Communications systems operating at frequencies above 10 GHz suffer from severe attenuation due to rain, clouds and atmospheric gases, though rain is the dominant factor responsible for most of the time-variant fading experienced. Systems currently in operation deal with this problem by allocating a fixed fade margin. However, for higher frequencies this is economically unfeasible as the fade margin required to provide a set quality of service becomes too high. For this reason, much attention is being paid to methods of dealing with fades on an adaptive and reactive basis. Such methods are collectively known as Fade Mitigation Techniques (FMTs). One FMT, which concerns the (time-variant) two dimensional distribution of the precipitation rate $R(x,y,t)$ (mm/h), is called Space Diversity.

**Application of fractal rain fields to radio systems**

Space diversity in a satellite system (also known as site diversity) employs two or more ground stations receiving the same satellite signal with a separation distance sufficiently large so that the rain at the two sites is de-correlated. The sites, in a properly configured arrangement, encounter intense rainfall at different times, and switching to the site experiencing the least fading improves system performance considerably.

To properly configure such a system requires knowledge of the temporal and spatial variations in rain fields, information which can be provided through a number of methods, including fractal techniques.

Fractal analysis of rain fields also leads us to the use of fractal methods to simulate visually and statistically realistic rain fields. These can then be used by systems designers in place of the expensive and difficult to obtain radar measurements of rain fields in order to test their proposed systems before deployment. The simulated rain fields presented here have been used in this context, in a case study of a switching algorithm for a two site Earth-space system using site diversity as a FMT, and in a project investigating the implementation of Adaptive Transmit Power Control (ATPC) on terrestrial links for bands above 18GHz.

**Mono- versus multi-fractal analysis for communications system design**

Most fractal models of rain are multi-fractal and include times/areas where no rain actually occurs. However, a simplified fractal model of rain suitable for communications engineering purposes can be created by only considering the times when it is raining, and modelling log rain rate rather than rain rate.

Multi-fractal analysis of rain rate fields shows a $K(q)$ function that is curved, a characteristic of multi-fractal fields. However, multi-fractal analysis of log rain rate fields shows $K(q)$ functions that can be approximated by straight lines, meaning that monofractal methods may be used to accurately describe them.

**Rain field simulator**

The rain field simulator is based on the Voss [1985] successive random additions algorithm for simulating fractional Brownian motion. It is an additive discrete cascade process and produces a monofractal field in the log-ratio domain.

The key parameters are the Hurst exponent $H$, which determines the fractal dimension of the simulated field and the lacunarity $r_l$ (equivalent to the cascade branching number) which determines whether the simulated fields are monofractal-like or convective-like.

**Conclusions and Further Work**

Multi-fractal analysis of rain rate and log rain rate fields shows that log rain rate fields can be approximated as monofractals. This provides a justification for using a discrete cascade method of simulating rain fields which is based on a monofractal, additive process in the log-ratio domain.

The algorithm for simulating rain fields used in this research produces synthetic fields that are visually and statistically realistic, with the same fractal dimension, power spectral density and autocorrelation functions as measured rain fields. These simulated fields can be applied to systems design in order to test the dynamic behaviour of a system on an event-by-event basis, without the need for costly rain rate measurements.

Further work with the simulated fields in on-going as part of a project to identify the spectrum efficiency gains resulting from the implementation of Adaptive Transmit Power Control (ATPC) on terrestrial links for bands above 18GHz. This project also evaluates the effectiveness of fractally simulated rain fields compared with measured rain fields, when applied to a communications engineering problem.

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