Indian Journal of Radio & Space Physics
Vol. 5, December 1976, pp. 281-284

Radio Refractivity Gradient in Lower Troposphere & Its Influence on Transhorizon Radiowave Propagation*

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Received 30 *April* 1975; *revised received* 10 *December* 1975

Based on recent radiosonde data from the India Meteorological Department, which have better accuracy than data available upto 1967, refractivity gradients for three years (1968-70) over the Indian subcontinent have been determined. The influence of high refractivity gradients usually observed in the lower troposphere on radiowave field strength and variability over transhorizon paths is discussed. The gradients in the lower layers, particularly upto an altitude of 250 m were found to be much higher than values determined from the difference between surface refractivity (N_s) and refractivity at 1 km (N_1). A significant percent of these were ducting gradients. Field strength observations over three typical transhorizon paths, which were characterized by high level and wide variability for a significant percentage of time, were found to be consistent with these refractivity gradients.

1. Introduction

The average gradient structure across rather large height intervals of the order of 1 or 1·5 km from surface of the earth has been studied in detail by a number of investigators.[1-3] However, most of the intense gradients occur near the surface of the earth, and their thickness is around 100 m (ref. 4 and 5); and consequently, such layers do not usually show their effect on gradient values obtained from difference of refractivity at the surface N_s and at a height of 1 or 1·5 km. The aim of the present paper is two-fold. One of these is to highlight the fact that the initial vertical gradient (which plays an important role in the transhorizon propagation) of radio refractivity N in the lower tropospheric region is significantly high. The second objective is to discuss field strength characteristics over transhorizon paths in the Indian Sub-continent in terms of wide variability and high signal values and to show that these observations are consistent with refractivity structure of the lower troposphere.

2. Initial Gradient in the Lower Troposphere

The refractivity data obtained from the more reliable radiosonde measurements for 16 radiosonde stations for a period of three years (1968-70) at 0000 and 1200 hrs GMT were analyzed by means of a computer. The resulting accuracy of refractivity determined from these data is 1·5% as compared to 5% realizable earlier. Refractivity gradients were determined from surface refractivity and refractivity at three standard radiosonde levels, viz. 1000, 950 and 900 mb. These gradients were employed to determine the gradient over a nominal height interval of 250 m. This interval was chosen since, on an average, the depth of modification[6] under stable conditions was found to be close to this value. If the calculated depth of modification exceeded this height, the initial gradient was determined from refractivity at the surface and the next level. Otherwise, initial gradient was determined as the arithmetic mean of the gradients obtained from refractivity at the surface and next two levels.

It was found that initial gradients so determined, were much higher than the average values over larger height intervals, viz. surface to 1 or 1·5 km as determined by the previous workers.[1,2] Super refractive and ducting situations were observed very frequently in coastal areas but even in areas like the northern plains of India, significant duct occurrence frequency was observed during the premonsoon and winter months. The ducting frequency was a minimum during the monsoon.

3. Correlation of N_s and ΔN

The monthly median field strength over a large number of paths is correlated[4] equally well to N_s and ΔN, due to high correlation between the surface value and refractivity gradients. While this may be true for the relationship between N_s and gradient values averaged over large height interval, we have observed significant departure from this conclusion in respect of correlation between monthly mean N_s and initial gradient over shallow height interval. Analysis has been carried out for the coastal regions and also inland situations for correlation between

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* Paper presented at the Symposium on Earth's Near Space Environment, 18-21 February 1975, held at the National Physical Laboratory, New Delhi-110012.

Table 1—Correlation Coefficient between Seasonal Mean N_s and ΔN

Region	Season	Correlation Coefficient between mean N_s and gradient from surface upto a height/corresponding to			
		1000 mb	950 mb	900 mb	850 mb
Northern plains	Winter	—	−0·32	−0·57	−0·66
	Premonsoon**	—	−0·43 (−0·52)*	−0·55 (−0·72)*	−0·70
	Monsoon	—	−0·22	−0·55	−0·59
Central India	Winter	—	0·18	−0·04	−0·25
	Premonsoon**	—	−0·26	−0·31	−0·76
	Monsoon	—	−0.15	−0·25	−0·67
East coast	Winter	0·01	−0·40	−0·50	−0 70
	Premonsoon**	−0·24 (−0·27)*	−0·31 (−0·84)*	−0·55 (−0·90)*	−0·87
	Monsoon	—	−0·14	−0·35	−0·50

* Indicates correlation coefficient for an exponential fit from surface upto the level in question.

