PRELIMINARY RESULTS OF TWO SITE DIVERSITY EXPERIMENTS IN TROPICAL REGIONS

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1. Introduction: High capacity satellite systems must achieve stringent availability requirements with allowable outages being usually less that 0.017% of a year. In the 14/11 GHz bands, significant outages can occur due to rain attenuation and, in severe rain climates, site diversity systems may be required to obtain the necessary availability. INTELSAT, with its unique global commitment, has been undertaking microwave propagation research for over a decade [1] in order to establish reliable propagation impairment models. In two important areas, insufficient data are available to produce accurate models: the first is slant path attenuation in tropical regions and the second is site diversity modelling. In order to overcome this lack of data, INTELSAT has begun to conduct site diversity experiments in tropical regions. This summary reports the preliminary results of the first two tropical site diversity experiments.

2. Description of Experiments: Both experiments were located in tropical regions on the borderline between rain climates N and P; the first was at Iquitos in the Amazonian region of Peru and the second was on the north-eastern shores of Queensland, Australia, near the towns of Innisfail and Cowley Beach. Two, 11.6 GHz radiometric receivers were deployed in both experiments together with appropriate meteorological measuring equipment. In addition, a 30/20 GHz radiometer was co-located with the 11.6 GHz mainstation in Iquitos and four 7 GHz radiometers co-located with the 11.6 GHz mainstation at Cowley Beach. Only the 11.6 GHz data are considered in this paper.

2.a. Peru Site: Figure 1 shows the geographical layout of the two sites and their immediate surroundings. The radiometers were similar to others deployed in earlier INTELSAT experiments [2] with the exception that an AIL-777 receiver was used as the radiometric receiver. The antennas were 2 m diameter, front-fed parabolas with 1° beamwidths. The mainstation was located at Iquitos, within the domestic earth station complex of ENTEL-Peru, while the outstation was at Indiana approximately 30 km away. Tipping bucket raingauges were located at both sites and a VHF radio was used as the telemetry link between the sites. Chart recorders were employed at both sites but the primary recording equipment was a digital Data Acquisition System (DAS) at the mainstation.

The DAS accepted both analog and digital data and stored the information in cartridge form. These cartridges were returned to INTELSAT for editing and subsequent data processing and analysis. ENTEL-Peru were contracted to run the experiment in Iquitos and Indiana.

2.b. Australian Site: Figure 2 gives the location of the two sites in Queensland. Again, two 11.6 GHz radiometers were deployed which were of a similar type to those used in Peru. The mainstation was at Cowley Beach in the grounds of the Joint Tropical Trials and Research Establishment of the Defense Research Centre (DRC) Adelaide. Co-located with the 11.6 GHz INTELSAT radiometer were four 7 GHz radiometers which were being operated by James Cook University for the Communications Systems Engineering Branch of the DRC. James Cook University were also contracted to run the INTELSAT experiment as well as to provide edited data tapes.

3. Data Analysis Procedures: The radiometer calibrations, performed approximately every two weeks, establish a "hot" reference temperature (approximately 343 K) and a "cold" reference temperature (approximately 80 K). Prior calibrations have established the linearity of the receivers. The radiometer output voltage can therefore be readily converted to a measured antenna temperature after taking due precautions for the non-perfect antenna sidelobes and antenna feed characteristics. The antenna temperatures, Ta, is then converted into a path attenuation, A, with the radiometer equation:

$$A = 10 \log [Tm/(Tm-Ta)] \quad dB \qquad (1)$$

where Tm is the effective temperature of the absorbing medium.

4. Preliminary Results: The two experiments have not been operating long enough to establish a statistically valid data base. Some interim results are available, however, and these are discussed below.

