Project	**IEEE 802.16 Broadband Wireless Access Working Group**
Title	**Coexistence Co-Channel Boundary pfd Simulations at 3.5 GHz (Inbound). Revision 1**
Date Submitted	**2002-03-01**
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Re:	Coexistence pfd Simulation Estimates in Support of 802.16a System Design
Abstract	This document examines inbound pfd requirements at 3.5 GHz. It identifies the distance limits for which coordination may be required between system operators. The conclusions are specific to the system model selected. Other system model parameters may modify the distance coordination requirements. This revision corrects text and Figure errors identified in the original contributiion.
Purpose	This document is provided to TG2a for consideration and inclusion in the amended Coexistence Practice Document for PMP systems operating below 11 GHz.
Notice	
Release	
IEEE Patent Policy	

Coexistence Co-Channel pfd Boundary

Simulations at 3.5 GHz (Inbound)

1.0 Introduction

This document examines inbound power flux density interference levels (pfd), and related distance requirement separations, that may be required for coordination between PMP service operators who operate in an adjacent area/same frequency environment. Using Monte Carlo simulation techniques, a computational analysis is developed to identify the percentage of inbound link exposures that may require coordination between operators who operate co-channel in adjacent geographical areas.

The simulation channel model and simulation methodology closely follow that described in [1] for 10.5 GHz. Consequently, only the differences are described herein. It is strongly recommended that the reader review [1] before examining this document.

2.0 Simulation Channel Model

At 3.5 GHz, the increased size of the 1'st Fresnel zone does allow for consideration of diffracted paths. But diffraction loss must fall within path loss limits necessary to support the link availability requirements. Using what are envisaged to be *typical and cost effective* equipment parameters, a link budget analysis indicates that the outbound link should be able to support 64-QAM. The link distance limit for achieving this is R = 7 km. Correspondingly, the link budget indicates that the inbound link can support 16-QAM in a LOS environment.

However, the available fade margin is quite modest and hence both diffraction loss and Rician fading are excluded from consideration. The ability to support higher modulation indices at 3.5 GHz is directly attributable to the probability of experiencing an atmospheric multipath Rayleigh fade. It is reduced by a factor of 3 as compared to 10.5 GHz.

Similar excess path loss exponents are employed as discussed in [1]. These are set at d^{-2} up to 7 km and d^{-4} beyond.

3.0 Simulation Transmission Parameters

Anticipated system parameters and *typical* equipment parameters are summarized as follows.

Propagation Models:	as per section 2
Atmospheric Multipath Model:	Vigants-Barnett (annual - 2 way)
Rician Fading Model:	Erceg (TG3 - 2 way)
Rain Fade Model:	ITU, Rain Region K
Maximum Cell Radius:	7 km
Channel Bandwidth:	7 MHz
TS TX Power:	+21 dBm
CS TX Power:	+29.5 dBm
TS Antenna Gain:	+18 dBi
CS Antenna Gain:	+14.5 dBi
Receiver Noise Figure:	5 dB
TX/RX RF Losses:	3 dB at each end
Link Availability:	99.99% @ BER=10^{-6}
Modulation Index Options:	4/16/64 QAM
Receiver C/N Threshold:	12 dB/18 dB/24 dB for the respective modulation indices

The preceding are incorporated into an inbound link budget for 16-QAM (Table 1). Based on the parameter assumptions, link budget estimates indicate that the modulation index is limited to 64-QAM outbound and 16-QAM inbound. As discussed in Section 2, the link budget cannot support excess diffraction loss, nor can it cater to excess loss or Rician fading resulting from foliage penetration. All victim links are therefore assumed to be LOS up to 7 km.

