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on Semiconductor and Electronics, Information and Communications Technology and Energy

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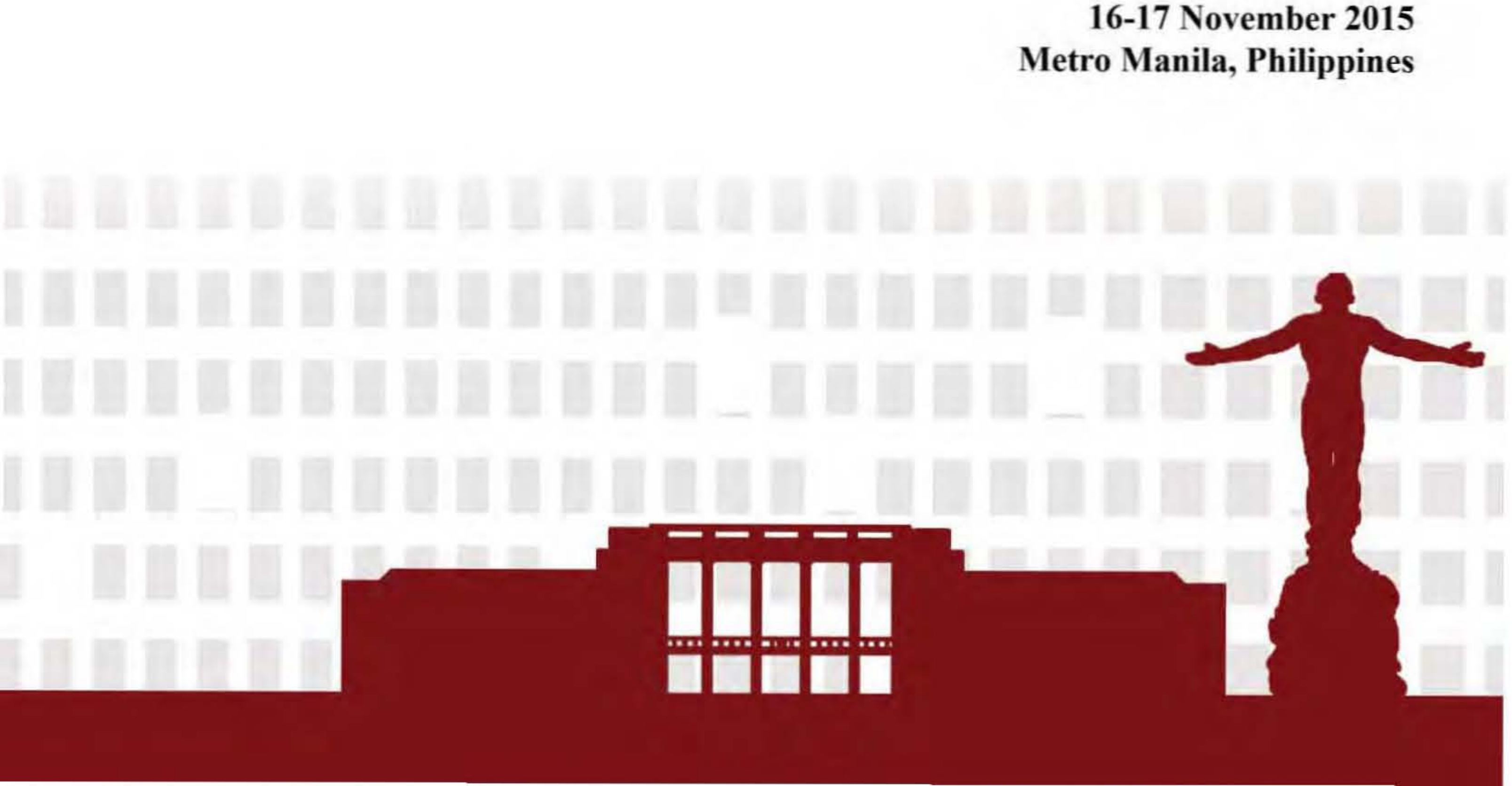

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ESTABLISHING CLEAR-SKY LEVELS ON GEOSTATIONARY SATELLITE LINKS

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ABSTRACT

Links between a geostationary satellite and a terminal on the ground are subject to changes in signal level with varying timescales. Assuming an extremely stable earth terminal, short-term variations, on the order of seconds in duration, are typically due to tropospheric scintillation; longer-term variations, on the order of many minutes, may be due to satellite instabilities (e.g. non-precise station-keeping and antenna pointing) and attenuation due to particulates in the atmosphere, the most important of which is rain; even longer-term variations, with periodicities on the order of days, seasons, and years, are due both to variations in the length (and constituents), along the path through the atmosphere, and the cyclical motion of the Earth-moon system and planets orbiting the sun. This research does not address tropospheric scintillation, even though it can be thought of as a clear-air phenomenon, and rain attenuation: both are well modelled in most climate regions [1]. The focus is to address the other phenomena that can change the clear-sky level on a geostationary satellite-to-ground link. Previous experiments in Papua New Guinea which used co-located radiometer and satellite beacon receivers, detected diurnal and seasonal variations in the received satellite beacon signal level during clear sky that suggested the atmosphere played a role in the signal variation. This research found additional evidence in several time series satellite propagation data collected from sites in North America and Brazil.

