Preliminary findings of the effect of some atmospheric parameters on Ku-band satellite link.

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ABSTRACT

A four-month study of the attenuation measurement on satellite TV transmission down link is reported. The time percentage distributions of the attenuation show a fairly large month-to month variation. However, such variations seem to be closely related to the variation of the rain-rate distribution. Comparison of exceedance and the cumulative rainfall during these four months with those of the ten-year data indicates a similar variation this year. Measurements on a "cloudy" day without any rain indicate that the attenuation by cloud is small

Keywords: *Microwave attenuation, Satellite Communication*

1 INTRODUCTION

The effect of attenuation and scintillation on radio wave communication has been of interest to many researchers, however, no such study has been reported from the Pacific Island countries. In island countries, like Fiji, the presence of a dry land nearby to a moist oceanic air mass leads to some complicated atmospheric mechanisms, which may affect the radio refractivity and therefore influence radio-wave propagation. This paper reports the preliminary findings of a systematic study of the effect of some of the atmospheric parameters on satellite links in the Ku-band. This project was started in March 2002 and is on going. Even though it is not possible to conclusively infer the effect of the atmospheric parameters on the satellite down link, because of the limited period of study, the findings enable us to understand the trend on the effect of these parameters on radio links.

To cope with the increasing demand and in the field of international satellite communications, the Ku-band of the spectrum is used in addition to the C-band. In satellite communications with frequencies above 10 GHz, signal-level fluctuations due to ionospheric and tropospheric scintillation, together with signal-level attenuation by rain, are among the major problems in radio-wave transmission. At these higher frequencies, the length of the falling droplets is close to a resonant sub-multiple of the signal wavelength. The droplets therefore are able to absorb, scatter and depolarize the microwaves passing through the Earth's atmosphere. Extensive studies on rain attenuation and scintillation have been reported by monitoring the beacon signal levels (Karasawa and Maekawa, 1997, Kikkert and Bowthorpe, 1997, Karasawa *et al.* 1998, Allnut and Haidara, 1998, Pan *et al.* 2000; 2001). Attenuation may also occur when radio waves pass through rain filled clouds passing overhead. Further when radio waves pass through highly charged thunderclouds and the layer of the atmosphere below the clouds; they will suffer attenuation and scintillation due to the complex refractive indices along the path of propagation. The influence of the effect of thunderclouds on tropospheric propagation of 10 MHz radio waves has been reported (Ramachandran *et al.* 2001). In this paper we report the findings of attenuation measurements carried out with satellite TV signals together with rain rate and Earth's local electric field.

2 SYSTEM DESCRIPTION

Intelsat 701 @ 180°E beams a Ku-band spot beam to Noumea, New Caledonia for TV broadcast. The down link frequency is 11 610 MHz. This beam is QPSK modulated with carrier suppression. This beam can be received in Fiji, though weak. The site for measurement of the radio waves is the University of the South Pacific (USP), Suva; Lat.: 18.08°S, Long.: 178.3° E and is about 1.5 km from the sea. The receiver antenna is an off-centre 1.2m parabolic dish. The frequency of the local oscillator of the LNB is 9.73 GHz giving an output signal at 1.88 GHz. The output of the LNB was connected to a spectrum analyzer, which was interfaced to a computer.

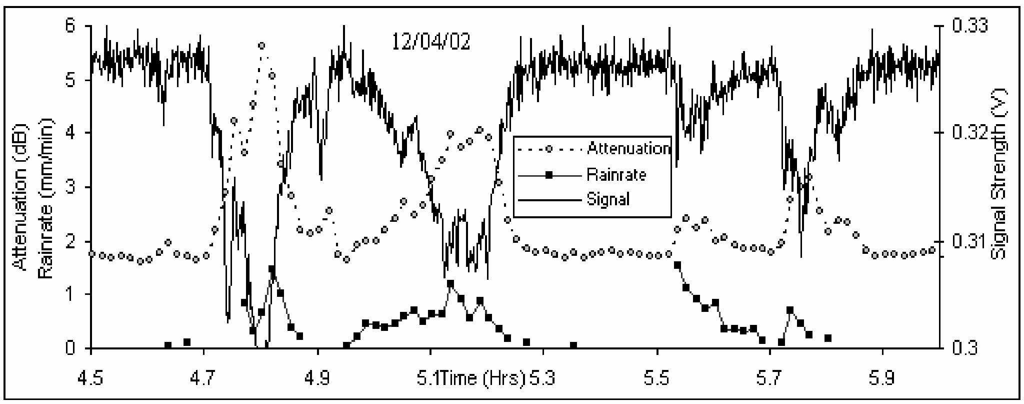
The rain rate was measured using a tipping bucket arrangement of diameter 20 cm. The large diameter of the tipping bucket rain gauge was selected so that a more accurate measurement of the rain rate can be made. The rain gauge had its own programmable data logger. The clock of this was regularly synchronized with that of the computer and the lag in time observed was 4 s in one week.