**This period includes March through May.

surface refractivity and gradient obtained over height interval varying from 50 m to 1·5 km from the surface. The correlation is extremely low in the case of the first gradient, and slowly improves as gradients over larger height intervals are considered. The results in respect of three regions of India for three different seasons are shown in Table 1. Here a negative correlation coefficient signifies a refractivity profile with a negative height gradient increasing in magnitude with increase of N_s, while a positive sign indicates the converse. In addition to linear correlation, correlation coefficient for exponential fit from surface upto various levels has also been examined. Some results are shown in Table 1 in brackets. In this case, correlation coefficient is better than linear correlation, but it is quite poor for the first level and improves for higher altitude levels.

4. Field Strength Observations over Transhorizon Paths

Since 1964, systematic field strength observations over several transhorizon paths at vhf (120 MHz) in the northern and eastern regions of India have shown very high field strengths at night and early morning hours during several months before monsoon and during winter. During these periods, the hourly median signal is subject to wide fluctuation in the course of a period from one to a few days. Similar results have been obtained during more recent observations at two other radio frequencies, viz. 2 GHz and 62 MHz (TV broadcast signal) in the northern plains of India. Some of these observations which are typical and are considered relevant for this paper are described below.

4.1 vhf Observations in the East Coast

These observations were made over Calcutta—Visakhapatnam path in which field strength was measured in an aircraft on low level flight missions. The transmitting equipment located at Calcutta had an effective radiated power of 100 kW at a radio frequency of 120 MHz. The airborne receiver had a detection capability of upto 1·5 μV signal strength. The altitude of the aircraft was usually kept in the range 100-200 m and signal strength observations were continued till the received signal fell to 1·5 μV. The measurements were carried out for 40 days over selected periods during 1968-71 when ducting was expected to be fairly frequent and observations for over 150 hours were obtained. On most of the days of observation, signal was received upto distances of about 400 km when aircraft altitude was less than 200 m. Typical ranges on some days in 1968 are presented in Fig. 1. During these days, the initial gradient across the lowest layer was in excess of ducting values (-157 N/km) while values of the gradient ΔN_{850} calculated from difference of N_s and N_{850} (850 mb level) were usually less intense than $-70N$/km. Assuming that ΔN_{850} determines the refraction on the radio ray and employing Eklund-Wickerts propagation model (1968) for transhorizon propagation, the expected range was calculated for these days and is shown in Fig. 1. Also shown is the calculated range when superrefraction is taken into account in accordance with refractivity gradients obtained from N_s and N at 250 m altitude. It is seen that the observed ranges agree much better with calculated ranges when intense gradients from surface to 250 m are considered, which highlights

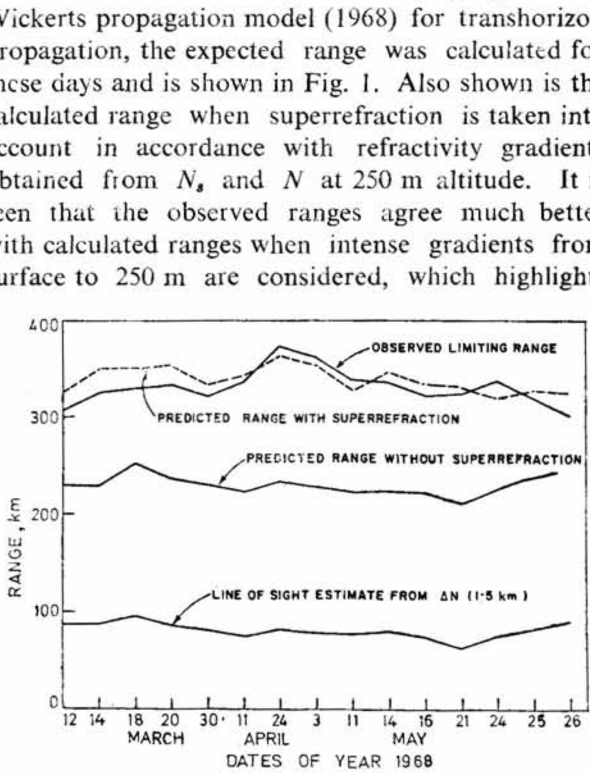

Fig. 1—Observed and calculated gradient ranges over the east coast region (120 MHz)

the importance of refractivity gradients across lower layers.

4.2 Microwave Observations in the Northern Plains

These observations were made at a frequency of 2 GHz in the northern plains of India over a path 269 km long between two terminals whose elevations were respectively 269 m and 1·92 km with respect to mean sea level. The transmitter power was 800 W, antenna gains on each side, 34·5 dB and the receiver sensitivity was about −100 dBm. Field strength observations were made over this path during June 1971 covering nearly 500 hr. The following significant results were obtained: (a) The average hourly median field strength during night and morning hours was found to be 30 dB more than the average midday value. (b) On several occasions during night and early morning, observed field strength was near the free space value for several hours.

