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Performance of Time Diversity Technique in Heavy Rain Region

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***Abstract* – Satellite communication systems operating at frequencies above 10 GHz are often subject to deep fades due to rain attenuation. One of the cost-effective countermeasures that can be used to counteract severe rain attenuation is time diversity. In this paper, performance of time diversity is investigated based on a one-year, Ku-band propagation measurement campaign carried out in heavy rain region. The results found show that the diversity gain increases as a function of time delay. The performance of time diversity is compared with prediction obtained by applying the Stratiform Convective-Synthetic Storm Technique (SC-SST) and a good agreement with measured statistics has been found.**

***Index Terms* — Diversity gain, Heavy rain region, Rain attenuation, Time diversity**

I. Introduction

In the past decade, the continue demand for huge data rate to support multimedia services such as high quality real-time audio and video streaming in telecommunication systems has led to the usage of frequencies higher than 10 GHz. Such frequency bands are able to provide larger bandwidths and higher data rates to the users. Unfortunately, at these frequency bands, heavy precipitation will severely degrade the performance of satellite communication system particularly in tropical and equatorial regions. Various Propagation Impairment Mitigation Techniques (PIMTs) exist to cope with deep fades, such as power control, signal processing and diversity techniques [1]. Among these techniques, time diversity appears to be a simple viable choice [2]. The main advantages of this technique are low and effectiveness in compensating fades.

Time diversity technique works by retransmitting the same information, with suitable time delay between successive transmissions. As a result, the receiver is able to collect and use the information gathered during good propagation conditions [2] and so it is suitable for certain application like video-on-demand, email, data transfer process that do not require real time communication [3].

The performance of time diversity technique can be evaluated through several methods. The most direct method is to carry out a measurement campaign to collect the received signal [3]. The second approach is through simulation on weather radar maps [2] and the third approach is based on modeling (i.e. Synthetic Storm Technique (SST) [4]). Up to date, only few data has been presented using direct measurements particular in equatorial region [5]. This work investigates the performance of time diversity in an equatorial site based on measured rain attenuation. To this purpose, one year of slant path attenuation measurements collected at Universiti Teknologi Malaysia (UTM), Malaysia is exploited. The measured results are compared against prediction model.

II. Time Diversity Technique And SC-SST

The time diversity technique makes use of the rain characteristic that it has limited time duration (i.e. rain will eventually stop); it is a countermeasure that works by retransmitting the information when the state of channel propagation is favorable [3]. The receiver selects either the current received signal or the delayed replica, whichever the best. Performance of time diversity technique is quantified by the diversity gain $G(P) = A_0(P) - A_\Delta(P)$ where $A_0(P)$ is the level of attenuation that is exceeded with probability P in a system that does not use diversity, and $A_\Delta(P)$ is the same quantity in a system that implements diversity (with a time lag, T_d) [2, 4].

In this work, Stratiform Convective-Synthetic Storm Technique (SC-SST) is used to simulate time series of rain attenuation at 12.2 GHz with slant path elevation angle of 75.61^0. SC-SST is a technique that is used to transform time series of rainfall rate into time series of rain attenuation by means of separately considering stratiform and convective events in the estimation of rain attenuation. Further details are explained in [6]. The results obtained from SC-SST are compared against measured statistics and the results discussed in Section III.

III. Results And Discussions

One of the major motivation of time diversity technique is the fact that most of the rain events have limited time span. It is reported that 64% of total rain events in heavy rain regions like Malaysia are convective [6] whose associated rain is often characterized by short duration and extreme intensity. Fig. 1 shows the cumulative distribution function (CDF) $P(A)$ of rain attenuation, defined as $P(A) = P[(A_0 \text{ and } A_\Delta) > A]$

where A_0 is attenuation at time lag zero and A_Δ at time lag T_d. Each curve correspond to a different value of time delay, T_d; the red solid line (T_d=0) correspond to measured attenuation distribution without the application of time diversity. It is found that as the time delay increases, the attenuation level exceed for a given percentage of time significantly decreases. For instance, at 1% of probability, the attenuation without the use of time diversity technique is 10.11 dB; if the time diversity technique is adopted, the attenuation value is reduced to 9.18, 7.22, 5.7, 3.77 and 2.58 dB for time delays of 1, 5, 10, 20 and 30 min respectively; this also correspond to diversity gain of 0.93, 2.89, 4.41, 6.34 and 7.53 dB respectively.