PARAMETER	NAME		V-POL	H-POL	UNITS
Location	New York				
Modulation	mod16	16 QAM			
Symbol Rate	fs	5.5			Ms/s
Noise Figure	nf	5			dB
Frequency	f0	3.5			GHz
Path Length	rmax	7			km
CCIR .01% Rain Rate	rr01ccir	42			mm/hr
Rice Factor	Kr	20			dB
TX Pwr/Cxr (clear sky)	ptx		21.00	21.00	dBm
Power Control	pcr		0.00	0.00	dB
TX Transmission Line Loss			0.00	0.00	dB
TX Branching Network Loss			-3.00	-3.00	dB
TX Antenna Gain	gsub		18.00	18.00	dBi
EIRP (clear sky)			36.00	36.00	dBm
EIRP (rain)			36.00	36.00	dbm
FSL to Distance R0			-120.18	-120.18	dB
Excess Loss to edge of coverage Rmax			0.00	0.00	dB
Atmospheric Absorption	aabsorb		-0.05	-0.05	dB
Foliage Loss			0.00	0.00	dB
Structure Loss			0.00	0.00	dB
Rx Antenna Gain	gbase		14.50	14.50	dBi
RX RF Losses			-3.00	-3.00	dB
RX Signal Level (clear sky)			-72.73	-72.73	dBm
RX Noise Level	n0		-101.52	-101.52	dBm
C/N (clear sky)	cnrcsv/h		28.79	28.79	dB
Required C/(N+I) for BER=E-6	cnir_E6		18.00	18.00	dB
C/I (HPA Intermod -clear sky)	hpaim		100.00	100.00	dB
C/I (adj-channel)	ciadjcs		100.00	100.00	dB
C/I (co-channel)	cicocs		100.00	100.00	dB
C/I Total	citotalcsv/h		95.23	95.23	dB
C/(N+I) (clear sky)	cnircsv/h		28.79	28.79	dB
Allowed C/N at Threshold	cnthreshv/h		18.00	18.00	dB
Fade Margin (clear sky)	margincsv/h		10.79	10.79	dB
C/I (HPA Intermod -rain)	hpaim		100.00	100.00	dB
C/I(adj-channel) plus Rain XPD	ciadjr		100.00	100.00	dB
C/I(co-channel plus Rain XPD)	cicor		100.00		dB
C/I Total	citotalv/h		96.99	96.99	dB
C/(N+I) (rain)	cnirrv/h		28.79	28.79	dB
Allowed C/N at Threshold	cnthreshrv/h		18.00	18.00	dB
Fade Margin (rain)	marginrainv/h		10.79	10.79	dB
Annual Availability (clear sky)-2 Way	availcsv_a_		99.99482	99.99482	%
Annual Availability (rain)	availrv/h_a		99.99999	99.99999	%
Annual Availability (Rice)-2 Way	avail_rice		100.00000	100.00000	%
Total Annual Availability			99.99481	99.99481	%
Outage			0.45446	0.45446	hrs

Table 1. Inbound Link Budget for 16-QAM @ 3.5 GHz

Table 1 indicates that the defining constraint on link availability up to 7 km is atmospheric multipath fading. Excess path loss and Rician fading have been excluded. Link margin to threshold is quite modest, being only about 11 dB.

Table 1 essentially excludes any allowance for either intra-system or inter-system interference. This later item is addressed in subsequent sections of this document.

4.0 Antenna RPE

Figures 1 and 2 describe the azimuth RPE patterns for the *representative* antenna patterns that have been assumed for this study.

