UPLINK INTERFERENCE CONSIDERATIONS BETWEEN INTELSAT III AND THE INDIA SATELLITE

This memo describes the interference potential of the uplinks associated with the India satellite upon the uplinks directed to an adjacent Intelsat III.

The India uplinks considered are of three types with the following characteristics.

1. Interferometer Beacon
   (a) Signal type: unmodulated carrier (CW)
   (b) Power: 100W
   (c) Earth antenna diameter: 15 feet
   (d) Uplink eirp: 66.5 dBW @ 6 GHz

2. Telephony Carrier
   (a) Modulation: FM
   (b) Number of channels: 600
   (c) RF bandwidth: 30 MHz
   (d) Baseband peak/rms ratio: 10 dB
   (e) RMS Mod. Index: 1.565
   (f) Power: 200W
   (g) Earth antenna diameter: 35 feet
   (h) Uplink eirp: 77 dBW @ 6 GHz

3. TV Carrier
   (a) Modulation: FM
   (b) RF bandwidth: 30 MHz
   (c) Mod. Index: 2

(d) Power: 200W

(e) Earth antenna diameter: 35 feet

(f) Uplink eirp: 77 dBW @ 6 GHz

The Intelsat III receives four types of carriers, as described below.*

1. Telephony I

(a) Modulation: FM/pre-emphasis

(b) Number of channels: 24

(c) RF bandwidth: 5 MHz

(d) Uplink eirp: 70.8 dBW @ 6 GHz

(e) RMS Mod. Index: 5.95 assuming 12 dB pk/rms ratio**

2. Telephony II

(a) Number of channels: 60

(b) RF bandwidth: 10 MHz

(c) Uplink eirp: 74.3 dBW

(d) RMS Mod. Index: 5.3 assuming 11 dB pk/rms ratio**

3. Telephony III

(a) Number of channels: 132

(b) RF bandwidth: 20 MHz

(c) Uplink eirp: 77.1 dBW

(d) RMS Mod. Index: 4.8 assuming 11 dB pk/rms ratio**

4. FM Television

(a) RF bandwidth: 40 MHz

(b) Uplink eirp: 82.2 dBW

(c) Mod. Index: 3**

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* Information obtained in telephone conversation with Peter Schultze, Comsat Corp., 9/2/70

** Assumption and calculation made by this writer.

A. Analysis

Before proceeding to specific calculations it is useful to review the analytical basis on which they depend. This varies according to whether the desired signal is telephony or TV and therefore these are considered separately.

A.1 Telephony

Telephone channel performance is described by the noise, N, in the channel measured in units of pW0p. This is related to the test-tone-to-noise ratio, (S/N), as follows:

$$N = 10^9 \, / \, (S/N) \qquad (1)$$

Denoting SNR = 10 log (S/N), we further have:

$$NPR = SNR - 18.8, \text{ dB} \qquad (2)$$

where NPR is the noise-power ratio, a customary unit of measurement in telephone work. Finally,

$$NPR = CXR + K \qquad (3)$$

where

CXR = carrier-to-interference ratio

K = a factor analogous to the FM improvement factor, and which depends on the specifics of wanted and unwanted signals. It may or may not include pre-emphasis, as the case may be.

Neglecting small differences in slant range, we can write:

$$CXR = CXR_t + G_{gu}(0) - G_{gu}(\Delta\theta) + G_{sw}(0) - G_{sw}(\phi) \qquad (4)$$

where

CXR_t = ratio of on-axis eirp of the two signals

$G_{gu}(0)$ = on-axis gain of unwanted ground station

$G_{gu}(\Delta\theta)$ = off-axis gain of unwanted ground station in direction of wanted satellite; $\Delta\theta \simeq$ satellite spacing.

$G_{sw}(0)$ = on-axis gain of wanted satellite

$G_{sw}(\phi)$ = off-axis gain of wanted satellite in direction of unwanted ground terminal.

Since Intelsat III, the "wanted" satellite, has an earth-coverage antenna, to a good approximation $G_{sw}(0) \approx G_{sw}(\phi)$. Hence,

$$CXR = CXR_t + I \qquad (5)$$

where $I = G_{gu}(0) - G_{gu}(\Delta\theta)$ is the isolation provided by the beam pattern of the interfering ground station.

