PROPAGATION PARAMETERS AND PREDICTION OF MULTIPATH OUTAGE PROBABILITY ON DIGITAL RADIO

DHEIN, N.R. and EINLOFT, C.M.
Centro de Estudos em Telecomunicações da Universidade Católica (CETUC)
R. Marquês de São Vicente,225-Rio de Janeiro - Brasil

ABSTRACT

Using the "signature" concept we have obtained a model to predict the outage probability due to tropospheric multipaths on microwave digital radio links. This model includes the parameters associated with stratifications occurrence and the path geometry. A comparison between measured values compiled from several published field tests and the values calculated by the model is also presented. There is a good agreement between measured and calculated values.

1. INTRODUCTION

Multipath fading is the main cause of performance impairment for high capacity microwave digital radio systems during clear air conditions. The composition of several propagation paths with different delays at the receiving antenna produces large amplitude and phase distortions in the transmission channel giving rise to intersymbol interference.

These multipaths occurs when the atmosphere is stratified in layers with different values of refractive index. The occurrence of these stratifications depends on climatic and terrain conditions. On other hand, once the atmosphere is stratified, the characteristics of the multipaths generated over a given microwave link depends on the path geometry (distance and antennas height) and the frequency.

The performance of digital systems is specified by the time fraction (termed outage probability) that the bit error rate(BER) exceeds a given threshold (usually 10^-3 or 10^-4).

The purpose of this paper is to obtain an expression to evaluate the outage probability including all the factors above cited.

2. MODEL DESCRIPTION

For a typical microwave link (no ground reflection and no diffraction) we consider a two ray model for multipath fading. The two-ray model was adopted because their inherent simplicity and predominant occurrence observed in several propagation experiments [1]. Based in reference [2] the outage probability in these conditions is given by
\[ P(\text{BER} \geq \text{BER}_{\text{max}}) = 4r m \Delta f \int_{0}^{\tau_{\text{max}}} \tau^2 p(\tau) d\tau \]  

(1)

where

\[ \tau : \text{delay of the interfering ray relative to the direct ray} \]
\[ \tau_{\text{max}} : \text{maximum value of } \tau \text{ depending on path geometry, frequency and climatic conditions} \]
\[ p(\tau) : \text{probability density function of } \tau \]
\[ \Delta f : \text{R.F. channel bandwidth} \]
\[ r : \text{multipath fading occurrence factor} \]
\[ m : \text{system parameter depending on modulation, bit rate, filter shaping, } \text{BER}_{\text{max}}, \text{etc.} \]

The general expression for \( r \) is [3]

\[ r = Q \left( \frac{f}{4} \right)^{\beta} d^{\alpha} \]  

(2)

where \( Q \) depends on climatic and terrain conditions, \( f \) is the carrier frequency (GHz) and \( d \) is the path length (km).

The proposed values for \( Q, \alpha \) and \( \beta \) may be obtained from the above reference.

Expressions for \( p(\tau) \) and \( \tau_{\text{max}} \) are derived from the following semi-empirical expressions based on the more consistent experiments[1]

\[ p(\Delta) = 1.79 \times 10^{-4} Q d^{\alpha} \Delta^{-2.4} \]  

(3)

\[ \Delta_{\text{max}} = 10 Q^{0.4} d^{0.4} \alpha e^{-0.45 \times 10^{3} t/d} \]  

(4)

where \( \Delta \) is the path length difference of the two rays (meters) and \( t \) is the height difference between transmitting and receiving antennas (meters).

Utilizing these relations in (1) we obtain the following expression to evaluate the outage probability

\[ P(\text{BER} \geq \text{BER}_{\text{max}}) = 5.3 \times 10^{-3} Q^{2.26} \left( \frac{f}{4} \right)^{\beta} d^{2.26} \alpha (m \Delta f) e^{-0.27 t/d} \]  

(5)

where \( d \) is expressed in kilometers, \( f \) in gigahertz, \( \Delta f \) in megahertz, \( t \) in meters and \( m \) in nanoseconds\(^{-1}\).

3. COMPARISON BETWEEN MEASURED AND EVALUATED VALUES

Measured outage probability for twelve experimental digital microwave links were compared with the values calculated from the model. The characteristics of these links are given in Table I jointly with the outage probabilities measured and evaluated, as well as the recommended values by CCIR [4].

4. CONCLUSIONS

The satisfactory agreement between measured and predicted outage probabilities shows that the model may be an useful tool to planning digital radio systems. Consequently we can conclude that the intersymbol interference due to multipath propagation is the main cause of performance degradation since other impairment factors are not considered at the calculation. On other hand, an analysis of expression (5) allows to obtain the following relevant conclusions:
- The high sensitivity of outage probability with the climatological and topographical parameters requires an accurate knowledge of the propagation conditions at the region.
- The path inclination can involve an improvement factor of the performance.
- The outage probability increases greatly with the path length.

REFERENCES


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* Measured \(Q\) (in all the other cases \(Q\) was calculated in according to CCIR)
**No data available (assumed zero)
+ The \(m\) value (when not available) was estimated from [2] and [5] \((\text{BER}_{\text{max}} = 10^{-3})\).