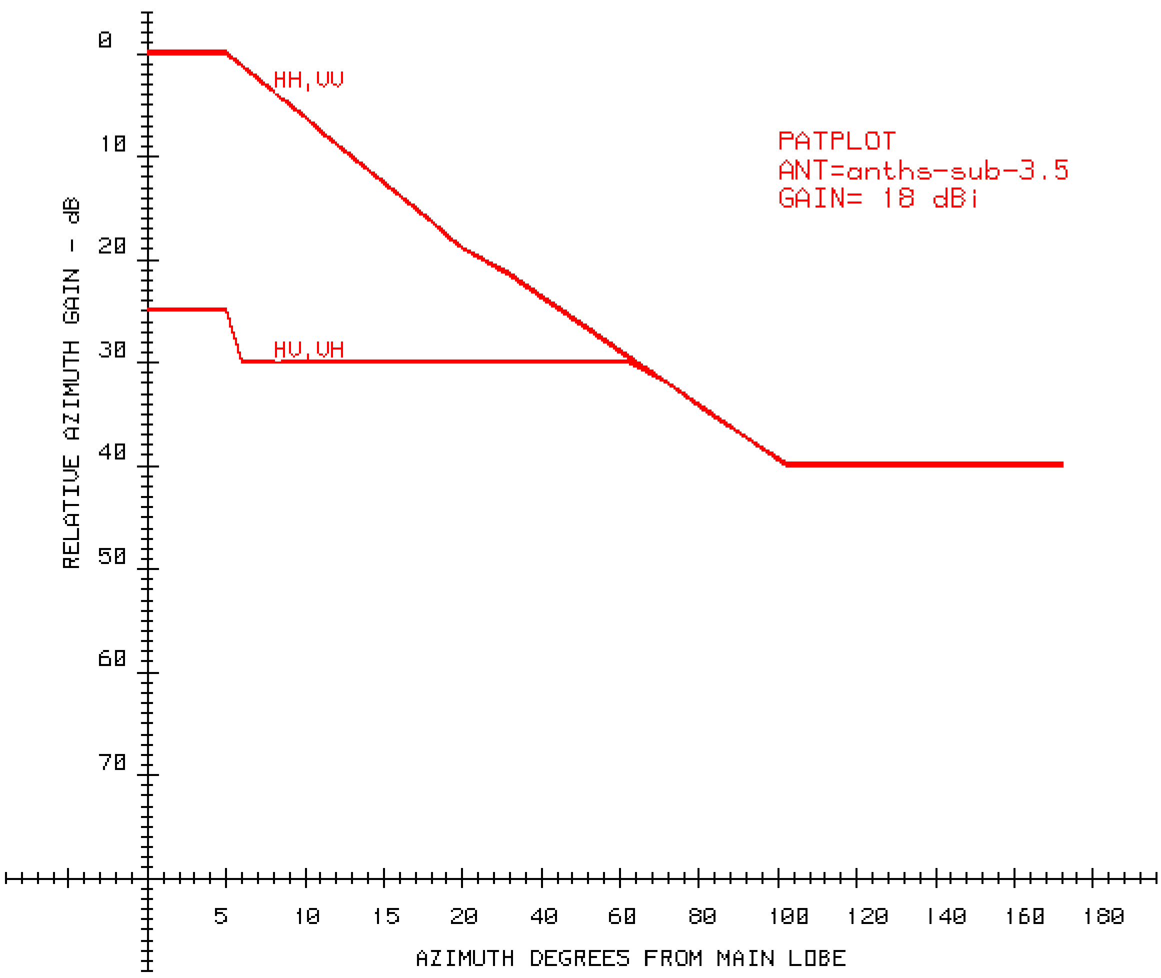

Figure 1. Representative TS Antenna RPE

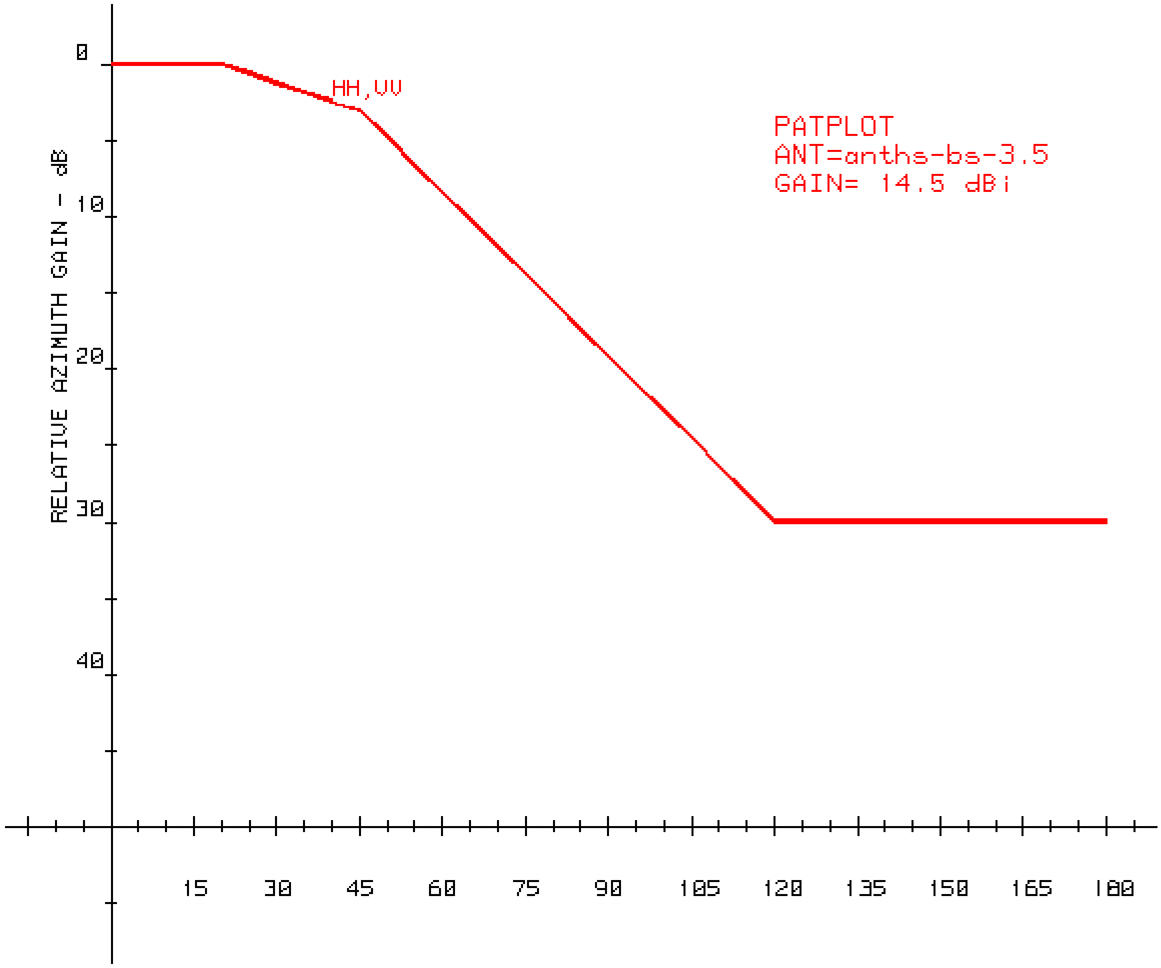

Figure 2 Representative CS Antenna RPE.

