International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R P.1853

(10/2009)

Tropospheric attenuation time series synthesis

P Series

Radiowave propagation

International Telecommunication Union

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

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Series of ITU-R Recommendations

(Also available online at http://www.itu.int/publ/R-REC/en)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	Mobile, radiodetermination, amateur and related satellite services
P	**Radiowave propagation**
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
V	Vocabulary and related subjects

Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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RECOMMENDATION ITU-R P.1853

Tropospheric attenuation time series synthesis

(2009)

Scope

This Recommendation provides methods to synthesize rain attenuation and scintillation for terrestrial and Earth-space paths.

The ITU Radiocommunication Assembly,

considering

a) that for the proper planning of terrestrial and Earth-space systems it is necessary to have appropriate methods to simulate the time dynamics of the propagation channel;

b) that methods have been developed to simulate the time dynamics of the propagation channel with sufficient accuracy,

recommends

1 that the method given in Annex 1 should be used to synthesize the time series of rain attenuation for terrestrial or Earth-space paths;

2 that the method given in Annex 1 should be used to synthesize the time series of scintillation for terrestrial or Earth-space paths.

Annex 1

1 Introduction

The planning and design of terrestrial and Earth-space radiocommunication systems requires the ability to synthesize the time dynamics of the propagation channel. For example, this information may be required to design various fade mitigation techniques such as, *inter alia*, adaptive coding and modulation, and transmit power control.

The methodology presented in this Annex provides a technique to synthesize rain attenuation and scintillation time series for terrestrial and Earth-space paths that approximate the rain attenuation statistics at a particular location.

2 Rain attenuation time series synthesis method

2.1 Overview

The time series synthesis method assumes that the long-term statistics of rain attenuation is a log-normal distribution. While the ITU-R rain attenuation prediction methods in Recommendation ITU-R P.530 for terrestrial paths and Recommendation ITU-R P.618 for Earth-space paths are not exactly log-normal, these rain attenuation distributions are well-approximated by a log-normal distribution over the most significant range of exceedance probabilities. The terrestrial and Earth-space rain attenuation prediction methods predict non-zero rain attenuation for exceedance probabilities greater than the probability of rain; however, the time series synthesis method adjusts the attenuation time series so the rain attenuation corresponding to exceedance probabilities greater than the probability of rain is 0 dB.

For terrestrial paths, the time series synthesis method is valid for frequencies between 4 GHz and 40 GHz and path lengths between 2 km and 60 km.

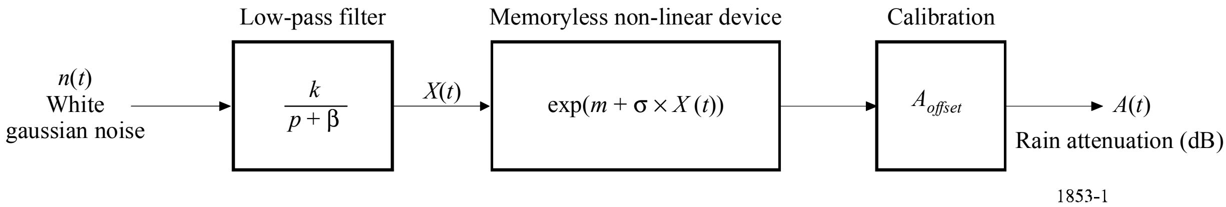
For Earth-space paths, the time series synthesis method is valid for frequencies between 4 GHz and 55 GHz and elevation angles between 5º and 90º.

The time series synthesis method generates a time series that reproduces the spectral characteristics, fade slope and fade duration statistics of rain attenuation events. Interfade duration statistics are also reproduced but only within individual attenuation events.

As shown in Fig. 1, the rain attenuation time series, $A(t)$, is synthesized from the discrete white Gaussian noise process, $n(t)$. The white Gaussian noise is low-pass filtered, transformed from a normal distribution to a log-normal distribution in a memoryless non-linearity, and calibrated to match the desired rain attenuation statistics.

FIGURE 1

Block diagram of the rain attenuation time series synthesizer



The time series synthesizer is defined by five parameters:

m: the mean of the log-normal rain attenuation distribution

σ: the standard deviation of the log-normal rain attenuation distribution

p: probability of rain

β: a parameter that describes the time dynamics

A_{offset}: an offset that adjusts the time series to match the probability of rain.

