CHARACTERISTICS OF EARTH-SPACE PROPAGATION IN CONTINENTAL AND PACIFIC MARITIME LOCATIONS BASED ON MULTIYEAR KU AND KA BAND MEASUREMENTS

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ABSTRACT

Statistics of attenuation (multiyear, annual average, seasonal, and diurnal) are analyzed to investigate particular features associated with two different climate regimes. Interannual variability, seasonal and diurnal features, and fade duration statistics of attenuation are interpreted in terms of prevailing conditions. Important climate influences such as rain height and a strong El Niño event in 1997 are shown to play an important role in propagation behavior and prediction.

INTRODUCTION

Propagation measurements at Ka-band (20.2 and 27.5 GHz) have been conducted for several years in Vancouver and Ottawa, Canada, with beacons of the Advanced Communications Technology Satellite (ACTS), complemented with radiometric and meteorological measurements. Characteristics of both links have been published elsewhere [1]. The two locations present distinctive climatic features: Vancouver, British Columbia, located on the southern Pacific coast, experiences a maritime climate with strong orographic influences. The presence of the western mountains aligned parallel to the coast and the prevailing westerly airflow flowing off the Pacific generates rain patterns characterized by important differences in annual precipitation at locations a few kilometers apart. Heavy rain is infrequent; instead, there is a great deal of widespread drizzle and lower-rate rainfall, a good part of which falls in the winter months. The annual rainfall is about 1020 mm. Ottawa, Ontario, located in eastern Canada, experiences a continental climate with cold winters and large annual variations in temperature (about -30° C to +30° C). The average annual rainfall is about 910 mm, and snowfall about 220 cm. An average of 24 days with thunderstorms occur over a year. Convective activity is more important during the summer season.

This paper presents measurement results for both sites, identifying relevant climatic parameters, namely rain rate, monthly rain accumulation, and seasonal freezing level heights, that influence propagation characteristics and require consideration in the modeling of long-term statistics of rain-induced attenuation. Multiyear, annual average, seasonal and diurnal cumulative statistics of attenuation derived for both locations are compared to identify site-specific propagation features. Fade duration statistics measured at Ku- and Ka-band, along with modeling considerations, are presented. Five calendar years of measurements (1994-1998) are covered for Vancouver and four years (September 1997-August 2001) for Ottawa. During the measurement period, an El Niño event occurred that had an important impact on the rain regime and therefore on propagation conditions, especially along the Pacific coast of Canada [2].

LONG-TERM MEASUREMENTS AND PROPAGATION ANALYSIS

The monthly rain accumulation and long-term rain rate statistics from measurements at the Vancouver and Ottawa sites clearly reflect the different rain regimes of maritime and continental climates. Exceptional precipitation levels were recorded at Vancouver in 1997, the year of the El Niño event. Comparisons of rain rate statistics with those predicted from Rec. ITU-R P.837-2 [3] show good agreement for Ottawa but substantial discrepancies for Vancouver [1].

Freezing-level heights during rainy conditions, extracted from radiosonde data for the period 1979-1990 [4], agree fairly well with observed summer heights in maritime and continental climates computed using the expression in Rec. ITU-R P.839-1 [5]; otherwise the heights are overestimated. This result has an important consequence on rain attenuation predictions for Vancouver, where precipitation is far more important in winter months. Average freezing level heights in winter and summer seasons in the southern Pacific coast of British Columbia are about 1 and 3 km, respectively.

