Marcio Eduardo da Costa Rodrigues

**Synthesis of rain attenuation time series
for Earth-space paths in tropical and
equatorial areas**

Tese de Doutorado

Thesis presented to the Postgraduate Program in Electrical Engineering of the Departamento de Engenharia Elétrica, PUC-Rio as partial fulfillment of the requirements for the degree of Doutor em Engenharia Elétrica.

Advisor: Luiz Alencar Reis da Silva Mello
Co-Advisor: Laurent Castanet

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Abstract

Rodrigues, Marcio Eduardo da Costa; Silva Mello, Luiz Alencar Reis (Advisor); Castanet, Laurent (Co-Advisor). **Synthesis of rain attenuation time series for Earth-space paths in tropical and equatorial areas**. Rio de Janeiro, 2010. 214 p. Doctoral Thesis – Departamento de Engenharia Elétrica, Pontifícia Universidade Católica do Rio de Janeiro.

Rain attenuation time series synthesizers constitute an important resource to the design, test and optimization of Fade Mitigation Techniques (FMTs). In the absence of experimental propagation data for every possible Earth-Space configuration, the synthesis of rain attenuation time series becomes an interesting solution to allow for the reproduction of the long-term dynamic characteristics of rain attenuation. In this thesis, channel models able to synthesize long- and short-term rain attenuation periods are discussed, tested and validated for the Brazilian tropical and equatorial climates. Critical issues determining the correct behavior of such time series generators are analyzed and their range of validity is presented.

Keywords

Time series synthesizers; channel models; radio-propagation modeling; stochastic models; satellite communication.

Resumo

Rodrigues, Marcio Eduardo da Costa; Silva Mello, Luiz Alencar Reis (Orientador); Castanet, Laurent (Co-Orientador). **Síntese de séries temporais de atenuação por chuva para enlaces Terra-espço em áreas tropicais e equatoriais**. Rio de Janeiro, 2010. 214 p. Tese de Doutorado – Departamento de Engenharia Elétrica, Pontifícia Universidade Católica do Rio de Janeiro.

Sintetizadores de séries temporais de atenuação por chuva constituem um importante recurso para o projeto, teste e otimização de Técnicas de Mitigação de Desvanecimento. Como dados experimentais de propagação não estão disponíveis para todas as configurações possíveis de enlaces Terra-espço, a síntese de séries temporais de atenuação por chuva torna-se uma solução interessante, permitindo a reprodução das características dinâmicas de longa duração da atenuação pela chuva. Nesta tese de doutorado, modelos de canal capazes de sintetizar períodos curtos e longos de atenuação por chuva são analisados, testados e validados para os climas tropical e equatorial brasileiros. Aspectos críticos que determinam o correto comportamento destes geradores de séries temporais são analisados e sua faixa de validade é apresentada.

Em regiões de clima tropical e equatorial, o desenvolvimento insuficiente da estrutura de telecomunicações terrestre e, por vezes, a necessidade de vencer distâncias continentais, amplificam a necessidade de implementação de sistemas de comunicação por satélite no médio prazo. Tais sistemas apresentam a vantagem de servir grandes áreas com curto tempo de implantação e a possibilidade de atingir mercado considerável. Para as novas aplicações, fortemente focadas em conteúdo multimídia para consumidores corporativos e residenciais, a banda C não é atraente porque o desenvolvimento de novos sistemas com pequenos terminais, como desejado, é incompatível com as grandes antenas necessárias para a proteção dos sistemas existentes nesta banda.

Para o fornecimento de serviços multimídia a altas taxas é previsto o uso da banda Ka. Problemas de propagação são severos nestas altas faixas de frequência de forma que figuras de mérito padrão para desempenho e disponibilidade são

difíceis de ser obtidas em regiões climáticas tropicais e equatoriais. Por esta razão, metodologias tradicionais de cálculo de enlaces, que levam ao uso de altas margens fixas não são as mais indicadas. Lança-se mão de Técnicas de Mitigação de Desvanecimento (*Fade Mitigation Techniques*, FMT).

No projeto e otimização de FMTs, o conhecimento do comportamento dinâmico do canal de radiopropagação é necessário. Objetivando preencher este requisito, são usadas séries temporais de atenuação por chuva nas simulações de sistema. Porém, séries temporais experimentais não estão disponíveis em nível global em todas as frequências e inclinações de enlace desejadas, para que se projete e teste FMTs. Portanto, a alternativa ao uso de séries experimentais é a geração (sintetização) de séries temporais de atenuação por chuva fazendo uso de características climatológicas bem como de parâmetros geométricos e de propagação relativos ao enlace.

Neste trabalho, modelos de canal baseados na abordagem original de Maseng e Bakken são testados com dados de *beacon* em 11,5 GHz (banda Ku), medidos em quatro localidades Brasileiras, representativas de climas tropical, subtropical e equatorial. Ainda, um modelo misto usando cadeias de Markov e um modelo, já existente, gerador de eventos de atenuação por chuva sob demanda é proposto e analisado.

Validação é realizada por meio de variáveis de teste propostas pela ITU-R e também pela análise da fidelidade que características específicas dos eventos sintetizados possuem em relação às características de eventos reais medidos.

Palavras-chave

Sintetizadores de séries temporais; modelos de canal; modelagem de rádio-propagação; modelos estocásticos; comunicação por satélite.

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