N94-14659

RESULTS FROM A STUDY OF SCINTILLATION BEHAVIOR AT 12, 20 AND 30 GHz USING THE RESULTS FROM THE VIRGINIA TECH OLYMPUS RECEIVERS

T. Pratt* and F. Haidara
Virginia Polytechnic Institute and State University
Bradley Department of Electrical Engineering
Satellite Communication Group
Blacksburg, VA 24061-0111

1. INTRODUCTION

Tropospheric scintillations are rapid fluctuations of signal caused by multiple scattering from the small scale turbulent refractive index inhomogeneities in the troposphere. They can strongly impair satellite communications links operating at frequency above 10 GHz. The VA Tech OLYMPUS propagation experiment [1] which includes 12, 20, 30 GHz beacon receivers at an elevation angle of 14° provides us with valuable multifrequency scintillation data.

In this paper a long term analysis of tropospheric scintillation results from the VA Tech OLYMPUS experiment is presented. It includes statistics of both the scintillation intensity and the attenuation relative to clear air as well as seasonal, diurnal and meteorological trends. A comparison with the CCIR predictive model for scintillation fading is presented.

2. DATA ANALYSIS

The long term analysis conducted covers the following twelve months: January to May 1991, June to August 1992 and September to December 1991. This choice was imposed by the temporary loss of the satellite OLYMPUS between May and August 1991. The analysis is performed for "non rain" periods. The criterion used to discriminate these periods is based on the radiometric attenuation ARD and was chosen in order to avoid calculation of the scintillation intensity in rain. It is made of the set of conditions:

PRECEDING PAGE BLANK NOT FILMED

$$ARD30 < 3\ dB \text{ and } ARD20 < 2.7\ dB \text{ and } ARD12 < 1\ dB \quad (1)$$

These conditions allow us to eliminate most periods of rain and correspond to 73, 80.7, 80.4 % of the total period for respectively 12, 20 and 30 GHz. The scintillation intensity is computed for each frequency for successive 1 minute periods. The monthly cumulative distributions and PDF of both the scintillation intensity and the attenuation with respect to clear air as well as the seasonal and diurnal distributions of the scintillation intensity for the non rain periods, are produced.

3. STATISTICS OF SCINTILLATIONS

The long term distributions of the scintillation intensity were computed on a monthly basis. Figure 1 presents the PDF for May 1991 together with the Gamma and log-normal distribution constructed from the mean and variance of the measured data. The PDF of the scintillation intensity is best approximated by a log-normal distribution. The fit is better for the low scintillations, winter months, and the lowest frequencies. The cumulative distribution of the scintillation intensity for the total period is shown in Figure 2. During this one year period scintillation intensities of 0.8, 1, 1.2 dB were exceeded for 0.1% of the time at 12, 20, 30 GHz respectively. The monthly PDFs of the scintillation fading, exemplified for May 1991 in Figure 3 are not Gaussian, contrary to the short term distribution. The monthly PDFs show a very good agreement with the Mousley-Vilar model [2] which assumes that the attenuation has a Gaussian distribution with a variable variance. The model is excellent for enhancements but slightly underestimates our measured data at the higher fading. We explain this discrepancy in part by the choice of "non rain" threshold which does not eliminate all the rain from the analyzed data. In all cases the agreement between measured and predicted distributions is best at 12 GHz.

3. SEASONAL, DIURNAL AND METEOROLOGICAL TRENDS

The seasonal and diurnal variation of tropospheric scintillations are illustrated in Figure 4. It shows the increase of the monthly average of the scintillation intensity as the season shifts from winter to spring and summer.

There is little diurnal variation in winter scintillations and no well defined hour of peak scintillations. The spring and summer scintillation on the contrary show a strong diurnal trend with a maximum scintillations occurring in the afternoon between local times 13:00 and 15:00. The diurnal behavior of the scintillation intensity on a monthly basis is strongly correlated to the ground temperature and humidity as shown for June 1992 in Figure 5. The correlation coefficient obtained between the monthly average of the hourly ground temperature and humidity and the scintillation intesity at 12, 20, and 30 GHz are respectively 0.841, 0.835, 0.789 and -0.880, -0.870, -0.827. Note that temperature and humidity are mirror image of each other and that the scintillation intensity (regardless of the frequency) exhibitsa slightly higher correlation with the humidity than with the temperature.

