standard employing a G.T. cut crystal manufactured by Rhode & Schquarz Co., West Germany, and another standard employing a bar cut crystal manufactured by Ebauches Oscilloquartz, Switzerland, were established in 1956. A third standard employing a G.T. cut crystal was added later. After an initial aging period of three months, the crystals were adjusted to synchronize with the signals obtained from WWV, JJY, etc.

The time control units consisting of frequency dividers, phase-shifters and time pulse generators were installed for each one of the crystal standards. The principle of generation of the seconds pulse is the same as that used in the transmission centre, described earlier. The performance of the crystals was computed with integrating phase meters and frequency comparators. Special precautions were taken to maintain a continuous operation of the crystal oscillator with a standby power supply system switching over automatically during the mains failure.

The time comparison is achieved with a cathode ray oscilloscope using a sweep technique. The time signal received from other stations is superimposed with a sharp pulse triggered by the second pulse of the local standard and the difference is interpolated in milliseconds with a phase-shifter and marker system. The advantage of this system is that the readings could be obtained even if the strength of the received signal is poor.

The comparison of the time signals generated from each one of the standards installed in the laboratory is achieved with an electronic counter chronograph and a chronoscope. These readings taken day to day give a good picture of the deviation of each one of the standards.

The measurement of time fundamentally depends upon the period of rotation of the earth on its axis. The interval between two successive transits of a distant star over a given meridian is termed a sidereal day. Usually, time is standardized by measuring the transit time of a number of stars with respect to the meridian line, and by computing the mean solar day thereafter. The instruments used for such transit observations are a suitable transit telescope and a calibrated quartz crystal clock. An ' Astrolab ' transit telescope, developed recently by Prof. Danjon at the Paris Observatory and a precision quartz clock using an A.T. cut 1 Mc/s. crystal, have been procured and installed at Dehra Dun under the IGY programme for latitude and longitude determination by the Geodesy Branch of the Survey of India. It is hoped that star observations and time computation will be started within the next few months.

Photographic Observation of the Moon's Position

M. K. VAINU BAPPU
Uttar Pradesh State Observatory, Naini Tal

IT has long been realized that the photographic method, as applied to the problem of determination of the moon's position, would prove to be more flexible and accurate than the classical methods. The first efforts in this direction were made by King at Harvard almost four decades ago. A snapshot of the moon was taken in the middle of a 10 min. exposure. Despite the several factors that have to be corrected for to attain a reliable measure of position, these plates indicated well the reliability of the photographic method.

In recent years, with the development of the Markowitz camera, the problem of moon photography for positions has received considerable stimulus, and we now have a reliable technique which has numerous applications in the fields of time determination and geodesy. Photographic positional determinations with the Markowitz camera have been included in the list of programmes to be worked on during the International Geophysical Year. The cameras have all been made at the U.S. Naval Observatory in Washington and distributed to about twenty

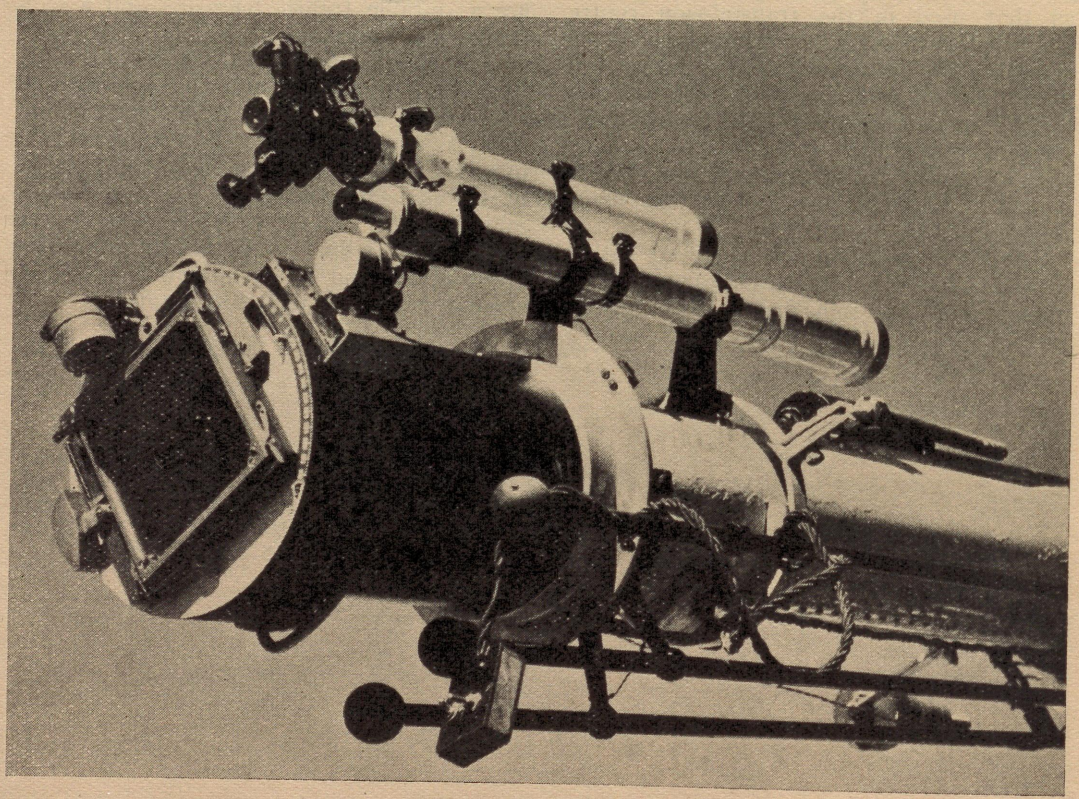

FIG. 1 — VIEW OF THE MARKOWITZ CAMERA ATTACHED TO THE 10 IN. REFRACTOR

different countries all over the world so as to have a good distribution in longitude. India received one camera and this was allotted by the Indian National Committee to the Uttar Pradesh State Observatory at Naini Tal.

Fig. 1 shows the camera mounted at the eye end of the 10 in. Cooke refractor. The camera, in principle, is a means of exposing simultaneously on both moon and stars for a duration not exceeding 20 sec. During this period the moon's image on the plate is held fixed relative to the stars. The epoch of the exposure is the instant when the moon's actual position in the sky relative to the stars is the same as that on the plate. A photograph of the moon taken at Naini Tal with the moon camera on 7 May 1957 is shown in Fig. 2.

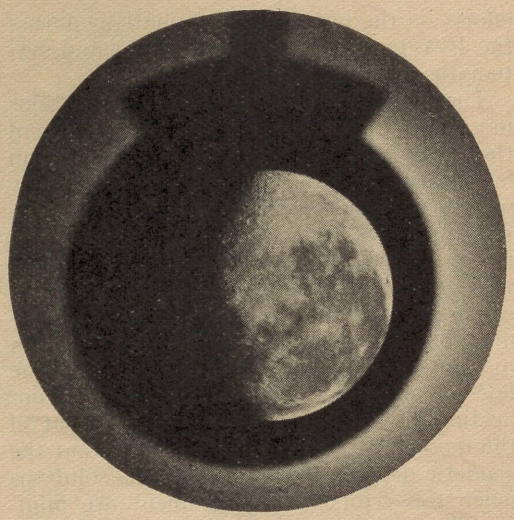

FIG. 2 — A PHOTOGRAPH OF THE MOON TAKEN AT NAINI TAL WITH THE MOON CAMERA ON 7 MAY 1958

All these are accomplished in the following way. Since the moon is exposed continuously for the entire 20 sec. duration, its light will have to be cut down considerably. Just before the focal plane a small circular plane parallel dark glass filter intercepts the moon's light. The dark glass reduces the moon's intensity by a factor of a thousand so that a properly exposed image can be obtained on the plate. During the entire exposure the clock drive is not used. Instead, the diurnal motion is corrected for by driving the entire plate holder in an east-west direction at the required rate by a small synchronous motor. This rate depends on the moon's declination and can be preset in the driving unit. The dark glass filter is held from the camera periphery by a slender rod and drive assembly. The rod forms the axis about which the dark glass filter is rotated at a known rate. This tilt of the filter by a known amount compensates the moon's motion against the starry background during the duration of the exposure. The position angle and actual value of drift motion are known prior to the night's work and the driving rate of the assembly adjusted accordingly. Since the photographs are all made with a visual refractor, a yellow filter of thickness equal to the dark glass filter lies ahead of the focal plane to absorb the steep portions of the colour curve of the telescope. The yellow filter has a hole in the centre so that the optical paths of both stars and moon before reaching the emulsion are the same.

An operation procedure for a night is as follows. The sidereal rate corresponding to the moon's declination, the speed of drift of the moon and the position angle of the axis of tilt are known and are set accordingly. The exposure is timed by an electrical timer which automatically opens and closes the shutter. Exposures of 10 sec. on II-G plates are employed near full moon phase. At other phases, when the moon is faint, 103-G plates and a 20 sec. exposure are used. The epoch of the exposure is when the dark glass filter is parallel to the focal plane. At this instant an electrical contact is made which actuates one of the pens of a chronograph. The chronograph is fed with time from the observatory's quartz clocks in order to interpolate the epoch of the photograph to better than 1/100 sec. After one plate has been taken the camera assembly is rotated through 180° and another plate taken. Four plates taken this way in a span of about 6 min. constitute a set taken for a particular hour angle of the moon on any night. A similar set is taken about 4 hr later. Photographs of the moon are taken usually during the period between the end of the first quarter until the beginning of the last quarter. The plates are processed and stars identified on them. The chronograph times are determined and the plates shipped to the measuring centre. Four such centres having similar specially made measuring engines are located at Greenwich, Paris, Washington and Cape Town. These measuring engines have been well investigated for errors so that

efforts on the position determinations during the IGY may have as few intrinsic and systematic errors as possible.

