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APPLICATION OF RADIO REFRACTIVE INDEX EQUATION TO INDIAN STANDARD ATMOSPHERE

1. The most commonly used equation for refractivity, N,

$$N = (n-1)10^6 = \frac{77.6}{T}\left(P + \frac{4810\, e_s\, RH}{T}\right)$$
$$= \frac{77.6}{T}\left(P + \frac{4810\, e}{T}\right) \quad (1)$$

where pressure, P, temperature, T and partial pressure of water vapour, e, are in the usual units of millibars, degrees absolute and millibars respectively. RH is the per cent of the saturation vapour pressure, e_s, in millibars at temperature T degrees absolute. The constants in equation (1) were determined by Smith and Weintraub (1953) and has been shown by Bean (1962) to be in error by no more than 0.5 per cent in the frequency range 0 to 30,000 MHz.

2. Assuming the expression for N to be exact and the errors in P, T and e to be uncorrelated, a

TABLE 1

Values of the constants *a*, *b* and *c* for Standard Atmosphere for the Asian Tropics and 60 per cent relative humidity

Height (Standard gpm)	*T* (°C)	*P* (mb)	*e* (mb)	*N*	*a* $(°K)^{-1}$	*b* $(mb)^{-1}$	*c* $(mb)^{-1}$
0	27.0	1013.25	21.39	351	-1.47	4.15	0.259
500	24.3	956.95	18.22	327	-1.41	4.22	0.261
1,000	21.6	903.30	15.48	305	-1.27	4.33	0.264
3,000	10.8	713.29	7.77	231	-0.94	4.63	0.273
5,000	0	558.12	3.66	177	-0.72	5.01	0.284
10,000	-32.5	286.79	0.24	94	-0.40	6.45	0.323
20,000	-69.0	57.05	0	22	-0.11	8.97	0.380

TABLE 2

Values of constant *a* for Standard Atmosphere for the Asian Tropics and 20, 40 and 80 per cent relative humidities

Height (Standard gpm)	*e* (mb)			*a* $(°K)^{-1}$		
	20%RH	40%RH	80% RH	20% RH	40% RH	80% RH
0	7.13	14.26	28.52	-1.07	-1.27	-1.66
500	6.08	12.15	24.30	-1.06	-1.24	-1.58
1,000	5.16	10.32	20.63	-0.97	-1.12	-1.42
3,000	2.59	5.18	10.36	-0.77	-0.86	-1.02
5,000	1.22	2.44	4.89	-0.63	-0.67	-0.76
10,000	0.08	0.16	0.32	-0.39	-0.39	-0.40
20,000	0	0	0	-0.11	-0.11	-0.11

relation between small changes in *N* and small changes in temperature, pressure and vapour pressure may be evaluated from :

$$dN = \frac{\partial N}{\partial T}\,dT + \frac{\partial N}{\partial e}\,de + \frac{\partial N}{\partial P}\,dp \quad \ldots (2)$$

which can be written in an approximate form :

$$\triangle N' = a \triangle T + b \triangle e + c \triangle P \quad \ldots\ldots (3)$$

The root mean square error in *N* is then

$$\triangle N = \left\{ (a \triangle T)^2 + (b \triangle e)^2 + (c \triangle P)^2 \right\}^{\frac{1}{2}} \quad (4)$$

Typical values of the constants a, b and c based upon Standard Atmosphere for the Asian Tropics (SAAT), applicable to Indian region, defined by Pisharoty (1959), are found and listed in Table 1 for various heights and 60 per cent relative humidity. The values of constant *a* for SAAT and 20, 40 and 80 per cent relative humidities are tabulated in Table 2.

3. Root mean square errors in the values of *N* due to errors in meteorological measurements are calculated using Eqn. (4), assuming errors of ± 1 mb in pressure, $\pm 0.1°$ C in temperature and ± 1 per cent in relative humidity in surface weather observations and ± 2 mb in pressure, $\pm 1°$ C in temperature and $\pm$ 5 per cent in relative humidity in radiosonde measurements. These values are given in Table 3 for a range of sea level temperatures. It is seen that the errors associated with radiosonde observations are significantly high.

4. The values of *a*, *b* and *c* from Table 1 if substituted in approximate eqn. (3) yields :

$$N = -1{\cdot}47 \triangle T + 4{\cdot}15 \triangle e + 0{\cdot}26 \triangle P \quad (5)$$

at 0 gpm

$$N = -1{\cdot}27 \triangle T + 4{\cdot}33 \triangle e + 0{\cdot}26 \triangle P \quad (6)$$

at 1,000 gpm

$$N = -0{\cdot}94 \triangle T + 4{\cdot}63 \triangle e + 0{\cdot}27 \triangle P \quad (7)$$

at 3,000 gpm

with the help of these equations, changes in the value of *N* at certain height increments from standard levels can be evaluated with the knowledge of changes in *T*, *P* and *e*.

5. The relative contributions of *P*, *T* and *e* to the variation of surface values of *N* is illustrated by Table 4 wherein the average summer to winter differences of *N* for Trivandrum, Bombay and Calcutta are tabulated. Values of $\triangle T$, $\triangle e$ and $\triangle P$ were determined as the difference of the highest and lowest average values of the morning and

TABLE 3

Comparison of errors in determining N from meteorological measurements (P=1013.25 mb and RH=60 per cent).

Source of error	Root mean square error in N units at			
	0°C	15°C	27°C	40°C
Surface weather observations				
(±1 mb pressure, ±0.1°C temperature and ±1% RH)	0.43	0.82	1.52	2.83
Radiosonde observations				
(±2 mb pressue , ±1°C temperature and ± 5% RH)	2.03	4.07	7.54	14.19

TABLE 4

Summer to winter differences of N at ground levels as derived from the approximate expressiion (5)

Station	$\triangle T$	$a\triangle T$	$\triangle e$	$b\triangle e$	$\triangle P$	$c\triangle P$	$\triangle N$
Trivandrum	1.6	-2.43	6.0	24.90	2.25	0.59	23.1
Bombay	6.4	-9.41	10.5	43.57	9.30	2.42	37.8
Calcutta	10.6	-15.58	18.1	74.91	16.70	4.34	63.7

evening observations of monthly pressure, dry bulb temperature and vapour pressure means from Climatological Tables (1960). January being the month of lowest average values of N. June values are highest in case of Bombay and Calcutta while Trivandrum values are highest in the month of May. The yearly range of N at Trivandrum, Bombay and Calcutta determined by Kulshrestha and Chatterjee (1966) is 23, 37 and 63 respectively. The values of $\triangle N$ found in Table 4 are quite in agreement with these values.

The primary contribution of $\triangle N$ at the surface arise from $\triangle T$ and $\triangle e$. The effect of $\triangle P$ is negligible. Further the effects of $\triangle T$ and $\triangle e$ are opposite in sign but since $|b\ \triangle e| > |a\ \triangle T|$; the total changes are all positive.

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