The relation between scintillation and weather parameters is further investigated in Figure 6, in which the scatter plots of the monthly average scintillation intensity as a function of ground temperature, humidity and the wet refractive index are shown together with the best curve fit. The dependence between ground temperature and scintillation intensity was best approximated by using an exponential formula of the type $\sigma_{\chi} = ae^{bT}$; this is consistent with result found by Merlo et al. [3]. The scintillation intensity however is well represented by a linear function of the ground relative humidity and the ground wet refractive index. The coefficients of the curve fit are also given in Figure 6. Note the very good agreement between the data and the fits specially in the case of the wet refractive index N_{wet} . This confirms the results obtained by Karasawa et al. [4] on which the current CCIR model is based.

4. COMPARISON WITH CCIR MODEL

The CCIR model used to compute the long term (at least a month) statistics of amplitude scintillation for elevation angle higher than 4° described in [5] was compared to our measured data. The monthly average humidity and temperature of Roanoke (located 35 km from our experimental site) were used in the model for the period going from January 1991 to May 1991 because of a malfunction of our humidity sensor during that time. For June 1992, however the meteorological quantities measured at our experimental site were used. The cumulative distribution of scintillation fade depths obtained using the CCIR technique are compared to the measured data as depicted in Figure 7. The average temperature and relative humidity used in the model are indicated on the graphs. There is a good agreement between measured and predicted scintillation fade depth on a monthly basis. In winter the CCIR model tends to underestimate the fade exceeded at low percentage (by a maximum of 0.2 dB at 30 GHz) but shows excellent agreement for the high percentage of time. The best fit is obtained at 12 GHz. In the spring and summer, on the contrary, the results obtained using the CCIR model exceed slightly the measured data at high percentages and match the experimental data at low percentages. The comparison of the CCIR model is not as good for the 6 month period of January-May 1991 combined with June 1992. The measured and predicted exceedance plots are very close at high percentages but diverge by as much as 1 dB at 30 GHz for low percentages. Globally, the difference between the CCIR model and measured scintillation fade depth is less than 0.5 dB for time percentages ranging between 0.1 and 10 %. For smaller percentages the rain attenuation would in any case be the dominant factor.

5. CONCLUSIONS

Scintillation results from the Virginia Tech OLYMPUS propagation experiment were presented. The statistics of both the scintillation intensity and the attenuation relative to clear air during dry weather were given and the seasonal, diurnal and meteorological trends were characterized. A comparison with the CCIR predictive model for scintillation fading was presented. The results presented here are unique in that they span the Ku, K and Ka frequency bands.

6. REFERENCES

[1] W.L. Stutzman et al., "Initial results form the 12, 20, and 30 GHz OLYMPUS propagation experiment in Blacksburg, Virginia," *IEEE AP-S Inter. Symp. Digest (Chicago)*, pp. 736-739, July 1992.

[2] T.J Mousley and E. Vilar, "Experimental and theoretical statistics of microwave amplitude scintillation on satellite down-link", *IEEE Trans. Ant. Propag.*, vol. AP 30, no. 6, pp. 1099-1106, Nov. 1982.

[3] U. Merlo, E. Fionda and P.G. Marchetti, "Amplitude scintillation cycles in

a SIRIO satellite link", *Electronics Letters,* vol. 21, no. 23, pp. , Nov. 1985.

[4] Y. Karasawa, K. Yasukawa, M. Yamada, "Tropospheric scintillation in the 14/11 GHz bands on earth-space paths with low elevation angles", *IEEE Trans. Ant. and Prop.*, vol. AP-36, no.4, pp. 563-569, Apr. 1988.

[5] Report of the CCIR 1990, Annex to vol. V, Report 718-3: "Effect of tropospheric refraction on radio wave propagation".

