Project	**IEEE 802.16 Broadband Wireless Access Working Group**
Title	**Uncorrelated Rain Fading and its Impact on Frequency Re-Use and Antenna RPE Specifications**
Date Submitted	**1999-01-16**
Source	G. Jack Garrison Wavtrace, Inc. 1545 134' th Ave NE Bellevue, WA 98005 Voice: (604) 524-6980 Fax: (604) 524-6980 E-mail: gjg@telus.net
Re:	This document is a formal submission of the presentation made to the 802.16.2 Coexistence Task Group at Meeting #5; held Jan. 10-14, 2000 in Richardson Texas. This document is in response to the Call For Contributions on Antenna Patterns and Interference Scenarios dated Dec. 17, 1999
Abstract	Uncorrelated rain fading can introduce coexistence interference problems both intra-system and inter-system. In the latter case, the interference issues can occur across boundaries (same frequency-adjacent area) and within boundaries (same area-adjacent frequency). Examples of the interference issues are described for an aggressive FDD frequency re-use plan that employs 90 degree sectored base station antennas. It is demonstrated that even antennas with ideal antenna RPE patterns are not sufficient to resolve all of the interference issues. Additional frequency assignments and alternative frequency re-use plans are also required.
Purpose	This document is submitted for both information and discussion purposes. It is proposed that the coexistence practice document include text which indicates that, by themselves, the recommended antenna specifications are not sufficient to ensure satisfactory coexistence interference suppression. Appropriate system frequency re-use plans are also required.
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Release	The contributor acknowledges and accepts that this contribution may be made public by 802.16.
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Uncorrelated Rain Fading