Annual average statistics of total attenuation at both ACTS frequencies, shown in Figs. 1a and 1b for 20 GHz, were produced from five and four years of measured data at Vancouver and Ottawa, respectively. Average seasonal statistics, shown in Figs. 2a and 2b for 30 GHz, were produced over 4 years at both sites (1997 was excluded from the seasonal analysis at Vancouver because of its exceptional impact on the results). Annual and seasonal statistics provide good insight into the behavior of attenuation in Pacific maritime and continental areas in Canada. The above-average rainfall along the Pacific coast of Canada in 1997 was strongly reflected in the statistics of attenuation for Vanvouver and significantly increased the five-year annual average fade levels. Except for 1997, interannual variability in attenuation levels was small at this site. Compared with a continental location, Vancouver exhibits lower attenuation at small time percentages and higher attenuation levels at large time percentages. The 5-year attenuation average agrees generally well with predictions using Rec. ITU-R P. 618-7 [6] even though, as mentioned above, the freezing level height used by the model is clearly too high. The impact of 1997 on the average annual statistics can explain this result. Good agreement with the 4-year average distribution (excluding 1997) was obtained using a rain height of 2 km [2]. The seasonal statistics for Vancouver (Fig. 2a) do not show important interseasonal variability, though winter shows somewhat more attenuation. In 1997 (not shown), spring experienced more attenuation. In Ottawa, important interannual variability in the average annual attenuation distributions (Fig. 1b) is observed. The 4-year average statistics at 20 and 30 GHz show generally good agreement with the ITU-R model. As expected for a continental climate, the seasonal distributions clearly show more attenuation in the summer (Fig.2b).

Average annual and seasonal diurnal distributions of 20 GHz attenuation for both sites are shown in Figs. 3 and 4. The day was divided into four periods of 6 hours each (local time). Fig. 3a displays the annual average diurnal distributions over 4-years (excluding 1997) at Vancouver. No significant difference in attenuation among the four periods is observed. In 1995 and 1997, the periods 18-24 hrs and 6-12 hrs indicate more attenuation, respectively. Diurnal statistics during the winter season at Vancouver (Fig. 4a) show a tendency of the period 0-6 hrs to exhibit somewhat higher attenuation. In Ottawa, the 4-year annual average (Fig. 3b) and summer (Fig. 4b) diurnal statistics indicate that the period 12-18 hrs displays higher attenuation in both cases.

Fade duration statistics were extracted from radiometric and beacon measurements at 20 and 27.5 GHz in Vancouver, and from 12 and 20 GHz radiometric and 20 and 27.5 GHz beacon measurements in Ottawa. A particular advantage of using radiometer data is that they are not affected by signal scintillations and do not need to be filtered to remove such fluctuations. Fig 5a displays fade duration distributions for the period 1996-1997 from radiometric measurements at 30 GHz at Vancouver for fade thresholds ranging from 2 to 10 dB. Similar distributions from radiometric measurements at Ku band at Ottawa are presented in Fig. 5b for the period 1996-1998. Several different models were used to examine the distributions of fade duration. Fade duration statistics at Ottawa derived from radiometric and beacon measurements both were satisfactorily fitted using a double-exponential function to account for short- and long-duration fades [7]-[8]. For Vancouver, results of fitting radiometric data at 20 and 30 GHz using a multiple-exponential function were not as good as for Ottawa [9]. One explanation could involve the aforementioned climate characteristics and the problem of antenna wetting affecting the antenna used in Vancouver [1].

CONCLUSIONS

Multiple years of meteorological and Ku- and Ka-band propagation data at two locations in Canada were analyzed to identify and characterize important features of earth-space propagation paths in maritime and continental climates. Important input parameters of attenuation prediction models, namely, rain rate distributions and freezing level heights, were compared with values recommended by the ITU-R. Substantial disagreement was found in the case of a Pacific maritime site, while generally good agreement was found for a continental location. Interesting particular aspects, such as the strong impact of the El Niño event on the statistics of attenuation for Vancouver, were identified. Interannual variability as well as seasonal and diurnal behavior of attenuation, linked to climatic characteristics, were presented and discussed. Analysis of fade durations at Ottawa and Vancouver indicate a climatic dependence. The use of multiple-exponential functions to model distributions of fade durations appears promising, and further work is being conducted in this area.

ACKNOWLEDGEMENTS

The contributions of G.N. Reed, T. Nguyen, and Y. Santoso to this work are greatly appreciated.

