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Variation of surface radio-refractivity at New Delhi

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ABSTRACT. Studies carried out in temperate latitudes indicate that a significant relation exists between the signal strength of microwave communication systems and the variations in surface radio-refractivity (N_s). With the expansion of microwave communication and television in India, communication engineers are vitally concerned in finding the extent of variations in N_s in the country. To this end, N_s values for four representative months have been calculated in respect of New Delhi (Safdarjung) based on ten years monthly mean data for six synoptic hours. A comparison with corresponding N_s values at New Delhi (Palam) has also been made to bring out the importance of proper site selection. The most significant feature of the analysis is the year round diurnal range of 20 N units or less accompanied by a strong seasonal range of about 70 N units in surface radio-refractivity. An attempt has been made to relate these changes with climatological features and to assess their likely effect on signal strength.

1. Introduction

Radio transmission at frequencies above 30 Mcs, that is, at frequencies used for television, frequency modulation, radar etc, is normally 'space-wave' or tropospheric propagation. The space-wave represents energy that travels from the transmitting to the receiving antenna in the lowest layer, called troposphere, of the atmosphere. The layer normally extends to about ten miles in the tropics. Both 'Line of Sight' (LOS) and 'Beyond the Horizon' tropospheric radio communication links are fast replacing the traditional methods of communication, specially over difficult terrain, due to their operational efficiency and cost effectiveness. In tropospheric propagation, radio rays undergo bending (refraction) depending on the characteristics of the intervening air. The radio refractive index of the air varies with its pressure, temperature and humidity. Detailed studies carried out in the U.S.A., France and other countries show that signal strength increases or fades with the surface refractivity (N_s) and both have diurnal and seasonal variations. For designing efficient tropo-communication links it is therefore vital to know the extent of such variations in surface refractivity, particularly at or near tropo hub centres. Some studies of variation of refractivity in respect of selected Indian stations have been carried out by Kulshrestha (1966) and Venkateswaran (1970). But these were confined to the two standard hours of observations (0830 and 1730 IST) or their mean value. It would be interesting to find diurnal and seasonal variations in respect of other hours of observations throughout the day. For this study New Delhi has been selected since it is the nerve centre of aeronautical and other vital communication systems besides being an important television centre.

2. Computation of radio refractivity

The radio refractive index, 'n' is the ratio of the speeds of radio waves in vacuo and in the medium under consideration. n has small values of the order of 1.0003. For convenience radio refractivity is measured in terms of N units where $N=(n-1) \times 10^6$. The radio refractivity of air for frequencies upto 30,000 Mcs is given by Smith and Weintraub as

$$N=77.6P/T+3.73\times10^5\, e/T^2 \qquad (1)$$

where, P—atmospheric pressure (mb)

T—temperature in degrees Kelvin (K)

e—water vapour pressure (mb).

The P/T term is generally referred to as the 'dry term' and the e/T^2 term as the 'wet term'.

It is seen that a rise of 0.8°C in temperature, a fall of 3.7 mb in pressure P or a fall of 0.22 mb in water vapour pressure e will lead to a decrease of 1 N in N_s. Radio refractivity is therefore very sensitive to changes in humidity.

3. Meteorological data

For the present study, mean monthly values of surface pressure, temperature and water vapour pressure for the four months recommended by C.C.I.R., *viz.*, February, May, August and November at New Delhi (Safdarjung) were

TABLE 1

Average and seasonal variations of N_s values at New Delhi (Safdarjung)

Time (IST)	Average N_s values (N units)				Change in N_s (N units)			
	Feb	May	Aug	Nov	$N_{(May)} - N_{(Feb)}$	$N_{(Aug)} - N_{(May)}$	$N_{(Nov)} - N_{(Aug)}$	$N_{(Feb)} - N_{(Nov)}$
0230	315	311	381	320	−4	+70	−61	−5
0530	314	314	381	321	0	+67	−60	−7
0830	313	312	379	319	−1	+67	−60	−6
1130	304	302	374	310	−2	+72	−64	−6
1730	300	294	371	312	−6	+77	−59	−12
2330	314	312	382	323	−2	+70	−59	−9

TABLE 2

Extreme values of N_s (N units) at New Delhi (1956-65)