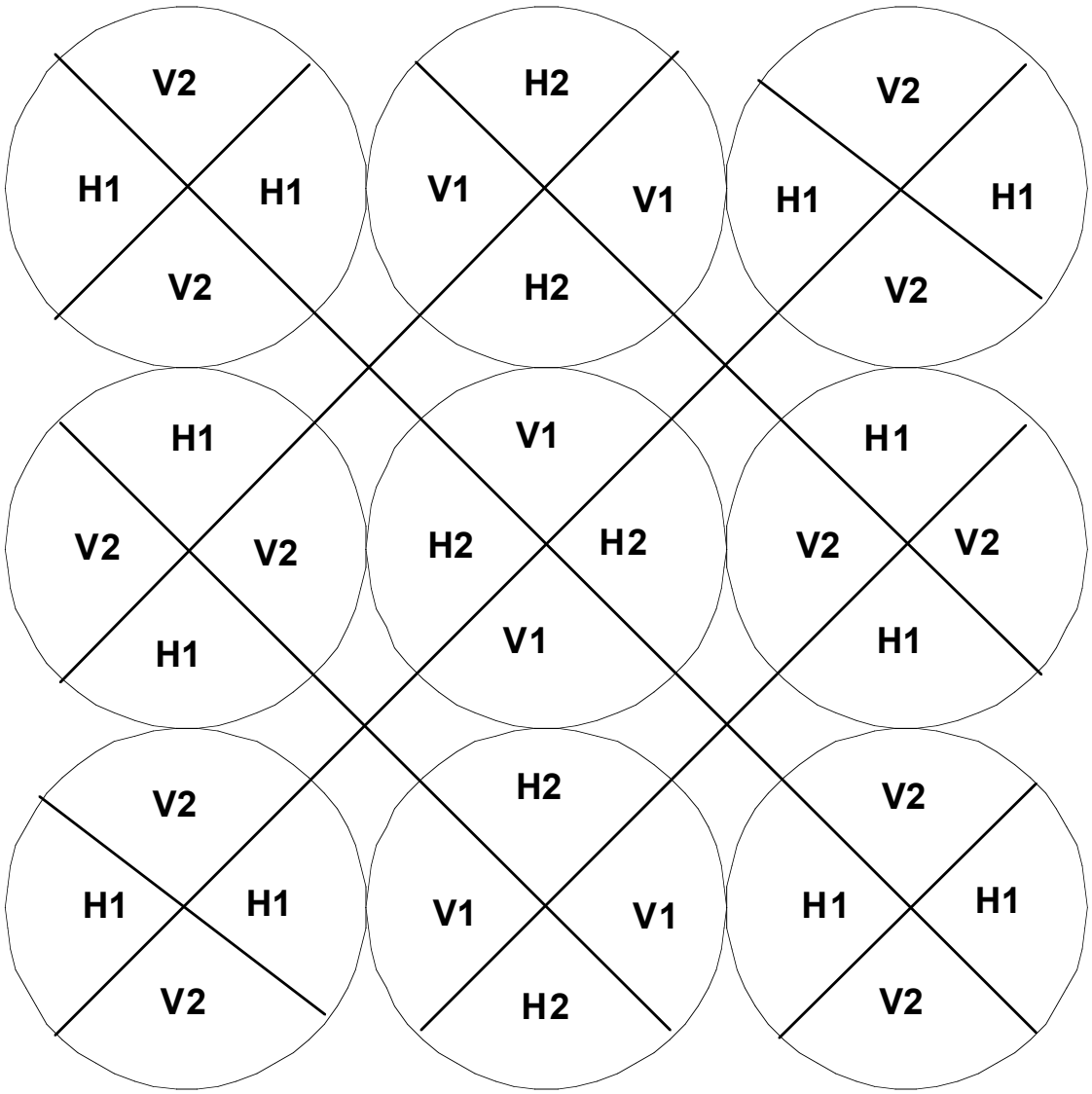
An Example

Objectives

- **To Identify the Constraints Placed on Frequency Re-Use Efficiency by Antenna RPE Parameters.**
- **To Estimate the Potential Re-Use Efficiency Improvement Limits Offered by Practical Antenna RPE Enhancements.**
- **To Demonstrate that Acceptable C/I System Performance Criteria is a Joint Antenna RPE/Frequency Re-Use System Design Problem.**
- **To Illustrate the Problem Referenced to Proposed FDD 90-Degree Sectored System Designs and Uncorrelated Rain Fading.**
- **To Recommend that the Coexistence Practice Document Includes Text which Indicates that, by Themselves, Antenna RPE Parameters are not Sufficient to Ensure Satisfactory Frequency Re-Use System Designs.**

FDD Frequency Re-Use Plan Example

- **FDD 90 Degree Sectored**
- **2 Frequencies – 2 Polarization's**
- **Frequency Re-Use Factor = 2 (All Available Frequencies Used Twice Within a Cell)**
- **Internal Grid Illustrated – Similar Sector Facings Can Occur at BTA Boundary Interfaces**



