TECHNICAL NOTE

V3400

(ANNEXURE - 3*)

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A General Model for Calculating Coordination Distances for the Giant Meterwave Radio Telescope (GMRT).

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SUMMARY. In this note we have calculated the coordination distances required to avoid harmful interference to the Giant Meterwave Radio Telescope (GMRT) to be operated in the following four frequency bands which have been allocated in India at WARC-79 for radio astronomy observations at meterwaves : (a) 37.50 - 38.25 MHz, (b) 150.05 - 153 MHz, (c) 322 - 328.6 MHz and (d) 608 - 614 MHz. GMRT is a receiving facility only. We have followed the guidelines of CCIR 224-5 and 696-1 which discuss the interference criterion for the radio astronomy service. However we have relaxed the Harmful level of interference for radio astronomy observations by 15 db because GMRT is a synthesis radio telescope and rejects interference to some extent. The above bands are also allocated in India to Fixed and Mobile Services. Our calculations show that the required coordination distances with these services are : (a) 750 km at 38 MHz, (b) 600 km at 150 MHz, (c) 525 km at 325 and (d) 450 km at 610 MHz. These coordination distances are about 100 to 150 km, smaller than given in CCIR 696-1 for the Radio astronomy service because of our relaxation by 15 db. Paging and Cordless phone service presently earmarked for operation in the 150.05 - 151.5 MHz band in India will produce radio interference to GMRT if located closer to about 300 and 200 km distance respectively. Since such a coordination may not be practical, a re-allocation may be required in this band or adjacent to it, in order to satisfy the important requirement of GMRT for operation near-about 150 MHz.

* Annexure to a letter to WPC for the required coordination distances for various frequency bands for GMRT

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1. INTRODUCTION

It is well known that in view of the very high sensitivities of radio telescopes, radioastronomy observations can suffer harmful interference from a transmitter located even many hundred kilometers away via normal tropo-scatter propagation (CCIR 696-1).

In this Annexure, we consider a few specific transmitter models for calculating harmful interference to GMRT. We have followed the guidelines of CCIR 696-1, NBS Technical Note 101 and also path loss measurements between the GMRT site at Narayangaon and Pune/Bombay.

Since 36 no. of 45m dia dishes of GMRT would primarily be working together as a synthesis radio telescope, it tends to reject interference for longer integeration times. Hence, we have relaxed the harmful level of interference given in CCIR 224-5 by 15 dB (Ref.7). This gives us about 100 to 150 kms. smaller coordination distances, compared to the distances recommended by CCIR 696-1.

We have assumed five transmitter models (Communication Service parameter) and have calculated the coordination distance requirement for each case, beyond which a particular model is not likely to have an harmful affect on the operation of the GMRT. Assumptions used for these calculations are described in detail in Section 2. Results are presented in Section 3 and conclusions in Section 4.

2. CALCULATIONS :

The harmful threshold power level P_r of the Radioastronomy service (Section 2.1c) is related to the average power of the interfering transmitter P_t, by the relation (CCIR 696-1) :

$$P_t - L(q) \leq P_r \quad \ldots\ldots \quad (1)$$

where $L(q)$ is the total transmission path loss for the above condition to be violated for q% of time.

2.1. ASSUMPTIONS USED IN THE CALCULATIONS :

a. Percentage of time, q, interference may be exceeded;

q = 10% (CCIR 696-1 recommendation).

Remarks : If P_r is exceeded by a maximum of 10 or 15 dB for only 10% of time, it would be acceptable for Radioastronomy observations (CCIR-696-1).

b. Effective Radius of earth; a = 8800 kms.

Remarks : This assumes a surface refractivity value N_S of 320 (p 185, Ref.3), which is the average value for the Indian Peninsula, at distances more than 100 miles from the sea.

c. Receiver antenna parameters :

i) Distance to radio horizon for GMRT receiving antenna is about 20 kms, and the feed point of the antenna is generally 150 m below the radio horizon. However, towards Bombay, the feed point is about 300 m below the radio horizon.

ii) The gain of the antenna G_r in the direction of the radio horizon is O db.