Where applicable, we shall use the CCIR sidelobe model which states that:

$$G_{gu}(\Delta\theta) = 32 - 25 \log (\Delta\theta). \qquad (6)$$

In order to determine how much isolation is needed it is necessary to specify the tolerable level of interference. The total allowable N is 10,000 pW0p, from all sources. We shall assume in this memo that the allowable amount of noise due to interference will not exceed 250 pW0p. (If another number is assumed, the results will be affected in a corresponding way.) With this assumption we have:

$$SNR = 90 - 10 \log 250 = 66 \text{ dB},$$

and from (2), (3), and (5), we get

$$CXR_t + I + K = 47.2 \qquad (7)$$

Equation (7) is the basic equation which governs interference calculations when the wanted signal is telephony.

A.2 Television

Interference performance for TV signals is commonly specified by a protection ratio, R, which is the required wanted-to-unwanted signal ratio for a given quality. The quality assumed here is that the interference is such as to produce "just perceptible" response or better. It is evident, also, that R will depend upon the specific characteristics of wanted and unwanted signal. The calculations following seek simply the conditions for which $R = CXT_t + I$.

B. Calculations

B.1 Unwanted Signal is Interferometer Beacon

B.1.1 Wanted Signals are Telephony Carriers

When the wanted signals are the Intelsat telephony carriers and the unwanted signal is the interferometer beacon, and assuming the beacon frequency coincident with the telephony carrier frequencies*, we obtain the following K factors**. Also listed are values of CXR_t obtainable from the given eirp values.

Signal	K (dB)	CXR_t (dB)
Telephony I	31.2	4.3
Telephony II	29.6	7.8
Telephony III	28.2	10.6

With these numbers and equation (7) we find that the required isolation is as listed in the following table.

Signal	I(dB)	$\Delta\theta$ (deg.)***
Telephony I	11.7	0.77
Telephony II	9.8	0.65
Telephony III	8.4	0.57

The $\Delta\theta$ column indicates the required spacing between the two satellites, to meet the corresponding isolation requirement; this number is based on the CCIR pattern. That is, we set

$$G_{gu}(0) -32 +25 \log \Delta\theta = I.$$

The validity of the CCIR pattern, however, is questionable for this size (15 feet) antenna and it would be advisable to check the results against the actual pattern,

* We shall always assume that the interference is co-channel with the wanted signal, which is the worst case. Improvements are possible by carrier offsetting.

** The K factors are given in CCIR Doc. USSG IV W/70, August 1, 1970.

*** Numbers smaller than half-power beamwidth should be viewed with caution.

taking into account the pointing accuracy as well as the satellite position drift. It does seem, however, that on the order of 1^{o} separation should fully protect Intelsat III.

It appears unnecessary to use spectrum-spreading on the beacon. An example calculation, however, may be of interest to see what kind of spreading would be required in a hypothetical situation. Suppose that the 11.7 dB isolation required for the Telephony I carrier were not available and would have to be provided by spreading. Since the wanted signal bandwidth is 5 MHz, this implies that the beacon would have to be spread over 5 x 14.8 = 74 MHz. Actually, the amount of spreading required would be less since the effect of the spread beacon may be more akin to that of thermal noise. In fact, if it did behave like thermal noise, it can be shown that only 21.3 MHz spreading is required. Thus, something like 25-30 MHz spreading might be needed in practice, if necessary. Similar calculations could be performed for the other Telephony carriers.

B.1.2 Wanted Signal is TV Carrier

If the wanted signal is the TV carrier, experiments* have shown that, for M = 3, a protection ratio on the order of 20 dB is necessary, regardless of the modulation index of another interfering TV carrier. Since the CW beacon can be considered such a carrier with $M \rightarrow 0$, the result should be applicable. Also, since CXR_t = 82.2 -66.5 = 15.7 dB, we have

$$I = 20 - 15.7 = 4.3 \text{ dB}$$

This amount of isolation is easy to get and is satisfied, of course, if the Telephony carriers are protected.

* These are reported in CCIR Doc. IV/299-E, 10 June 1969.

B.2 Unwanted Signal is Telephony Carrier

B.2.1 Wanted Signals are Telephony Carriers

In this situation, the India Telephony carrier is the "unwanted" signal and the Intelsat Telephony carriers are the "wanted" signals.