5.0 Limiting pfd Considerations

As was noted for the 10.5 GHz simulations described in [1], limiting pfd objectives are conditioned on the transmission parameter assumptions that are selected. These include modulation index/threshold, channel bandwidth/symbol rate and TX power. As a starting point, we will assume that both operators employ comparable transmission parameters such as those identified in Section 3. Subsequently, we will employ a sensitivity analysis to examine what different conclusions might apply. For the assumptions stated in Section 3, and the associated link budget given in Table 1, the following critical C/N, C/I and pfd values given in Table 2 apply.

Given that the available fade margin is only 11 dB, it is questionable as to whether or not ATPC would be applied at cell edge. At most, it would likely be restricted to 5 dB. Only a cell edge ATPC of 0 dB has been considered in the subsequent simulations.

From an examination of Table 2, it may be noted that critical interference pfd levels fall in the range between -101 and -107 $dBW/m^2/MHz$.

Parameter	Value
$(C/N)_{threshold}$ 16-QAM	18 dB
pfd_sig_threshold	-101.1 $dBW/m^2/MHz$
$(C/N)_{unfaded}$ QPSK (FM=11 dB) - without ATPC	28.8 dB
pfd_sig_unfaded - without ATPC	-90.4 $dBW/m^2/MHz$
effective pfd_noise	-119.1 $dB/m^2/MHz$
$(C/I)_{1\ dB\ threshold\ impairment}$(I/N=-6 dB)	24 dB
pfd_int_1dB (I/N=-6 dB)	-125.1 $dBW/m^2/MHz$

Table 2. C/N, C/I and pfd Relationships.

6.0 Simulation Methodology and Results

The reader is again referred to [1] for a detailed description of the simulation methodology and a description of the simulation model. As noted therein, separation distance D corresponds to the distance D between the interference and victim cell centers.

Figure 3 illustrates a simulation for the case where all cell edge interference transmitters operate at full power without ATPC. The simulation also assumes that all interference paths are LOS and do not experience any excess path loss. Under these assumptions, it can be noted 10-15 % of the exposures up to D = 80 km would exceed the 1 dB performance threshold pfd of - 125 dBW/m[2]/MHz.