These propagation databases contain time series data of the received signal level from geostationary satellite beacons together with inferred attenuation from co-located radiometer directed along the same path. Some databases also contain meteorological time series data collected at or near the receiver. Upon investigation, the time data plot of the received beacon signal level and inferred attenuation from the radiometer contained concomitant seasonal as well as diurnal variations. Results from three different spectral estimation techniques showed that the diurnal variation detected in the beacon and radiometer were both of a solar day periodicity. This showed that solar heating effects are driving the diurnal variation observed, and that they are not satellite induced. There is also a general trend of decreasing solar tidal effect as the climate becomes less warm and humid. The only site that did not show evidence of a solar day variation was in Fairbanks, Alaska from the ACTS database. This site is both the coldest, and has the lowest elevation angle. Other possible causes of variations in received beacon level such as front end instabilities, as well as a possible noise contribution from the antenna side lobes, were found to be untenable.

In some warmer and more humid sites, a sidereal and anti-sidereal peak was also detected to the right and left of the solar peak, respectively. These side peaks are found mainly in cosmic ray research. They are generated when a daily solar variation is amplitude modulated by a seasonal variation of one cycle/year, producing sidebands at the sidereal and anti-sidereal frequencies, as shown in Fig.1. The seasonal variation detected in both the ACTS and Texas database were closely estimated using the gaseous attenuation model provided in the ITU recommendation P676-9. This calculation uses meteorological values such as averages of pressure, temperature and humidity together with the earth station's elevation angle with respect to the satellite, to calculate attenuation along the path in clear sky. From the result of the simulation we were able to identify as well as quantify the sources of the mean clear sky variation. The seasonal variation was highest in Alaska, with more than a 3dB difference between the maximum detected in summer and minimum detected during winter, as shown in Fig.2 [2]. For a Ku-band VSAT system that is designed to operate with a 7 dB margin, a change of 3 dB in just clear sky conditions is significant.

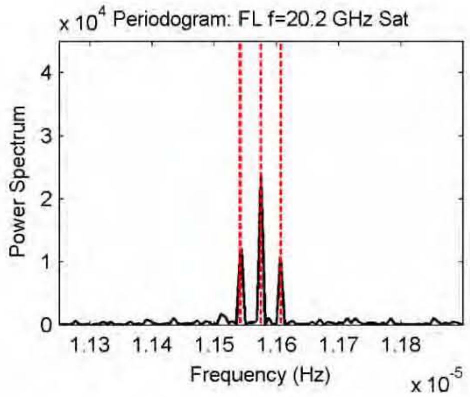

Figure 1. Periodogram result for Florida at 20.2GHz

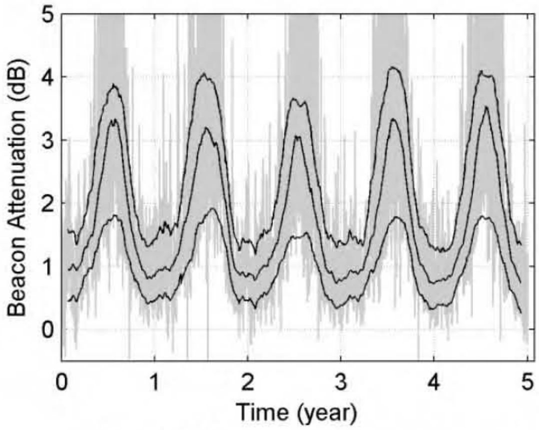

Figure 2. Variations in received beacon attenuation for 5 years in. Middle line is the average beacon attenuation.

Factors that contribute to the existence of atmospheric tides, and procedures that can help limit these effects in measuring clear-sky mean levels were also proposed.

Keywords: Satellite communications, clear-sky level, path attenuation, diurnal effects, seasonal effects, annual effects, sidereal and anti-sidereal effects.

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[1] *Propagation data and prediction methods required for the design of Earth-space telecommunication systems*, ITU-R Recommendation P.618-11, September 2013

[2] N. Mohamed Shah, "Establishing Clear-Sky Mean Signal Levels on Geostationary Satellite Links", PhD dissertation, George Mason University, 2014