The moon camera has several applications in geodetic measures. The size and shape of the earth and intercontinental distances can be measured to a high order of accuracy when the data received from various observatories are considered. The distances between observing locations can be determined with an uncertainty of a hundred feet or less when positions of the moon can be determined with high accuracy. A position measured at an observatory represents the line passing through the telescope and connecting the centre of the earth and that of the moon. It is obvious, therefore, that the geodetic distances emerge from the solutions when the errors of measurement are minimized. Observations of the moon are also bound to lead to a more exact determination of the constants in the theory of the motion of the moon as developed by Brown.

The moon camera will also provide a means of determination of absolute frequency accurate to about 1 to 2 parts in 10^9. This is possible by determining the correction to the mean longitude of the moon as given by the new lunar ephemeris. If ΔL is the longitude correction, then ΔT, which is the difference between Ephemeris Time (uniform) and Universal Time (non-uniform) becomes

$$\Delta T = 1{\cdot}821\ \Delta L$$

where ΔT is in seconds of time and ΔL in seconds of arc. ΔT can thus be determined at any one station and in the course of a year it should be possible to determine absolute frequency to about 3 parts in 10^9, since the probable error in ΔT during one lunation is of the order of 0·1 sec. When results from different observatories are taken together, it should be possible to determine absolute frequency to within 1 part in 10^9.

Study of Some of the Central Himalayan Glaciers*

B. S. JANGPANGI
Geological Survey of India, Calcutta

THE Geological Survey of India have undertaken a study of some of the Himalayan glaciers during the International Geophysical Year, at the instance of the Indian Glaciological Subcommittee. Certain Himalayan glaciers which had been surveyed in the past were selected for the current glaciological studies. During this period, the author had an opportunity to study some of the Central Himalayan glaciers such as the Gangotri glacier in Tehri Garhwal; Glacier No. III, Arwa Valley; and Satopanth and Bhagirath Kharak glaciers in Garhwal, Uttar Pradesh. As a result of the survey, valuable information regarding secular movement of the glacier snouts has been obtained. During the period of the IGY, Shri C. P. Vohra and the author have studied the Milam, Poting and Shunkalpa glaciers in Almora district, Uttar Pradesh, from August to October 1957 and since August 1958 Shri A. P. Tewari and the author have been engaged in surveying the Pindari and Kaphani glaciers in the Almora district. A short description of each glacier and the results of the glaciological study are given in the following paragraphs.

Gangotri Glacier

The Gangotri glacier, the largest in the Central Himalayas, is about 18 miles long, and flows longitudinally from the Chaukhamba Peak (30°44′N: 79°16′30″E) down to Gaumukh (30°56′N: 79°04′E) in WNW direction where the Bhagirathi river emerges. The glacier is fed by five tributaries. The glacier has developed a large amount of ablation moraine and is bordered by prominent lateral moraines. The lateral moraines converge into terminal moraine about one and a half miles downstream from the snout. The mapping of the snout of the glacier revealed that the glacier has retreated about 700 ft since 1935, when Auden[1] mapped it. The present snout stands at an altitude of 12,770 ft above M.S.L. while large glacial terraces and moraine accumulations are found down to Gangotri (30°55′30″N: 78°56′30″E), and evidences of glaciation have been found down to Jangla (31°02′30″N: 78°50′30″E) at the height of 8500 ft above M.S.L., 18 miles downstream from the snout.

Glacier No. III, Arwa Valley

The glacier is situated on the southern side of the Arwa Valley. This glacier flows transverse by northwards over its own moraine fen, which is about 300 ft thick. The glacier has retreated about 650 ft since 1932, when the snout was surveyed by Gilbert and Auden[2]. This deposition of 300 ft thick moraine fen may be due to several retreats when successive ablation moraines were deposited. Thus the level of the glacier was progressively raised higher with respect to its own thickness. The glacier also showed a reduction in thickness of about 25 ft at the snout.

Satopanth and Bhagirath Kharak Glaciers

The Satopanth glacier is 8 miles long, and originates from the south-eastern slope of the Chaukhamba Peak II (30°44′30″N: 79°17′E), flowing ENE, and terminating about

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2000 ft SSW of the snout of the Bhagirath Kharak glacier (30°46′30″N : 79°25′E) and about 7 miles west of Mana village (30°46′30″N : 79°29′30″E). The Bhagirath Kharak glacier is 11 miles long and originates from the Satopanth Peak region (30°50′N: 70°15′E). Both the glaciers show considerable retreat in recent years as indicated by the fresh moraine and dead ice blocks found a few hundred feet from their snouts. Glacial valley with terraces is found down to Badrinath (30°44′30″N: 79°29′30″E) at a height of 10,159 ft. Evidences of glaciation are, however, found as far south as Binaik, one and a half miles north of Pandukeshwar (30°38′N: 79°33′E) at a height of about 7000 ft, and 16 miles downstream from the present glacial snouts.

Milam Glacier

The Milam glacier, the second largest in the Central Himalayas, is about 12 miles in length. It starts from a snow-field in the Trisuli Peak region (23,210 ft) and terminates at about two and a half miles north-west of Milam village (30°26′N: 80°09′E) where it forms the Gori river. The snout of the glacier has retreated 2030 ft since 1906 when the snout was mapped by Cotter and Brown[3], and 350 ft since a survey by Major Osmanston[4]. Morphologically, the retreat and the reduction in thickness of the glacier are indicated by three lateral moraine ridges to the east of the snout. The lateral moraines converge to form the terminal moraine, about a mile downstream from the snout, where it partly overrides the older glacial terrace — thereby indicating a subsequent advance of the glacier after the earlier retreat from the lower valley. Glacial valley with terraces is found down to Rilkot at a height of 10,270 ft, although evidences of glaciation were found down to Suini (30°12′N: 81°14′E) in the Gori Valley at a distance of 22 miles from the snout. The rate of movement at the surface of the glacier, which has been measured at five and six and half miles upstream of the snout, showed a faster movement in the upper portion in respect to the downstream part of the glacier. This can probably be attributed to higher gradient on the upstream side.

Poting Glacier

The Poting glacier (30°12′45″N: 80°09′30″E) is a small transverse glacier south-east of the Nandakot Peak, descending with a variable gradient from the cirque at about 16,000 ft. The direction of flow rate of the movement of the glacier shows a considerable variation. The fastest movement recorded towards the right margin near the curvature is 15 in. in 24 hr. Ablation, lateral and terminal moraines are conspicuously developed. The Poting Valley is in a transverse position with reference to the Gori Valley. The glacier has retreated 860 ft since the survey by Cotter and Brown[3]. If the information given by an old shepherd is taken as authentic, the glacier, about 20 years ago, was nearly at the same place as it was in 1906, suggesting that the glacier has retreated only since the thirties.

Shunkalpa Glacier

The Shunkalpa glacier(30°20′N: 80°19′30″E) is fed by two principal tributary glaciers, the Kala Baland and the Yangchar, each nearly 7 miles long. Downstream of the confluence the glacier flows transversely for about two and a half miles with two cascades or steps, finally terminating at about two and a half miles north-east of Ralam village. At the cascade, just below the junction, folding in the stratification of ice was seen, which, according to Heim and Gansser[5], is due to lateral compression of the Kala Baland glacier. The snout of the glacier has shown a total retreat of nearly 1000 ft since the survey by Cotter and Brown[3] in 1906. The retreat has exposed a ' roche moutonnée ' which has a gentle upstream slope of about 12°. The velocity at the surface of the glacier at the base of the lower cascade showed a slower rate of movement than in the downstream side.

Pindari Glacier

The Pindari glacier is a small transverse glacier west of the Nandakot Peak. Of all the glaciers surveyed this has shown the maximum retreat of the snout since 1906.

Conclusions

The glaciers of the Central Himalayas, in general, are now in a retreating phase. But had there been minor advances, these could not have been detected on account of lack of observational data.

There exists an indication of advance in some of the transverse glaciers like Poting and Glacier No. III in the Arwa Valley in

the thirties. In most of the glaciers the terminal moraines are found a few thousand feet downstream from the snouts of these glaciers. But sometimes a few glaciers seem to transgress old glacial terraces, thereby indicating a temporary advance of the glaciers, as in the case of Milam and Shunkalpa glaciers. Thus some of these glaciers seem to have a phase of advance between the initial retreat and the final retreat which occurred, in general, after the thirties.

At least three stages of past glaciation have been noticed as indicated by the evidences gathered. Firstly, there is a comparatively less conspicuous evidence of glaciation of an altitude of about 7000 ft. During the second stage glacial valleys and predominant terraces were deposited to an elevation of 10,000 ft. The third stage of glacial activity is borne out by the formation of terminal moraines, immediately downstream of the existing snouts of the glaciers.

There has also been a considerable reduction in the volume of glaciers as seen by the level of the lateral moraines, which occur at an elevation of more than 100 ft from the surface of the glacier.

A feature 'roche moutonnée' was discovered just in front of the snout of the Shunkalpa glacier. With a gentle upstream slope the glacier might have occupied a larger area in the past. Because of the plastic flow of the glacier ice, the underground topography is not reflected at the surface.

Many lakes have been noticed in the glacier regions, which are formed between a moraine and the solid rock on the sides.