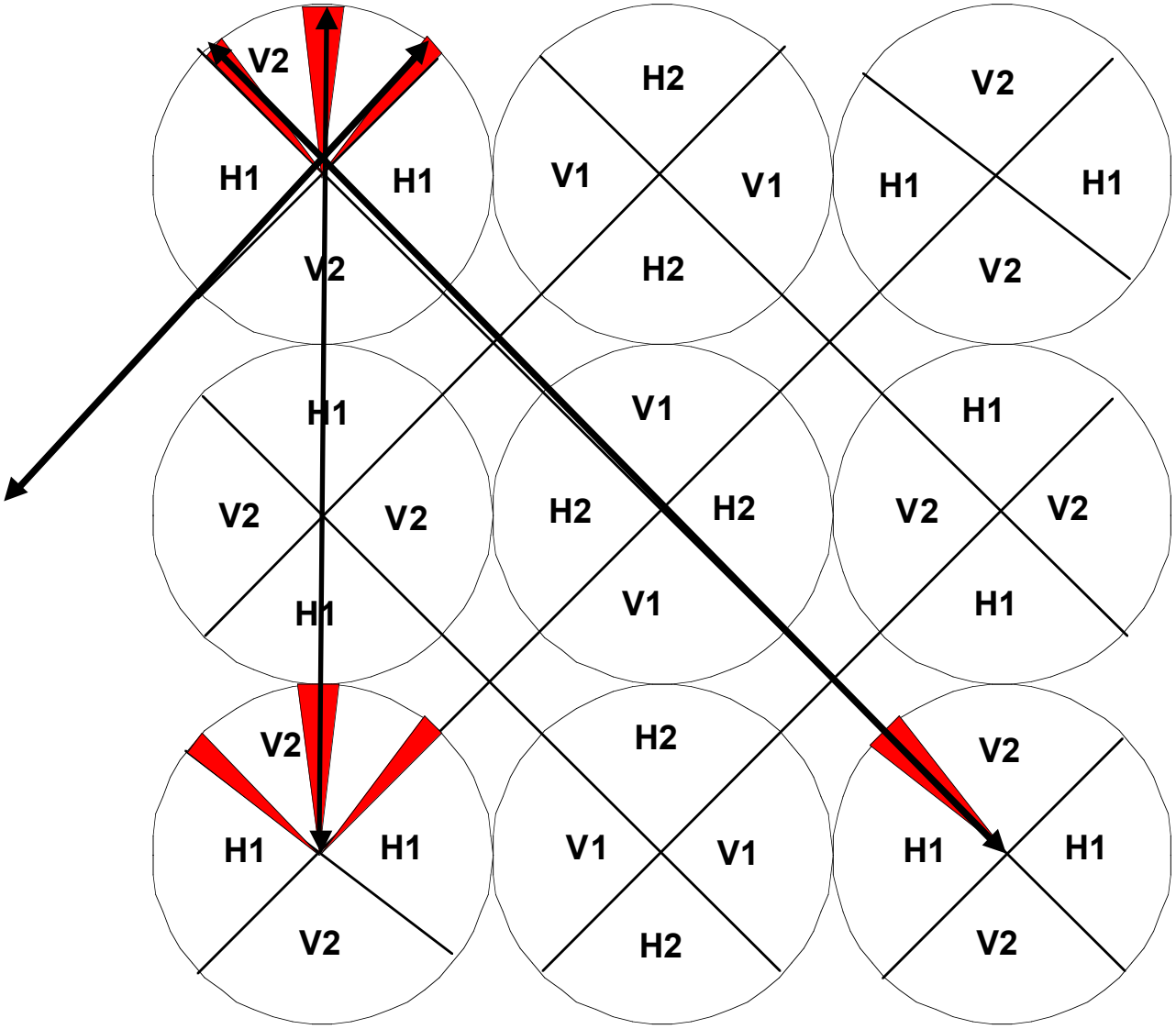
Two Frequencies 1 and 2
Each Used Twice in a Cell
Re-Use Factor=2

US Patent #5,838,670 Nov. 17,1998

Clear Sky Direct Facing Co-Channel Exposures

- **Each Sector of Each Cell Experiences 3 Direct Facing Interference Exposures**
- **LOS Distance Protection is Approximately 5R (14 dB)**
- **Cell Radius R = 3 – 3.6 km (ITU Rain Region K)**
- **ETSI TS1 Remote Antenna Assumed (+/- 2 Degrees)**
- **Threshold Criteria Requires Exclusion Area for Remote Locations as Indicated**
- **Problem Resolution:**
  - **Increased Number of Carrier Frequencies**
  - **Alternative Frequency Re-Use Plan (Reduced Re-Use Factor)**
  - **Reduced Antenna Beam Width (Partial Solution)**

Clear Sky Co-Channel Exposures



All Sectors of All Cells have 3 Exposures

Distance = 5R (14 dB)

4QAM Threshold Angle: 2+4+2=8 degrees (9% of Sector)

4QAM 1dB Impairment Angle: 3+6+3=12 degrees (13%)