2.2 Step-by-step method

The following step-by-step method is used to synthesize the attenuation time series $A_{rain}(kT_s)$, $k = 1, 2, 3, ...$, where T_s is the time interval between samples, and k is the index of each sample.

A *Estimation of m and σ*

The parameters m and σ are determined from the cumulative distribution of rain attenuation vs. probability of occurrence. Rain attenuation statistics can be determined from local measured data, or, in the absence of measured data, the rain attenuation prediction methods in Recommendation ITU-R P.530 for terrestrial paths and Recommendation ITU-R P.618 for Earth-space paths can be used.

For the path and frequency of interest, perform a log-normal fit of rain attenuation vs. probability of occurrence as follows:

Step A1: Determine P^{rain} (% of time), the probability of rain on the path. P^{rain} can be well approximated as $P_0(Lat,Lon)$ derived in Recommendation ITU-R P.837.

Step A2: Construct the set of pairs $[P_i, A_i]$ where P_i (% of time) is the probability the attenuation A_i(dB) is exceeded where $P_i \le P^{rain}$. The specific values of P_i should consider the probability range of interest; however, a suggested set of time percentages is 0.01, 0.02, 0.03, 0.05, 0.1, 0.2, 0.3, 0.5, 1, 2, 3, 5, and 10%, with the constraint that $P_i \le P^{rain}$.

Step A3: Transform the set of pairs $[P_i, A_i]$ to $\left[Q^{-1}(P_i), \ln A_i\right]$,

where:

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} e^{-\frac{t^2}{2}} \mathrm{d}t \qquad (1)$$

Step A4: Determine the variables $m_{\ln A_i}$ and $\sigma_{\ln A_i}$ by performing a least-squares fit to $\ln A_i = \sigma_{\ln A_i}\, Q^{-1}(P_i) + m_{\ln A_i}$ for all i. The least-squares fit can be determined using the "Step-by-step procedure to approximate a complementary cumulative distribution by a log-normal complementary cumulative distribution" described in Recommendation ITU-R P.1057.

B *Low-pass filter parameter*

Step B1: The parameter $\beta = 2 \times 10^{-4}$ (s^{-1}).

C *Attenuation offset*

Step C1: The attenuation offset, A_{offset} (dB), is computed as:

$$A_{offset} = e^{m + \sigma Q^{-1}\left(\frac{P^{rain}}{100}\right)} \qquad (2)$$

D *Time series synthesis*

The time series, $A_{rain}(kT_s)$, $k = 1, 2, 3, \ldots$ is synthesized as follows:

Step D1: Synthesize a white Gaussian noise time series, $n(kT_s)$, where $k = 1, 2, 3, \ldots$ with zero mean and unit variance at a sampling period, T_s, of 1 s.

Step D2: Set $X(0) = 0$

Step D3: Filter the noise time series, $n(kT_s)$, with a recursive low-pass filter defined by:

$$X(kT_s) = \rho \times X((k-1)T_s) + \sqrt{1-\rho^2} \times n(kT_s) \qquad \text{for } k = 1, 2, 3, \ldots \qquad (3)$$

where:

$$\rho = e^{-\beta T_s} \qquad (4)$$

Step D4: Compute $Y_{rain}(kT_s)$, for $k = 1, 2, 3, ...$ as follows:

$$Y_{rain}(kT_s) = \mathrm{e}^{m + \sigma X(kT_s)} \tag{5}$$

Step D5: Compute $A_{rain}(kT_s)$ (dB), for $k = 1, 2, 3, ...$ as follows:

$$A_{rain}(kT_s) = \text{Maximum}\left[Y(kT_s) - A_{offset}, 0\right] \tag{6}$$

Step D6: Discard the first 200 000 samples from the synthesized time series (corresponding to the filter transient). Rain attenuation events are represented by sequences whose values are above 0 dB for a consecutive number of samples.

3 Scintillation time series synthesis method

As shown in Fig. 2, a scintillation time series, $sci(t)$, can be generated by filtering white Gaussian noise, $n(t)$, such that the asymptotic power spectrum of the filtered time series has an $f^{-8/3}$ roll-off and acut-off frequency, f_c, of 0.1 Hz. Note that the standard deviation of the scintillation increases as the rain attenuation increases.

FIGURE 2

Block diagram of the scintillation time series synthesizer