A flat plate antenna (50 cm x 50 cm) was used to measure the Earth's electric field. The height of the antenna above the ground level was 3.5 m. Due to the limitations on the available space and accessibility, the antenna was placed in an open space, with the nearest building about 20 m away from the antenna. The antenna was connected to a MOSFET opamp voltage follower. The output of the follower was also interfaced to the computer.

3 RESULTS AND ANALYSIS

Commercially available LabVIEW DAQ device was used to sample and record the strength of the radio wave signals and the Earth's electric field. In the measurement of the strength of the radio waves, the software was programmed to record the peaks of sixty successive samples each of 1 ms duration. The software then calculates the mean of these sixty peak values. This recording was then repeated every 10 s giving six averaged peak values in a minute.

Figure 1 Typical recordings of signal strength, attenuation and rain-rate.



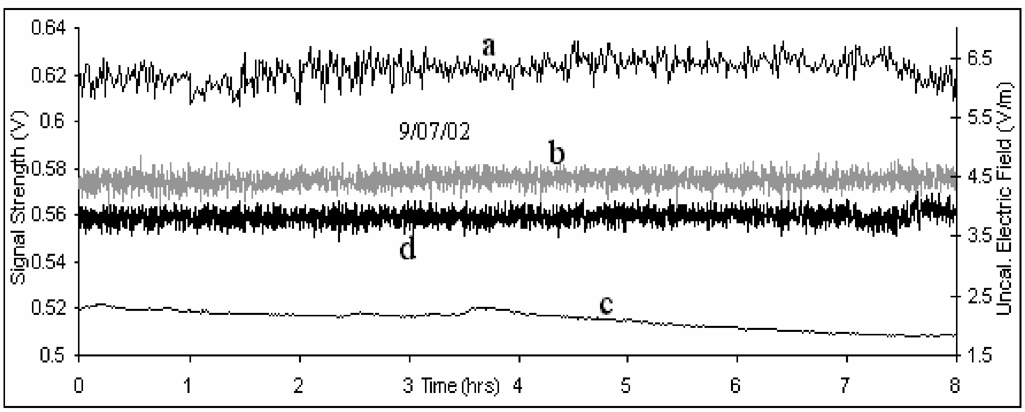


Figure 2 Variation of antenna potential (∝ earth's field) and signal strength.

The variation strength of the microwaves together with the scintillation is shown in figure 1. To account for any variation in the satellite signal strength, the average clear day signal strengths on the day prior to and after the rainy day(s) was used in computing the rain attenuation. A typical variation of the average attenuation (*i.e.* average of the six peak strengths) of the signal is also shown in figure1. The mean rate of signal level variations due to rain attenuation is much smaller than that of scintillation. The S/N ratio on a clear day was 17 dB. Using special DSP technique Kikkert *et.al.* (1998) have reported larger deep fades (> 30dB) for Ku-band beacon signals at 12.75 GHz.

The rain rate was computed from the frequency of the tips of the tipping bucket rain gauge. The standard tipping bucket used had a calibration of 0.2mm/tip. The tip times were recorded on the built in data logger of the rain gauge. The average rain rate was calculated using the time elapsed between successive tips and the corresponding rain rate is included in figure 1. The fine structure of the rainfall is evident in the plot.

The variation in the Earth's electric field was assumed to be slow, thus the electric field was recorded every minute. In the measurement of the electric field the software was programmed to record the peaks of sixty successive samples each of 1 ms duration in a minute. The software then calculates the mean of these sixty peak values and records it as an average electric field for the minute. The electric field was also measured continuously during the period of study reported in this paper. The presence of cloud in the path of propagation not only introduces scattering particles (ice, water droplets) but also a charged medium. The net electric field produced by the cloud reduces the earth's electric field. A thundercloud will produce a large change in the field, even a reversal. The potential attained by the flat plate antenna will be proportional to the electric field in the vicinity of the antenna. Figures 2 a) and b) show a typical variation of the antenna potential and the strength of the microwaves on a "clear day" and those for a "cloudy day" are shown in c) and d). The average attenuation on cloudy days was about 1.5 dB. The cloud coverage was present over the entire horizon.

