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The Prediction of Rain Fade Slope on Satellite Link and calculation of the Slope of the Attenuation component from Measured Time Series

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Abstract: The prediction of rain fade slope on satellite link is currently an essential parameter used by system designers for the development of communication power control and error-correction schemes, which mini-mize effects of the link outages for their systems. It is also useful for the implementation of computer generated received signal for primary experiments. Due to its time variation and dependence on the rain type and characteristics, it will be useful to develop an efficient model that fits the fade slope evaluated from the link. Fade slope indicates the rate of change of rain attenuation. The knowledge of fade slope of attenuation caused by rain or other meteorological events are very important for fade mitigation techniques. Knowledge of this parameter is important for determining the required tracking speed of fade mitigation techniques. The fade slope depends on attenuation level, on sampling time and on climatic parameters (drop size distribution and therefore on the type of rain).

I. INTRODUCTION

It is important to be able to quantify fade slope for satellite communication systems for which Fade Mitigation Techniques may be implemented. The knowledge of the fade slope of the received signal is useful either to design a control loop that can follow signal variations, or to allow a better short term prediction of the propagation conditions. In both cases, the relevant information is the slope of the slowly varying component of the signal which involves filtering out scintillation and rapid variations of rain attenuation.

REQUIREMENTS FOR FADE SLOPE INFORMATION:

The quantification of fade slope is important for SatCom systems operating at Ka-band and above, in which FMT have to be implemented. Knowledge of the fade slope of the received signal is useful in the design of a control loop that can follow signal variations, but also to enable a better short term prediction of the propagation conditions. For both applications, the relevant information is the slope of the slow varying component of the signal, i.e. rain attenuation.

To calculate the slope of the attenuation component from measured time series, it is necessary to remove the rapid component of the signal, containing fast fluctuations of both rain attenuation and scintillation. Depending on the quality of filtering of the rapid component, the obtained attenuation slopes can be different.

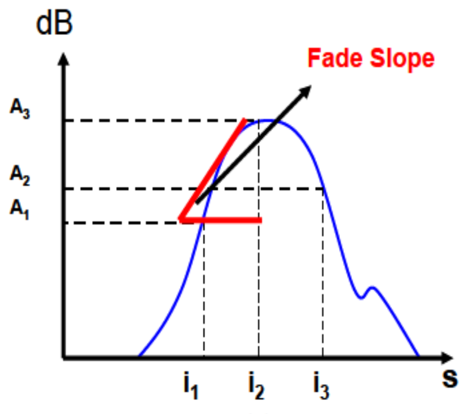

Figure1:fade slope.

FADE SLOPE PREDICTION METHOD:

The fade slope probability distribution depends on climatic parameters, drop size distribution and
therefore on the type of rain. The horizontal wind velocity perpendicular to the path is another climatic parameter of influence, determining the speed at which the horizontal rain profile passes
across the propagation path. Also, the expected fade slope at a given attenuation level is likely to
decrease as path length increases due to the smoothing effect of summing different rain contributions, and,

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therefore, will increase as elevation angle increases on Earth-space paths.

The predicted distribution of fade slope is dependent on attenuation level $A(t)$ and on the time interval length ⊗*t*. Also, the distribution depends on the 3 dB cut-off frequency of the low-pass filter which is used to remove tropospheric scintillation and rapid variations of rain attenuation from the signal. Experimental results show that a 3 dB cut-off frequency of 0.02 Hz allows scintillation and rapid variations of rain attenuation to be filtered out adequately. If scintillation and rapid variations of rain attenuation are not filtered out, the signal will exhibit stronger fluctuations and the model will only predict those due to rain attenuation. In that case, the cut-off frequency required as an input is the sampling frequency.

In this model, the fade slope ζ at a certain point in time is defined from the filtered data as:

$$\zeta(t) = \frac{A\left(t+\frac{1}{2}\Delta t\right) - A\left(t-\frac{1}{2}\Delta t\right)}{\Delta t} \qquad \text{dB/s}$$

II. THE MODEL IS VALID FOR THE FOLLOWING RANGES OF PARAMETERS:

– frequencies from 10 to 30 GHz
– elevation angles from 10° to 50°.

THE FOLLOWING PARAMETERS ARE REQUIRED AS INPUT TO THE MODEL:

A: attenuation level (dB): 0-20 dB

fB : 3 dB cut-off frequency of the low pass filter (Hz): 0.001-1 Hz

Δ*t* : time interval length over which fade slope is calculated (s): 2-200 s.