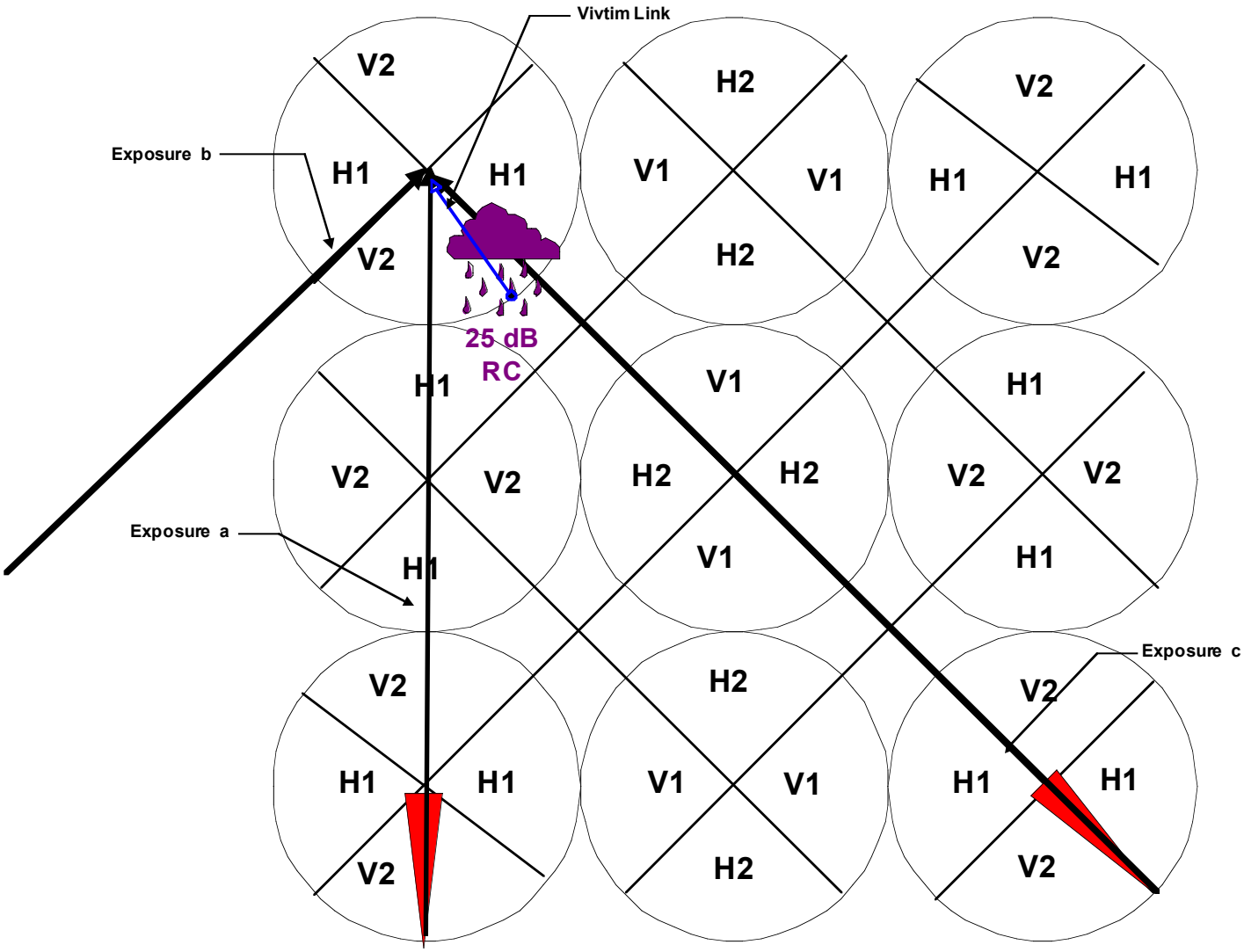
16 QAM Threshold Angle: 3+6+3=12 degrees (13 %)

16 QAM 1 dB Impairment Angle: 5+10+5=20 degrees (22 %)

Rain Faded Direct Facing Co-Channel Exposures

- **Each Sector of Each Cell Experiences 3 Direct Facing Interference Exposures**
- **LOS Distance Protection is Approximately 5R (14 dB)**
- **Cell Radius R = 3 – 3.6 km (ITU Rain Region K)**
- **Rain Cell Diameter Rc = 2.4 km (ITU-R Rec. 452)**
- **Rain Cell/Sector Size Relationships Establish 1 or 2 Interference Vectors at Minimal Rain Loss**
- **Threshold Criteria Increases Exclusion Area for Remote Locations as Indicated**
- **Problem Resolution:**
  - **Increased Number of Carrier Frequencies**
  - **Alternative Frequency Re-Use Plan (Reduced Re-Use Factor)**
  - **Reduced Antenna Beam Width (Partial Solution)**