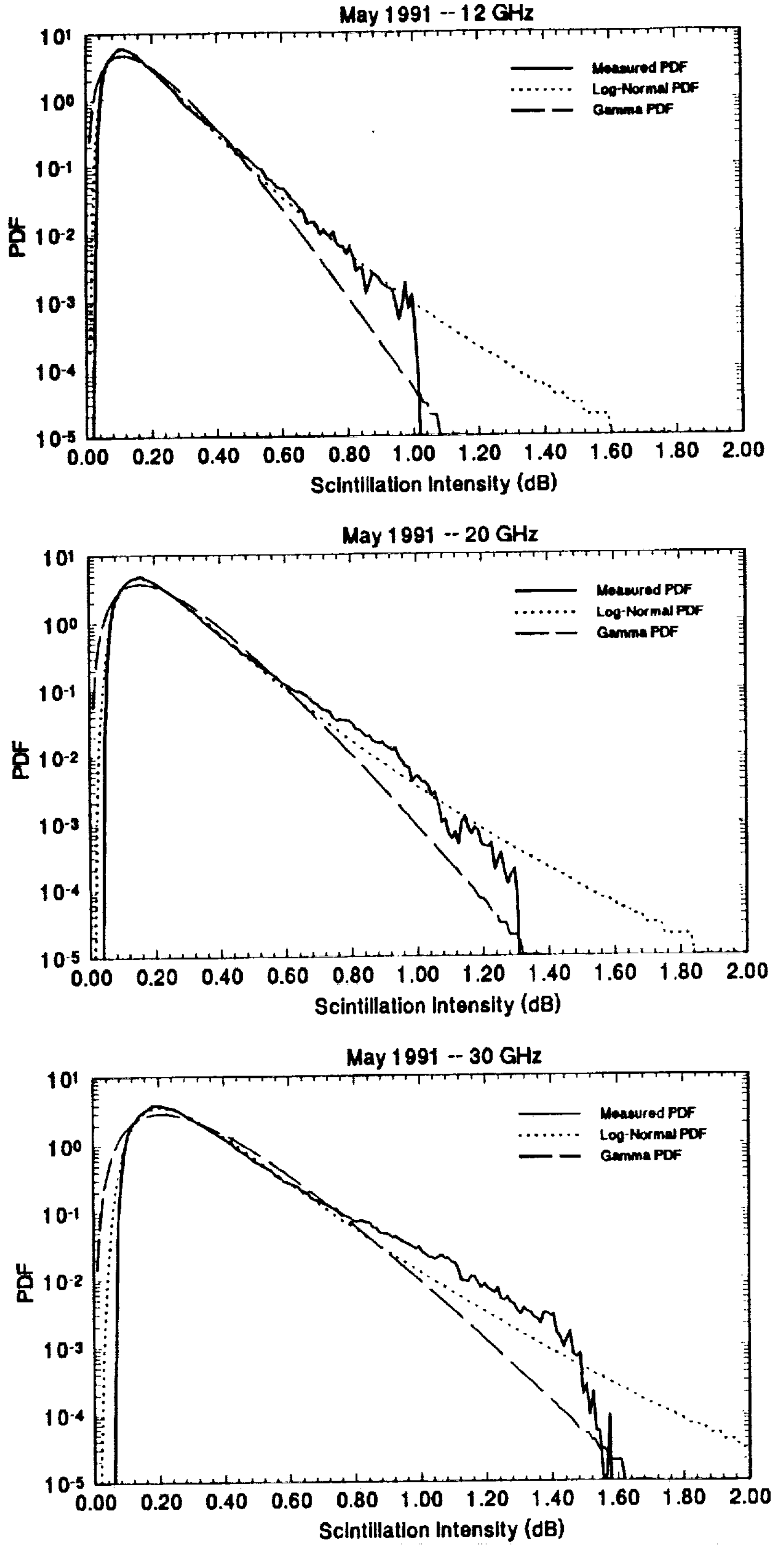


Figure 1: Monthly PDF of the scintillation intensity σ_χ for 12, 20 and 30 GHz compared to the corresponding Gamma and Log-normal distributions for May 1991.