To compute K we need the parameters

$$M'_{rms} = M_{rmsi}\, f_{mi}/f_{mw}$$

$$M = (M^2_{rmsw} + M'^{\,2}_{rms})^{1/2}$$

where

M_{rmsi} = rms modulation index of interfering carrier

f_{mi} = top baseband frequency of interfering carrier

M_{rmsw} = rms modulation index of wanted carrier

f_{mw} = top baseband frequency of wanted carrier

These parameters, the K factors, and values of CXR_t are given below:

Signal	M'_{rms}	M	K(dB)	CXR_t(dB)
Telephony I	39.1	39.6	39.5	-6.2
Telephony II	15.7	16.5	35.5	-2.7
Telephony III	7.1	8.6	32.5	+0.1

Using the values above, and equation (7) we find the following required values of isolation and the corresponding required satellite spacing:

Signal	I(dB)	$\Delta\theta$(degrees)
Telephony I	13.9	0.475
Telephony II	14.4	0.497
Telephony III	14.6	0.506

The separations were computed from

$$G_{gu}(0) - 32 + 25 \log \Delta\theta = I$$

with $G_{gu}(0) = 54$ dB.

B.2.2 Wanted Signal is TV Carrier

The effect of a telephony carrier on a TV carrier is known for only very few combinations of parameters, which do not include the present ones. It appears*, however, from the available data, that the effect of a telephony carrier on a TV carrier is less severe than that of another TV carrier. We shall assume here, therefore, that the required protection ratio is still 20 dB. Since $CXR_t = 82.2 - 77 = 5.2$ dB, we find that the required isolation is 14.8 dB, which requires a satellite separation $\Delta\theta \approx 0.52$ degrees.

B.3 Unwanted Signal is TV Carrier

B.3.1 Wanted Signals are Telephony Carriers

Little information is known about the effects of TV carrier interfering with telephony carriers. Certain data** shows that, for a telephony carrier with $M_{rms} = 2.0$ and a TV interfering carrier with bandwidth roughly 30 MHz, the factor K = 17 dB, without pre-emphasis. Assuming an M^3_{rms} law***, we will extrapolate to find the K factors applicable to the Intelsat telephony carriers (plus pre-emphasis.) These are shown below.

Signal	K(dB)	CXR_t
Telephony I	35.2	-6.2
Telephony II	33.7	-2.7
Telephony III	32.4	+0.1

The corresponding isolation and satellite spacings are shown below.

Signal	I(dB)	$\Delta\theta$ (degrees)
Telephony I	18.2	0.71
Telephony II	16.2	0.59
Telephony III	14.7	0.51

* Op. Cit.

** Comsat Tech. Memo DS-1-68, Oct. 25, 1968, by J. P. Beyer, et al.

*** This assumption arises from the known fact that such a law exists between identical, high-index telephony carriers.

In view of the uncertainty surrounding the factor K, the above numbers should be treated very cautiously.

B.3.2 Wanted Signal is TV Carrier

It was mentioned above that the protection ratio, when one FM TV signal interferes with another, is largely independent of the modulation index of the interfering carrier. Therefore, we still have R = 20 dB, and since CXR_t = 82.2 -77 = 5.2 dB, the required isolation is 14.8 dB, which corresponds to a satellite spacing $\Delta\theta$=0.5 2 degrees.

C. Conclusions

It is well to reiterate that some of the information concerning the effect of interference of one type of signal upon another is sketchy at best. Keeping this precaution in mind, the previous calculations show that the interferometer beacon imposes the most stringent spacing requirement between Intelsat III and the India satellite. However, it seems that a spacing of about one degree will insure a minimal amount of uplink interference for any combination of wanted and interfering signals. This requirement could further be reduced by careful frequency planning.