The seasonal climatic condition in Fiji is broadly classified into wet and dry seasons. In the wet-season (November – April) the rainfall is maximum. The past ten year average rainfall was 281 mm/month. For the rest of the year (dry-season) the average rainfall recorded for the same period was 210 mm/month. For the four months reported in this study the average rainfall was 226 mm/month. Even though it is conventional to present the statistical data of annual exceedence of rain-rate and attenuation, due to the limited period of study, the authors are presenting the results obtained for the four months of investigation. The rain-rate exceedances and the attenuation exceedances for the four months April – July are given in figures 3 and 4. The cumulative data for the four months are also included in the two figures.

The time percentage of the distributions shown in figure 4 indicates a fairly large month-to-month variation of the attenuation.

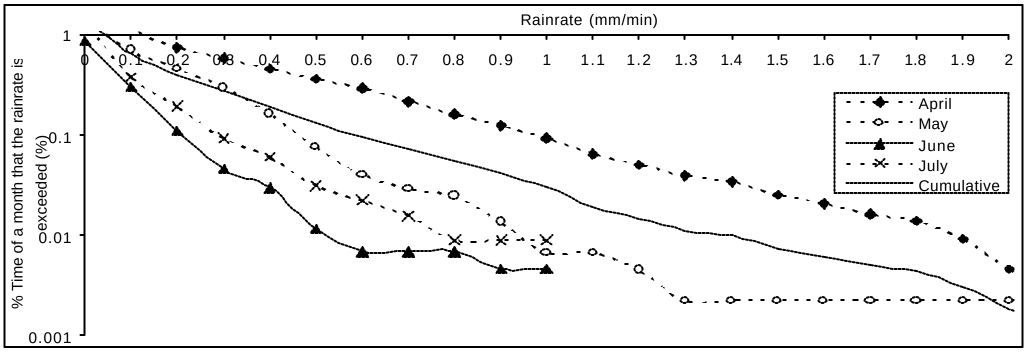


Figure 3 Four month comparison of rain-rate exceedances
Total rainfall (mm) April-483.9; May-197.8; June-94.4; July-135.9