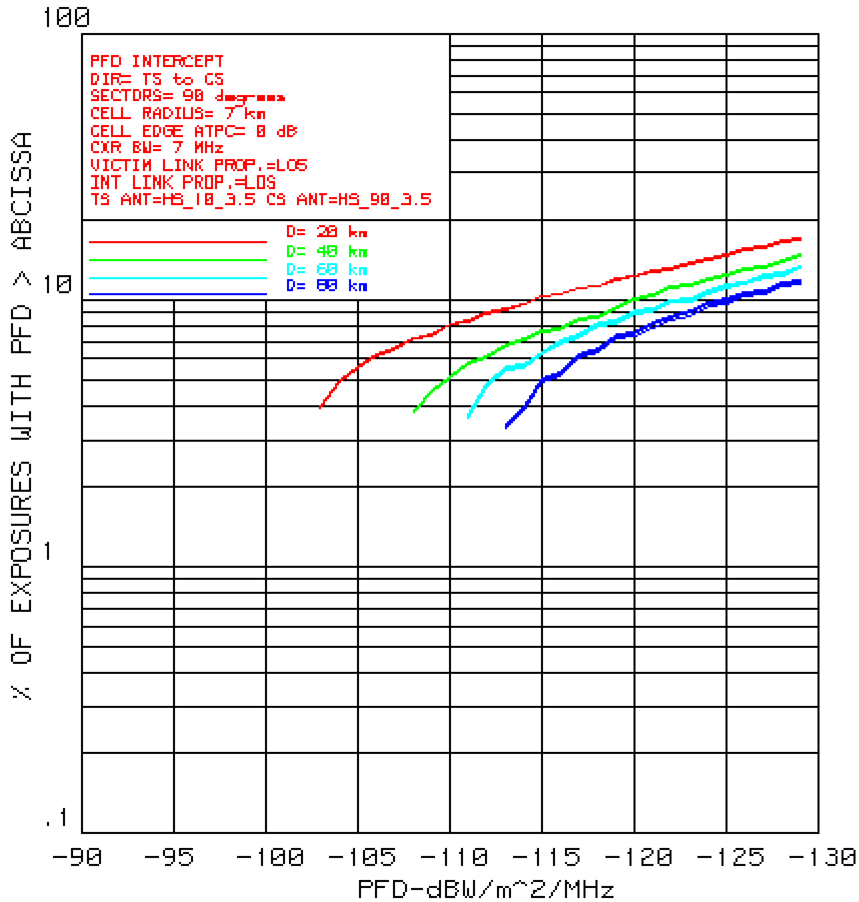

Figure 3. CDF Simulation Estimates for Full Power LOS Interference Vectors

Figure 4 illustrates a simulation for excess loss assigned to all interference paths. For this simulation, all interference vectors are set to operate at full power. Interference link path loss exponents are set to be d^{-2} up to 7 km and d^{-4} beyond 7 km. Beyond D = 40 km, the critical pfd limit of -125 dBW/m^2/MHz is not exceeded.

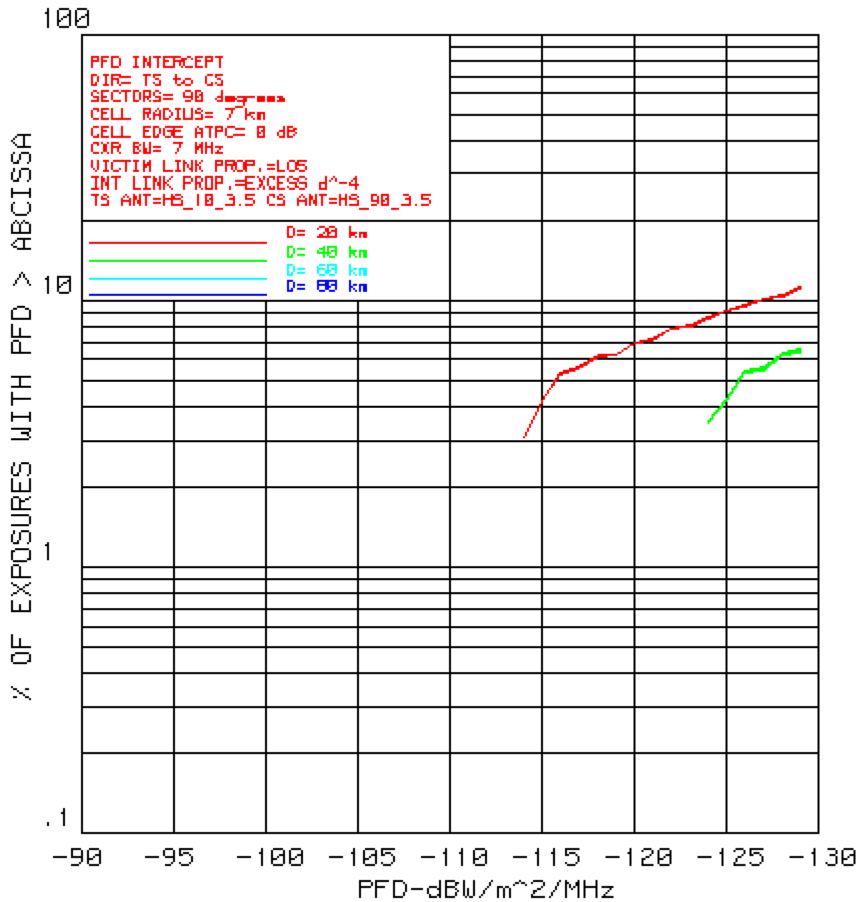

Figure 4. CDF Simulation Estimates for Interference Vectors with Excess Path Loss.

Figure 5 illustrates a simulation example where all interference transmitters operate at full power, however interference vectors are randomly assigned to have a path loss exponent of d^{-2} for the full interference distance or to be d^{-4} beyond 7 km. The CDF results are only marginally improved referenced to Figure 3, indicating that a significant number of worst case exposures were randomly identified to have an LOS propagation exponent.

