SHORT COMMUNICATON

[1]Effect of thunderclouds on space wave propagation at 10 GHz

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In satellite transmission at frequencies above 10 GHz, signal fading, and hence outage, is mainly attributed to rain. It has been reported that the specific attenuation by rain varies with the rate of rainfall. Typical values are 0.01 dB km^{-1} at a rainfall rate of 1mm per hour and 0.15 dB km^{-1} at 10 mm per hour (Crane, 1996). Annual, seasonal and monthly cumulative statistics of diurnal fade variations and fade duration data from radiometric measurements in equatorial Africa has been published (Allnutt and Haidara, 1998 *a, b*). Seasonal and diurnal rainfall data and its effects on Ku-band (12.5 GHz) satellite links (OPTUS-B) in Papua New Guinea have been reported (Pan *et al.,* 2000 *a, b*). Investigations carried out at the University of the South Pacific (USP) with 10.38 GHz signals show little or no attenuation by rain at this frequency. However, the results show that formation of thunderclouds affects the propagation characteristics of the microwaves at this frequency.

The transmitter and receiver antenna heights in USP investigations were 10 m and 100 m respectively and the distance between the two antennas was about 6 km (well below the radio horizon distance). The communication path between the antennas is thus *line of sight* and close to the surface of the earth. The space waves reaching the receiver have two components: the ground (or other surfaces) reflected waves and direct waves that come about by the bending effect of the atmosphere due to the gradient of refractive index.

In tropospheric scatter propagation and satellite communication, the electromagnetic waves will pass through the charge layers in a thundercloud. In this preliminary investigation, the proximity of the antennas suggests exclusion of the waves passing through charged layers of the cloud (tropospheric scatter). However, the negative charge layer at the bottom of a thundercloud will create, on the surface of the earth, an electric field that is several orders of magnitude greater than the fair-weather field. This field can then produce an ionized and/or polarized medium. The cumulative effect is that the medium introduces a complex refractive index in the path of the microwaves. The rate of build up of this medium depends on the rate of build up of the charge layer in the cloud.

The transmitter was stationed in the University premises at Laucala Bay (18° S and 178° E), Suva, Fiji. Vertically polarized waves were transmitted at 10.38 GHz and at a power output of 20 mW. A horn antenna (23 cm x 18 cm) was used at the transmitting end and a dish antenna (64 cm diameter) was used at the receiving end. The dish had a reflex waveguide feed. Behind the dish was mounted a Low Noise Broadband (LNB) converter, and the entire assembly could be rotated in the horizontal plane for the purpose of alignment. The LNB was connected to ICOM-R7100 receiver. The receiver was operated in the wideband FM mode and with the automatic frequency control on. This compensated for any frequency drift in the transmitted frequency. The clear-sky signal-to-noise ratio of the beacon at the receiver was determined by comparing the signal strengths of the ICOM receiver with and without those of the transmitter signal and this was about 26 dB.

Measurements were carried out for several days that covered clear days, rainy days, rainy days with thunder, and 'dry' days with thunder only. The receiver output was connected to a chart recorder. The traces recorded were compared with the thunder and rainfall records at the transmitting station.

The traces showed that, even on a clear 'dry' day, the output of the receiver was carrying noise and at times the signal suffered severe attenuation. This could be attributed to variation of refractive index along the path of propagation of the waves. This process is commonly referred to as *scintillation*. The output obtained on rainy days did not show appreciable attenuation. This is understandable considering the relatively small attenuation caused by moderate rates of rainfall and the small distance between the antennas. On **all** days during which thunder activities were recorded, the recorded signal showed a decrease in intensity. Comparison of the time of the thunder activity and the time of the signal decrease showed a remarkable correlation.

Figure 1 shows two-hour sections of sample traces of the output. Defining the *thunder hour* (T. Hr) as the end of a clock hour when thunder activity was observed, the interval labeled T. Hr on the trace was coincident with the hour during which thunder was recorded.

In general, lightning is associated with rain. Researchers have found a close relationship between lightning and rain gushes (Jayaratne and Ramachandran, 1995 and 1998). A detailed study of the data on rainfall and thunder activity in Suva did not suggest any such relationship; in fact the

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majority of the thunder hours did not have any associated rain.