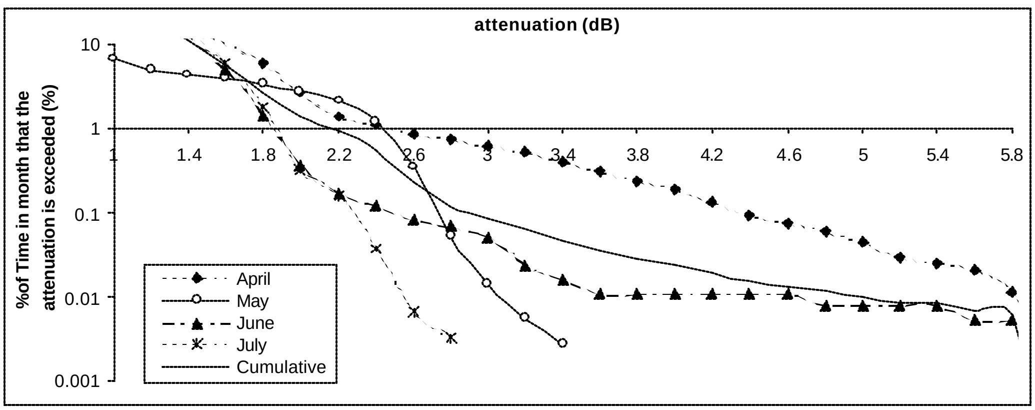


Figure 4 Four month comparison of attenuation exceedances

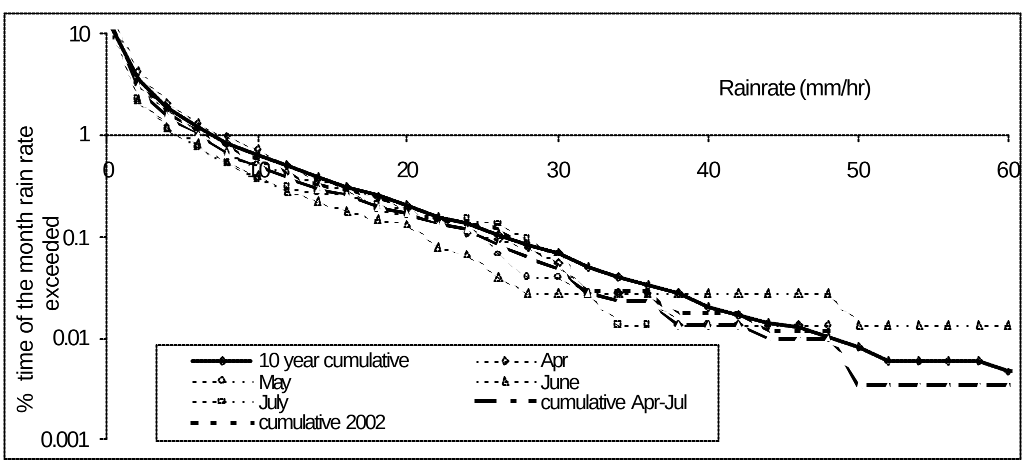


Figure 5 Rain-rate exceedance

Average cumulative rainfall (mm): April–333.7; May–197.8; June–94.4; July–135.9.

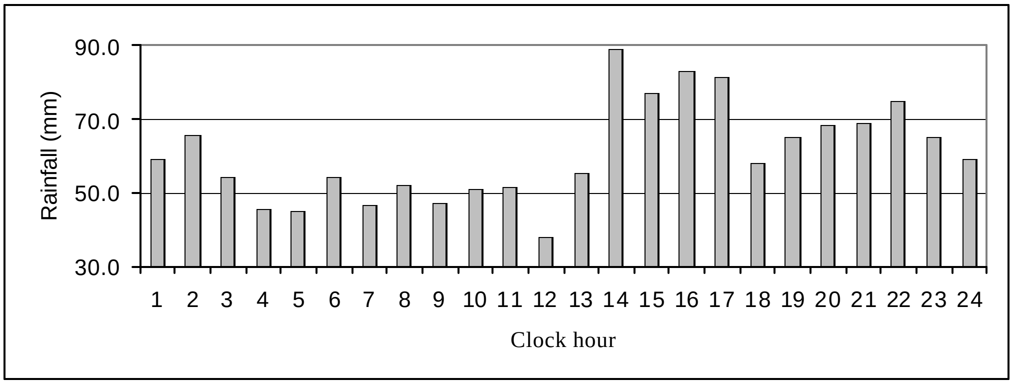


Figure 6 Average diurnal variation of rainfall (1992-2001).

Such large variations seem to be closely related to those of the rain-rate variation. It is interesting to note from cumulative plot in figure 3 that heavy down pour for a relatively short spell is not unusual and points to a higher attenuation of the radio wave signals. Using the hourly rainfall data, for the past ten years, obtained from the Department of Meteorological Services, Fiji, (1 km from USP) the exceedances were calculated for the months April– July and are shown in figure 5. For comparison, the ten-year cumulative rain-rate exceedance, for these months and for 2002, calculated from the hourly rainfall data, are included in the figure. These variations closely follow each other. The highest rain-rate recorded in the past five years is 81.8 mm/hr.

Figure 6 shows the diurnal variation of the ten-year average monthly rainfall with local time. The CCIR classification of rainfall places Fiji in the **N** region with rain rate exceedance of 0.01% ($R_{0.01}$) of 95 mm/hr. However the measured rainfall for the past ten years (figure 5) show $R_{0.01}$ as 49 mm/hr. Applying the ITU-R Prediction Model for attenuation (Ippolito, 1986) for latitudes less than 20° and an elevation angle of 68.5°, the predicted attenuation exceedance of 0.01% is $A_{0.01} = 0.045\, R_{0.01}^{1.164}$. Assuming $R_{0.01}$ as 49 mm/hr the predicted $A_{0.01}$ is 4.2 dB. The measured $A_{0.01}$ is about 8 dB.

In the findings of a five year period of study in Lae, Papua New Guinea, a station in the Pacific region (latitude < 20°, elevation angle 72.8°) monitoring satellite beacon signal levels, it was reported (Pan *et al.* 2001) that about 0.01% exceedance of attenuation occurred at 18 dB. A similar exceedance of rainfall was observed at 110 mm/hr.

Our preliminary findings suggest a lower attenuation and rainfall as compared to Lae, but the attenuation is higher than that predicted by the ITU-R model. The diurnal variation shown in figure 6 indicates that an increased attenuation of the satellite link will be observed after mid-day to early hours in the morning.

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