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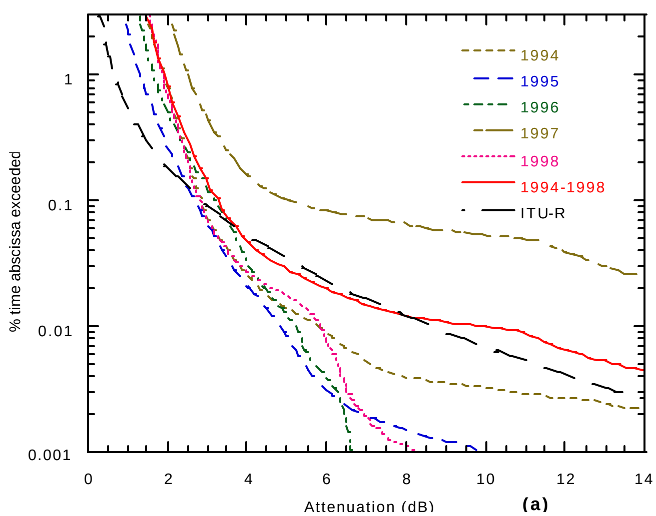


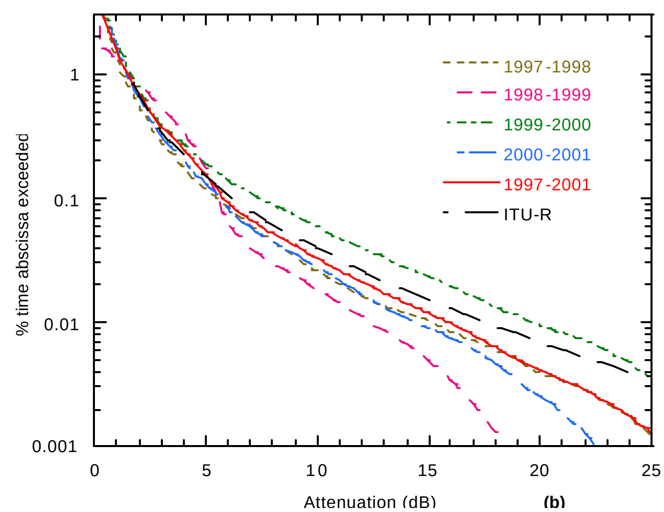
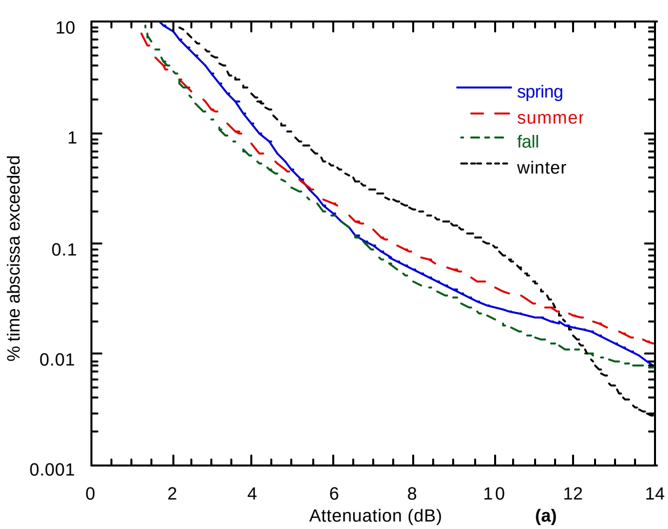


Fig. 1 Average annual cumulative distributions of total attenuation at 20 GHz at: (a) Vancouver, and (b) Ottawa



