IONOSPHERIC FADING EFFECTS ON THE EQUATORIAL ZONE

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Through the Goddard program of ionospheric scintillation investigation, we made a discovery of major significance to microwave communications from space. We have found that in the equatorial region, unlike the auroral region, there appears to be significant fading of microwave signals due to the effects of the ionosphere. Our observations at microwave frequencies have been from 1550 to 2300 megahertz. Channels in these bands have been allocated for manned and unmanned spacecraft, and for traffic management satellite applications. By equatorial region I mean that region of the earth between plus and minus 25 degrees geomagnetic latitude. By auroral region I mean that region of the world between 60 degrees geomagnetic latitude and the magnetic poles. When I speak of scintillation fading, I mean that fluctuation of the received signal power caused by effects of a disturbed ionosphere.

In Figure 1 we see plots of received signal power as a function of time. The upper traces

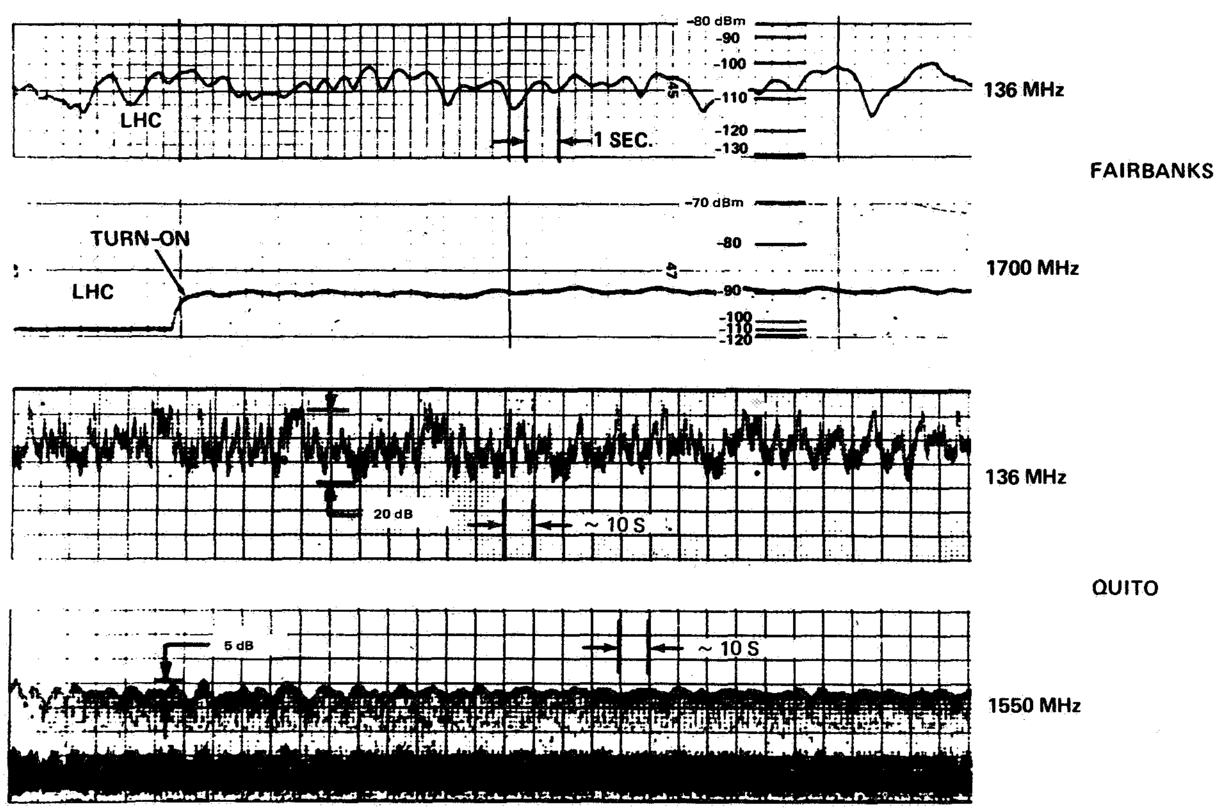

Figure 1. Comparison of VHF and microwave fading in the auroral zone (microwave 1700 MHz) and the equatorial zone (microwave 1550 MHz).

are from the auroral zone at Fairbanks, and were recorded simultaneously from a weather satellite at 136 megahertz and 1700 megahertz. The important thing here is that while the intensity of the 136 megahertz fading amounts to about 14 dB, the fading at 1700 megahertz is essentially negligible, about 0.6 dB. This behavior follows a theoretical inverse frequency dependence, which is as predicted for these fading effects. On the geographic equator at Quito, Ecuador, however, this inverse frequency dependence law is violated. The simultaneous records from ATS-5 show that at VHF, we saw 20 dB of fluctuation of the signal, and at the same time, we saw a surprising 5 dB at 1550 megahertz, or L-band. The bottom record appears the way it does because of the spinning of ATS-5 and it corroborates Jim Baker's statement that we are unable to extend beyond simple amplitude analysis because of the lack of a good satellite transponder at L-band.