The climatic conditions during the last three years were abnormal. As a result of an early snowfall by the second half of September, and greater amount of snowfall during successive winter seasons, the mountain passes to Tibet were closed to traffic till late summer. Such conditions may eventually involve a somewhat large accumulation of snow in the regimen of glaciers.

Since there had been very little scientific studies of the Himalayan glaciers in the last few decades, it is felt that prominent glaciers in the Himalayas may be accurately surveyed in the region of the snout from time to time so as to find out any change near the margin of the glacier and the corresponding increase or decrease in the volume of ice.

Some of the representative glaciers of each region may be selected for greater glaciological details, such as measurement of diurnal or seasonal variation of temperature, snowfall, periodic velocity in the centre and sides of the glacier and the velocity on the surface and bottom of the glacier, the discharge of the melt water of the glaciers, and other scientific details.

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IGY Activities in Oceanography

THE programme of IGY activity in oceanography (whose principal aims are to add to our knowledge of short and long period changes in sea level, and of general circulation of water in oceans) was taken up by the Oceanography Wing of the Central Board of Geophysics. Observations on surface temperature and salinity were carried out near Bombay, Cochin and Visakhapatnam harbours, while the work at Madras harbour was undertaken by the Central Marine and Fisheries Organization. The salinity and temperature observations were extended up to 20 miles into the ocean near the tide gauges concerned. In addition to the above, data are being received from Aden, Mundra, Kandla, Veraval, Bombay, Ratnagiri, Mangalore, Sagar, Diamond Harbour, Calcutta (Garden Reach), Rangoon, Port Blair, and from the port authorities at Kandla, Mangalore, Cochin, Mandapam (Camp), Palm Beach (Andhra University, Waltair).

Meteorological data consisting of direction and velocity of wind, surface air pressure, and temperature are also being recorded at many of these places.

The Andhra University has carried out two cruises for making observations on bathysmetry, deep sea temperature, salinity, sea and well at 34 sites off Visakhapatnam.

The Survey of India has also carried out tidal stream observations at 30 sites in the Gulf of Cambay, in addition to 31-day round-the-clock half hourly observations of water level on tide poles at Pamban, Tuticorin, Trivandrum and Alleppy. Similar tide pole observations are in progress at Nagapatnam. In addition to the above, the estuarine hydrography of Ernakulam canal has been investigated in detail. At Cochin and Jamnagar super refraction of radio waves has been studied. Long ranges are noticed in the direction of the coastline near Cochin. The fluctuations of underwater sound transmissions have been measured and contribution by scattering air sacks, perhaps due to zooplankton, is calculated to explain the observed large fluctuation.

The computation of near sea levels and compilation of other results are in hand.

Optical Tracking of Artificial Satellites

M. K. VAINU BAPPU
Uttar Pradesh State Observatory, Naini Tal

AN artificial satellite, when launched with a full payload of instruments, will prove to be of maximum utility only when we know its orbit to some degree of exactness. Measures of position of the satellite at various known instants are the basic data needed for deriving the orbital characteristics. Various perturbation effects like atmospheric drag, gravitation anomalies and the oblateness of the earth enter such an orbital analysis. At the same time it is possible to study the nature of these perturbations and the secular changes in the orbital characteristics by continued observations of high accuracy of the positions of the satellite.

Three types of observations make possible the derivation of an orbit of the satellite. Visual observations are accurate enough to give an approximate orbit while photographic observations are capable of extremely high accuracy if the techniques available are modified to yield the precision required. A third mode of deriving positions is by having a radio transmitter in the satellite thus facilitating triangulation from ground stations. The radio observations are dependent on the functioning of the satellite transmitter and its source of power.

The visual observations are carried out by 'Moonwatch' teams that are scattered all over the world. Each team consists of about fifteen observers each of whom is equipped with a telescope of about two inches aperture. The telescopes are arranged in such a way that each observer looks at a fixed region of the sky in the meridian plane. Since there is an overlapping coverage of the regions, a satellite transit across the meridian at a given station will be observed at least by one observer. An eyepiece reticle and a tape recorder facilitate the determination of the position to an accuracy of better than one degree of arc and about one second of time, in the determination of the epoch.

'Moonwatch' observations, despite their low accuracy, are exceedingly important in both early and final stages of the lifetime of the satellite. Both 'Moonwatch' and radio tracking data are the only means of providing an approximate orbit immediately after launching. Similarly, in the final crucial days of the satellite, when very likely the radio transmitter may have ceased to function, and air drag effects become too conspicuous and do not permit the derivation of correct ephemeris predictions for photographic tracking, the visual observations are the only means of supplying vital information regarding the air density at heights in the earth's atmosphere lower than the original perigee altitude.

A precise determination of the position of a satellite at a given instant, when it is visible over a station, can be derived only by photographic means. A limitation imposed on optical techniques is that at a given region a satellite can be observed optically only in the twilight sky and when the geometrical conditions affecting the illumination of the satellite are favourable for visibility. Radio measures of position with the aid of 'Minitrack' stations, while less precise than the photographic measures, have the advantage that the object can be observed on every passage regardless of the time of day or weather conditions. During the current International Geophysical Year numerous countries have been cooperating in the establishment of optical and radio tracking stations for satellite observations. A major share of the credit in this enterprise goes to the IGY National Committee in the United States of America for their efforts in setting up a worldwide

network of observing stations, with the co-operation of the local National Committees. Indian contributions to this effort are in the field of precise photographic tracking. This programme was allotted by the Indian National Committee to the Uttar Pradesh State Observatory at Naini Tal. The project is a co-operative effort between the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, and the observatory at Naini Tal. On Manora Peak, Naini Tal, is thus one of the twelve precise photographic stations which encircle the globe. The tracking camera and associated equipment have been supplied by the Smithsonian Astrophysical Observatory. Approximate positions obtained by projecting the film containing the image of the satellite and starry background on to a B.D. chart are cabled immediately to Cambridge. The frames obtained are sent later for precise measurement.

The camera used is a 20 in. aperture f/1 Schmidt system in an altazimuth mounting with an extra degree of freedom to facilitate tracking. The primary mirror is 31 in. in diameter with the focal plane located 20 in. away. The 20 in. focal length provides a scale of 401 sec. of arc per millimetre. The corrector plate has three components. Two surfaces of the corrector plate system are spherical while the remaining four are aspherical. The system has been made apochromatic by proper choice of the materials that constitute it. Ray tracing data indicate that a circle of confusion of 20 microns contains 80 per cent of the visible and ultraviolet regions of the spectrum. The camera has a field 30° long and 5° wide photographed on a film strip in the focal plane. The focal surface is curved and since the backing plate against which the film rests under tension is curved accordingly, good quality images having diameters close to the resolving power of the emulsion are obtained.

The mounting departs considerably from the standard form commonly used for astronomical purposes. Since the camera is designed specially for work on faint satellites, it is necessary for it to ' follow ' the satellite in order to build up exposure, particularly when it is near the threshold of detection. This principle is well known in cometary or minor planet photography for position determinations. The difference between the

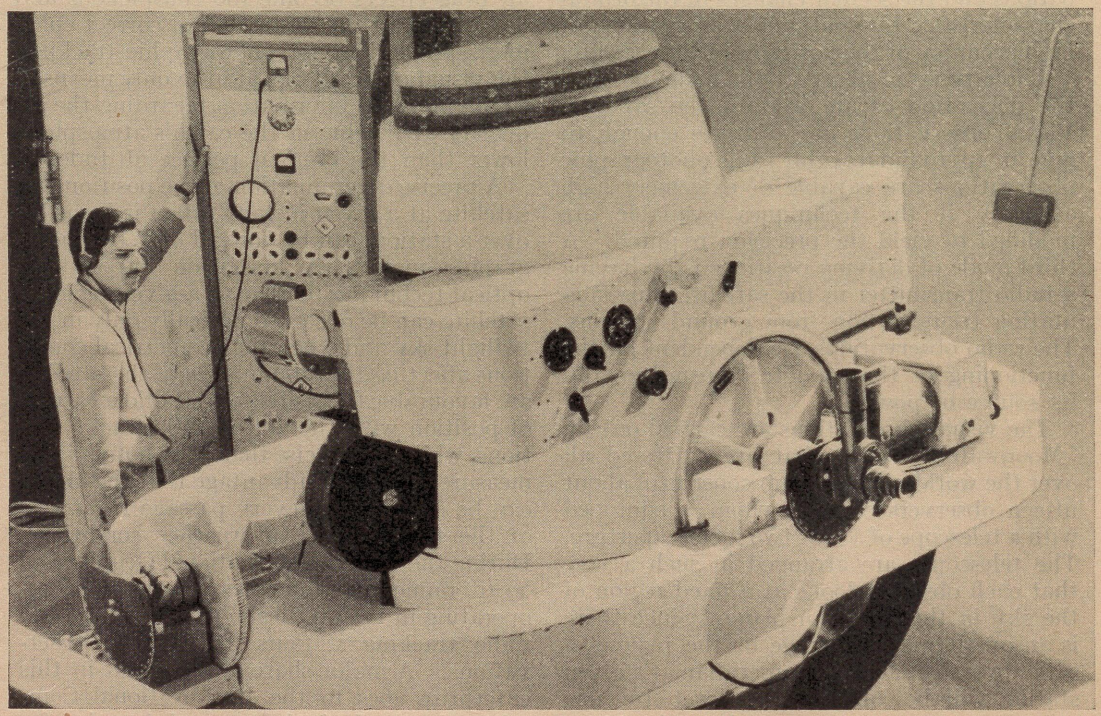

FIG. 1 — THE BAKER-NUNN CAMERA AT NAINI TAL [The time standard is seen in the background]