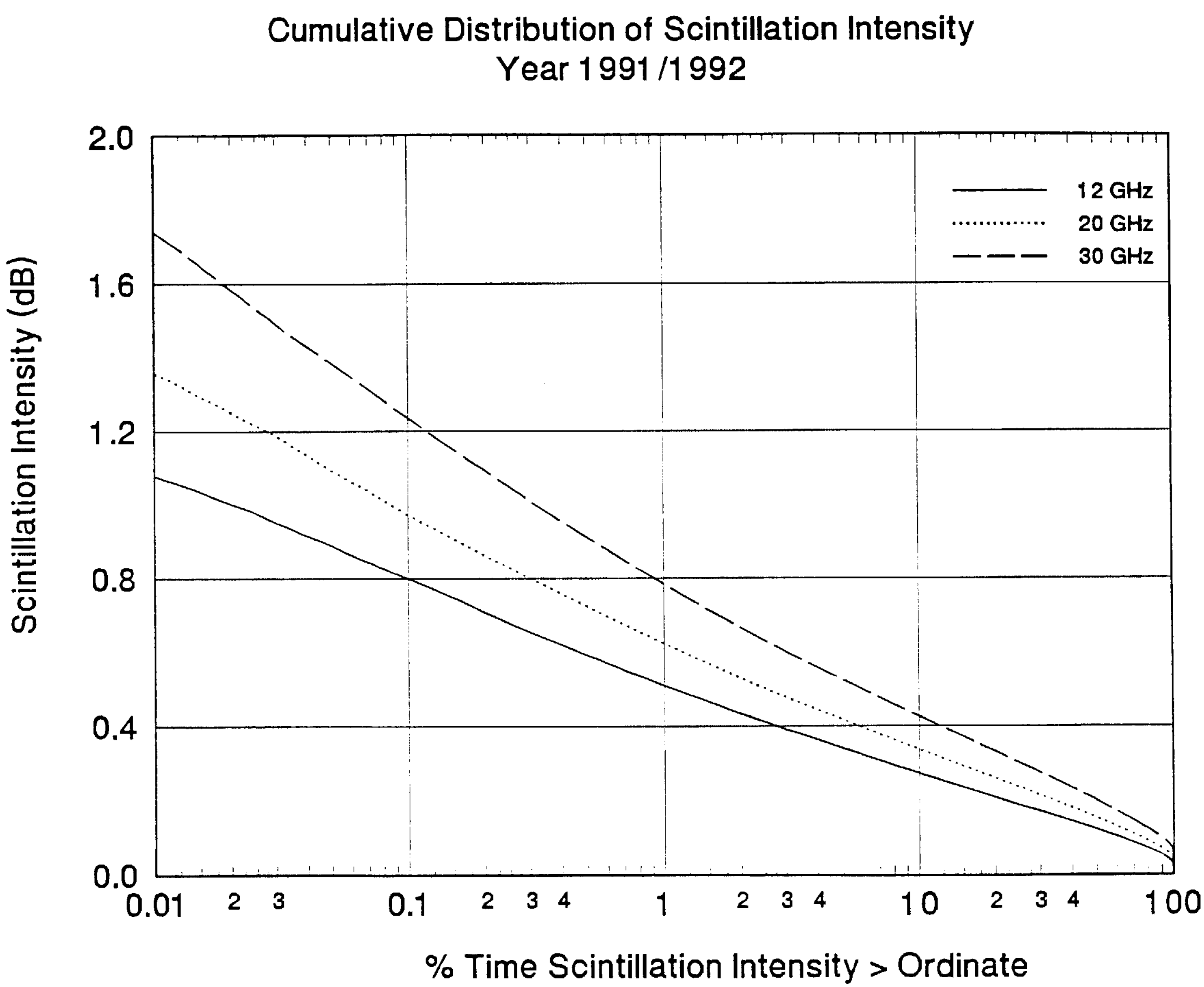


Figure 2. Monthly PDF of the scintillation fade depth for 12, 20 and 30 GHz compared to the corresponding Gaussian and Mousley-Vilar distributions for May 1991.