Figure 2 shows us when fading is likely to occur in the equatorial region. Here we see a plot of the 136 megahertz fading events that were reported over an entire year of Minitrack operations at Quito, Ecuador. These operations were distributed more or less uniformly throughout all the hours of the year. Data are presented by the week along the longer axis, and by hour of the day along the shorter axis. The third, or vertical dimension is the percentage of the scheduled passes for which scintillation effects were reported.

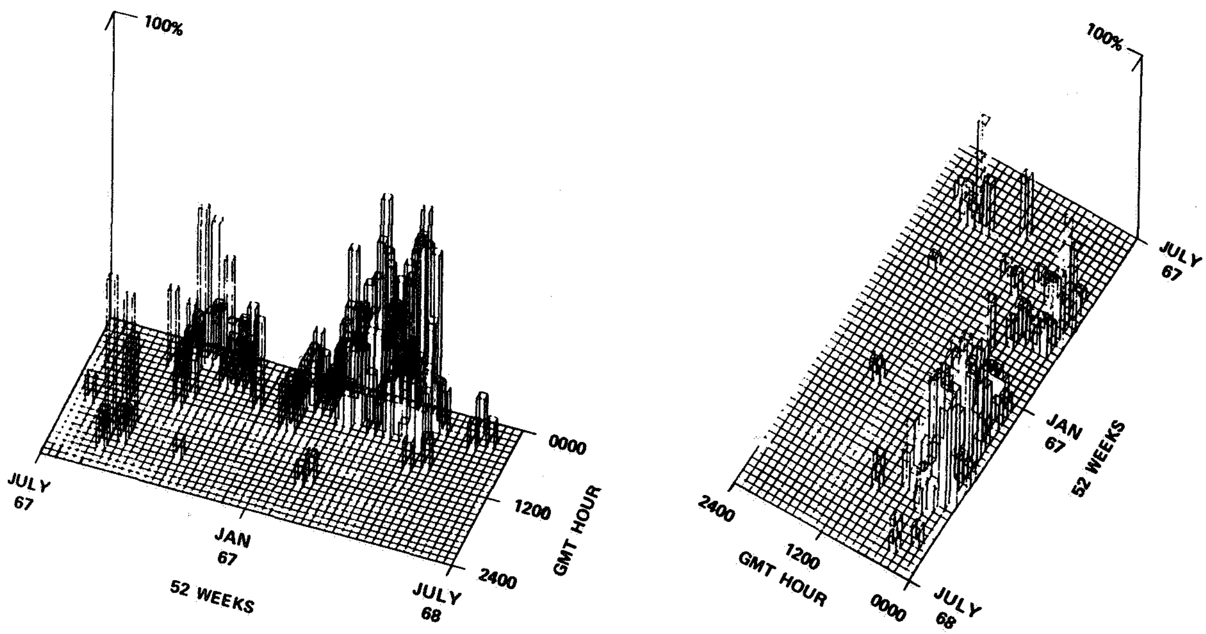

Figure 2. Three-dimensional plot of percentage occurence of VHF scintillation effects shown as a function of time of the day and week of the year. Equitorial and nighttime predominance are illustrated.

While this represents VHF behavior, it's the kind of behavior our observations have led us to expect at microwave frequencies as well.

You can see in the right-hand picture now, that most of the events occur between 0000 and 1000 hours, Greenwich mean time. This happens to be during nighttime at Quito, since midnight there is 0500 hours.

The left-hand view of this same data shows another trend, namely, the increased percentage of occurrences around the weeks of the equinox. There is hardly any scintillation at all during the weeks around June and December. However, during the times of March and April and September and October, you can see definite behavior characteristics that have been identified as ionospheric scintillation. The important thing here is that the greatest probability of occurrence of fading in the equatorial region seems to be at night at the time of the equinoxes.