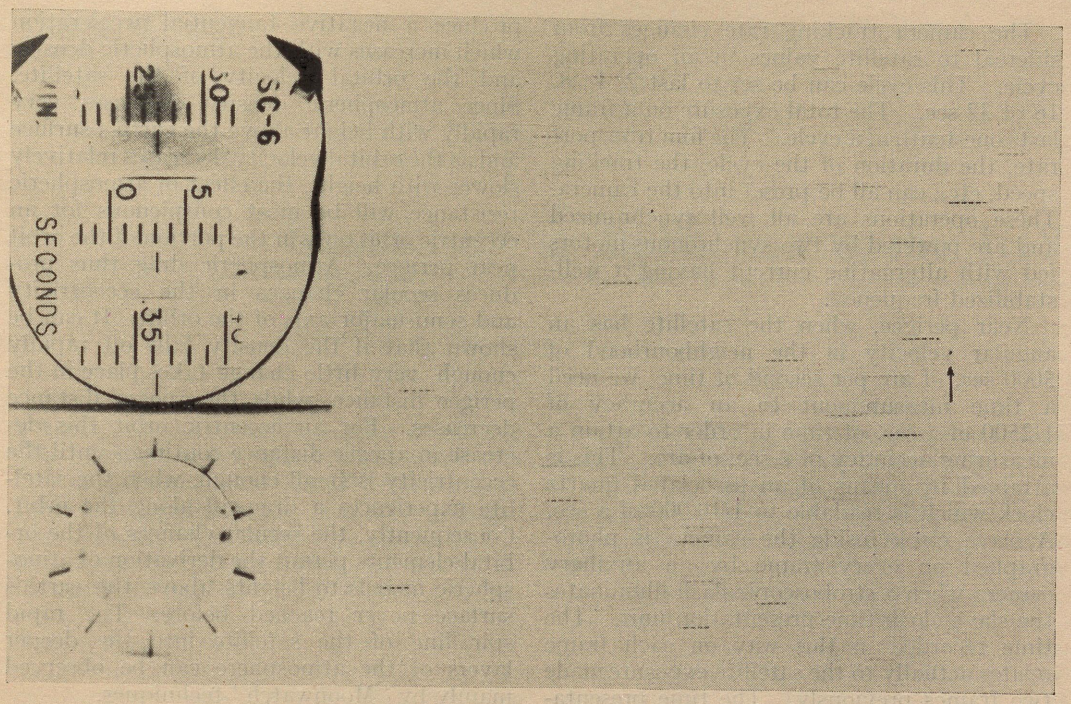

FIG. 2 — PHOTOGRAPH OF 1958 α_1 TAKEN WITH THE BAKER-NUNN CAMERA AT NAINI TAL ON 4 OCTOBER 1958 [The time presentation is seen on the left of the picture and reads 23 hrs 27 min. 3·3612 sec. The oscilloscope yields fractions of 10 millisec. The angular velocity of the satellite was 541 sec. of arc per second of time. The total exposure on the satellite equals 1·6 sec. The satellite image is marked by an arrow]

cometary case and that of the satellite is the comparatively large angular velocity that the latter has. Special tracking facilities are, therefore, called for to drive the camera at the prescribed angular velocity. The altitude axis of the altazimuth mount consists of a gimbal ring in which the camera is fixed. The camera is supported on an axis in the plane of this ring and in a direction perpendicular to the altitude axis as can be seen in Fig. 1. This permits the setting of the camera towards any point in the sky along the track of the satellite and the tracking is done by swinging the camera about the third axis. The rate of tracking depends on the angular velocity of the satellite. Information on the angular velocity and the azimuth and altitude of the culmination point is cabled from the computing centre of the Smithsonian Astrophysical Observatory prior to the transit. These are obtained in the early stages of the life of a satellite from an approximate orbit derived from the 'Moonwatch' and 'Minitrack' data.

The reduction procedure to be used for the derivation of a position necessarily follows the normal principles employed in photographic astrometry. To enable such procedures without large errors, the camera can be made to track alternately at sidereal and at satellite rates, so that in the first case the satellite leaves a trail with the star images as points and in the second the satellite image is a point. Since all these events can be recorded on the same frame of exposure of the film, the point image of the satellite can be measured against the faint star background with adequate correction for the motion of the satellite during the exposure.

For time measurement on the emulsion a rotating shutter produces sharp breaks in the trails. These can be seen in Fig. 2 which is a photograph of 1958 α_1 taken at Naini Tal. The camera tracked at the satellite's angular velocity for the duration of the exposure and hence the satellite image can be seen as a point with the star images trailed.

The camera tracking rate changes from sidereal to satellite values in an operating cycle. This cycle can be set to last 2, 4, 8, 16 or 32 sec. The total exposure on a frame lasts one-tenth of a cycle. The film transport rate, the duration of the cycle, the tracking speed, etc., can all be preset into the camera. These operations are all well synchronized and are powered by two synchronous motors fed with alternating current having a well-stabilized frequency.

Near perigee, when the satellite has an angular velocity in the neighbourhood of 5000 sec. of arc per second of time, we need a time measurement to an accuracy of 1/2500 of a sec. of time in order to attain a measuring accuracy of 2 sec. of arc. This is attained by means of an associated quartz clock which is readable to 1/10,000 of a sec. A slave clock inside the camera is photographed on every frame by an auxiliary camera when a stroboscopic flash illuminates the slave clock time presentation unit. The time recorded in this way on each frame relates actually to the satellite exposure made two frames previously. The time presentation on both ' master ' and ' slave ' clocks has a rotating dial reading to 1/100 sec. and an amplitude modulated circular sweep oscilloscope readable to 1/10,000 sec. These are seen in Fig. 2. The master clock is frequently compared with WWVH time signals for exact data on clock performance.

An important requirement for proper functioning of such a satellite tracking station is a very rapid communication facility between Cambridge and Naini Tal. A few hours before a transit, the latest data giving settings of azimuth, altitude, angular velocity and the expected instant of culmination of the satellite at the station are cabled from the Smithsonian Astrophysical Observatory. A transit observation may contain over a hundred photographs. The films are immediately processed and searched for the satellite images. If the transit is successful, the epoch and B.D. positions are cabled to Cambridge within a few hours after the transit. These cablegrams are given very high priority so that a message can be received at Cambridge from Naini Tal or vice versa within an hour.

The study of secular changes of the orbital parameters of an artificial satellite has opened new vistas in the fields of atmospheric density determinations and geodetic measurements. The effect of the earth's atmosphere is to produce a negative tangential acceleration which increases with the atmospheric density and the orbital velocity of the satellite. Since atmospheric density decreases very rapidly with height above the earth's surface and as the orbital velocity decreases relatively slower with height, the effect of atmospheric resistance will be most conspicuous for an eccentric orbit only in the portion of the orbit near perigee. Atmospheric drag thus produces secular changes in the eccentricity and semi-major axis of the orbit. It can be shown that if the density falls off rapidly enough, very little change takes place in the perigee distance, while the apogee distance decreases. For an eccentric orbit this decrease in apogee distance continues until the eccentricity is small enough, when the satellite experiences a drag all along the orbit. Consequently, the secular changes of the orbital elements permit the derivation of atmospheric models to heights above the earth's surface never reached before. The rapid spiralling of the satellite into the deeper layers of the atmosphere can be observed mainly by ' Moonwatch ' techniques.

We now have a new and exceedingly sound technique for determining the figure of the earth, and intercontinental distances. When we consider the motion of an infinitesimal particle about an oblate spheroid, we find that the longitude of the ascending node of the satellite orbit on the earth's equatorial plane shifts continually. A similar change is to be expected in the line of apsides or the line joining perigee and apogee. These changes are a function of the inclination of the orbit of the satellite, in the sense that the effect is zero for a satellite having an orbital plane perpendicular to the equator. Measurements of the precession of the plane of a satellite orbit of known inclination will provide a value of the oblateness more accurate than any available before the satellite era. Recently derived values of the oblateness are the results of such efforts.

An important field that can be tackled efficiently is the measurement of intercontinental distances. The Markowitz moon camera discussed in an article appearing elsewhere in this issue is expected to achieve a similar goal. At stations like Naini Tal, where both programmes are run concurrently, it will be of interest to compare the values obtained by two independent instrumental techniques.

Seismology in India during the IGY

A. N. TANDON
Meteorological Office, New Delhi

SEISMOLOGY, an important branch of geophysics, has been included for special study during the IGY programme. India is also participating in this programme. The main object of the programme is to collect seismological data from the worldwide network of existing seismological observatories and from new observatories specially opened during the IGY in furtherance of the main objectives. The data from all the participating countries are being collected at three world data centres, namely Washington, Moscow and Strasbourg. This collective data, when available in published form, could be used for special studies in the determination of the precise shape of figure of the earth, on earth tides, seismicity and structure of the crust of the earth, mantle and interior of the earth, and many other related problems. Besides strengthening of the general seismic network of stations by opening new observatories, some countries have organized survey parties for studies on regional problems. In this connection special reference may be made to seismic stations opened during the IGY period in the Arctic and the Antarctic regions, information from which was hitherto lacking.

India's programme of work in this discipline consisted of the maintenance of the network of seismological observatories existing at the beginning of IGY and the opening of two new stations. The existing stations at the following centres are controlled by the India Meteorological Department: (1) Shillong, (2) Bombay, (3) New Delhi, (4) Calcutta, (5) Kodaikanal, (6) Poona, (7) Dehra Dun, (8) Tocklai (Assam), (9) Bokaro (Bihar) and (10) Madras.