Inbound Rain Faded Co-Channel Exposures



All Sectors of All Cells have 3 Exposures

	Exposure a	Exposure b/c
Distance:	14 dB	16.5 dB
PC:	15 dB	15 dB
Rain Fade:	-25 dB	-25 dB
C/I:	4 dB	6.5 dB

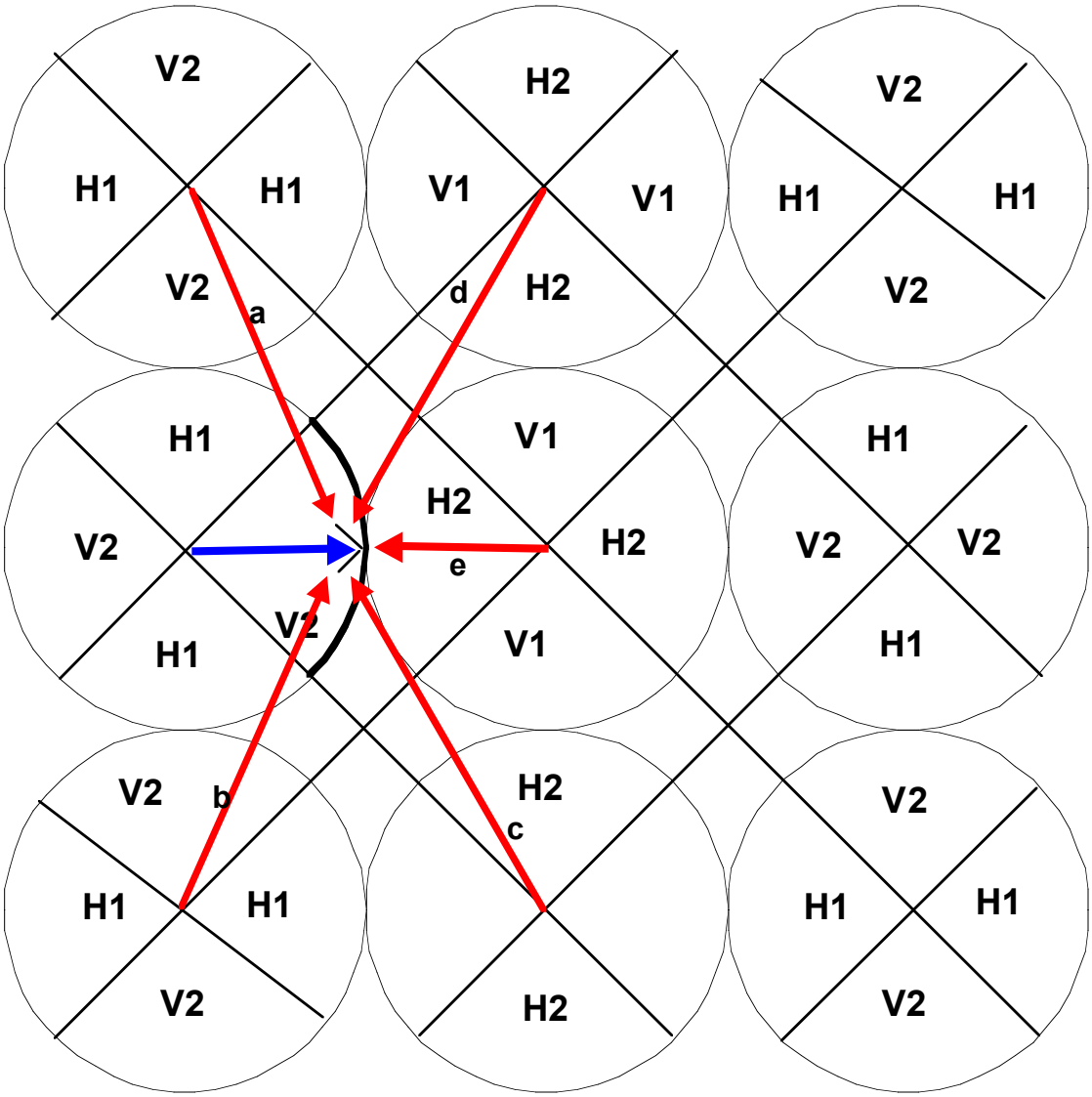
Exclusion Angles (Exposure a)	ETSI TS1	Andrew 0.3 m	Andrew 0.6 m
4QAM Threshold Angle:	10 deg. (11%)	6 deg. (7%)	3 deg. (3%)
4QAM 1dB Impairment Angle:	16 deg. (18%)	6 deg. (7%)	4 deg. (4%)
16 QAM Threshold Angle:	16 deg. (18%)	6 deg. (7%)	4 deg. (4%)
16 QAM 1 dB Impairment Angle:	40 deg. (44%)	14 deg. (15%)	6 deg. (7%)