What about AIR transmitter?

```
        c 3520,1
    3520  300  FORMAT(1H ,'SSP  FLANG  LES  OAA',/)
    3520                     '|| ssp||clang|  lfs|||| oaa',/)
    3520  300  FORMAT(1H ,'    SSP  FLANG   LES      OAA',/)
        %i 3304,2,1
    3304            BW=BW+C
    3306          ssp=ssp+c
    3308 %
VERB INVALID.
        %end
        /save
        /submit cyrlb501
ENTER INPUT.
        ?=jcl1
        ?=oba5
        ?=jcl3
        ?=ds50
        ?endinput
JOB CYRLB501 SUBMITTED 79.320 AT 14:59:34.
        /submit cyrlb502
ENTER INPUT.
OPERATOR  320/1459: JOB B0321 CYRLB501 TO JOBQUEUE
        ?=jcl1
        ?=oba5
        ?=jcl2
        ?=ds50
        ?endinput
JOB CYRLB502 SUBMITTED 79.320 AT 15:01:19.
        /purge *
        /fetch oba5
OPERATOR  320/1501: JOB B0323 CYRLB502 TO JOBQUEUE
        %end
        /purge *
        /fetch ds50
        %list 0,last
     100  &DATA
     200  BN=51.5,BW=0. &END
OPERATOR  320/1507. JOB CYRLB502 READY
     300  &DATA
     400  BN=49.,BW=-3. &END
     500  &DATA
     600  BN=45.75,BW=-5. &END
     700  &DATA
     800  BN=43.,BW=-5.5 &END
     900  &DATA
    1000  BN=46.5,BW=-8.5 &END

    1100  &DATA
    1200  BN=48.25,BW=-11.5 &END
    1300  &DATA
    1400  BN=52.5,BW=-13. &END
    1500  &DATA
    1600  BN=40.5,BW=3.5 &END
    1700  &DATA
    1800  BN=49.,BW=-12.5 &END
    1900  &DATA
    2000  BN=55.7,BW=-37.5 &END

        %end
```

DATA

```
 $en'
 /purg *
 /Lring [illegible].cyrl1500,v=m2scr1
 %1 0,last
1 TS2371 FT03F001 ON M2SCR2 NAMED R32015.CYRL1500.FT06
 $end
 /purg * r32015.cyrl1500.ft06,v=m2scr2
 /Lring '=
 $1 0,last
 1     21.00 -70.00  51.50    0.00        LONDON
 2       SSP  ELANG   LES      OAA
             °               dB
 3
 4       0.0  31.05   0.64     8.11
 5       5.0  30.87   0.64     8.52
 6      10.0  30.31   0.65     8.84
 7      15.0  29.39   0.67    10.00
 8      20.0  28.13   0.70    10.26
 9      25.0  26.57   0.73    10.36
10      30.0  24.72   0.77    10.37

11      35.0  22.63   0.81    10.29
12      40.0  20.33   0.86    10.15
13      45.0  17.84   0.92     9.87
14      50.0  15.19   0.98     9.54
15      55.0  12.42   1.04     9.12
16      60.0   9.56   1.10     8.63
17      65.0   6.61   1.17     8.07
18      70.0   3.61   1.24     7.46
19      75.0   0.57   1.31     6.80
20     21.00 -70.00  40.00   -3.00        PARIS

21       SSP  ELANG   LES      OAA
22
23       0.0  33.70   0.59     8.75
24       5.0  33.74   0.59     9.16
25      10.0  33.37   0.59     9.51
26      15.0  32.60   0.61     9.80
27      20.0  31.44   0.63    10.01
28      25.0  29.93   0.66    10.15
29      30.0  28.10   0.70    10.20
30      35.0  25.99   0.74    10.16

31      40.0  23.63   0.79    10.04
32      45.0  21.06   0.85     9.82
33      50.0  18.32   0.91     9.52
34      55.0  15.44   0.97     9.14
35      60.0  12.44   1.04     8.68
36      65,0   9.35   1.11     8.15
37      70.0   6.20   1.18     7.55
38      75.0   3.01   1.25     6.92
39     21.00 -70.00  45.75   -5.00        LYON
40       SSP  ELANG   LES      OAA

41
42       0.0  37.11   0.52     8.38
43       5.0  37.34   0.52     8.83
44      10.0  37.11   0.52     9.22
45      15.0  36.42   0.54     9.55
46      20.0  35.28   0.56     9.81
```