In addition to these, the seismological stations at Hyderabad, Vizianagram and Chatra, operated by state governments, have continued to function uninterruptedly.

Indian IGY programme for seismology included the opening of a seismograph-cum-microseismograph station at Port Blair and a special seismograph station at Agra. Both these observatories have special significance. The observatory at Port Blair started functioning regularly from April 1957. Its equipment included two Wood-Anderson type seismographs for the study of local and regional tremors, one Milne-Shaw seismograph for teleseismic work and a Sprengnether type electromagnetic microseismograph for special studies of microseisms. The observatory at Agra started continuous operation from December 1957. It is equipped with 3 components of a specially designed long-period electromagnetic seismograph, loaned to the India Meteorological Department by the Lamont Geological Observatory, Palisades, of the Columbia University, New York. The seismographs have an unusually large period of 15 sec. and are coupled to galvanometers having periods of the order of 100 sec. This combination makes the instruments specially sensitive for very long wavelengths which are usually not well recorded on sensitive short-period seismographs. The Columbia University, New York, has loaned similar equipment to other countries for establishing a worldwide network of such stations. The data collected from these instruments, besides being of general interest to seismologists, will be of special significance to workers engaged in the study of structure of the earth's crust from Raleigh and Love waves. Such instruments in the recent past have revealed the presence of surface waves having periods of the order of several minutes in records of major earthquakes.

The nature and origin of microseisms having a period range of 2-10 sec. have been receiving the attention of seismologists for more than three decades. The exact cause of the origin of the phenomenon has not been understood. Considering the importance of the subject and its possible application in the tracking of storms at sea, the countries participating in the IGY programme were requested to undertake special studies in this branch. Before the IGY, seismograph stations at Madras, Bombay and Shillong were equipped with sensitive microseismographs. These stations were standardized and are being maintained continuously during the IGY. In addition to these, the newly opened station at Port Blair was also equipped with a standardized Sprengnether type microseismograph. Since a large number of storms in the Bay of Bengal originate near the Andamans, the data obtained at Port Blair will be of great value. It is proposed to continue this station beyond the IGY period. The seismograph stations at (1) Howrah run by the Bengal Engineering College and (2) Cochin operated by the Naval Physical Observatory are also co-operating in the study of microseisms by running their stations continuously and sending their monthly microseismic data to the world data centres.

The seismological and microseismic data from all Indian observatories are being collected at the Central Seismological Observatory, Shillong, and are forwarded monthly in a consolidated form to World Data Centre 'C' at Strasbourg. It is perhaps too early to expect any immediate results from these data, but it is hoped that the consolidated data will reveal many new and interesting facts.

Microseismic Work at the Bengal Engineering College

S. K. CHAKRABARTY
Bengal Engineering College, Howrah

THE International Geophysical Year has provided a great opportunity for the study of geophysical phenomena which occur simultaneously over large regions of the world. A co-ordinated programme of investigation is required for the proper understanding of these problems. The Geophysical Laboratory of the Bengal Engineering College has been co-operating in the study of problems relating to microseisms recorded by very sensitive seismographs of the electromagnetic type. Details of the nature of the data that are being supplied to the IGY data collection centres under the project mentioned above together with the results of analyses are given below.

Microseisms are elastic waves produced by various causes. These waves generally travel over the surface of the earth and are probably Rayleigh waves. Some authors have, however, indicated a possibility of the presence of Love waves also. Some of the suggested mechanisms of their production are: (i) surf in coastal regions, (ii) beating of high waves on steep coast, (iii) movement of heavy traffic, and (iv) action of wind on trees and tall buildings in the neighbourhood of the recording equipment. The most important of the types so far known are possibly the microseisms associated with cyclones or even depressions which are occasionally produced in the sea. They are also produced by the norwesters when the centre of disturbance after passing over the land lies over the sea and beyond a certain optimum distance from the coast. During the last world war considerable emphasis was laid, at different geophysical laboratories of the world, on the study of microseisms and their correlations with cyclonic disturbances as that is possibly the only means of getting any information about the existence of cyclones in the deep ocean. The IGY programme has thus rightly emphasized on the systematic collection of microseismic data from the world network of stations, and the Geophysical

Laboratory of the Bengal Engineering College, Howrah, has been regularly supplying such data, in the standard form, through the Indian National Committee. It is expected that from a careful analysis of these data important and interesting information will be available on the mechanism of the generation and transmission of different types of microseisms. The microseisms associated with cyclonic disturbances are likely to be an important means of detecting storms even when they are far into the sea and are not affecting the weather of the coastal regions. Although qualitatively correlation is known to exist between cyclones and microseisms, a quantitative method has yet to be developed for precise location and tracking of cyclones and depressions. Such a method will supplement the usual methods of studying weather and will help considerably in giving necessary warnings on the possibility of the occurrence of cyclones, well in advance.

The data processed and communicated to the IGY data collection centres consist of the amplitudes measured in microns, and also the periods of the microseismic waves recorded by the electromagnetic seismographs of our laboratory at Howrah (22°33′N: 88°18′E), at prescribed hours, viz. 0, 6, 12, and 18 hrs GMT. The amplitudes are derived by taking the mean value of the maximum amplitudes of five groups of most important waves recorded within a period of 20 min. centred at the full hours indicated above. On 'International days' the data for every hour are tabulated and supplied. Additional measurements are also made on the microseismic amplitudes and periods at 3, 9, 15 and 21 hrs GMT whenever a microseismic storm occurs.

The data from the different centres, when analysed, will yield important information regarding the generation and transmission of microseismic waves, and also about the regional variations of the characteristics of microseisms and the variations of their types with the mechanisms of their generation. It has been observed[1] that the nature of typical microseisms associated with 'cyclonic storms' and depressions and norwesters depends critically on the structure of the ocean bed and that of the continental shelf. It has been established from the records taken in our laboratory that for the generation of microseisms a minimum depth of water over the sea bed is necessary, and that the period of the recorded microseisms increases as the depth of the water layer over the continental shelf and just under the centre of disturbance increases. A theoretical explanation for it has been given by Mitra[2]. This has also been found in the records where the microseisms have travelled a long distance across the continent. In Fig. 1 is shown a portion of the records of microseisms obtained at the Geophysical Laboratory, Howrah, associated with a cyclone which was formed in the Arabian Sea on 10 November 1957. The microseismic waves travelled a distance of about 2000 km. across the Indian continent, yet the recorded amplitudes were prominent. Moreover, the periods of the waves recorded at Bombay (data kindly supplied by the Director, Colaba Observatory) and Howrah are similar. The period of the microseismic waves was always nearly 4 sec. and did not change with the rise or fall of the amplitude of the recorded microseisms. It is easy to understand that this was due to the fact that the core of the cyclone in this case did not travel a long distance, and in any case the depth of the water layer over the sea bed and under the core of the cyclone did not change appreciably, although the amplitude of the microseisms changed with the rise and fall of intensity of the cyclone. A similar conclusion can be arrived at from the records of microseisms associated with norwesters. In Fig. 2 are shown the records of microseisms associated with a norwester which travelled over Calcutta and moved into the Bay of Bengal. The arrow in the record corresponds to the time at which the norwester was over the coast, and high waves and gusty winds were produced in the coastal region. No microseisms were recorded at that time but they started to appear after about an hour. The amplitudes and periods of the microseisms increased as the centre of disturbance travelled away from the coast. Various workers are engaged in the study of this important correlation between typical microseisms and weather disturbances, and also in the different aspects of the recorded microseisms. It appears that the recorded amplitudes depend on various factors, particularly on the intensity and position of the disturbance and the degree of refraction at the coastal region, whereas the variation of the period of microseisms depends critically on the position of cyclonic disturbance as well as