Time (IST)	February		May		August		November	
	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest
0230	324	307	319	297	391	365	337	313
0530	325	307	321	307	390	366	337	313
0830	323	305	320	298	387	363	336	311
1130	316	291	312	286	387	356	337	302
1730	313	290	301	283	383	352	336	302
2330	327	304	321	304	388	365	339	315

analysed. These months correspond to the winter, pre-monsoon, monsoon and post-monsoon seasons at New Delhi and are fairly representative. Monthly means of observations recorded at 0230, 0530, 0830, 1130, 1730 and 2330 IST at Safdarjung observatory (altitude 216 m), New Delhi were extracted from the *Monthly Weather Reviews* published by the India Meteorological Department. Data in respect of 1430 and 2030 IST were available for three years only. Surface refractivity values (N_s) were calculated from the monthly means for the ten-year period 1956 through 1965 and the average N_s value for each synoptic hour obtained. These are summarised in Table 1.

4. Seasonal variation of N_s

From Table 1, it will be evident that among the representative months, the surface refractivity at New Delhi is maximum in August and minimum in May. Variations in N_s for each quarter are also indicated in Table 1.

It will be seen that there is a sharp rise in N_s of the order of 70 N units from May to August followed by a fall of 60 N units in the next quarter. From November to February there is a further fall of about 5-10 N units while in the succeeding three months the fall is still smaller. The seasonal vriation in N_s is generally maximum in afternoon hours.

These changes in N_s can be easily explained. In the pre-monsoon months, there is a well marked low pressure area over Sind (Pakistan) and neighbourhood and mostly hot and dry winds sweep northwest India. As a result, New Delhi records the lowest N_s value in May. With the onset of the southwest monsoon over Delhi area by the end of June, there is a rapid incursion of moisture and a fall in day temperature. For example, at 1730 IST the mean value at New Delhi (Safdarjung) of vapour pressure is 29.7 mb in August as compared to 12.2 mb in May while the mean dry temperature of 39.3° C in May drops to 31.7°C in August. The sharp increase in N_s in August is therefore largely due to the increase in the wet term.

The southwest monsoon withdraws from Delhi by the end of September and there is a fall in humidity. However, this is accompanied by a rise in surface pressure and fall in temperatures at New Delhi. There is some increase in the dry term value of N_s from August to November. This leads to a smaller change in N_s from August to November as compared to the preceding quarter.

5. Seasonal and diurnal variation of N_s

The vaiations of N_s at various hours in different seasons are shown in Fig. 1.

Some of the salient features brought out by Fig. 1 and Table 1 are :

(*a*) The lower values of N_s are reached in the afternoons.

(*b*) In non-monsoon months, N_s is fairly constant after 1730 hours and upto about 0900 IST. It starts decreasing thereafter, the lowest value being reached between 1130 and 1730 IST. The diurnal range of mean N_s is 15 to 20 N units.

(*c*) In the monsoon months, peak values of N_s occur about midnight and early morning. The diurnal range of mean N_s is of the order of 10 N units.

(*d*) Seasonal variations in N_s are generally of the same order at all hours, except at noon and in afternoons.

Higher temperatures and lower pressures mainly account for lower values of N_s in afternoons hours. The lowest values of N_s occur in the pre-monsoon months when the day temperatures are highest, also giving rise to maximum range in diurnal variation of N_s. On the other hand, during the monsoon months due to rain and cloudiness, the temperature rise during the day is not so marked. Consequently the diurnal range of mean N_s in this season is much lower.

6. Year to year variation of N_s

There are large variations from year to year in the activities of the monsoon and the western disturbances which mainly account for the rainfall over New Delhi as also in the severity of its summer. These in turn lead to large variations in surface refractivity at New Delhi. Table 2 indicates the highest and lowest values of mean surface refractivity reached at various hours at New Delhi (Safdarjung) during the ten-year period 1956 to 1965.