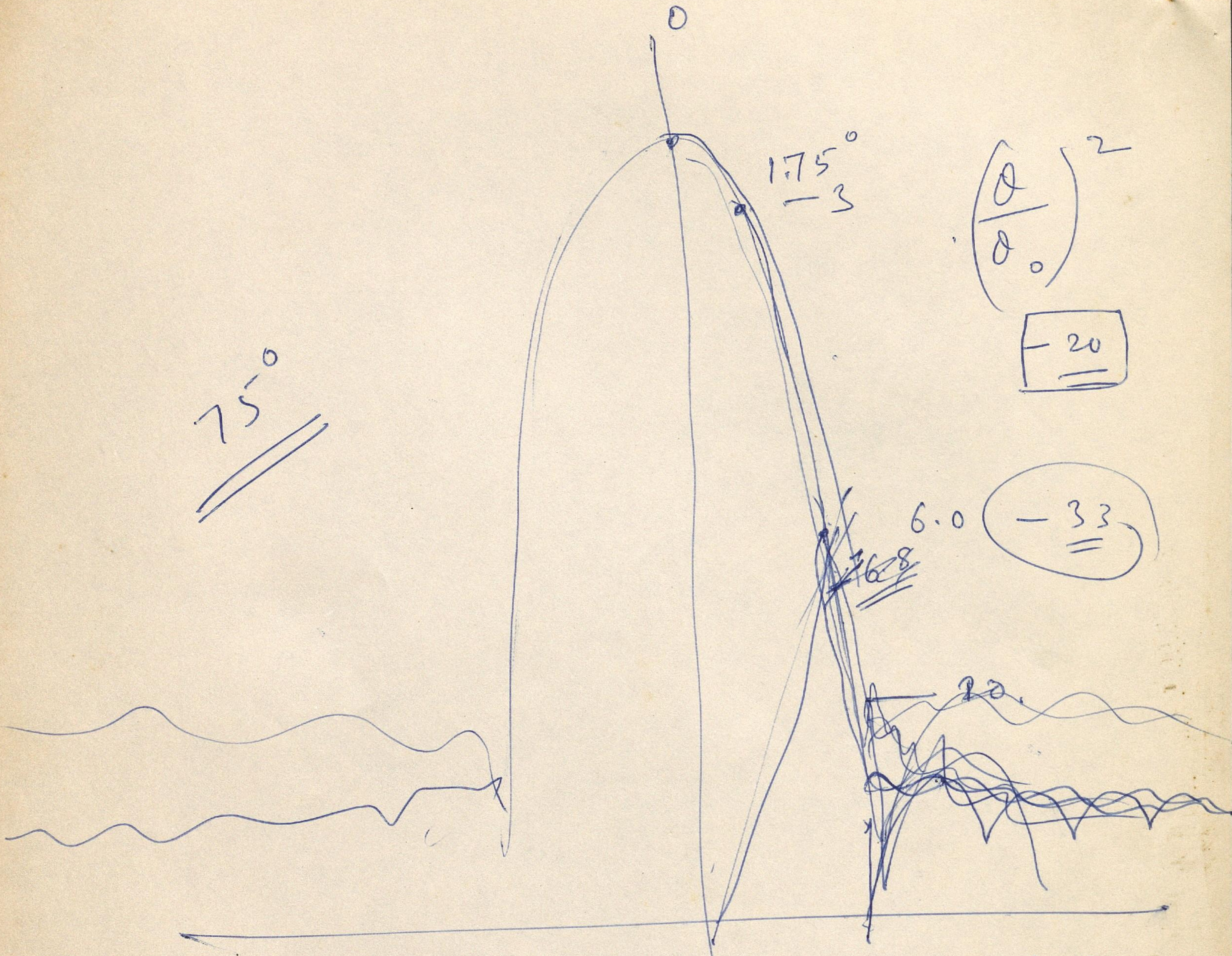
46	20.0	35.[illegible]	0.56	9.81	
47	25.0	33.75	0.59	9.99	
48	30.0	31.[illegible]	0.63	10.[illegible]	
49	35.0	29.[illegible]	0.[illegible]7	10.[illegible]	
50	40.0	27.12	0.72	10.01	
51	45.0	24.39	0.78	9.83	
52	50.0	21.47	0.84	9.57	
53	55.0	18.40	0.91	9.22	
54	60.0	15.20	0.98	8.78	
55	65.0	11.91	1.05	8.28	
56	70.0	8.55	1.13	7.70	
57	75.0	5.14	1.21	7.07	
58	21.00	-79.00	43.[illegible]	-5.50	MARSEILL
59	SSP	ELANG	LFS	OAA	↓
60					
61	0.0	40.07	0.47	8.17	
62	5.0	40.38	0.46	8.65	
63	10.0	40.17	0.47	9.09	
64	15.0	39.46	0.48	9.45	
65	20.0	38.25	0.50	9.75	
66	25.0	36.61	0.53	9.96	
67	30.0	34.56	0.57	10.09	
68	35.0	32.18	0.62	10.12	
69	40.0	29.50	0.67	10.06	
70	45.0	26.58	0.73	9.91	
71	50.0	23.47	0.80	9.67	
72	55.0	20.19	0.87	9.34	
73	60.0	16.80	0.94	8.92	
74	65.0	13.32	1.02	8.42	
75	70.0	9.78	1.10	7.85	
76	75.0	6.19	1.18	7.22	
77	21.00	-79.00	46.50	-6.50	GENEVA
78	SSP	ELANG	LFS	OAA	↓
79					
80	0.0	36.13	0.54	8.26	
81	5.0	36.50	0.53	8.70	
82	10.0	36.40	0.54	9.09	
83	15.0	35.86	0.55	9.41	
84	20.0	34.89	0.57	9.66	
85	25.0	33.50	0.59	9.84	
86	30.0	31.75	0.63	9.93	
87	35.0	29.67	0.67	9.94	
88	40.0	27.30	0.72	9.86	
89	45.0	24.70	0.77	9.69	
90	50.0	21.88	0.83	9.43	
91	55.0	18.91	0.89	9.09	
92	60.0	15.80	0.96	8.67	
93	65.0	12.59	1.03	8.17	
94	70.0	9.30	1.11	7.61	
95	75.0	5.96	1.19	7.00	
96	21.00	-79.00	48.25	-11.50	MUNICH
97	SSP	ELANG	LFS	OAA	↓
98					
99	0.0	33.48	0.59	7.88	
100	5.0	34.24	0.58	8.29	
101	10.0	34.58	0.57	8.64	
102	15.0	34.40	0.57	8.95	
103	20.0	33.98	0.58	9.18	
104	25.0	33.07	0.60	9.35	
105	30.0	31.77	0.63	9.45	
106	35.0	30.12	0.66	9.46	