As a typical result under category (b) above, received signal for a period of 24 hr is shown in Fig. 2. This shows that for a period of 6 hr the hourly median field strength was near the free space level. On five other occasions, maximum hourly median signal was within 15 dB of free space level, signifying that nearly ducting conditions prevailed over this path. Influence of such high signal conditions is reflected in the cumulative distribution of hourly median signal for the whole period as shown in Fig. 3. Here, one notes that hourly median signal for 1% time is equal to the free space signal.

A noteworthy feature in Fig. 3 is the wide variability of the hourly median signal which shows a range of over 60 dB between 1 and 99% probability levels. In the same diagram we have also shown the cumulative distribution of refractivity gradients (i) ΔN_{950} (surface to 950 mb), (ii) ΔN_{850} (surface to 850 mb), (iii) $\Delta_{850-800}$ (850-800 mb) and (iv) of the equivalent gradient[7] obtained from (i) and (iii), which is considered to represent the refractive conditions over this path. A wider range of variation of (iv) than (ii) would appear to be more consistent with the variation of signal. In an attempt to determine the level and variability of the 2 GHz signal by means of Eklund-Wickert's model without considering the effect of superrefractive layers near the surface, Fig. 4 is drawn to show the calculated signal for this path over a wide and representative range of parameters variation for this model. It is observed that neither the high field strength nor the wide variability can be accounted for without considering the effect of superrefraction.

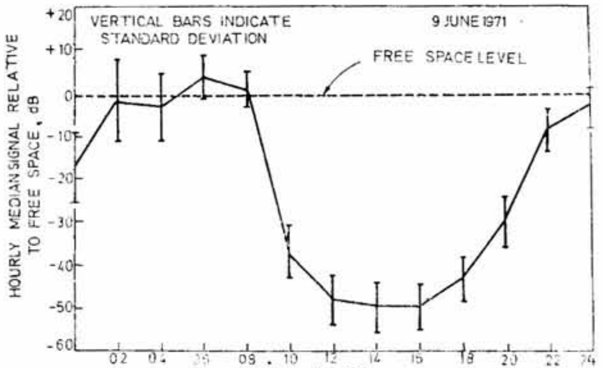

Fig. 2—Diurnal variation of hourly median signal relative to free space level

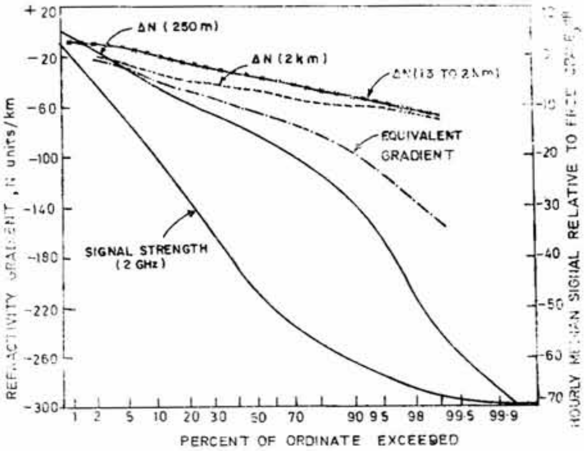

Fig. 3—Cumulative distribution of refractivity gradients and transmission signal over northern India

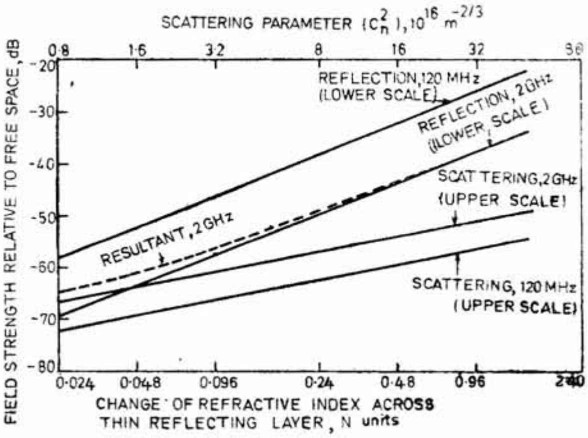

Fig. 4—Calculated values of field strength at 2 GHz and 120 MHz based on theoretical propagation models

4·3 vhf Observations in the TV Band 1

Observations on AIR TV broadcast signal made by Rangole[8] and Lalit[9] reveal that the received field strengths were significantly high and were more consistent with superrefractive and ducting gradients observed in the lower troposphere rather than modest refractivity gradients indicated by averaged values across large height intervals.

Acknowledgement

The authors are grateful to the India Meteorological Department for providing the meteorological data for this study, and to Mr V C Jain for doing the data analysis using electronic computer. Thanks are due to Mr P K Rangole, Scientist Central Electronics Engineering Research Institute, Pilani, and Mr S V Lalit, Engineer-in-charge, Rural Broadcasting, Govt. of Gujarat, for communicating the results of their observations.

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