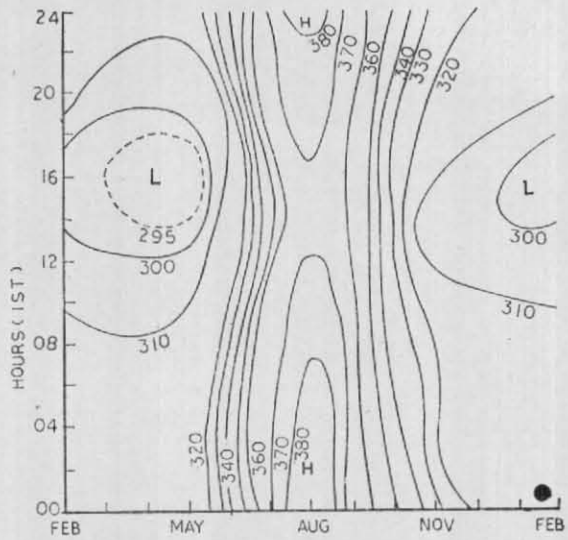

Fig. 1. Diurnal and seasonal variation of Ns over New Delhi (Safdarjung)

Vigorous monsoon conditions, passage of active western disturbances or incidence of mild summer conditions all lead to high N_s values. On the other hand unusually hot summer, weak monsoon or absence of active western disturbances may result in very low values of N_s. The year 1963 serves as a good illustration. In that year, New Delhi was blessed with mild summer conditions in May, good monsoon rain (50 per cent in excess) in August, and increased incursion of moisture in November in association with six western disturbances. All these favourable factors contributed to exceedingly high values of N_s for these months. In fact, the highest values of N_s for these months given in Table 2 are mostly for the year 1963.

The differences between the highest and lowest values of N_s recorded in the winter and pre-monsoon seasons in the ten-year period are of the order of 20 N units while those in the monsoon and post-monsoon seasons are about 25-30 N units. The larger differences in N_s in August are primarily due to the vagaries of the monsoon from year to year.

6. Variation of N_s with site

The Safdarjung Observatory (altitude 216 m) is located near Safdarjung aerodrome in south Delhi. Another fully equipped meteorological observatory (altitude 233 m) is located at Palam Airport, about 10 km to the west of Safdarjung Observatory. The surrounding country is fairly plain except for a ridge which is surrounding New Delhi in a semi circle. The river *Jamuna* flows to the north and the east of Delhi. To find out whether variations in surface refractivity are affected by a change to a neighbouring site, N_s

TABLE 3

Difference in N_s (N unit) between Palam and Safdarjung

Time (IST)	$N_{(PLM)} - N_{(SFD)}$			
	Feb	May	Aug	Nov
0230	+2	+3	+2	—1
0530	+2	+3	+2	0
0830	+2	+3	+2	+2
1130	+3	+2	+4	+5
1730	+2	+3	+4	+4
2330	+2	0	+1	—3

values were similarly computed for Palam Airport, for the seven-year period 1959 to 1965 and their monthly means compared with the mean values of N_s for Safdarjung for the same period. Table 3 shows the differences at various hours in surface radio refractivity (N_s) between Palam and Safdarjung.

It will be seen from Table 3 that the values of N_s at Palam are in good agreement with those at Safdarjung throughout the year. The diurnal variations in N_s at Palam exhibit the same trend and the seasonal changes are of the same order as those at Safdarjung as discussed earlier.

7. Effects of N_s variation on signal strength

Identically equipped communcation systems have been found to display large differences in mean signal strength from season to season. From path-loss data it has been found that variations of signal levels during the day and from month to month can be explained in part by their observed correlation with surface refractivity. Based on several studies, C. C. I. R. have tentatively accepted a variation of 0.2 dB in field strength per unit change in N_s for the tropospheric wave propagation in the band 100 to 50,000 Mcs. Bean (1966) and other workers have estimated climatic effects on signal strength in different parts of the world. Venkiteshwaran (1970) has carried out a study about the likely effect on signal strength at some stations in India based on N_s values in January and July. But no detailed studies have been carried out in India. Assuming that other factors remain nearly same, mean diurnal and seasonal variations in N_s at New Delhi may affect the tropospheric signal strength as follows.

(*a*) Signal strength would be relatively higher at night as compared to that in the late afternoon throughout the year. The signal strength variation would be of the order of 2-4 dB, the maximum diurnal variation being recorded in May and minimum in August.

(*b*) Optimum signal strength condition during the year would be experienced in the monsoon months. The signal strength in August would be higher by about 14 dB than that in May and also higher by about 12 dB than that in November.

(*c*) Signal strength at Palam would be higher by about 0·5 dB than at Safdarjung most of the time.

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