Remarks : Each of the 36 antennas of GMRT will be a 45 m. diameter parabolic dish, capable of being pointed to any point in the sky, above an elevation angle of 10°. The gain of each of the 45 m antennas ($= 4\pi A/\lambda^2$) is expected to be about 22, 35, 41 and 47 dB at the frequencies of 38, 151, 325 and 611 MHz respectively. However, the distant side-lobe level would be about O db in all the four bands, considering that we would be using dipole feeds at the lower frequencies and horn-feeds at the higher frequencies. Thus, the gain of GMRT antennas towards horizons O db independent of the direction to which antenna is pointed. The value of O db towards horizon is also taken in CCIR 224-5 and 696-1.

d. Transmitter antenna parameters : (for all transmitter models)

i) The transmitting antenna is assumed to be 15 m above the ground level on a smooth earth with a distance to the radio horizon of 16 kms.

ii) If there are N identical transmitters each radiating P watts, of which X% are operational at any given time, the equivalent power transmitted $P_t = \frac{PNX}{100}$ watts. This is the basis we have used with X of the order 2 to 20 percent. (an alternative scenario in which transmitter are ON at any time randomly gives rms of $P_t \simeq P\sqrt{N}$; both approaches give similar answer and we have taken the first approach due to its simplicity).

iii) The five types of transmitter models considered are listed in Table 1 on Page 5 with their assumed characteristics.

e) Harmful interference threshold, P_r :

CCIR 224-5 recommends a value of - 199 dBw at 150 MHz (Ref 6, Col. 7, Sec.3 reproduced here as Table 2). Our careful calculations indicate that we can relax this figure by atmost 15 dB, because GMRT will consist of a large number of individual telescopes using aperture synthesis techniques (Ref. 7). The values of P_r for the frequency bands of GMRT are given in an extra column in Table 2 (See page 11.)

f) Harmonic Radiation :

As per ITU-RR, the harmonic radiation in the VHF-VHF bands is to be kept - 60 dbC or 1 mW whichever is higher. Since the transmitters in the first few sub-harmonics of the above bands are allotted to only FX & MO services (not broadcast), we may take the harmonic level at the output of the transmitter = 25 μ W and the radiated power ≤ 10 μW as antenna will be mismatched.

2.2. COMMUNICATION SERVICE PARAMETERS :

Table 1. TRANSMITTER MODELS.

No. Model Description	P[W] (1)	N (2)	X[%] (3)	P_t[dBW] (4)	G_t[dB] (5)
1. Point-to-point fixed communication	25	15	20	19	0
2. Master Station of rural communication network	10	10	20	13	3
3. Village level stn. of rural comm.network	1	100	4	6	-5
4. Paging System	0.1	50	10	-3	-10
5. Cordless phones	0.05	1000	2	0	-20

Column Description.

(1) P = Power of each transmitter in watts.

(2) N = Assumed number of licenced transmitters for a model.

(3) X = Assumed percentage of N, which may be operational at any instant.

(4) P_t : Equivalent power transmitted in dBW.

$$= 10 \log \left(\frac{PNX}{100} \right)$$

(5) G_t = Equivalent gain of N transmitting antennas, including the effects of ground reflection. We think that the numbers used in Table 1 are a reasonable estimate of the real situation, where $P_t \cdot G_t$ gives rms fluctuations of the total power radiated towards the GMRT site on a few MHz band.

2.3. TRANSMISSION LOSS EQUATION

The transmission loss by tropospheric forward scatter mechanism can be expressed as (see Ref.5, NBS Technical Note 101 and Ref.2 CCIR 238-4)

$$L(10) = 30 \log f - 20 \log d + F(\theta d) - V(de) - Y(10) - F_o + H_o + A_a \quad \text{dB}$$

(Ref. 2, Sec. 2 and Ref. 5, p.9-1).

where A_a, the loss due to atmospheric absorbtion,is negligible at the frequencies of our interest (Fig.3-6, Ref.5).

H_o, the frequency gain function (loss due to ground reflections), is 5dB for the kind of terrain described in 1(c) and 1(d) above. It is accounted for by reducing the transmitting antenna gain G_t.

F_o, the scattering efficiency correction, is negligible (p 9-5, Ref.5).

Y(10), the factor for converting L(50) to L(10), (equal to -Y(90) as given in Fig. 4, Ref.2)

V(de), the climactic correction factor, is taken from Fig.2, Ref.2 (for climate type 2).

$F(\theta d)$, the attenuation function, is computed according to the formulae on p III-24, Ref. 5. The correction for Ns is also made.

(also refer to p. 192, p. 230, Ref. 4).

$\underline{\theta}$, the scattering angle, is calculated according to Ch.6, Sec.4, Ref.5. The various terrain parameters used are those given in 1(c) and 1(d) above.

$\underline{d}$ is the distance in kms between the transmitting and receiving antennas.

$\underline{f}$ is the frequency in MHz.