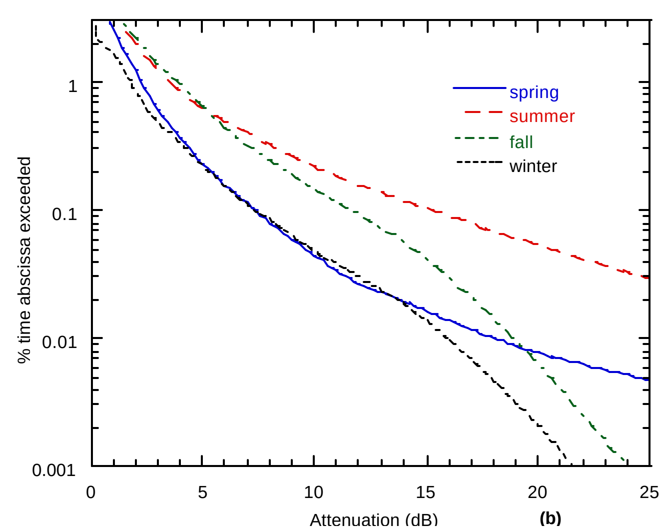


Fig. 2 Average seasonal distributions of attenuation at 30 GHz over 4 years at: (a) Vancouver, and (b) Ottawa

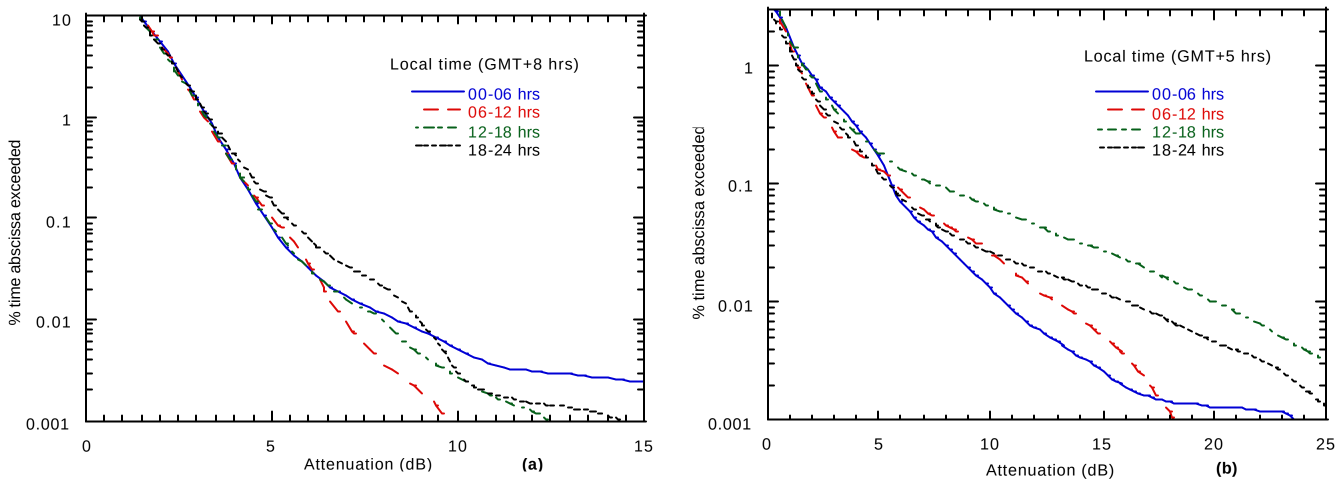


Fig. 3 Average annual diurnal distributions of attenuation at 20 GHz over 4 years at: (a) Vancouver, and (b) Ottawa