60.0	17.91	0.92	8.31	
65.0	14.93	0.98	7.95	
70.0	11.85	1.05	7.34	
75.0	8.68	1.12	6.77	
21.00	-79.00	52.50	-13.00	BERLIN
SGP	ELANG	LES	OAA	
0.0	28.76	0.69	8.05	
5.0	29.51	0.67	8.40	
10.0	29.90	0.66	8.70	
15.0	29.94	0.66	8.95	
20.0	29.62	0.67	9.17	
25.0	28.94	0.68	9.25	
30.0	27.92	0.70	9.30	
35.0	26.59	0.73	9.28	
40.0	24.96	0.76	9.18	
45.0	23.08	0.80	9.00	
50.0	20.97	0.85	8.74	
55.0	18.66	0.90	8.42	
60.0	16.18	0.95	8.02	
65.0	13.55	1.01	7.57	
70.0	10.82	1.07	7.06	
75.0	7.99	1.14	6.52	
21.00	-79.00	40.50	3.50	MADRID
SGP	ELANG	LES	OAA	
0.0	43.03	0.42	9.11	
5.0	42.35	0.43	9.63	
10.0	41.14	0.45	10.08	
15.0	39.44	0.48	10.46	
20.0	37.39	0.52	10.75	
25.0	34.89	0.57	10.94	
30.0	31.98	0.62	11.04	
35.0	28.91	0.68	11.03	
40.0	25.64	0.75	10.92	
45.0	22.29	0.82	10.71	
50.0	18.65	0.90	10.40	
55.0	15.01	0.98	9.99	
60.0	11.39	1.06	9.48	
65.0	7.56	1.15	8.90	
70.0	3.79	1.24	8.24	
75.0	0.02	1.32	7.51	
21.00	-79.00	42.00	-12.50	ROME
SGP	ELANG	LES	OAA	
0.0	39.84	0.47	7.32	
5.0	40.89	0.46	7.80	
10.0	41.43	0.45	8.24	
15.0	41.43	0.45	8.62	
20.0	40.89	0.46	8.94	
25.0	39.84	0.47	9.19	
30.0	38.32	0.50	9.35	
35.0	36.36	0.54	9.44	
40.0	34.03	0.58	9.44	
45.0	31.39	0.63	9.35	
50.0	28.49	0.69	9.17	
55.0	25.37	0.76	8.90	
60.0	22.08	0.83	8.55	
65.0	18.66	0.90	8.13	
70.0	[illegible]	[illegible]	[illegible]	
75.0	11.54	1.06	[illegible]	
21.00	-79.00	55.70	-37.50	MOSCOW
SGP	ELANG	LES	OAA	