2.4 PLOTS OF TRANSMISSION LOSS FOR GMRT FREQUENCY BANDS

Fig. 1 plots L(10) as a function of distance for tropospheric forward scatter propagation at 38, 150, 325 and 611 MHz. The curve for a given frequency applies to all the transmitted models considered in this Annexure. Fig.1 is derived from the equation gives in the previous Section. In Fig.1 we have also plotted values of L(10) for 0.1 GHz and 0.5 GHz taken from Fig. I.7 and I.9 of Rf.5 and it is seen that the values are consistent with our plots. At 148 MHz we have measured a loss of 145 db and 165 db between the GMRT site and Pune and Bombay respectively, which is also consistent with the plots in Fig.1.

To determine the coordination distance for a specific transmitter model we calculate (Sec.4, Ref.1) the value of $L(10)_{min}$, which gives the minimum path loss required in order to avoid harmful radio interference to GMRT as follows :

$$L(10)_{min} = P_t + G_t + G_r - P_r$$

Using the curve for the appropriate frequency, we find the distance corresponding to $L(10)_{min}$. Values of P_t and G_t are given in Table 1 for various models. G_r is assumed as O db as discussed in Section 2.1. Values of P_r are given in Table 2.

3. RESULTS

3.1 We firstly tabulate below L(10) for the various models considered and also the required coordination distances at 150 MHz.

Model	$L(10)_{min} = (P_t+G_t+G_r-P_{r\ min})$	Coordination distance
1. Point-to-Point Communication	203 dB	635 kms
2. Master stn. of rural communication network	200 dB	600 km
3. Village level stn. of rural comm.network	185 dB	420 km
4. Paging System	171 dB	290 km
5. Cordless phone	164 dB	230 km

3.2 The required coordination distance at other bands of GMRT, for a point-to-point or mobile link (Model 1) are :

Frequency	L(10)dB.	Coord. distance
38 MHz	192 dB	735 km
325 MHz	205	525 km
611 MHz	206	450 km.

3.3 The required coordination distances for harmonic radiations from transmitters of other services is about 100 km, particularly for transmitters of FX services with tall towers.

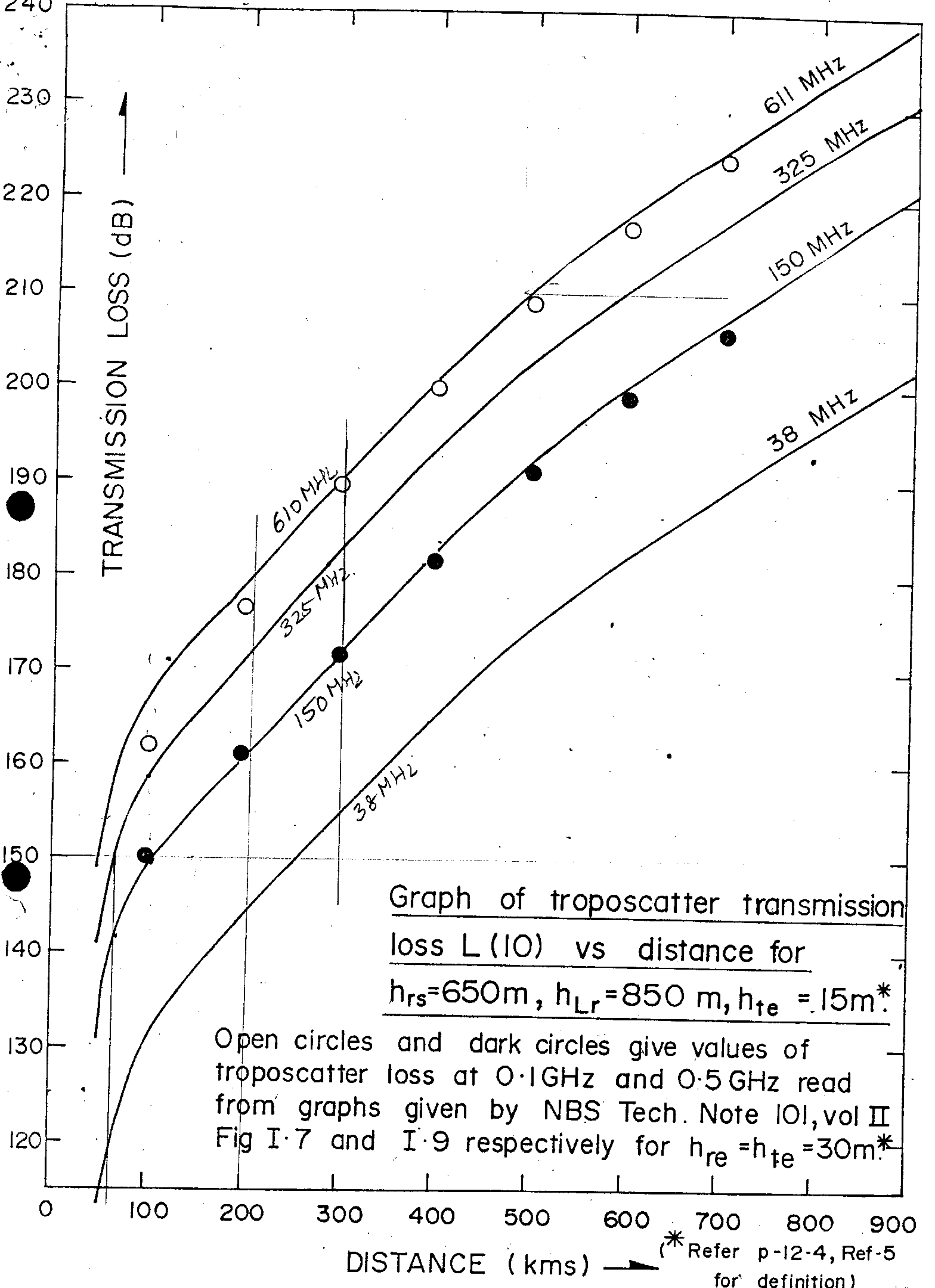
TABLE 2 – *Sensitivities and harmful interference levels for radioastronomy continuum observations with 2000 s integration time*