Clear Sky Indirect Facing Co-Channel Exposures

(Hub – Remote)

- **Each Sector of Each Cell Experiences 5 Indirect Facing Interference Exposures**
- **LOS Distance Protection is 1R to 2.2R (0-7 dB)**
- **Cell Radius R = 3 – 3.6 km (ITU Rain Region K)**
- **ETSI TS1 Remote Antenna Assumed (+/- 2 Degrees)**
- **C/I Estimates Apply for Remote Location Across Victim Sector (Modest Change in Interference Distance and Antenna Discrimination Angles)**
- **Threshold Criteria Meets 16-QAM Requirements as Indicated**

Clear Sky Hub-Sub Exposures



Exposures a and b

Distance=2.2R=7 dB
TS1 Ant at 63 Degrees=26 dB
C/I=33-3=30 dB

Exposures a and b

Distance=2.2R=7 dB
TS1 Ant at 117 Degrees=35 dB
C/I=42-3=39 dB

Exposure c

Distance=1.0R=0 dB
TS1 Ant at 180 Degrees=40 dB
C/I=40 dB

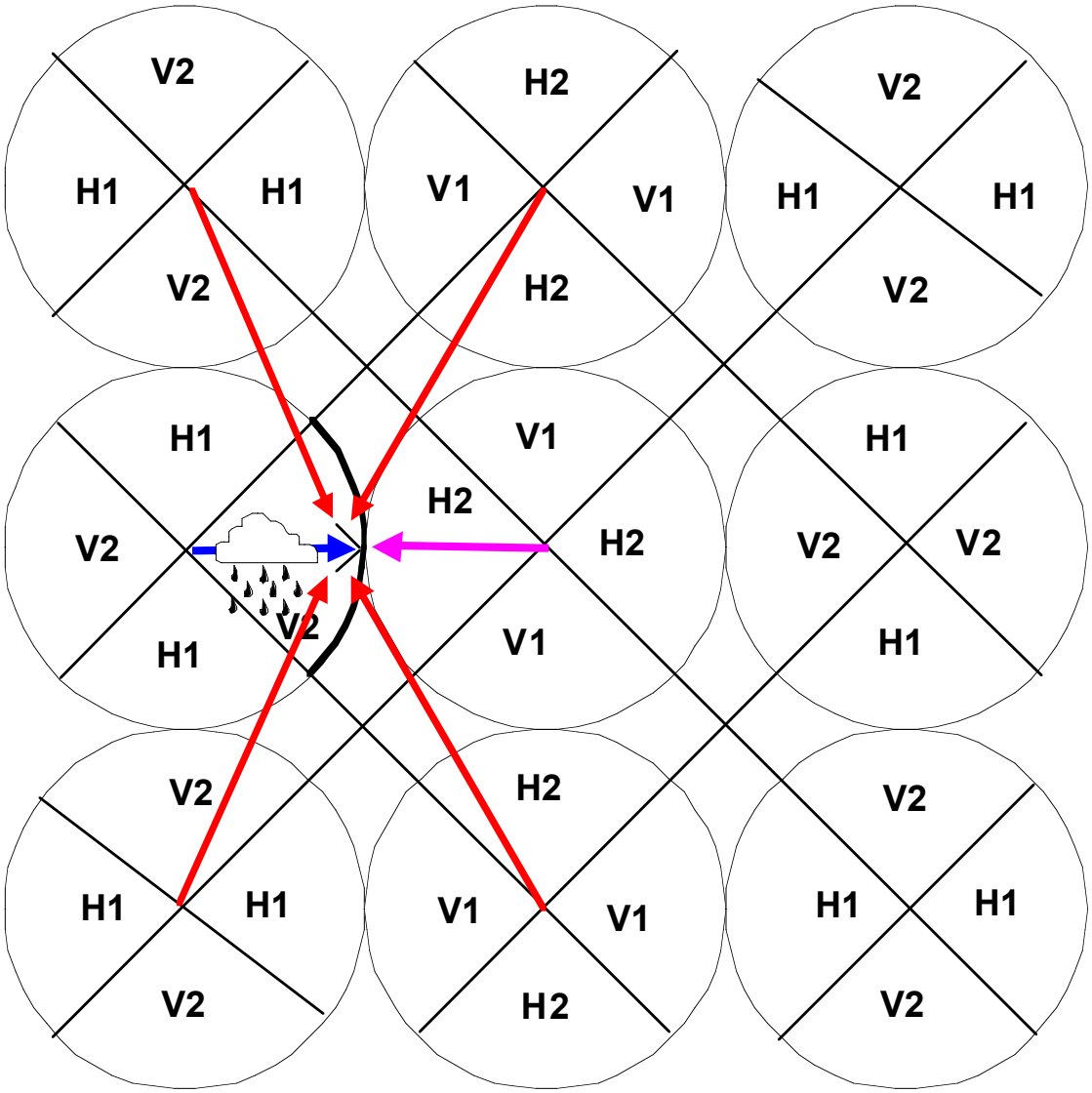
Total C/I=29 dB

Rain Faded Sky Indirect Facing Co-Channel Exposures

(Hub to Remote)

- **Each Sector of Each Cell Experiences 5 Indirect Facing Interference Exposures**
- **LOS Distance Protection is 1R to 2.2R (0-7 dB)**
- **Cell Radius R = 3 – 3.6 km (ITU Rain Region K)**
- **ETSI TS1 Remote Antenna Assumed (+/- 2 Degrees)**
- **Rain Cell Diameter Rc = 2.4 km**
- **C/I Estimates Apply for Remote Location Across Victim Sector (Modest Change in Interference Distance and Antenna Discrimination Angles)**
- **Threshold Performance Significantly Impaired for all Modulation Techniques**
- **Problem Resolution:**
  - **Increased Number of Carrier Frequencies**
  - **Alternative Frequency Re-Use Plan (Reduced Re-Use Factor)**
  - **Significantly Improved Antenna RPE**