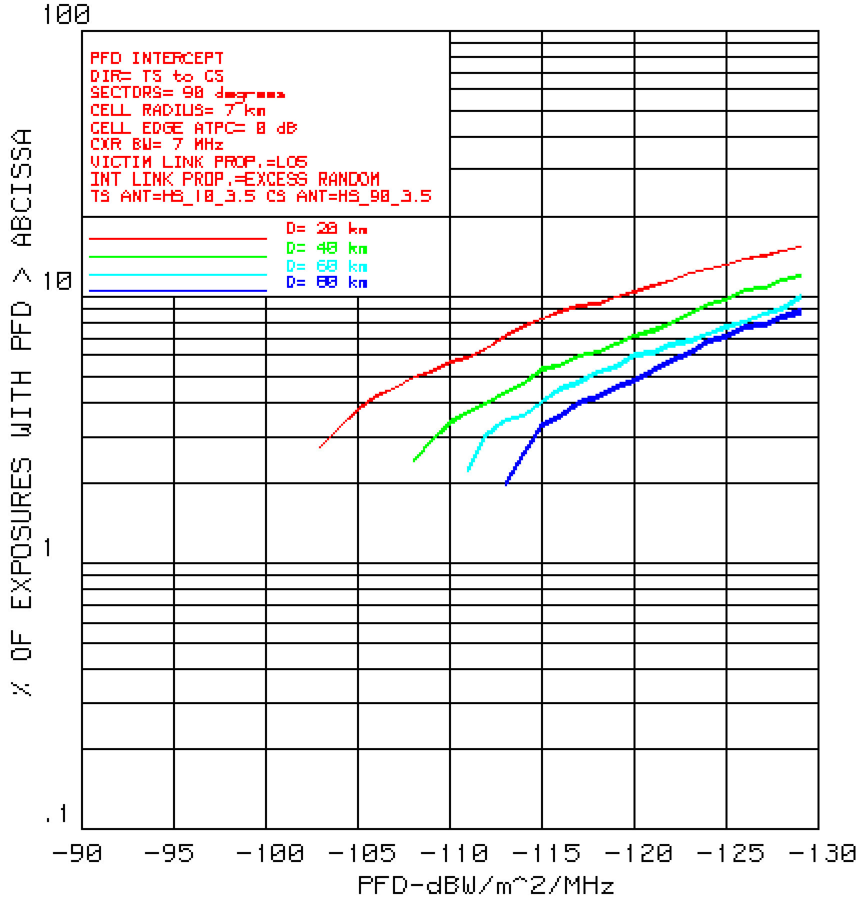

Figure 5. CDF Simulation Estimates for Interference Vectors with Random LOS or Excess Path Loss.

7.0 Sensitivity Analysis

There are an extremely large number of system configuration options that could impact on estimates for pfd coordination distance limits. These include TX power, modulation index and channel bandwidth. These options may be the same for both operators or may differ. In this section we will examine but a few of these options, just to see if the impact on pfd limits and coordination distance can be quantified. For all simulation estimates, the victim link is assumed to operate at 16-QAM in a 7 MHz channel and without ATPC at cell edge. Therefore, the critical pfd values identified in Section 5 still apply. All links are assumed to be LOS, hence the CDF results given in Figure 3 can be employed as a reference.

7.1 Modulation Index

It is possible that two operators, A and B, operate between a boundary using different modulation indices. Operator A (interference source) employs 4-QAM while Operator B employs 16-QAM (victim link) on inbound transmissions. Assuming comparable system parameters, it is likely that Operator A employs a +3 dB increase in TX Power at +24 dBm. This is roughly the difference in HPA OBO that applies to the achievement of emission limits for the two modulation techniques.

As to be expected, the pfd levels simply shift 3 dB to the left. Accordingly, the probability of pfd levels that exceed critical limits increase. For example, at a worst case horizon limit of D = 80 km, roughly 10 % of the exposures are greater than -125 dBW/m^2/MHz.

