Project	**IEEE 802.16 Broadband Wireless Access Working Group**
Title	**A Simplified Method for the Estimation of Rain Attenuation at 10.5 GHz**
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Re:	Coexistence C/I Simulation Estimates in Support of 802.16a System Design
Abstract	This document describes a simplified method for the estimation of rain attenuation at 10.5 GHz. An estimation of the rain loss differential between interference and victim links is necessary for same area-adjacent frequency coexistence studies. This procedure will be employed in subsequent 10.5 GHz coexistence studies.
Purpose	This document is provided for consideration and inclusion in the amended Coexistence Practice Document for PMP systems operating below 11 GHz (P802.16.2a).
Notice	
Release	
IEEE Patent Policy	

A Simplified Method for the Estimation of Rain Attenuation at 10.5 GHz

1.0 Introduction

PMP systems are expected to be popular at frequencies below 11 GHz in sub-tropical and tropical geographical locations. This is a direct result of the much reduced rain attenuation to be expected, as compared to PMP operation at EHF frequencies. While insignificant at 3.5 GHz, rain attenuation may be of concern at 10.5 GHz and system operators must account for it within their link budget estimates. Table 1 illustrates the expected fade margin requirements for 16-QAM transmission in a selected number of ITU-R rain regions [1]. For the table, a C/N performance threshold of 18 dB is assumed, in conjunction with a BER = 10^{-6} at a link availability of 99.99 %.

ITU Rain Region	0.01 % Rain Rate - mm/hr	Required Fade Margin - dB
E	22	3.4
K	42	7.1
M	63	10.7
N	95	14.2
P	145	16.2

Table 1. Rain Fade Margin Requirements for a 16-QAM Link Availability of 99.99 %

When examining coexistence issues between multiple operators, who deploy on adjacent frequencies in the same geographical area, it is necessary to estimate relative signal levels. This applies to both clear sky conditions and during rain fade conditions. In the following, we describe a computational procedure that can be employed to estimate the rain attenuation differential between interference and victim paths.

2.0 Rain Attenuation Model

Figure 1 illustrates the simulation model for outbound interference. Within the victim sector, an interference base station (CS) is positioned at some parameterized distance S, and is randomly located along the arc defined by distance S at some angle θ. As the deployment of the two operators is assumed to be uncoordinated, the boresight alignment of the interference CS is set to some angle α. There are also a number of victim link subscribers (TS's) that are expected to be randomly located within the sector. Each of these is at some randomly specified distance R_0 from it's serving CS and at some random angle γ.

Under severe rain fading conditions, there is likely to be at least one TS that is experiencing rain attenuation that approaches the threshold performance limit. So, overlaid on the clear sky simulation model is a rain cell as illustrated by Figure 2. There is no rational reason to assume that the rain cell takes on any specific geometrical shape, thus we might just as well assume that it is circular at a constant rain rate as proposed in [2]. While other rain cell geometry assumptions, and associated tapered rain rate distributions, have recently appeared in the technical literature, none of them allow for a practical estimation of rain attenuation at transmission link angles that are off-boresight through the rain cell.

From [2], it is estimated that the diameter of the significant attenuation of a rain cell is approximately equal to D_{rc} = 2.4 km. This is roughly in conformance with the radar reflectivity measurements discussed in [3]. So, this assumption is the starting point for the following. As well, it is assumed that the intensity of the rain cell is such that it corresponds to the fade margin requirements (FM) at a link distance of 7 km.