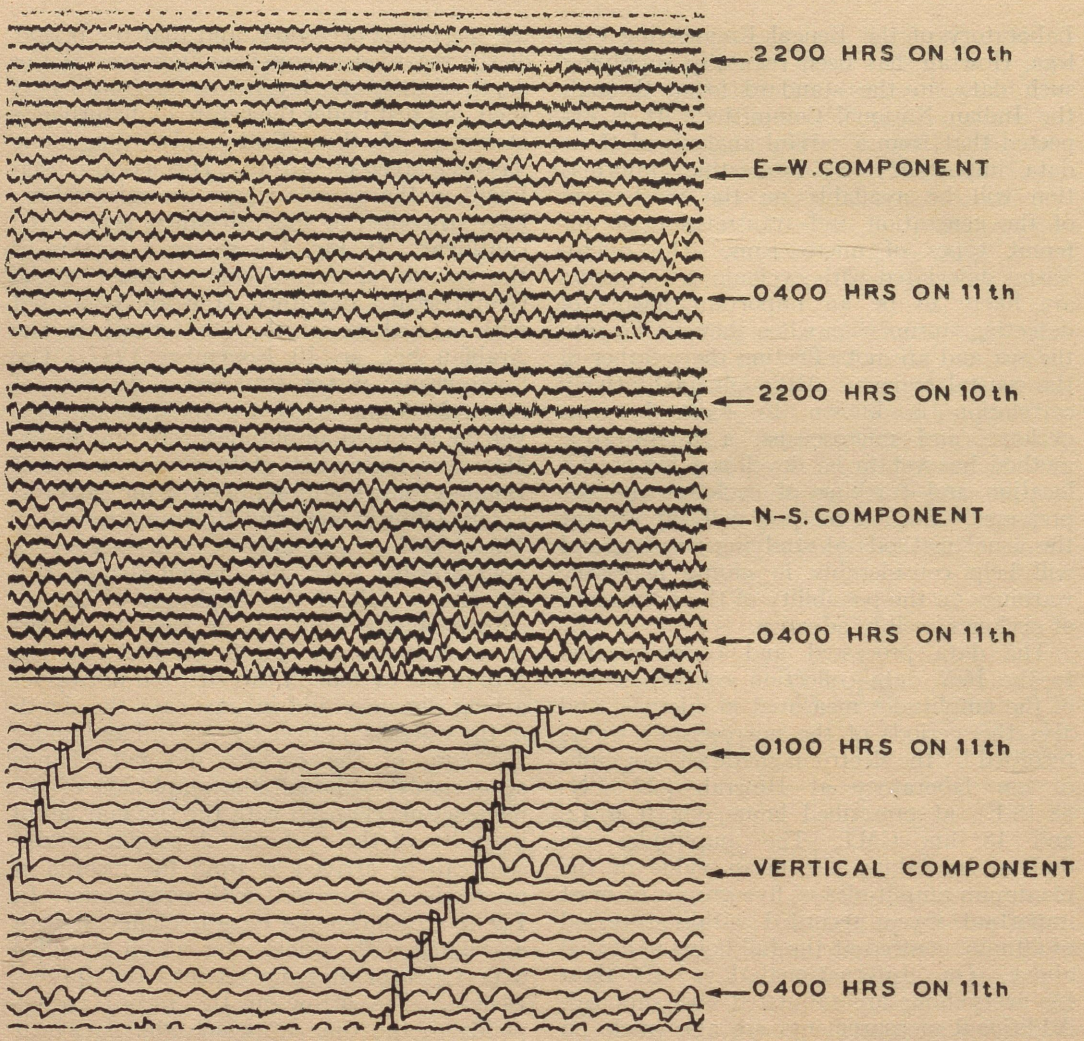

FIG. 1 — RECORDS OF MICROSEISMS ASSOCIATED WITH THE ARABIAN SEA CYCLONE OF 10-12 NOVEMBER 1957. MICROSEISMS BECAME SIGNIFICANT EVEN AT 0100 HRS IST ON 11 NOVEMBER

on the structure of the sea bed. It is, therefore, advisable to concentrate more on the study of the periods of the microseisms from the standpoint of the ease in analysis and their interpretation. With the analysis of a large mass of data it will be possible to devise accurate methods of locating and tracking cyclones even when they are far off from the coastal region. These studies will also give important information about the structure of the sea beds.

A different type of microseisms of a very short period (0·4 sec. or less) is occasionally recorded in our seismogram. The amplitudes of such microseisms remain practically steady and significantly above the normal background for about half an hour to sometimes as much as 2-3 hr. The nature of the records suggests their possible connection with some resettlement of underground structures. Records of a similar type have also been obtained at some of the stations in U.S.A. located near the oilfields. Further studies on this point are necessary, particularly a comparison of similar records from a close network of stations.

The microseisms associated with the advance of monsoons are of a type different

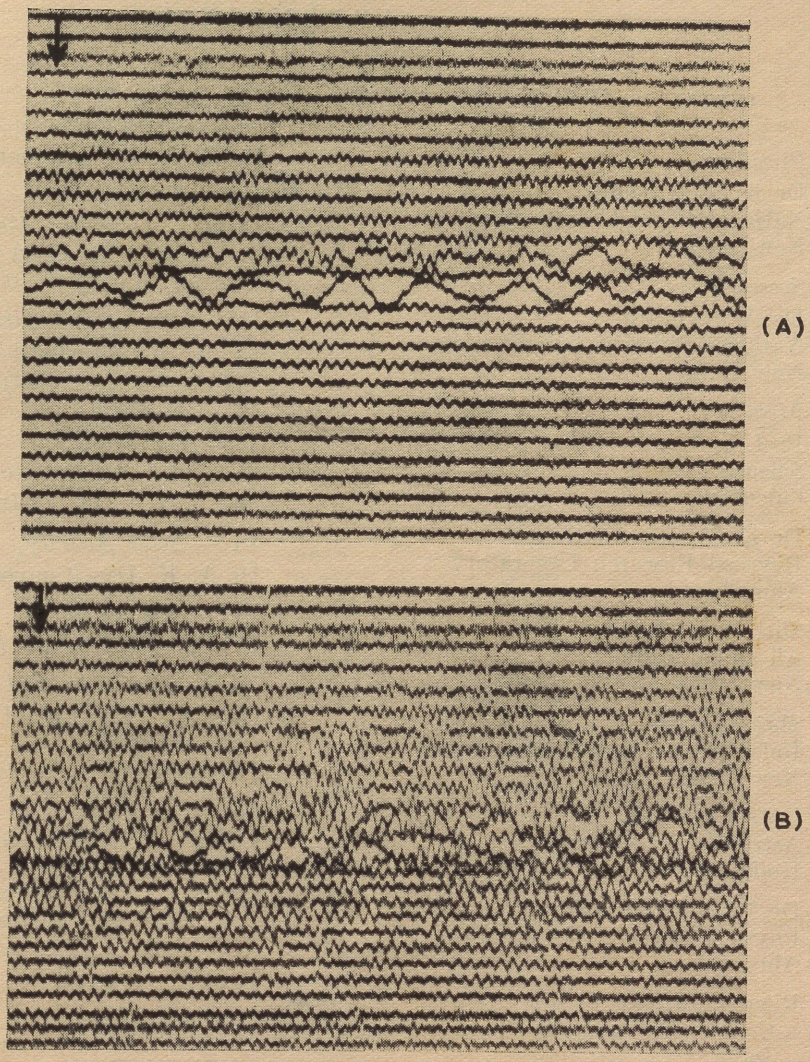

FIG. 2 — RECORDS OF MICROSEISMS ASSOCIATED WITH THE NORWESTER OF 6 MAY 1953 [(A), E-W component; (B) N-S component. Time scale, 30 mm./min. The arrows indicate the same instant on the records (1830 hrs IST). The time interval between corresponding points on consecutive lines is 30 min.]

from those associated with cyclones discussed above. Even weeks before the onset of the monsoons on the coast of the Bay of Bengal, typical types of microseisms are recorded in our seismograms. Their variations agree qualitatively with the progress of 'monsoons' and significant indications are available of the weakening and strengthening of monsoons even when the coastal regions are not disturbed. A co-ordinated study of the records of different stations on the coast of the Bay of Bengal will give important information about the progress of monsoons and the data collected during the IGY will be very useful for such studies.

Acknowledgement

The author's thanks are due to the Council of Scientific & Industrial Research, New Delhi, for financing the research project referred to above. Thanks are also due to Shri K. R. Nag and Shri G. C. Chowdhury, who are working on the IGY programme, for their hard and sincere work.

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APPENDIX I

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APPENDIX II

TABLE 1 — GEOGRAPHICAL DISTRIBUTION OF INDIAN STATIONS*

	Geographic latitude	Geomagnetic latitude	Geographic longitude	Geomagnetic longitude
NC. Northern Minauroral Belt				
1. Tokyo	35°40′N	25°37′N	139°45′E	205°46′E
2. Machhoi Glacier (near Zoji La)	34°18′N	24°18′N	75°32′E	148°24′E
3. Srinagar	34°07′N	24°09′N	74°48′E	147°48′E
4. Gulmarg	34°03′N	24°10′N	74°24′E	147°24′E
5. Beirut	33°53′N	30°47′N	35°30′E	111°26′E
6. Shigri Glacier	32°15′N	22°42′N	77°28′E	149°31′E
7. Amritsar	31°37′N	22°37′N	74°53′E	146°53′E
8. Gangotri Glacier	30°55′N	21°06′N	79°04′E	151°04′E
9. Dehra Dun	30°20′N	20°43′N	78°03′E	150°03′E
Equatorial Belt				
10. Naini Tal	29°23′N	19°30′N	79°27′E	151°10′E
11. Delhi	28°38′N	19°11′N	77°13′E	148°55′E
12. Darjeeling	27°03′N	16°24′N	88°16′E	159°16′E
13. Chatra	26°50′N	16°24′N	87°10′E	158°10′E
14. Toklai	26°45′N	15°45′N	94°15′E	164°24′E
15. Jodhpur	26°17′N	17°17′N	73°02′E	145°02′E
16. Gauhati	26°10′N	15°10′N	91°45′E	162°24′E
17. Shillong	25°34′N	14°34′N	91°53′E	162°23′E
18. Allahabad	26°27′N	15°28′N	81°54′E	152°50′E
19. Banaras	25°20′N	15°20′N	83°01′E	154°01′E
20. Mt Abu	24°36′N	15°36′N	72°43′E	144°21′E
21. Bokaro	23°50′N	13°40′N	85°48′E	156°34′E
22. Kandla	23°01′N	14°01′N	70°13′E	141°12′E
23. Ahmedabad	23°01′N	14°01′N	72°36′E	143°50′E
24. Navalakhi	22°58′N	13°58′N	70°27′E	141°53′E
25. Mundra	22°44′N	13°47′N	69°46′E	141°09′E
26. Haringhata	22°58′N	12°15′N	88°34′E	158°42′E
27. Calcutta	22°34′N	11°54′N	88°21′E	158°27′E
28. Garden Reach	22°33′N	11°53′N	88°18′E	158°24′E
29. Diamond Harbour	22°12′N	11°34′N	88°10′E	158°13′E
30. Bhavnagar	21°48′N	12°47′N	72°09′E	143°09′E
31. Sagar (West Bengal)	21°39′N	11°02′N	88°03′E	158°03′E
32. Nagpur	21°09′N	11°20′N	79°06′E	150°06′E
33. Veraval	20°54′N	11°54′N	70°23′E	141°23′E
34. Mahanadi river mouth	20°25′N	10°04′N	86°47′E	156°47′E
35. Bombay	19°00′N	10°00′N	72°50′E	143°50′E
36. Alibag	18°38′N	09°38′N	72°53′E	143°53′E
37. Poona	18°31′N	09°31′N	73°52′E	144°52′E
38. Vizianagram	18°07′N	08°07′N	83°27′E	153°27′E
39. Hyderabad	17°26′N	07°45′N	78°27′E	148°40′E
40. Visakhapatnam-Waltair	17°43′N	07°43′N	83°18′E	153°18′E
41. Ratnagiri	16°59′N	07°59′N	73°18′E	143°58′E
42. Rangoon	16°46′N	05°46′N	90°10′E	160°10′E
43. Moulmein	16°29′N	05°29′N	97°37′E	167°06′E
44. Khartoum	15°35′N	13°04′N	32°35′N	104°27′E
45. Dharwar	15°27′N	06°27′N	75°01′E	145°01′E
46. Madras	13°05′N	03°05′N	80°17′E	150°17′E
47. Bangalore	12°58′N	03°26′N	77°38′E	147°38′E
48. Mangalore	12°51′N	03°51′N	74°50′E	144°50′E
49. Aden	12°47′N	07°47′N	44°59′E	115°59′E
50. Chidambaram	11°24′N	01°28′N	79°42′E	149°42′E
51. Tiruchirapalli	10°49′N	01°05′N	78°42′E	148°42′E
52. Kodaikanal	10°14′N	00°44′N	77°29′E	147°29′E
53. Cochin	09°58′N	00°43′N	76°16′E	146°15′E
54. Mandapam	09°17′N	00°33′N	79°08′E	148°46′E
55. Trivandrum	08°29′N	00°54′S	76°57′E	146°11′E
56. Port Blair	11°40′N	00°40′N	92°46′E	161°46′E
57. Minicoy	08°19′N	00°41′S	73°04′E	142°14′E
58. Singapore	01°17′N	09°43′S	103°51′E	172°51′E

