Microwave Line-of-sight Link—Tornado Effect

M Ramakrishna, P K Banerjee, S K Sarkar & H N Dutta
Radio Science Division, National Physical Laboratory, New Delhi 110 012

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The general signal strength prediction methods in tropospheric propagation mode with the statistical knowledge of conventional radiosonde data are inadequate to explain the microwave signal behaviour during a localized phenomenon like tornado. The tornado that struck North Delhi on 17 Mar. 1978, severely affected the microwave line-of-sight link. A study of the signal behaviour during and after the event is reported.

1. Introduction

It is now well established that the microwave propagation characteristics through the troposphere are critically determined by the spectrum of the radio refractivity of the tropospheric medium. The dependence of the received signal strength on the initial refractivity gradient \( \Delta N_i \) taken up to 250 m has been well established by Majumdar\(^4\) for both line-of-sight (LOS) and transhorizon microwave links over the Indian subcontinent. Deep fades of the order of 20 dB are expected, sometimes causing link outages even on LOS links of path lengths of the order of 40 km and above\(^2\) and generally occurring during nighttime due to the layered structure of the troposphere. An altogether different type of fading pattern is observed after sunrise and sunset due to the mixing and forming of layers, respectively.\(^3\) The received signal is steady to within 2 to 5 dB during daytime. These fades are found to fit Rayleigh distribution.\(^4\)\(^5\)

2. Path Description

Delhi-Sonepat microwave LOS link operating at 7.6 GHz is being monitored since 1973 for various tropospheric propagation studies.

The path length of the link is about 42 km and its terrain profile\(^6\) is almost the rolling type of irrigated land and hence it can be presumed that the signal behaviour can be attributed essentially to variations in the radio refractivity spectrum of troposphere. A significant and catastrophic event occurred on 17 Mar. 1978 at about 1800 hrs across this link and the signal exhibited a markedly unusual behaviour. This event relates to the devastating tornado that hit North Delhi on that particular day.

3. Tornado

A tornado develops when a thunderstorm is formed ahead of a week cold front in a convergence area and starts building up in severity depending upon a number of atmospheric conditions. The occurrence of severe tornadoes is rather uncommon in India but the one on 17 Mar. 1978 left a trail of destruction of life and property of a great magnitude. It moved from north to south, almost parallel to Najafgarh drain, with a width of about 50 m and through a distance of 5 km. This tornado happened to run across the Delhi-Sonepat LOS link. Though its meteorological parameters are not available (as such events have not been monitored) from eye witnesses and press reports it seems to be comparable with the one that occurred on 13 June 1975 in Oklahoma, USA\(^7\) which was monitored and observed to possess the following characteristics.

- Maximum tangential velocity at a height of 630 m
- Maximum tangential velocity at a height of 1.5 km
- Tornado diameter on the surface

4. Tornado Effect on LOS Link

Though the tornado is a highly localized phenomenon lasting only for a very short duration unlike a cyclone, the received field strength recordings before, during and after the event showed a marked deviation from the clear day recordings and are shown in Fig.1. The general characteristics of the signal recordings may be summarized as follows.

(i) Unusually steady signal persisted during the night preceding the event.
Fig. 1 — Received signals during 16-20 Mar. 1978 from 0000 to 2400 hrs [1 division on the X-axis represents 200 min. Parts (a)-(f) in the figure relate to different dates: (a) 15 Mar. 1978, (b) 16 Mar. 1978; (c) 18 Mar. 1978; (d) 17 Mar. 1978; (e) 19 Mar. 1978; and (f) 20 Mar. 1978]

5. Discussion

From Maxwell's equations, the complete vector wave equation, assuming \( \mu \) constant, can be written as

\[
\Delta \vec{E} + k^2 n^2 \vec{E} + 2 \nabla (\vec{E} \cdot \nabla \log n) = 0 \quad \ldots \ (1)
\]

where

- \( \vec{E} \) Electric field intensity
- \( k = 2\pi / \lambda \)
- \( \lambda \) Free space wavelength
- \( n \) Refractive index of the medium
- \( \mu \) Magnetic permeability

The refractive index \( n \) of the troposphere is a random function both with respect to time and space, though it can be assumed that there exists some type of translation for space and time like the Taylor's hypothesis. Additionally, in spite of several questionable assumptions, it is generally

(ii) An hour before the event, the signal strength rose by about 5 dB above median value.

(iii) During the event, the signal showed deep fading of as much as 20 dB and its period was about 27 min. This fading continued for about 8 hr with fading depth progressively decreasing.

(iv) During the nights preceding and following the event, the median signal level was lower by about 2 dB compared to the median on control days. But surprisingly on the third night after the event, the signal level increased by about 3 dB.

(v) On 18 Mar. 1978, the signal was most unsteady even during daytime having the fading pattern similar to that of nighttime.

(vi) Though the dawn and dusk fading patterns were quick with deep fadings, the average signal levels were not different from those on clear days; but on 18 Mar. 1978, the average value at sunrise was 2 dB above and at sunset 2 dB below clear day levels.
agreed that the phase relation is directly related to frequency due to the spatial average of \( n \) and wind velocity.\(^{8,9} \) Also, it is rather difficult to describe the distribution of \( n \) and other meteorological parameters in short durations of time and in small volumes as in the case of tornado.

The radio refractivity \( N \) is obtained from meteorological parameters by the Debye relationship

\[
N = \frac{77.6 P}{T} + \frac{3.7 \times 10^4 \times e}{T^2} \quad (N \text{ units})
\]

\[= N_D + N_W \]

where

- \( P \) Pressure in millibars
- \( T \) Temperature in degrees Kelvin
- \( e \) Water vapour pressure in millibars

\( N = (n-1) \times 10^8 \), \( n \) being the refractive index

The suffixes \( D \) and \( W \) denote, respectively, the dry and wet term contributions to \( N \). Under normal conditions, it is believed\(^{10} \) that the contributions from \( N_W \) dominates the refractivity gradient, \( \Delta N_i \), in the lower troposphere and \( N_D \) contribution is negligible. Though it is stated in NBS-101 method\(^{11,12} \) that surface refractivity, \( N_s \), has correlation with signal strength, it is now increasingly felt that much better correlation exists with initial refractivity gradient, \( \Delta N_i \), and received signal strength.\(^{12,13} \) Fig. 2 shows the plots of \( \Delta N_i, N_s \), and signal strength pertaining to the tornado event. It is seen that little correlation exists as is expected because the tornado is characterized by sudden and deep pressure gradients horizontally. The pressure difference of tornado and outside atmosphere can be as much as 200 millibars, and the \( N_D \) contribution to \( N \) is not negligible: As the air from all sides of the tornado gushes into it resulting in the upward motion, the microwaves undergo scintillation\(^4 \) type of fading with constant period, but with larger than usual fade periods and depths.

In order that Eq. (1) be satisfied with any degree of accuracy, it is essential to consider the \( n \) distribution in both \( X \) and \( Z \) directions. As \( N_s \) and \( \Delta N_i \) are obtained from a site located at about 20 km from the location of the tornado, no correlation study is possible with the signal strength.

Also, the tornado was accompanied by a thunderstorm. No explanation could be drawn from rain data for the observed 20 dB fade. Another aspect of the tornado on the microwave LOS link is the after effect. The microwave propagation behaviour continued to be affected for a few days and hence it is suggested that a continuous dynamic process of forming and breaking of small dimension but large gradient layers, both in vertical and horizontal directions, is likely to precede the event and persist for some time following the event. Further studies of this nature are likely to throw light on the tornado behaviour.

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