Performance of time diversity can be quantified through the diversity gain. Fig. 2 depicts diversity gain as a function of attenuation, A. It is worth noting that the gain increases for increasing value of attenuation. This is due to the fact that high-intensity (i.e. high attenuation) rain events tend to have shorter duration as compared to low-intensity rain events, and this may contribute to better performance in countermeasure [2]. A comparison with SC-SST is also shown in Fig. 2 for time delay 1, 10 and 30 min. The performance was found to be good especially at 1 and 30 min time lag. In addition, Fig. 3 shows the comparison of relative diversity gain (defined in [2]) between measurement and SC-SST predictions for attenuation thresholds of 2 and 4 dB. Once again, the predicted and measured relative diversity gain are in excellent agreement despite the slightly underestimation at attenuation of 4 dB. It can also be noted that the relative gain curve is steeper for short time lags (up to 10 min) and its tend to saturate for longer time delays (i.e. more than 20 min). This could be due to the fact that time diversity reaches its efficiency limit for longer time delays [3].

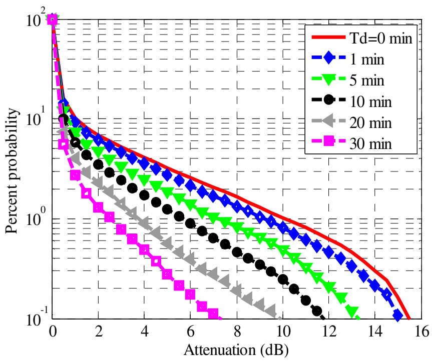

Fig. 1. Normalized probability that the value of attenuation is exceeded as a function of time delay.

IV. Conclusion

This work investigated the performances of time diversity technique in mitigating rain attenuation for Ku-band satellite systems in an Equatorial (heavy rain) region. Time diversity appears to be a powerful technique if the time delay is wisely chosen, taking advantage of local characteristics of rain attenuation (i.e. higher intensity and shorter duration of raining events). The results obtained are based on one year measurement campaign. As expected, the diversity gain increases for increasing values of time delay and attenuation threshold. In addition, the performances of time diversity as predicted by the SC-SST have been compared against the measurements. The results were found to be good for over the entire percentage of relative diversity gain. As a matter of fact, it could be a viable option to use SC-SST technique in predicting time diversity performances particularly in heavy rain areas when the directly measured data are not readily available.

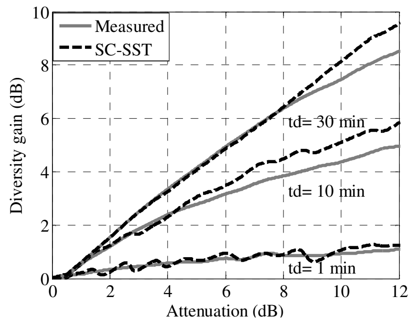

Fig. 2. Diversity gain as a function of rain attenuation. Comparison between measurements (solid lines) and SC-SST (dashed lines).

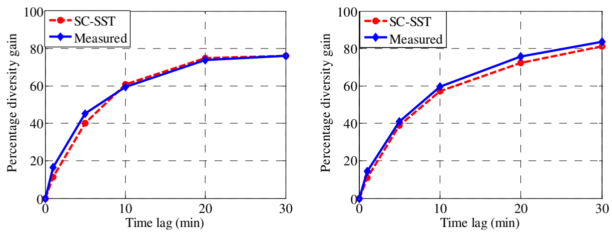

Fig. 3. Comparison of relative diversity gain as a function of time lag between measurements and SC-SST for 2 dB (left) and 4 dB (right) of attenuation threshold.

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