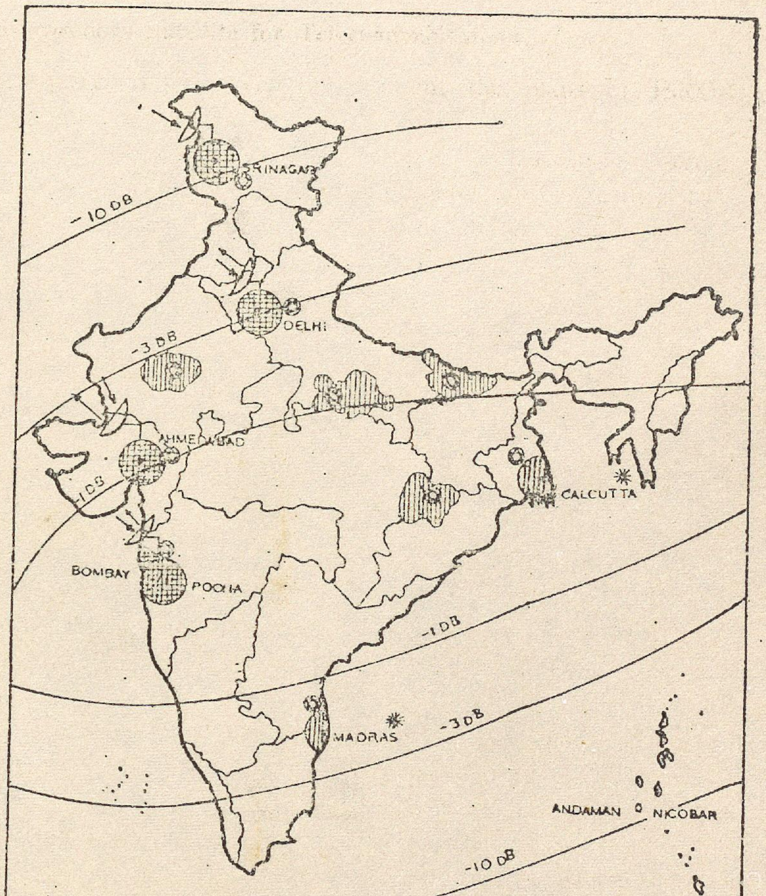
156	[illegible]	[illegible].84	0.47	7.70
157	5.0	[illegible]	0.46	7.8[illegible]
158	10.0	[illegible].47	0.45	[illegible]
159	15.0	[illegible].47	0.45	[illegible]
160	20.0	40.89	0.46	8.94
161	25.0	39.84	0.47	9.18
162	30.0	38.38	0.50	9.35
163	35.0	36.36	0.54	9.44
164	40.0	34.03	0.58	9.44
165	45.0	31.39	0.63	9.35
166	50.0	28.49	0.69	9.17
167	55.0	25.37	0.78	8.88
168	60.0	22.[illegible]	[illegible]	8.55
169	65.0	18.[illegible]	[illegible]	8.13
170	70.0	15.14	0.99	7.63
171	75.0	11.54	1.06	7.08
172	21.89	-72.00	55.70	-77.5[illegible]
173	[illegible]	[illegible]	[illegible]	[illegible]
174				
175	0.0	18.70	0.91	6.63
176	5.0	20.22	0.87	6.85
177	10.0	21.90	0.83	7.07
178	15.0	23.39	0.80	7.19
179	20.0	24.60	0.77	7.30
180	25.0	25.53	0.75	7.38
181	30.0	26.16	0.74	7.41
182	35.0	26.48	0.73	7.38
183	40.0	26.48	0.73	7.31
184	45.0	26.16	0.74	7.19
185	50.0	25.53	0.75	7.01
186	55.0	24.60	0.77	6.79
187	60.0	23.39	0.80	6.53
188	65.0	21.92	0.83	6.22
189	70.0	20.22	0.87	5.89
190	75.0	18.30	0.91	5.54