Rain Faded Hub-Hub Exposures



Clear Sky C/I=29 dB

Rain Fade=-25 dB

Rain Faded C/I=4 dB

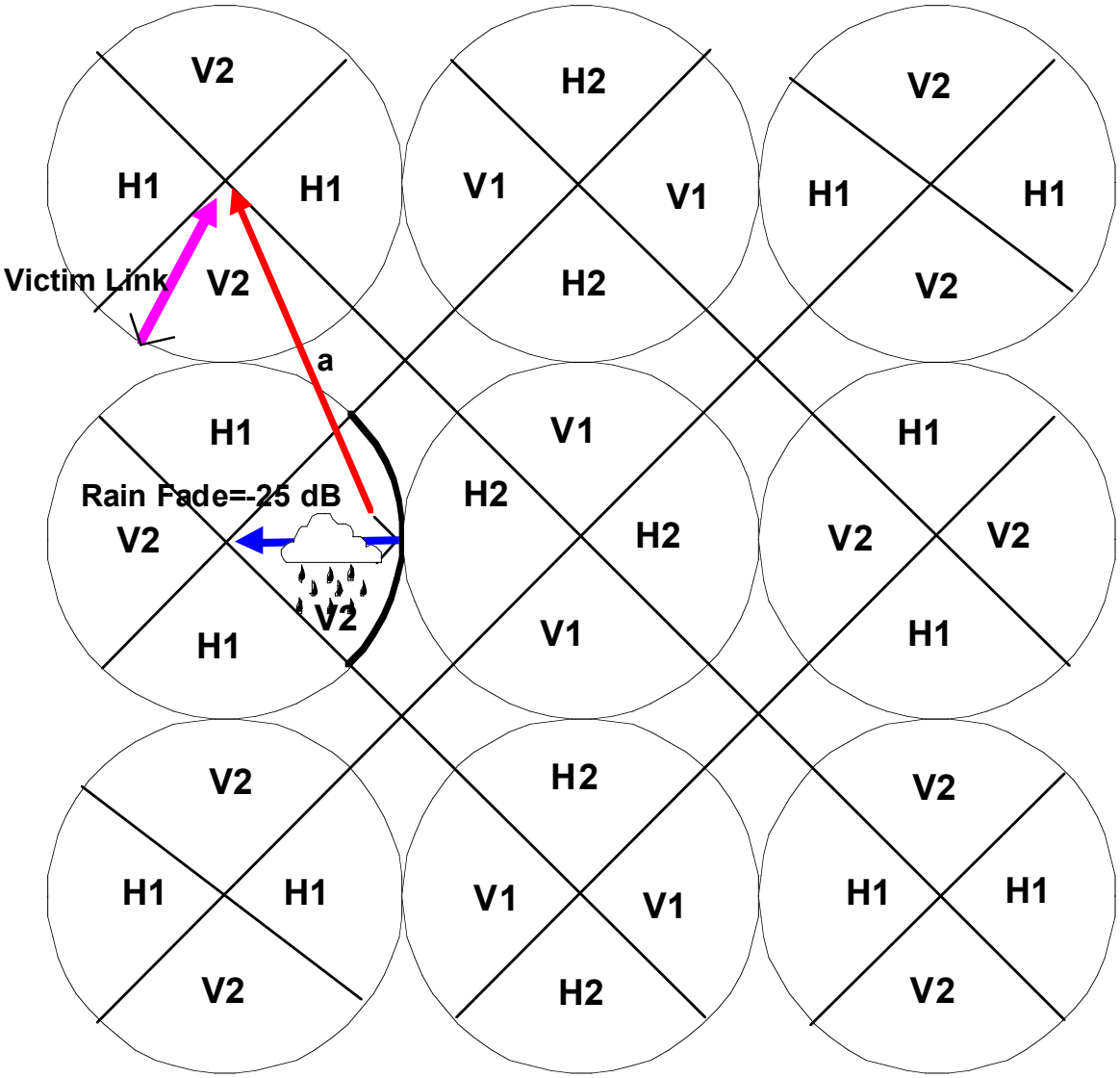
-The Problem Applies to All Sectors of All Cells

-The Problem Applies Throughout the Sector (modest change of distance and angle)

Rain Faded Sky Indirect Facing Co-Channel Exposures (Remote to Hub)

- **Rain Faded Link Operates at Full TX Power**
- **Adjacent Cell Links Operating Under Power Control**
- **ETSI TS1 Remote Antenna Assumed (+/- 2 Degrees)**
- **Rain Cell Diameter Rc = 2.4 km**
- **C/I Estimates Apply for Remote Location Across Victim Sector (Modest Change in Interference Distance and Antenna Discrimination Angles)**
- **Rain Fade in One Cell Introduces Interference Problems in Adjacent Cells**
- **Problem Resolution:**
  - **Increased Number of Carrier Frequencies**
  - **Alternative Frequency Re-Use Plan (Reduced Re-Use Factor)**
  - **Improved Antenna RPE**

Rain Faded Sub-Hub Exposures



Exposure a

Distance=2.2R=7 dB

TS1 Ant at 63 Degrees=26 dB

Power Control on Victim Link=10-15 dB

Power Control on Faded Link=0 dB

-The Problem Applies to All Sectors of All Cells

-The Problem Applies Throughout the Sector (modest change of distance and angle)

Rain Faded C/I=26+7-PC=18-23 dB

(Unfaded Victim Link Fails for 16 QAM)

Summary

- **Overly Aggressive Frequency Re-Use Plans Can Cause Inter-Operator Boundary and Intra-Operator Interference Problems**
- **Without Proper Frequency Re-Use Planning Antenna RPE Requirements Become Very Stringent**
- **Full Interference Resolution is not Achievable with Only Improved Antenna RPE Specifications**
- **Full Interference Resolution Requires Increased Carrier Frequency Assignments and Alternative Frequency Re-Use Plans**