Centre frequency (¹) f_c (MHz)	Assumed bandwidth Δf (MHz)	Minimum antenna noise temperature T_A (K)	Receiver noise temperature T_R (K)	System sensitivity (noise fluctuations)		Harmful interference levels			Input Power for GMRT ΔP_H Case * (dBW)
				Temperature ΔT (mK)	Power spectral density ΔP (dB(W/Hz))	Input power ΔP_H (dBW)	Power flux-density $S_H \Delta f$ (dB(W/m²))	Spectral power flux-density S_H (dB(W/(m²·Hz)))	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
13.385	0.05	60 000	100	4250	– 222	– 185	– 201	– 248	
25.610	0.120	20 000	100	917	– 229	– 188	– 199	– 249	
73.8	1.6	1 000	100	14	– 247	– 195	– 196	– 258	
151.525	2.95	200	100	2.76	– 254	– 199	– 194	– 259	173 @ 38 MHz
325.3	6.6	40	100	0.86	– 259	– 201	– 189	– 259	184
408.05	3.9	25	100	1.00	– 259	– 203	– 189	– 258	186
611	6.0	15	100	0.74	– 260	– 202	– 185	– 255	
1 413.5	27	10	20	0.091	– 269	– 205	– 180	– 253	187
2 695	10	10	20	0.15	– 267	– 207	– 177	– 255	
4 995	10	10	20	0.15	– 267	– 207	– 171	– 247	
10 650	100	12	20	0.05	– 272	– 202	– 160	– 241	
15 375	50	15	30	0.10	– 269	– 202	– 156	– 240	
23 800	400	15	50	0.051	– 271	– 195	– 147	– 233	
31 550	500	18	100	0.083	– 269	– 192	– 141	– 233	
43 000	1 000	25	100	0.063	– 271	– 191	– 137	– 228	
89 000	6 000	30	150	0.037	– 273	– 185	– 125	– 227	
110 500	11 000	40	150	0.029	– 274	– 184	– 121	– 222	
166 000	4 000	40	150	0.048	– 272	– 186	– 120	– 222	
224 000	14 000	40	200	0.032	– 274	– 182	– 114	– 216	
270 000	10 000	40	200	0.038	– 273	– 183	– 113	– 215	

(¹) Calculation of harmful interference levels is based on the centre frequency shown in this column although not all regions have the same allocations.