MOSCOW

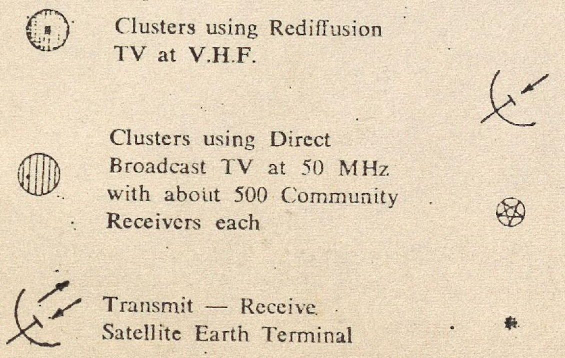

```
        $end
        /save data5
DATA5    IN LIBRARY. ENTER NEW FNAME OR EOB.
        ?/
VERB INVALID.
        /purge data5
        /save data5
QUEUED FOR USER LIBRARY CONDENSATION.  EXPECT DELAY.
LIBRARY CONDENSATION SUCCESSFULLY COMPLETED.
        /purge *
        /signoff
SIGNOFF PROCESSED 70.320 AT 15:26:27.
--
```



$$G(\theta) = G(0) \mp P\left(\frac{\theta}{\theta_0}\right)$$



DAE — NASA ITV PROGRAMME IN 1972-73 USING ATS-F SATELLITE, INTEGRATED WITH A.I.R T.V. PLAN



Clusters using Rediffusion TV at V.H.F.

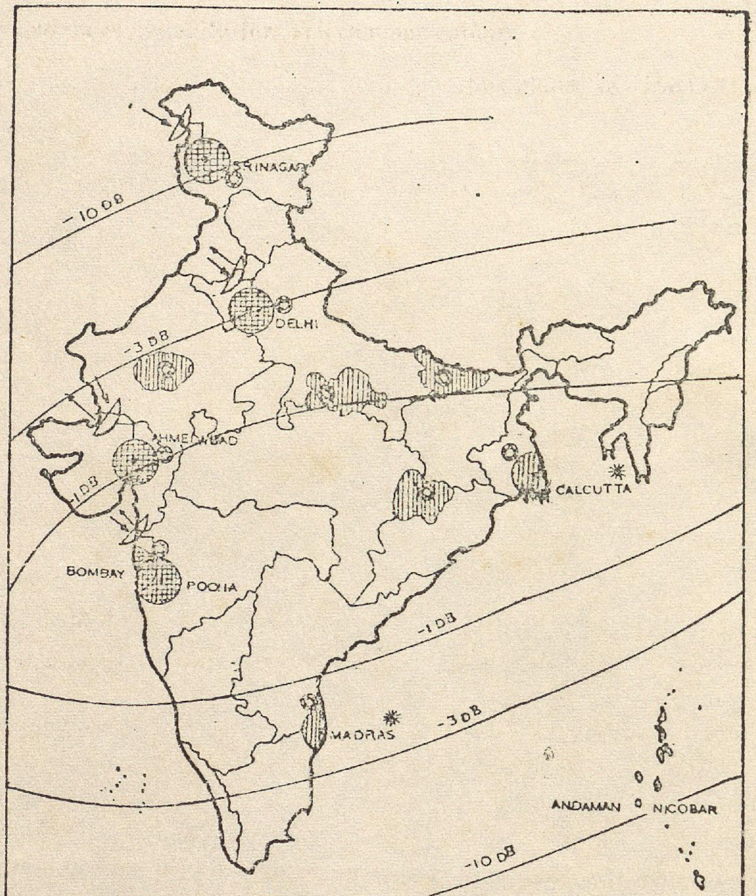
Clusters using Direct Broadcast TV at 50 MHz with about 500 Community Receivers each

Transmit — Receive Satellite Earth Terminal

Receive only Satellite Earth Terminal

Programming Centers

To be converted to Rediffusion TV



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