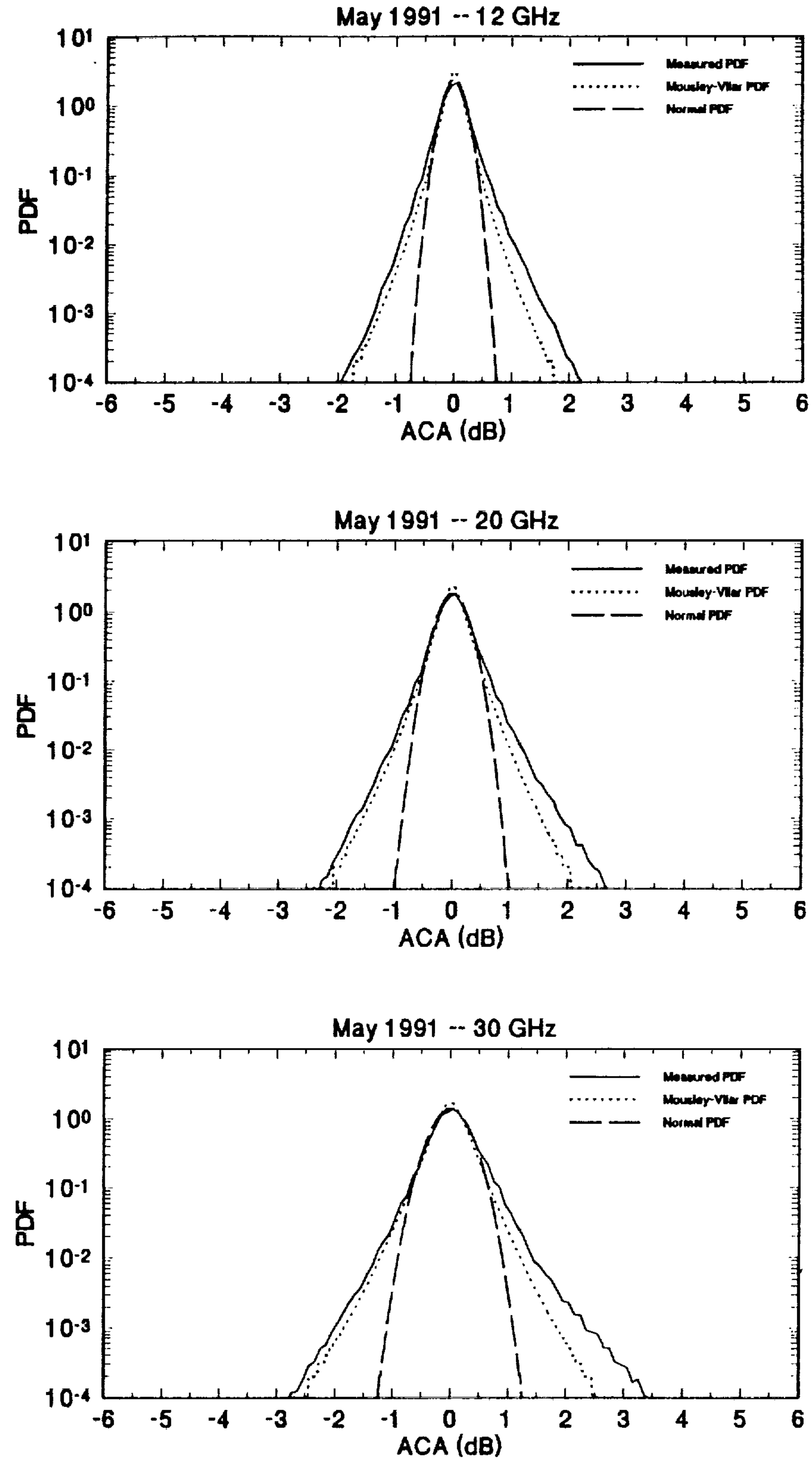
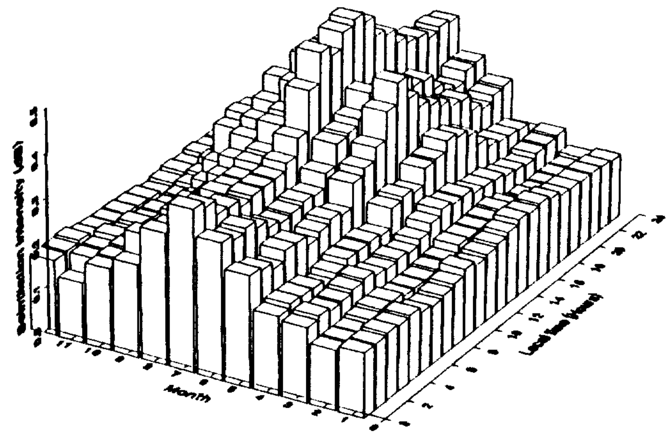
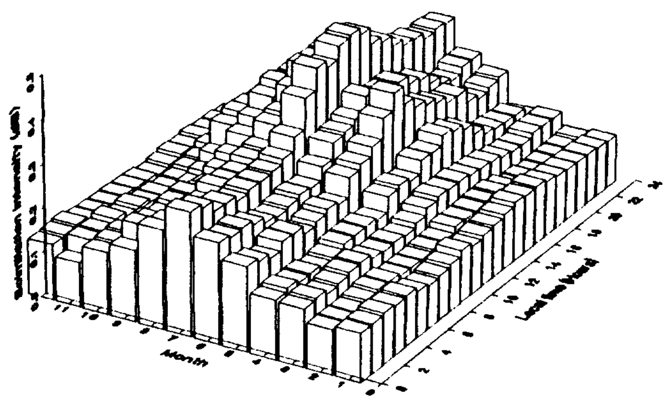


Figure 3: Monthly PDF of the scintillation fade depth for 12, 20 and 30 GHz compared to the corresponding Gaussian and Mousley-Vilar distributions for May 1991.