The step-by-step calculation of the fade slope distribution is as follows:

Step 1: Calculate the function *F* which gives the dependence on the time interval length Δ*t* and the 3 dB cut-off frequency of the low pass filter *fB*:

$$F(f_B, \Delta t) = \sqrt{\frac{2\pi^2}{\left(1/f_B^b + (2\Delta t)^b\right)^{1/b}}}$$

……… ……… **(1)**

with $b = 2.3$.

Step 2: Calculate the standard deviation σζ of the conditional fade slope at a given attenuation level as….

$$\sigma_\zeta = s\,F(f_B, \Delta t)A \qquad \text{dB/s}$$

………… …….. **(2)**

where s is a parameter which depends on climate and elevation angle; an overall average value in Europe and the United States of America, at elevations between 10° and 50°, is s = 0.01.

Step 3*:* Calculate the probability density *p* of fade slope ⎛ at a given attenuation value as:

$$p(\zeta|A) = \frac{2}{\pi\sigma_\zeta\left(1+(\zeta/\sigma_\zeta)^2\right)^2} \qquad (\text{dB/s})^{-1}$$

……… **(3)**

This model was tested against data at 12.5 GHz, 20 GHz and 30 GHz. These results showed a good match to the shape of the fade slope distribution as well as its variation with attenuation threshold *A*, interval length Δ*t* and 3 dB cut-off frequency of the low pass filter *fB*.

III. MATHEMATICAL ANALYSIS AND INTRODUCTION OF NEW SOLVED EQUATIONS IN THIS PAPER :

1)standard deviation σζ of the conditional fade slope at a given attenuation level :

$$\sigma_\zeta = 0.442$$

2) the probability density *p* of fade slope :

$$P = \frac{1.449}{\left(1+\left(\frac{\zeta}{0.442}\right)^2\right)^2}$$

SIMULATION RESULTS OF FADE SLOPE:

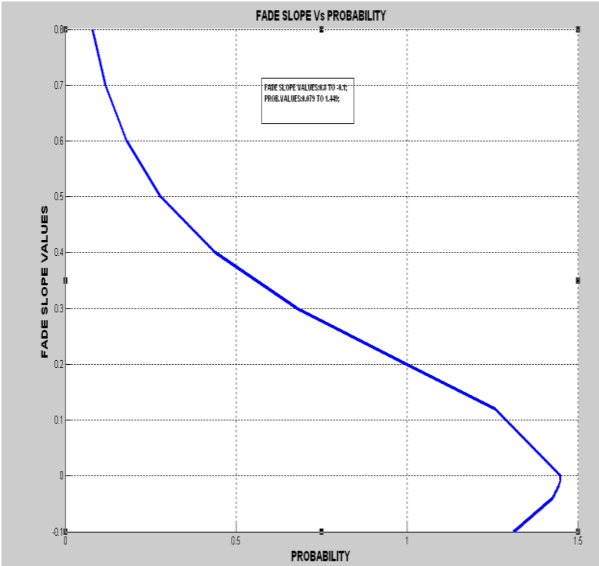

Figure : simulated fade slope.

The above figure shows fade slope obtained with the parameters Δ*t* : time interval length over which fade slope is calculated (s): 2sec; *fB* : 3 dB cut-off frequency of the low pass filter (Hz):1 Hz; standard deviation σζ of the conditional fade slope at a given attenuation level :0.442; ‘S’ is a parameter which depends on climate and elevation angle. An overall average value in India and VSP at

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elevation angles between 10 degrees and 50 degrees. So s=0.01; As path length increases the expected fade slope at a given attenuation level is likely to decrease.
From the above simulated figure as the probability of percentage of period of reference time (p) increases then the fade slope will be decreased.

TABULARFORM SHOWING VARIATION OF FADESLOPE WITH PROBABILITY DENSITY:(TABLE)

PROBABILITY	FADE SLOPE
0.079	0.8
0.117	0.7
0.179	0.6
0.278	0.5
0.438	0.4
0.679	0.3
0.998	0.2
1.257	0.12
1.317	0
1.426	-0.0080
1.445	-0.017
1.448	-0.04
1.449	-0.1

IV. CONCLUSION

The knowledge of the fade slope of the received signal is useful either to design a control loop that can follow signal variations, or to allow a better short term prediction of the propagation conditions. In both cases, the relevant information is the slope of the slowly varying component of the signal which involves filtering out scintillation and rapid variations of rain attenuation. The concepts of fade duration and fade slope was analysed. Based on the Recommendation ITU-R P.1623 formulae of fade duration and fade slope was to be analysed. In fade slope standard deviation of the conditional fade slope at a given attenuation and the probability density *p* of fade slope was calculated. And the new formula for the probability density *p* of fade slope was introduced in this paper. And for probability of occurance(p) and probability of exceedance(F), Fade slope also the simulated results was obtained.

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