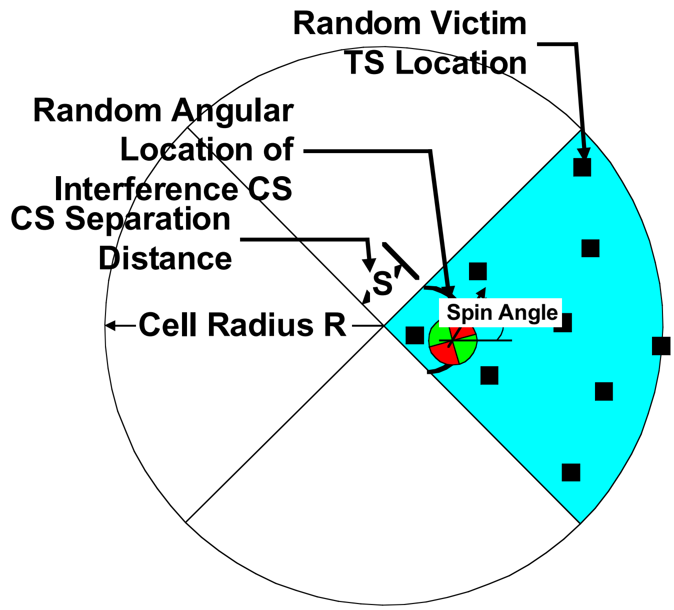

Figure 1. Simulation Model

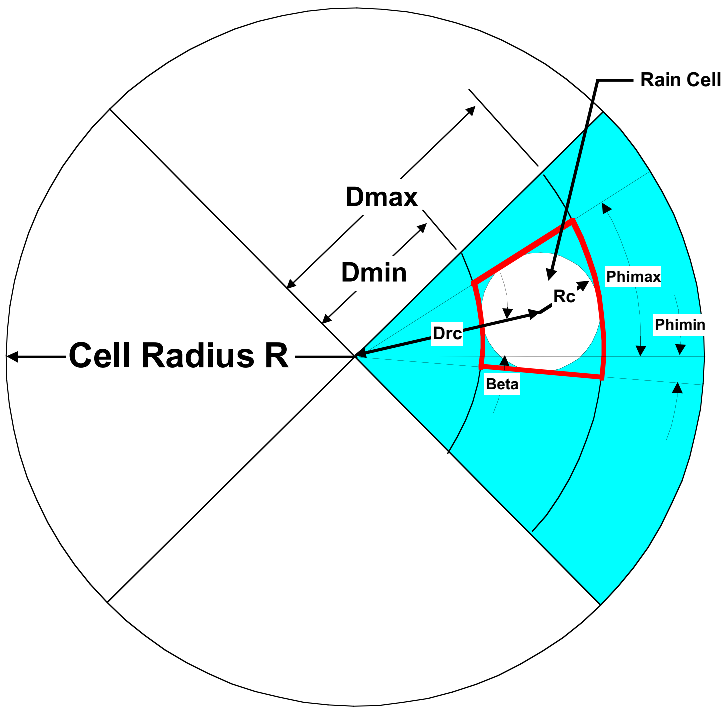

Figure 2 Rain Cell Overlay

Referenced to Figure 2, we can identify both inclusion and exclusion zones for the signal and interference vectors. The rain cell has been randomly overlaid within the victim sector at some distance D_{rc} and some angle β . Based on the geometry, we can readily approximate the rain cell to be bounded by the distances D_{min} to D_{max} and within the angles bounded by φ_{min} to φ_{max}. For the bounded area, illustrated in red, we will assume that the rain loss is such that it equates to the fade margin requirement FM.

The rain loss R_{lv} assigned to the victim signal vector is thus:

1. If γ falls outside the angles bounded by φ_{min} to φ_{max}, then $R_{lv} = 0$.

2. For γ falling within the bounded angles, then

   - if $R_0 < D_{min}$ then $R_{lv} = 0$.
   - if $R_0 > D_{max}$ then $R_{lv} = FM$.

- if R_0 is bounded between D_{min} and D_{max} then $R_{lv} = (R_0 - D_{min}) / D_{rc} \leftrightarrow FM$

Now, the interference CS was positioned at distance S and angle θ. For each victim subscriber TS, an interference link distance R_i is created. A portion of the R_i vector may or may not fall within the rain cell and result in an interference rain loss R_{li}. Significant interference is created only when there is boresight, or near, boresight alignment of the interference CS and victim TS antennas. Thus, when the victim TS is within the inclusion angles defined by φ_{min} to φ_{max}, then so must be the interference CS.

It is possible for the interference CS to be outside the inclusion angles, but for the interference vector to still experience some rain loss. Typically speaking, these alignments generate relatively large RPE discrimination angles from the narrow beam width TS antenna, Hence, we will just ignore these cases and set $R_{li} = 0$ if the CS is located outside the inclusion angles. This is a pessimistic assumption that favors the interference link. There are still a number of cases that need to be quantified. These are as follows:

i. $S < D_{min}$

- if $R_0 < D_{min}$ then $R_{li} = 0$.
- if $R_0 > D_{max}$ then $R_{li} = FM$
- if R_0 is bounded between D_{min} and D_{max} then $R_{li} = (R_0 - D_{min}) / D_{rc} \leftrightarrow FM$

ii. $S > D_{max}$

- if $R_0 < D_{min}$ then $R_{li} = FM$.
- if $R_0 > D_{max}$ then $R_{li} = 0$
- if R_0 is bounded between D_{min} and D_{max} then $R_{li} = (R_i - D_{max}) / D_{rc} \leftrightarrow FM$

iii. S bounded between D_{min} and D_{max}

- if $R_0 < D_{min}$ then $R_{li} = (R_i - D_{min}) / D_{rc} \leftrightarrow FM$
- if $R_0 > D_{max}$ then $R_{li} = (R_i - D_{max}) / D_{rc} \leftrightarrow FM$
- if R_0 is bounded between D_{min} and D_{max} then $R_{li} = R_i / D_{rc} \leftrightarrow FM$

3.0 Comments

The preceding has defined the computational methodology that will be employed to identify rain loss attenuation for subsequent 10.5 GHz simulations.

4.0 References

[1] Radiometeorological Data, Report 563-3, CCIR, 1986.

[2] Prediction Procedure for the Evaluation of Microwave Interference Between Stations on the Surface of the Earth at Frequencies Above About 0.7 GHz, ITU -R P.452-8.

[3] Electromagnetic Wave Propagation Through Rain, R. K. Crane, Wiley, New York, 1996.