A gradual decrease in intensity of the signal and then an increase to its initial value was observed for over 80% of the events analysed. These gradual changes lasted for several minutes (40 - 100 min) (figure 1a, 1b). The observed peak signal attenuation were between – 0.30 dB and – 1.55 dB, giving an average of – 1.21 dB. The gradual decrease may have been due to the gradual build up of charges in the thundercloud thus causing a gradual increase in the field. After a lightning discharge, which appears as a spike on the record, the electric field disappears and the ions gradually dissipate. About 15% of the events showed a gradual/abrupt change in intensity, (figure 1c, 1d) which lasted for 40 - 80 minutes with an attenuation of about –3.5 dB.

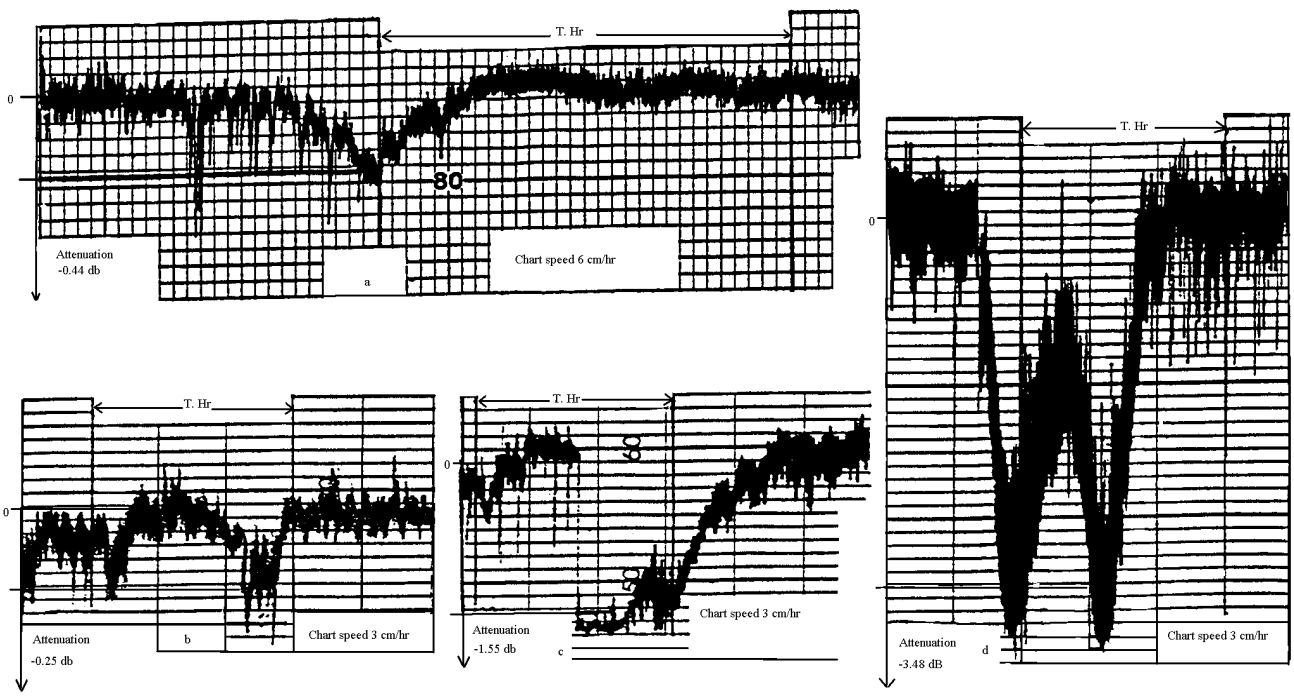

Figure 1 Sample traces of the receiver output

Further research: A build up of an active cloud may not result in lightning, but will be producing a strong electric field. Simultaneous monitoring of the earth's electric field and the propagation characteristics of microwaves may explain some of the observations recorded during this study. A detailed study of the spatial distribution of lightning around Suva should be carried out.

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