LOW ANGLE TROPOSPHERIC FADING IN

RELATION TO SATELLITE COMMUNICATIONS AND BROADCASTING

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During the period from 24 Oct. to 15 Nov. 1970, measurements were made of the received signal strength of the U.S. TACSATCOM-1 satellite beacon at 7.3 GHz. Two receiving systems were employed in this experiment, one using a precision 9 m tracking antenna and the other a transportable 1.8 m antenna.

The satellite, in a near-synchronous orbit, was drifting in a westerly direction so that its elevation angle decreased at a rate of about 0.25 deg. per day. The measurements were begun when the satellite, as viewed from Ottawa, was at an elevation angle of approximately six deg., and nearly continuous observations were made until it reached an elevation angle of 0.5 deg.

Fig. 1 shows samples of received signals on 1 Nov. 1970. During this time, the elevation angle to the satellite was 4.0 deg. It is evident that signal fluctuations of about +2 dB occur during this interval. These data were used to calculate cumulative amplitude distributions, auto-correlation functions and cross-correlation functions between the two received signals.
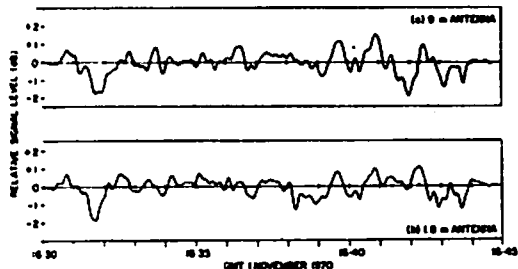

Fig. 1   Received Signal Strength as a Function of Time

The medians for the nine metre system are plotted as a function of time in Fig. 2. For periods after Nov. 9 the elevation angles were below 2 deg. At these low elevation angles, the median level decreased much more rapidly than can be explained by the increase in atmospheric absorption as the path length through the troposphere increases. Effects such as beam divergence due to regular refraction may be significant but cannot account for the entire loss.
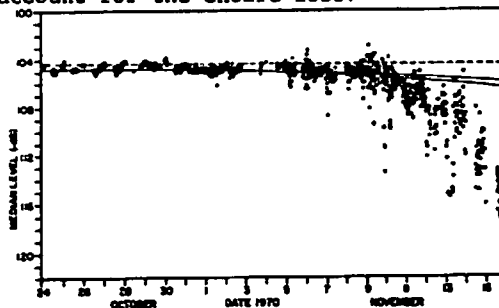

Fig. 2   Median Signal Strength as a Function of Time

In this paper, it is assumed that the power scattered by refractive inhomogeneities is a linear function of frequency. Using this assumption, Fig. 3 shows the predicted distributions of fading amplitudes, based on the 7.3 GHz data at 4-5 deg. elevation angle, for various frequencies between 1 and 20 GHz. The 99 percent margins increase from 0.8 dB at 1 GHz to 3.6 dB at 20 GHz.
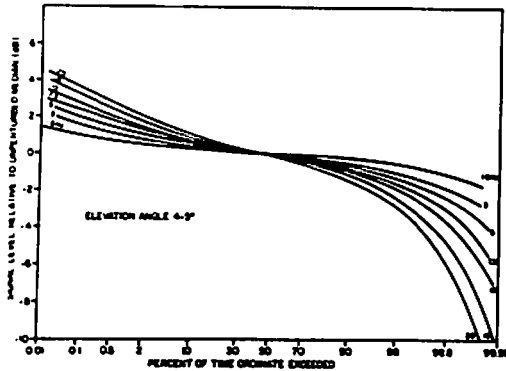
Fig. 3   Predicted Distribution of
          Fading Amplitude at Various
          Frequencies

SCALE SIZE OF THE REFRACTIVE STRUCTURES

The time delay between the two
curves of Fig. 1, and the correlation
between the fading patterns suggest
that the refractive structures causing
the fading are drifting.

Fig. 4 shows the cross-cor-
relation function for the data of Fig.
1. The function falls to a value of
1/e in a time of about 15 sec., and
shows a maximum value of 0.63 with a
lag of -7 sec. Since the separation
of the two antennas was 23 m, this
implies a drift velocity in the trans-
verse direction of 3.3 ms^{-1}, and a
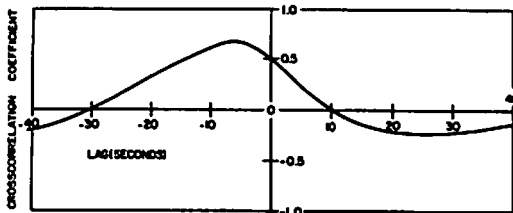scale size of the scattering struc-
ture of 50 m.

Fig. 4   Cross-correlation Function
          for Data of Fig. 1

Fig. 5 shows, for the 9 m
antenna and for different ranges of
elevation angle, distributions of
scale sizes derived in the above
manner. Values of scale size up to a
maximum of about 300 m were observed
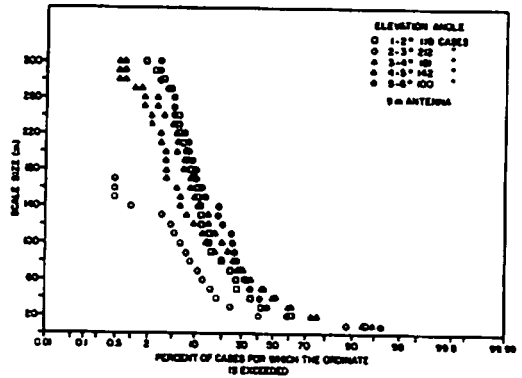with a median value of the order of 30 m.

Fig. 5   Distributions of Scale
          Sizes

SUMMARY

For any given geostationary
satellite, there will be large regions
of the earth for which the satellite
is visible only at low elevation angles.
To ensure reliable operation at these
low angles, a fairly large propa-
gation margin must be included in the
system design to overcome the effects
of tropospheric fading. This fading
depends on elevation angle and meteoro-
logical conditions.

Estimates of the scale size
of the structures causing the fading
suggest that separation distances of
about 300 m would be required if space
diversity systems are to be used to
overcome the effects of the fading.