Seasonal and Diurnal Variation of Scintillations
30 GHz Year 91/92



Seasonal and Diurnal Variation of Scintillations
20 GHz Year 91/92



Seasonal and Diurnal Variation of Scintillations
12 GHz Year 91/92

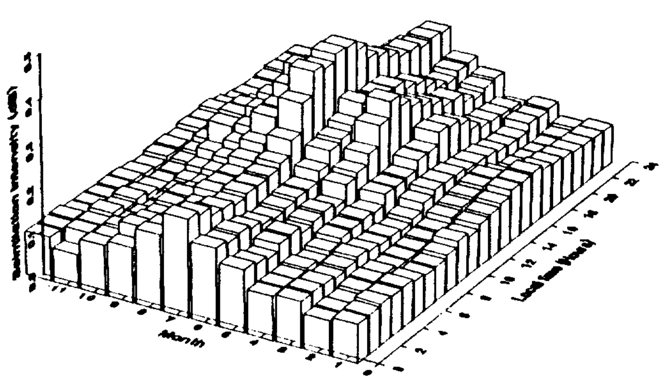


Figure 4: Diurnal and seasonal variation of the average monthly 12, 20, and 30 GHz scintillation intensities for one year of data. The scintillation intensities shown are the monthly average for of the scintillation intensity for each hour of the day.

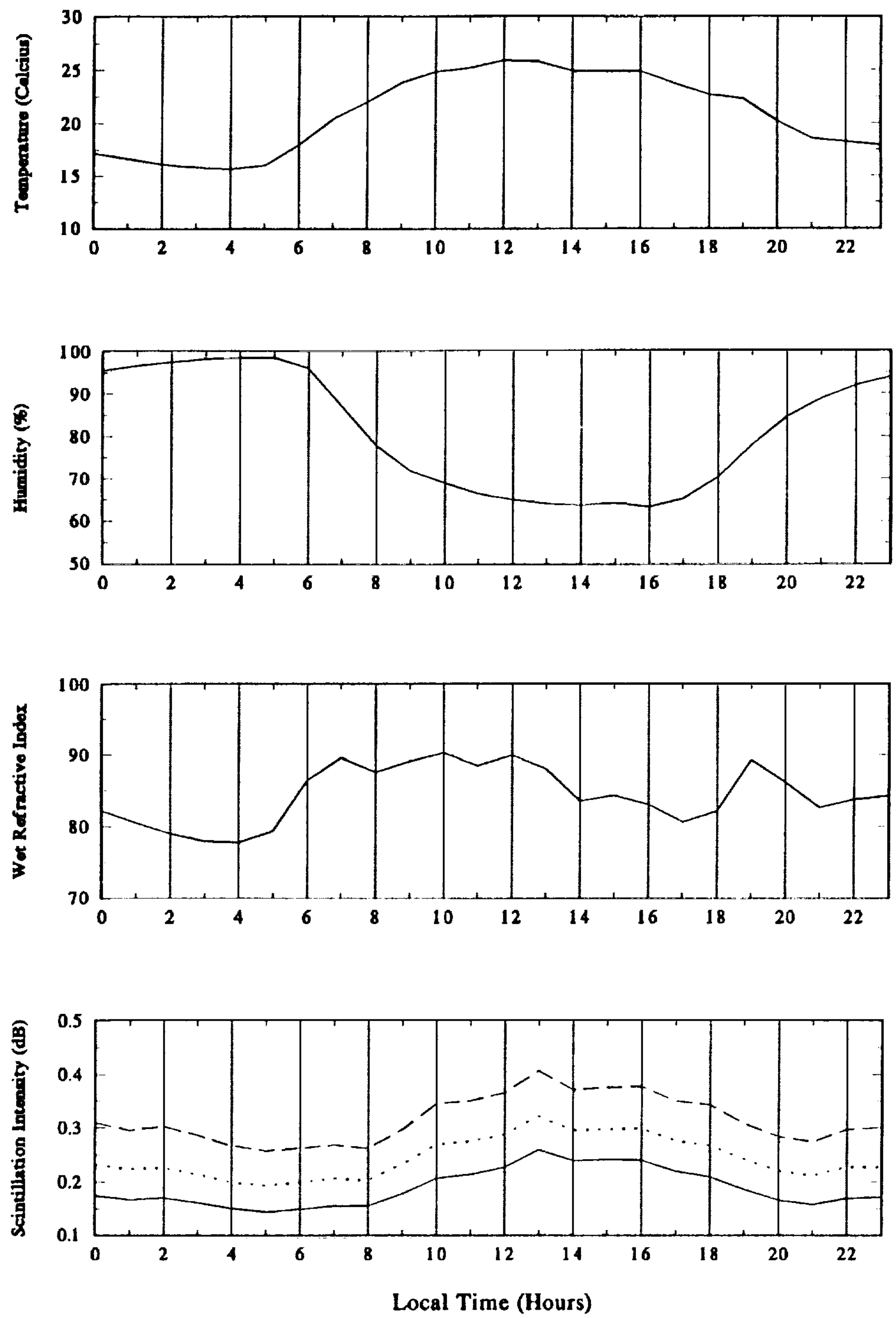


Figure 5: Diurnal variation of the average monthly ground temperature, ground relative humidity, ground wet refractive index and 12, 20, and 30 GHz scintillation intensities for June 1992. The quantities shown are monthly average for each hour of the day.