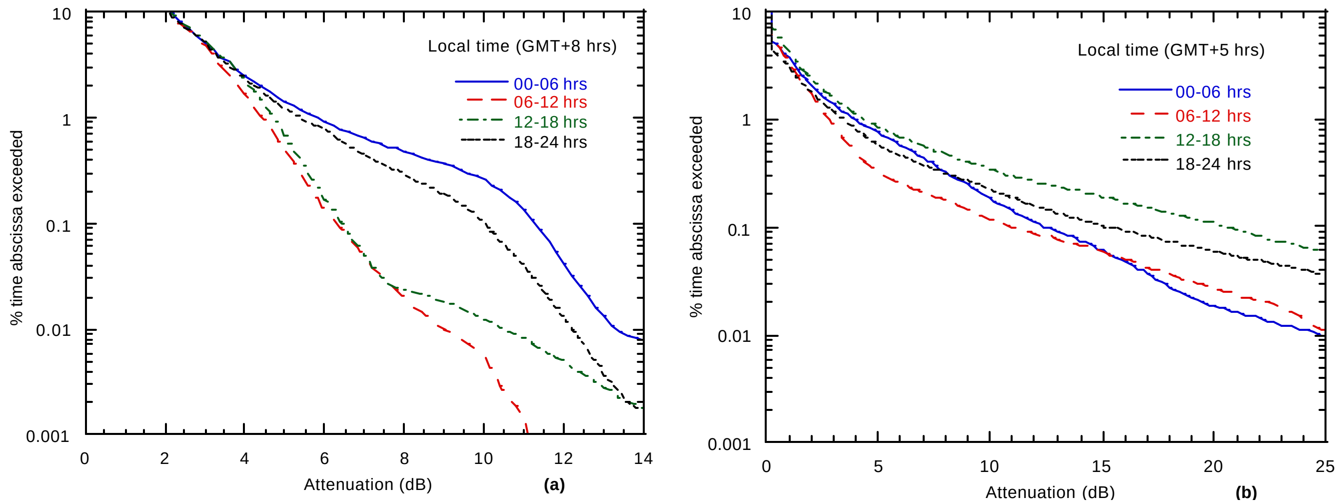


Fig. 4 Diurnal distributions of attenuation at 30 GHz over 4 years for: (a) Winter, Vancouver, and (b) Summer, Ottawa

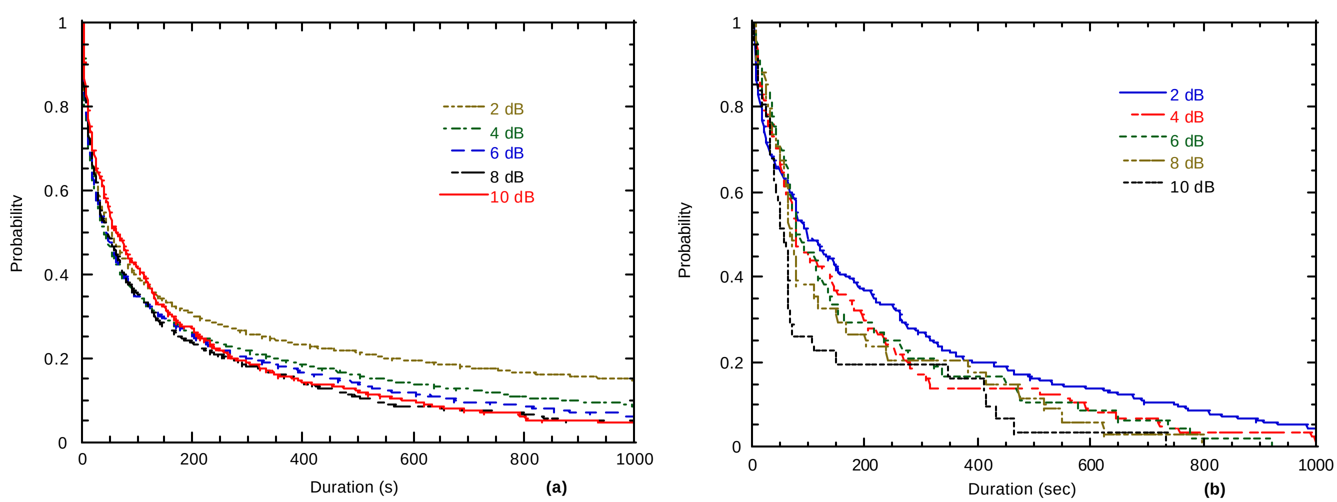


Fig. 5 Fade duration distributions from radiometric measurements at: (a) 30 GHz, Vancouver, and (b) 12 GHz, Ottawa