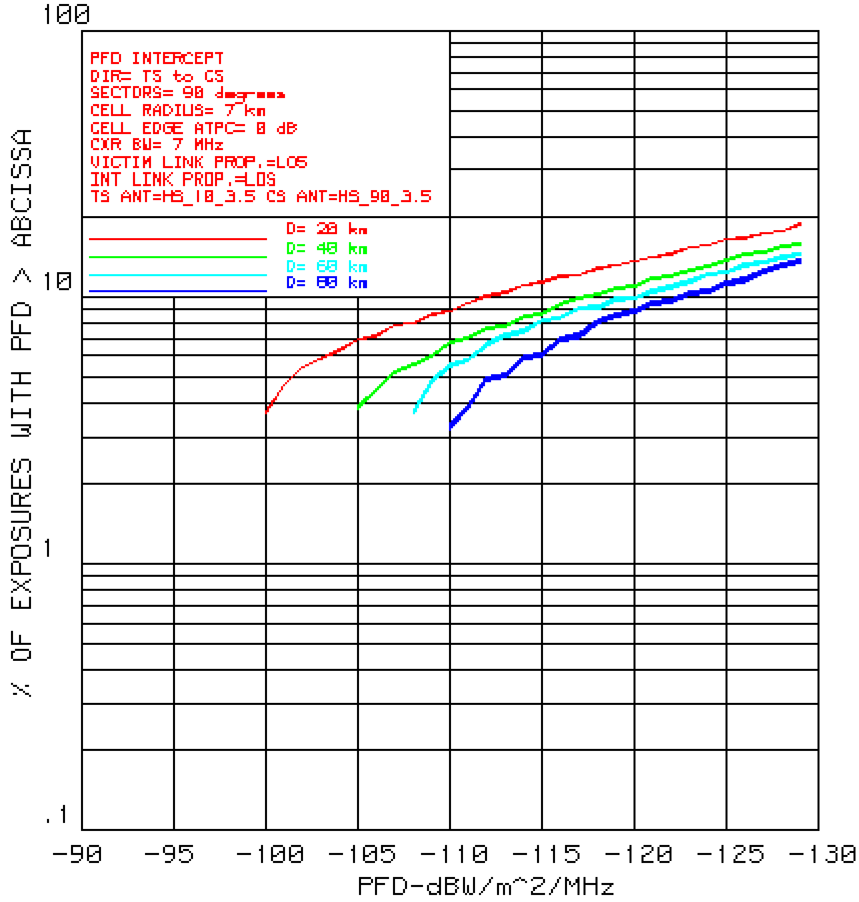

Figure 6. CDF Simulation Estimates for Interference Vectors at +24 dBm TX Power.

7.2 TX Power

Regardless of modulation index, it is possible that Operator A might decide to operate at substantially higher TX power levels (say), +9 dB at +30 dBm. This would allow Operator A enough link margin to allocate some of the excess link margin to modestly diffracted paths and hence improve coverage. We could go further and assume a 10 W transmitter of +40 dBm. But we are now into the realm where the cost of $/W of TX power becomes a significant design consideration. So, we will therefore just stop at +30 dBm (1 W).

Again, the pfd signal levels just simply move to the left. But we are now faced with a very significant percentage of operator coordination requirements at all distance limits. Simply stated, this just says; that if operators do not communicate their system parameters to each other, then coexistence is going to be a very difficult problem.

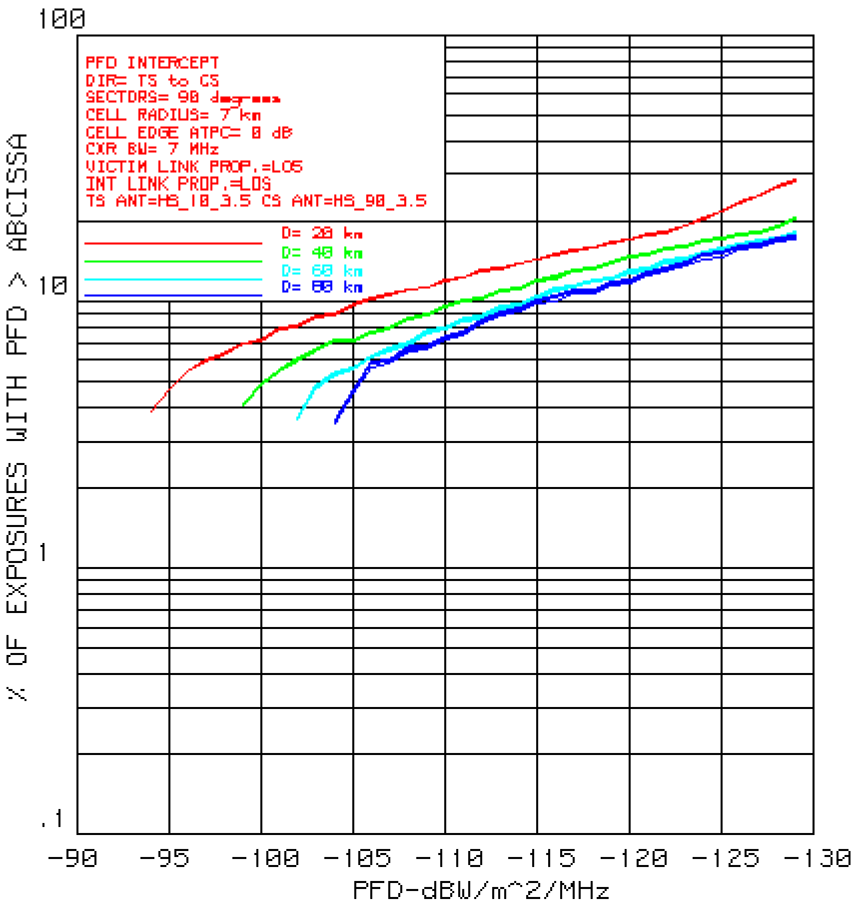

Figure 7. CDF Simulation Estimates for Interference Vectors at +30 dBm TX Power.