In Figure 3 we can see what the impact of this fading is on a communication link. This is a

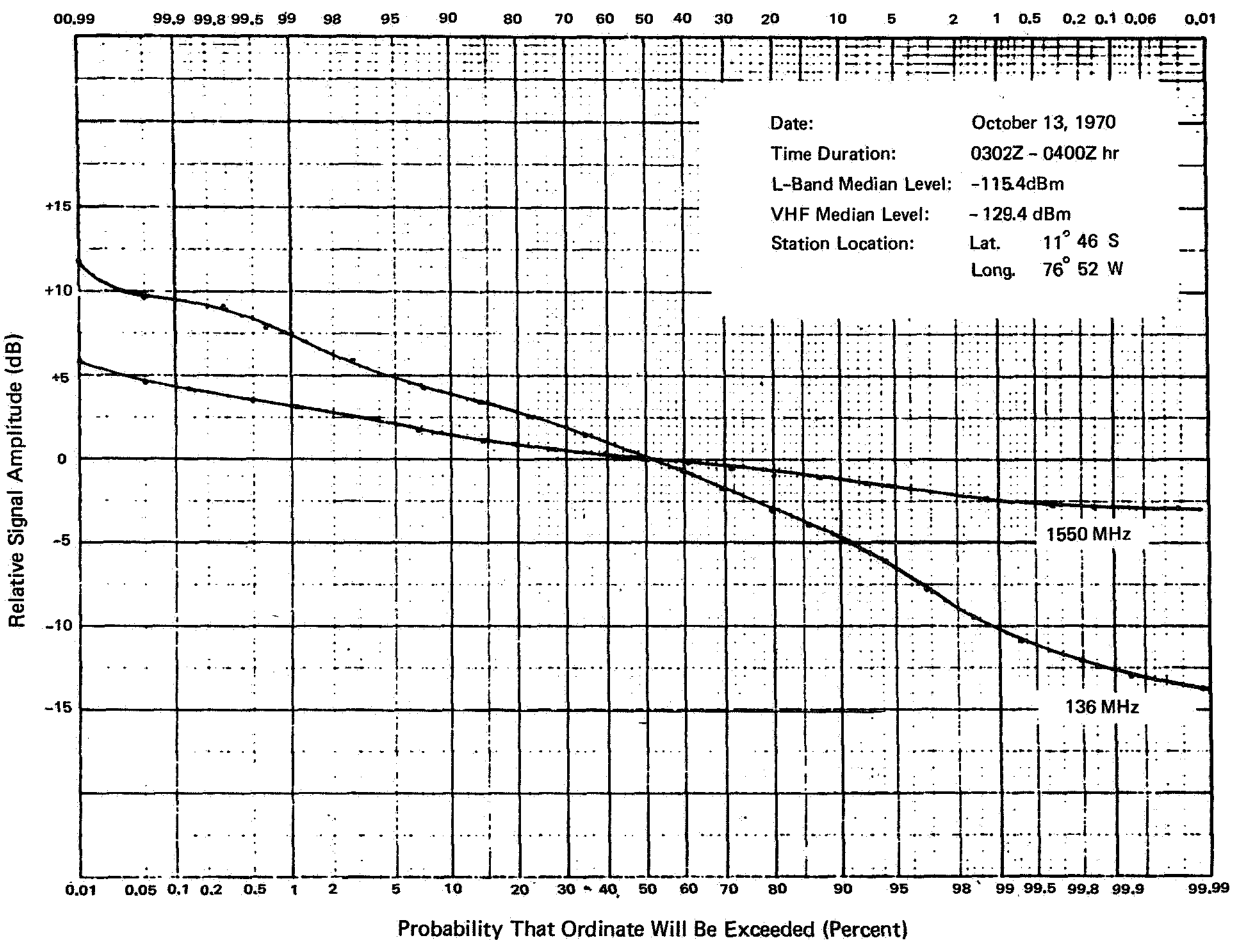

Figure 3. Typical fading in dB below the median signal value versus percent of time. Illustrates margin requirements for reliability of communication.

cumulative probability distribution of fading over a two hour period taken at Lima, Peru, on the geomagnetic equator. This curve means that for one percent of the time, read across the top, during this two hour period, the signal level for 1550 megahertz was 2 dB below the median level. Incidentally, the departure from median signal level is plotted in dB above and below zero. For 136 megahertz, this was 10 dB for one percent of the time. And for 0.1 percent of the time, at 1500, the fading is 3 dB below the median. This constitutes a serious problem to communication links if you have to communicate during periods of scintillation, since 3 dB essentially means two to one in transmitter power or channel capacity from your satellite.

The conclusion is that while fading occurs at night, around the times of the equinoxes, the fading depth is large enough that it must be considered in designing a space communications system. The magnitude of fading we've discovered at the equator violates existing theories for scattering, and constitutes a problem that must be reckoned with in system design.