*Data are also collected by ships in the Indian Ocean, the Bay of Bengal and the Arabian Sea.

APPENDIX III

TABLE 1 — SOLAR FLARES DURING JULY 1957 TO SEPTEMBER 1958

[*From the observations at the Astrophysical Observatory, Kodaikanal (K) and the Nizamiah Observatory (N), Hyderabad; time, GMT*]

Month	Date	Beginning *hrs*	Max. *hrs*	End *hrs*	Latitude	Longitude	Importance	H-alpha line width *A*	Observatory
July 1957	1	0346	0352	0414	14°N	14°W	1^+	1·9	N
	2	0544	—	—	15°N	34°W	1^+	2·0	N
	3	—	—	—	11°N	41°W	Probably 2	—	K
August 1957	30	0348	—	0448	27°S	15°E	1	1·6	N
	30	0355	—	0402	26°S	15°E	1	1·8	K
	31	0252	—	0312	15°N	4°E	1	2·1	N
	31	0548	0551	0556	15°N	4°E	1	1·6	N
	31	0627	—	0653	30°S	0°E	2	2·0	N
September 1957	1	0204	0209	0223	13°N	08°W	1	2·0	K
	2	0410	0413	0430	13°N	26°W	1	1·8	K
	2	0434	—	0445	14°N	24°W	1	1·0	N
	3	1024	1028	1052	17°N	42°W	2	2·6	N
	4	0541	0545	0555	13°N	49°W	1	1·8	N
	14	0230	0236	0249	10°N	38°W	1	2·0	K
	15	0333	0334	0400	07°N	70°W	2	5·2	K
	15	0336	—	0349	01°N	18°E	1	1·8	N
	16	0309	0312	0321	25°N	38°E	1	1·4	N
	17	0416	0418	0539	23°N	28°E	1^+	2·7	N
	18	0425	0428	0442	22°N	15°E	1	1·2	N
	19	0250	—	0320	24°N	02°E	2	1·6	N
	19	0405	0410	0432	22°N	06°E	2	3·0	K
	20	0450	—	0454	21°S	0°	1	1·8	K
	20	0347	0355	0434	24°N	02°E	3	2·6	N
	20	0529	0533	0552	23°N	13°W	1	1·3	N
	21	0415	0423	0428	22°N	23°W	1	2·0	K
	21	0423	—	0456	22°N	28°W	1^+	1·8	N
	24	0257	0300	0310	10°N	45°W	1	2·7	K
	27	0523	0528	0544	24°S	22°E	1	2·2	N
	28	0913	0916	0933	20°N	17°W	1^+	2·6	N
October 1957	2	0343	0348	0405	11°N	49°W	1	1·6	N
	2	0430	0433	0451	16°S	44°E	1	1·7	N
	2	0436	0438	0443	S	E	1^-	—	N
	3	0340	0353	0438	37°S	16°W	1^+	2·1	N
	12	0903	0906	0919	15°N	66°W	1^+	1·9	N
	12	—	—	—	S	E	1	—	N
	13	0500	—	0521	25°S	59°E	1^+	2·2	N
	13	0534	0539	0556	13°N	41°E	2^+	2·5	N
	15	0252	—	0319	24°S	37°E	1	1·5	N
	16	0326	0328	0324	26°S	22°E	1^-	1·2	N
	16	0423	—	—	26°S	22°E	1	1·5	N
	16	0529	—	0530	26°S	22°E	1	1·6	N
	17	0427	0431	0436	27°S	09°E	1^-	1·4	N
	28	0540	—	—	S	E	1	1·5	N
November 1957	13	0323	0326	0331	15°S	80°W	1^-	1·0	N
	15	0529	0540	0605	18°N	45°W	1^+	2·0	N
	17	0539	0542	0552	28°N	26°E	1^+	2·3	N
	26	0337	0339	0343	13°S	07°W	Probably 1	2·0	K

TABLE 1 — SOLAR FLARES DURING JULY 1957 TO SEPTEMBER 1958 — *contd*

[*From the observations at the Astrophysical Observatory, Kodaikanal (K) and the Nizamiah Observatory (N), Hyderabad; time, GMT*]

Month	Date	Beginning *hrs*	Max. *hrs*	End *hrs*	Latitude	Longitude	Importance	H-alpha line width *A*	Observatory
December 1957	3	1021	1024	1032	18°S	50°W	1^-	1·6	N
	6	0404	0423	0423	14°N	44°E	Probably 2	2·0	K
	7	0859	0910	0945	15°N	28°E	1	2·0	N
	12	0258	—	0313	34°S	10°W	1	1·6	N
	17	0907	0912	0923	17°N	39°E	1^-	1·8	N
	18	0444	0451	0528	17°N	26°E	1	2·6	N
	20	0543	0545	0606	15°N	01°E	1^+	2·5	N
	25	0435	—	0437	07°S	59°W	1	1·5	N
	25	0459	—	0533	17°N	59°W	1	1·8	N
	25	1030	1034	1041	09°N	61°W	1^-	1·6	N
	27	0913	0917	0926	27°N	59°W	1	2·0	N
January 1958	2	0557	—	0616	14°S	29°E	1	1·6	N
	15	0509	0526	0553	11°S	54°W	1^+	1·6	N
	15	0500	0514	0537	14°S	52°W	1	1·9	K
	16	0927	0937	0940	15°S	57°E	1	2·1	N
	23	0520	—	—	—	—	1	1·5	N
	24	0334	0347	0424	23°S	55°W	1	1·7	N
	25	0927	0950	1029	21°S	69°W	2	2·54	N
	25	1010	—	—	25°S	73°W	Probably 2	2·4	K
February 1958	4	0439	0442	0450	15°S	25°E	1	1·6	N
	4	0901	0906	0916	15°S	51°E	1	1·0	N
	11	0252	—	0308	10°N	27°E	1	1·0	N
	11	0532	0536	0546	10°N	27°W	1	1·2	N
	12	0937	0940	0953	22°S	31°W	1	1·6	N
	13	0444	—	0449	11°S	01°E	1	1·5	N
	25	0453	0555	0535	26°S	21°W	2	1·8	N
	26	0449	—	0452	17°S	60°W	1	1·8	K
	26	0550	—	0600	17°S	60°W	1	2·0	K
	28	0438	0441	0450	10°N	85°W	1	1·2	N
	28	0508	—	0510	16°S	36°W	1	1·0	N
March 1958	3	1013	1078	1048	19°S	60°E	3	3·6	N
	3	—	—	—	15°S	54°E	Probably 2	2·0	K
	8	1050	1052	1058	22°S	14°W	1^-	1·0	N
	10	0210	0213	0217	11°N	35°E	1	2·0	K
	13	0344	0349	0357	10°N	07°E	1^-	1·4	N
	14	0442	0446	0458	09°N	11°W	1	1·6	N
	17	0438	0444	0453	10°N	18°E	1^+	2·0	N
	17	1027	1033	1043	10°N	18°E	1	1·8	N
	21	1040	—	—	N	E	1	1·8	N
	21	1021	1022	1040	20°N	20°E	1^+	4·0	K
	22	0541	0544	0550	17°N	61°E	1^-	1·2	N
	23	1016	1018	1027	18°N	60°E	2	3·6	N
	25	0257	—	0304	20°N	35°W	1^-	1·2	N
	25	0347	0349	0354	13°S	51°E	1	1·2	N
	25	0529	0530	0555	18°N	22°E	2	2·3	N
	25	0557	0603	0626	13°S	51°E	2	2·5	N
	25	0558	—	0547	15°N	25°E	1^+	2·0	K
	27	0537	0542	0549	24°N	58°W	1	1·7	N
	31	0856	—	0904	19°S	28°E	1	1·6	N
	31	1025	—	1030	10°S	27°W	1^-	1·4	N