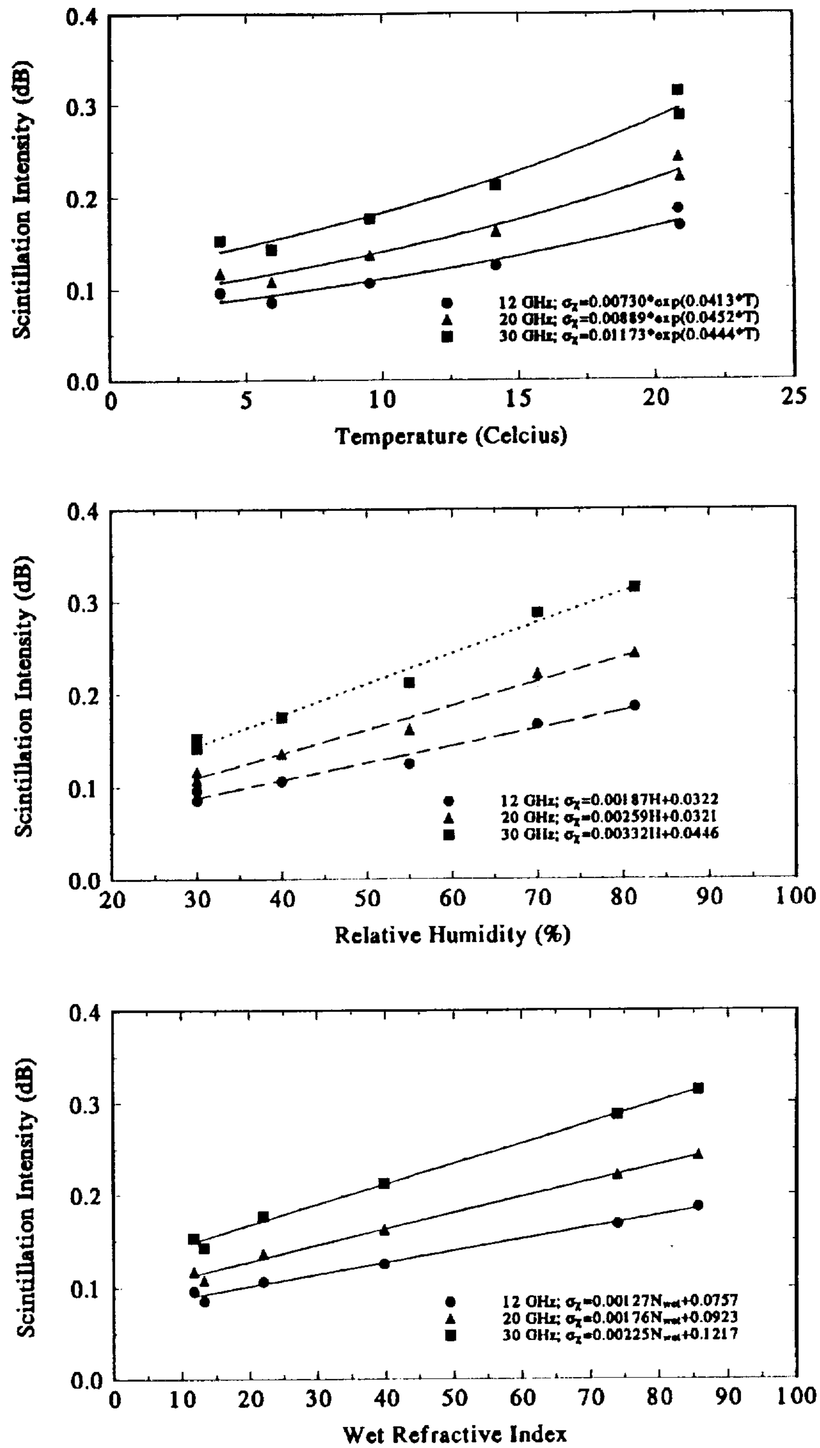
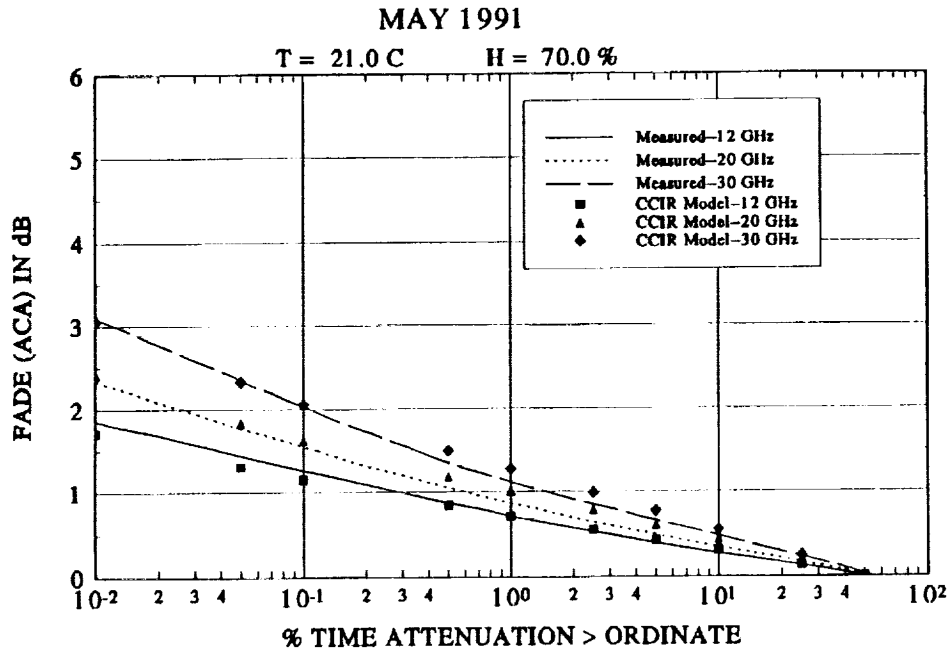
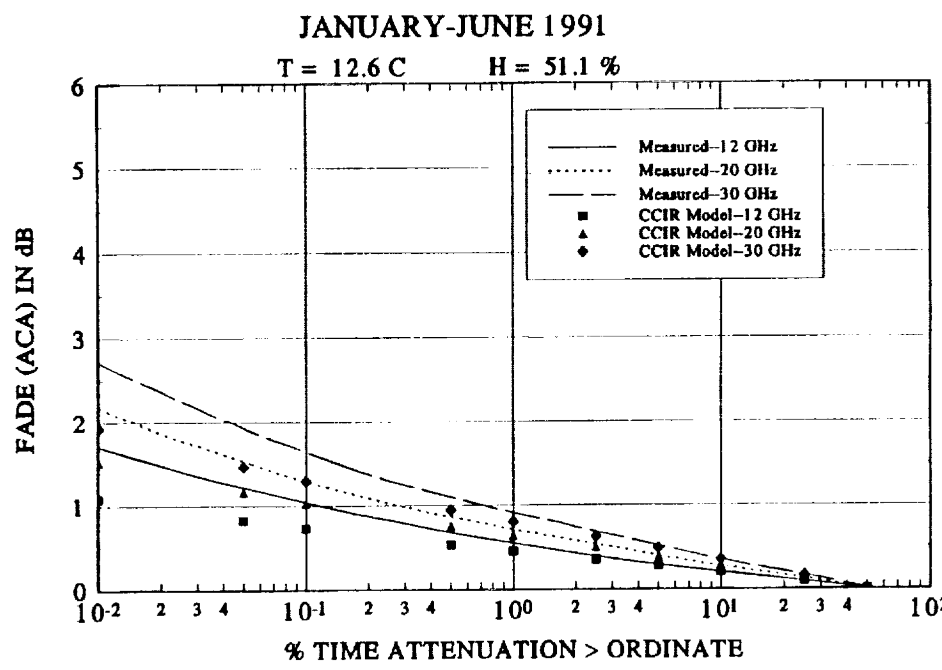


Figure 6: Scatter plot of the monthly average 12, 20 and 30 GHz scintillation intensities as a function of the monthly average of the ground temperature, ground relative humidity and ground wet refractive index for January to May 1991 and June 1992. The best fit curves and their equations are also shown.



(a)



(b)

Figure 7: Comparison of the measured 12, 20 and 30 GHz scintillation fade depths to those obtained using the CCIR model with the ground temperature and relative humidity indicated on the graph: (a) May 1991 (b) January-May 1991.

The following papers were presented at NAPEX XVII but are not available for the proceedings:

OLYMPUS EXPERIMENTS IN PORTUGAL

Jose Carlos Neves
University of Aveiro

ITELSAT PROPAGATION STUDIES

Apolonia Pawlina Bonati
Polytechnic of Milan