4.a. Peru Experiment: A number of significant events have been recorded and seven of them were arbitrarily selected for the preliminary statistical evaluation. The convective storms typically occurred in the late evening hours, with rain rates of over 30 mm/h lasting for periods of up to 10 minutes. The 12 GHz noise temperature exceeded 200 K for an average of 10 minutes per storm. The time-shift between the peak sky noise values of the remote and the central site was 1 hour on average which corresponds to a translation velocity of about 30 km/h. This is on the low side of comparable mid-latitude thunderstorm velocities which can exceed 50 km/h. Typically, the remote site (Indiana) located further north-east was the first one to encounter a convective rainstorm. The plot in Figure 3 shows the 11.6 GHz diversity gain versus the main single attenuation using the Hodge presentation [3]. To calculate the attenuation, a value of 293 K was assumed for Tm in Equation [1]. Later analysis will incorporate a surface temperature relationship to Tm in order to provide a more accurate estimate of Tm. Since the seven events presented were summer thunderstorms, a high value of Tm was assumed. It is anticipated, that due to wide-spread rain, the final results will be somewhat more conservative in the 3 to 5 dB single site fading region, but no significant changes are expected for the high end of the attenuation range.

The 20/30 GHz radiometers were well into saturation at the peak rain rates of the corrective storms, but, at lower rain rates, the frequency scaling of attenuation can be verified and used for calculating the attenuation at low percentages of time.

4.b. Australia Experiment: The experiment started in July 1984 and, due to the dry season, did not encounter any rain events causing fading above 3 dB to occur until October 1984. Insufficient deep-fade events were available at the time this manuscript was prepared for a statistical analysis. However, extensive testing of the hardware configuration during this period has ensured that, with the start of the wet season, a highly reliable result will be obtained.

5. Conclusions: The preliminary results from Peru would indicate that good site diversity performance can be achieved in the tropics, as expected, but that the diversity offset is larger than anticipated. This may be a feature of the horizontal size of the severe rain storms, their translational velocity, or both. Further analysis is continuing.

6. References

1. J.E. Allnutt: "The INTELSAT Propagation Measurements Programme", ICAP 81, IEE Conf. Publ., 195, Part 2, pp. 46-53.

2. D.V. Rogers: "Diversity- and single-site Radiometric Measurements of 12 GHz Rain Attenuation in Different Climates", ibidem, pp. 118-123.

3. D.B. Hodge: "An Empirical Relationship for Path Diversity Gain," IEEE Trans. AP-24, 1976, pp. 250-251.

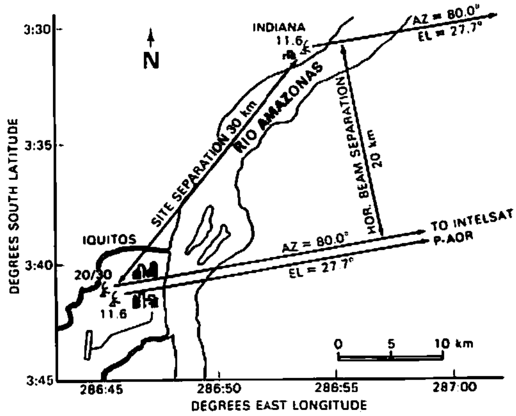

Fig. 1: Geographical layout of the IQUITOS (Peru) experiment.

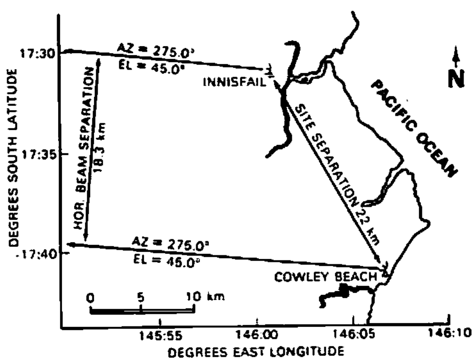

Fig. 2: Geographical layout of the COWLEY BEACH (Australia) experiment.

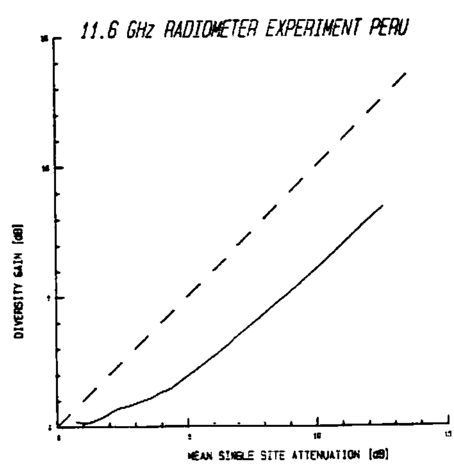

Fig. 3: Diversity gain vs. Mean single site Attenuation.