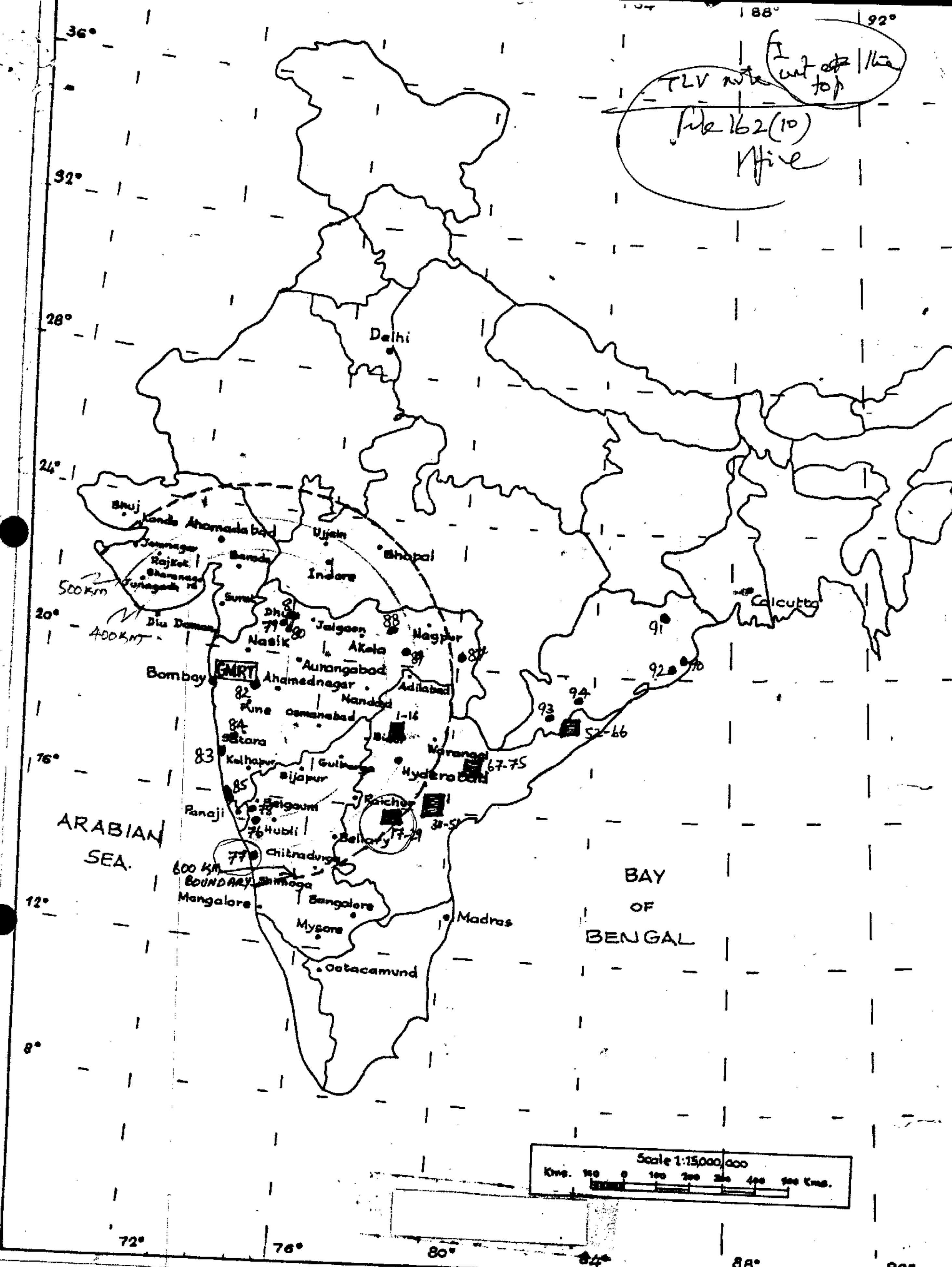
Note. – If an integration time of 15 minutes, one hour, two hours, five hours or ten hours is used, the relevant values in the Table should be varied by + 1.7, – 1.3, – 2.8, – 4.8 or – 6.3 dB respectively.

* Column (10) = Column (7) + 15 db.



TRANSMISSION LOSS (dB)
240
230
220
210
200
190
180
170
160
150
140
130
120
611 MHz
325 MHz
150 MHz
38 MHz
610 MHz
325 MHz
150 MHz
38 MHz
Graph of troposcatter transmission loss L (10) vs distance for
h_{rs}=650m, h_{Lr}=850 m, h_{te} = 15m*
Open circles and dark circles give values of troposcatter loss at 0·1GHz and 0·5 GHz read from graphs given by NBS Tech. Note 101, vol II Fig I·7 and I·9 respectively for h_{re}=h_{te}=30m*
0
100
200
300
400
500
600
700
800
900
DISTANCE (kms)
(* Refer p-12-4, Ref-5 for definition)

FIGURE-1



NOTE :- NUMBERS INDICATE SERIAL NUMBERS OF DOT MAR TRANSMITTERS for Rural Communications IN THE LIST SUPPLIED BY DOT