7.3 Channel Bandwidth

It is also possible that operators might elect to employ different carrier bandwidths. For example, assume that Operators A and B employ comparable transmission parameters but that Operator A utilizes 1.75 MHz carriers. As compared to the 7 MHz reference model of Figure 3, power density per MHz is increased by a factor of 4 and hence the pfd estimates simply shift 6 dB to the left.

But in this example, pfd has become a deceptive estimate of interference impact. This results from the fact that any one narrow band carrier has the same TX power as any one wide band carrier and hence their interference impact would be the same (ignoring receiver filtering). Conversely, if operator A is viewed to be the victim, then (roughly), only 1/4 of the wide band carrier power passes through the narrow band victim receiver filter. Hence, C/I impact would be reduced by 6 dB.

There is a caveat to the preceding in that Operator A now has four times as many carriers to deploy. Dependant upon how the intra-system frequency re-use plan of Operator A is configured, there is an increased probability for the numbers of interference exposures into a victim Operator B receiver.

The preceding simply highlights the fact that, by itself, pfd is not a sufficient metric for the establishment of satisfactory C/I levels. A knowledge of the system and transmission link parameters is also required.

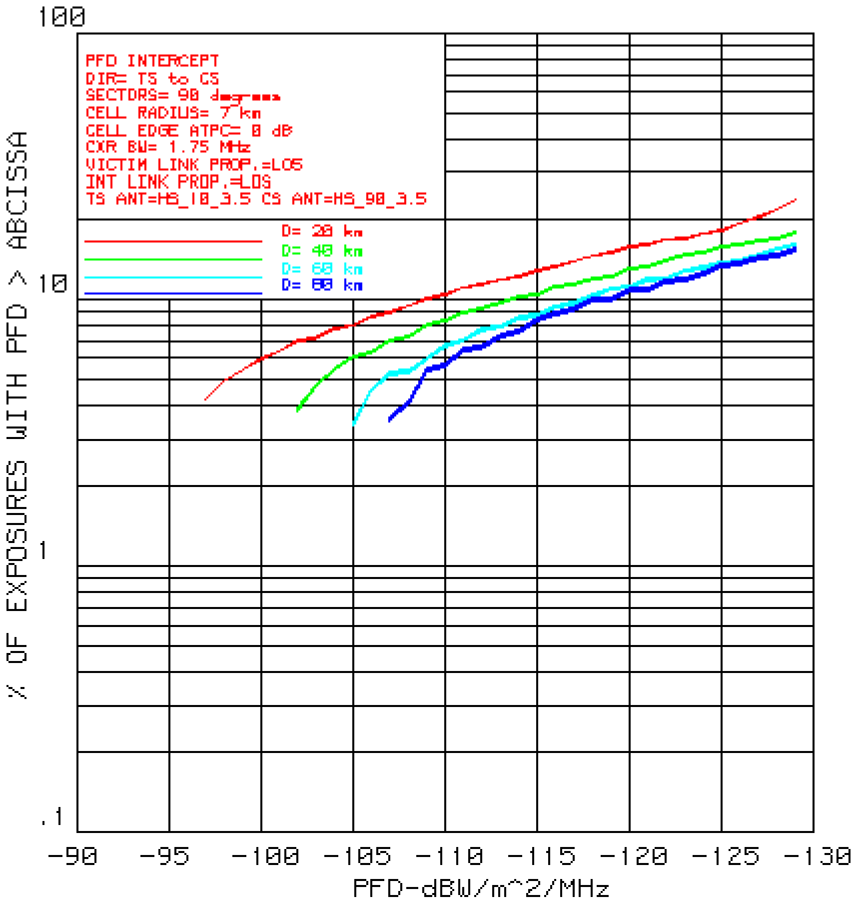

Figure 8. CDF Simulation Estimates for Full Power 1.75 MHz LOS Interference Vectors.

8.0 Summary Discussion

As with the simulation results performed for 10.5 GHz, these results indicate that inter-operation coordination may be required up to a coordination distance of 80 km. However, as indicated by the simulation sensitivity analysis, differing system parameters can have a dramatic impact on the significance for coordination requirements. Without operator knowledge of such differing parameters, coexistence can be expected to be a quite difficult problem. From the sensitivity analysis, it has been demonstrated that pfd, taken in isolation, is not a sufficient metric for identification of C/I impairment. A knowledge of operator system and transmission link parameters is also required.

9.0 References

[1] "Coexistence Co-Channel Boundary pfd Simulations at 10.5 GHz (Inbound). Revision 1", IEEE C802.16.2a-02/01r1.