TABLE 1 — SOLAR FLARES DURING JULY 1957 TO SEPTEMBER 1958 — *contd*

[*From the observations at the Astrophysical Observatory, Kodaikanal (K) and the Nizamiah Observatory (N), Hyderabad; time, GMT*]

Month	Date	Beginning *hrs*	Max. *hrs*	End *hrs*	Latitude	Longitude	Importance	H-alpha line width *A*	Observatory
April 1958	1	0445	0447	0453	09°S	68°W	1	1·8	N
	1	0502	—	0505	35°N	39°E	1^-	1·1	N
	2	0427	0433	0441	15°S	58°W	1	2·0	N
	2	0505	—	0515	23°S	34°W	1^+	2·3	N
	2	0502	—	0507	26°S	34°W	2	4·8	K
	3	0412	0420	0428	15°S	19°E	1	2·2	K
	7	1025	—	1033	15°N	32°E	2	2·6	N
	8	0301	0309	0329	17°S	44°W	1	1·9	N
	8	0305	0318	0338	17°S	47°W	1	2·8	K
	16	0535	0537	0542	20°S	64°E	1^-	1·5	N
	28	1032	1034	1040	21°N	49°E	1^-	1·2	N
May 1958	1	1007	1010	1016	21°N	19°E	1^-	1·7	N
	2	0546	—	0548	14°S	07°E	1	1·3	N
	5	0407	0415	0435	15°S	32°W	1^+	2·6	N
	8	0549	0551	0556	19°N	73°W	1	1·8	N
	30	0326	—	0332	22°N	46°W	1^+	2·0	N
June 1958	5	0520	—	0527	46°N	60°E	1	1·9	N
	5	0850	0858	0913	15°N	68°W	1^+	2·3	N
	6	0438	0448	0503	16°N	75°W	1^+	3·0	N
	6	0458	—	0507	17°N	78°W	2	2·4	K
	10	0307	0310	0319	44°N	04°W	1	2·0	N
	10	0602	—	0612	44°N	03°W	1	1·6	K
	11	0552	0553	0557	44°N	15°W	1^-	1·2	N
	11	0231	—	0240	44°N	17°W	1^+	2·6	K
	14	0530	—	0534	15°N	50°E	1	1·2	N
	18	0319	—	0321	18°N	06°W	1	1·5	N
	18	0538	0540	0543	18°N	07°W	1	1·9	N
	19	0456	0457	0501	15°N	22°W	1^-	1·4	N
	19	1005	1007	1033	16°N	25°W	1^+	2·7	N
	19	0212	0218	0237	15°N	19°W	2	2·7	K
	26	0300	—	0320	10°N	49°E	2^+	2·6	N
	26	0225	0346	0250	10°N	48°E	1	1·6	K
	27	0307	0309	0318	12°N	38°E	1^+	2·1	N
July 1958	26	0301	—	0303	17°S	05°W	1	1·41	N
	26	0205	0202	0222	15°S	04°W	1	1·6	K
September 1958	2	0257	0259	0305	14°N	23°W	1	1·7	N
	4	0532	—	0541	07°S	58°E	1	1·5	N
	12	0908	0914	0927	14°N	19°E	1	2·3	N
	13	0328	0332	0338	13°S	41°E	1	1·8	N
	13	0546	—	0552	12°S	61°W	1^+	1·8	N
	18	0350	0412	0444	15°S	11°E	2	2·4	N

TABLE 2 — SUDDEN ENHANCEMENT OF ATMOSPHERICS (SEA) DURING JULY 1957 TO AUGUST 1958*

(*Time, GMT*)

Month	Date	Freq. *kc/s.*	Beginning *hrs*	Max. *hrs*	End *hrs*	Month	Date	Freq. *kc/s.*	Beginning *hrs*	Max. *hrs*	End *hrs*
July 1957	8	27	0925	0940	1025	January 1958	4	100	0200	0203	0220
	8	27	1330	1340	1419		9	100	0133	0137	0153
	11	100	1255	1310	1430		10	100	2300	2310	2340
	14	100	0540	0600	0630		12	100	0405	0410	0430
	14	100	0645	0705	0740		15	100	0945	0950	1005
	14	27	2255	2307	2350		16	100	0923	0935	1023
	18	27	0000	0010	0130		25	100	0025	0040	0125
	20	27	0840	0852	0915		27	100	0815	0820	0840
	26	100	1137	1143	1230		28	100	0710	0715	0730
	28	27	0958	1007	1030						
	28	100	0954	1010	1030	March 1958	12	100	0245	0250	0300
	28	27	1033	1055	1145		15	100	0042	0047	0105
	29	27	1010	1030	1110		20	100	0040	0043	0100
		100	1005	1030	1115		23	100	0030	0035	0120
	30	100	2315	2325	2355		25	100	2337	2345	0000
August 1957	2	27	0823	0830	0850						
	2	27	0857	0905	0930	May 1958	29	100	2330	2335	0025
	8	100	0540	0515	0532		29	100	0130	0135	0145
	9	27	0130	0145	0320						
	9	27	0805	0814	0902	June 1958	6	100	0615	0618	0630
	9	100	1255	1320	1545		15	100	1200	1207	1223
	9	100	2320	2340	0015		18	100	2337	2341	2355
	10	100	1000	1030	1110		18	100	0045	0050	0100
	14	27	1150	1200	1223		18	100	0625	0630	0645
	15	27	0915	0930	1018		18	100	0800	0806	0820
	16	27	2320	2325	2345						
	17	27	0415	0435	0510	July 1958	3	100	0653	0700	0714
	20	100	0200	0215	0315		18	100	1030	1040	1110
	26	100	0005	0025	0315		18	100	1130	1133	1145
September 1957	18	100	0640	0645	0730	August 1958	13	100	—	—	—
	18	100	1237	1245	1255		13	100	1300	1305	1320
December 1957	20	100	0610	0615	0630		14	100	1120	1126	1200
	21	100	0400	0403	0415		16	100	2330	2335	0000
	22	100	0200	0210	0245		25	100	1350	1357	1410

*The data are obtained from the observations made at the National Physical Laboratory, New Delhi.

TABLE 3 — SUDDEN COSMIC ABSORPTION (SCA) DURING JULY 1957 TO JULY 1958*

(*Time, GMT*)

Month	Date	Beginning *hrs*	Max. *hrs*	End *hrs*	Amp.	Month	Date	Beginning *hrs*	Max. *hrs*	End *hrs*	Amp.
July 1957†	27	0658	0703	0715	3·42	September 1957†	21	0412	0420	—	3·56
	28	1032	1041	1055	3·56		23	0645	0655	—	3·98
	30	2310	2317	—	2·30		30	0602	0605	—	4·15
August 1957†	1	0635	0643	—	2·15	October 1957†	20	0252	0255	—	3·28
							23	0625	0628	0643	2·65
September 1957†	3	0758	0803	—	1·94		26	0348	0351	—	4·39
	7	0812	0816	0841	8·30	March 1958‡	23	0945	—	1245	13·90
	19	0405	0410	—	4·47						
	20	0745	0800	—	3·01	July 1958‡	29	0300	0306	—	13·00

*The data are obtained from the observations made at the National Physical Laboratory, New Delhi.
†Frequency, 22·4 Mc/s. ‡Frequency, 30·0 Mc/s.

TABLE 4 — SOLAR FLARE EFFECTS RECORDED DURING JULY 1957 TO JUNE 1958*

Month	Date	Time of crochet or solar flare effect (beginning) *hrs*	Initial impulse ΔH γ	Initial impulse ΔV γ	Month	Date	Time of crochet or solar flare effect (beginning) *hrs*	Initial impulse ΔH γ	Initial impulse ΔV γ
July 1957	11	0942			November 1957	10	0654		
		ABG	+9	−3			ABG	+4	−5
	16	0732					0657		
		ABG	+14	−3			TRV	+32	−30
	21	0655					0655		
		ABG	+11	−5			AMR	+26	+4
	23	0532				22	0406		
		ABG	+34	−6			TRV	+31	−26
							AMR	+26	−10
August 1957	31	0553			December 1957	19	0800		
		ABG	+17	−5			ABG	−2	+9
September 1957	7	0810					TRV	+44	−33
		ABG	+7	−12			AMR	+32	−30
	12	0708			February 1958	13	0816		
		ABG	+6	−3			ABG	+7	−4
	19	0402					0818		
		ABG	+15	+12			TRV	+20	−18
	19	0806					0816		
		ABG	+4	−2			AMR	+16	−4
	20	0903			March 1958	23	0954		
		ABG	+7	−2			ABG	+30	−12
							TRV	+6	−8
November 1957	5	1203					AMR	+7	−6
		TRV	+3	−5					
	6	0839			June 1958	13	0703		
		ABG	+4	−1			ABG	+5	−2
		TRV	+19	−21			TRV	+5	−7
		AMR	+16	−3			AMR	−4	+5

ABG, Primary Magnetic Observatory, Alibag; TRV, Field Magnetic Observatory, Trivandrum; AMR, Field Magnetic Observatory, Annamalainagar.

*The data are obtained from the observations made at the National Physical Laboratory, New Delhi.

IMPULSE
ΔV
γ

−5

−30

+4

−26
−10

+9
−33
−30

−4

−18

−4

−12
−8
−6

−2
−7
+5

netic Obser-

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