Interference Relationships Between Point-to-Multipoint Stations at about 28 GHz Authorized by Area License

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Purpose:

The chart titled "Potential Separation Distance from Spurious Emissions" was presented during Session #7. The 802.16.2 Chairman invited the author to contribute the other charts as well. The charts are extracted from presentations the author has given to various administrations involved with fixed wireless policy development.

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Interference Relationships -- Outline

- P-MP Radio and Area License Concept
- Basic Propagation Model
- P-MP Radio Cells and Self-Interference
- Separation Distance and Coordination Trigger
- Separation Distance and Spurious Emissions
- Transmit Power Control and Interference

Area License Concept

- Point-to-multipoint (P-MP) Stations are often used for area coverage.
- Assume an area license where an exclusive permit authorizes any number of stations in a geographic area and frequency block.
- Assume an operator manages bandplan, self-interference, and in-band unwanted emissions for lowest operating cost.
- Coordination triggered if signals crossing area boundary can cause harmful interference.

Propagation Model

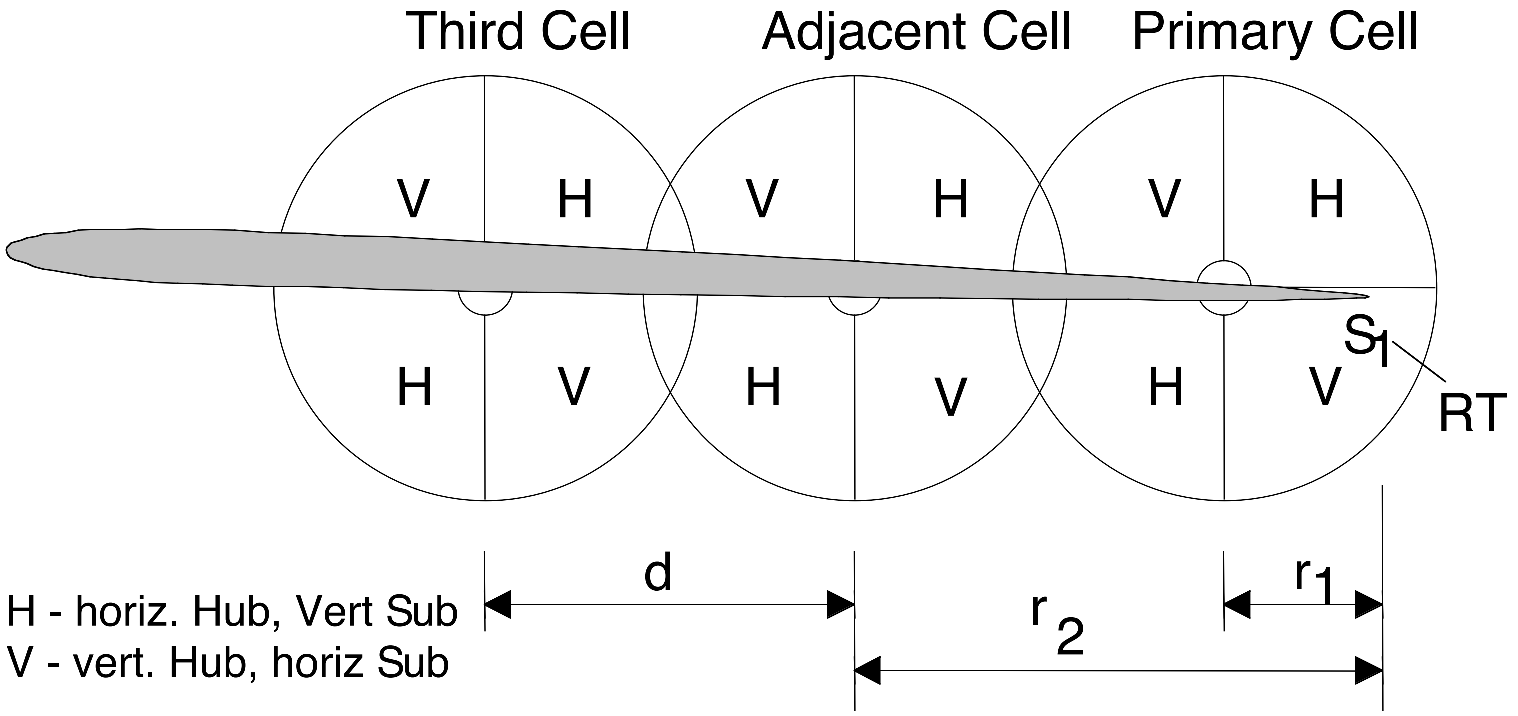
- Received Power (or interference), P_r , Watts/MHz is:

$$P_r = P_t G_t G_r (\lambda /4 \pi d)^2 / L_x = PFD A_e / L_x$$

where P_t = transmit power, Watts/MHz, G_t = transmit antenna gain, G_r = receiver antenna gain, λ = wavelength in meters, and d = distance in meters. The received power also by power flux density, PFD = $P_t G_t /(4 \pi d^2)$, often in dBW/MHz-m^2 and the antenna area, $A_e = G_r \lambda^2 / (4 \pi)$, in m^2.

- Excess Terrestrial Path Loss, L_x , (ITU-R Rec P.530) includes:
  - L_d, Fresnel diffraction near obstructions, 0 dB w/line-of-sight clearance of a few meters.
  - L_{sd}, sand and dust, 0 dB clear-sky
  - L_α, atmospheric gases, 0.15 dB/km nom. in clear-sky @ 28 GHz
  - L_m, multipath, beam-spreading, and scintillation, 0 dB nom., std. dev. > ~ 5 dB for d > 5 km
  - L_r, loss from precipitation, 0 dB nom. clear-sky, fades depend on rain-rate
- L_x = 0 dB in Free-Space, L_x ~= 1 dB in Clear-Air @ 5 km, 28 GHz
- Fades > 20 dB due mostly to precipitation @ < 5 km, 28 GHz.

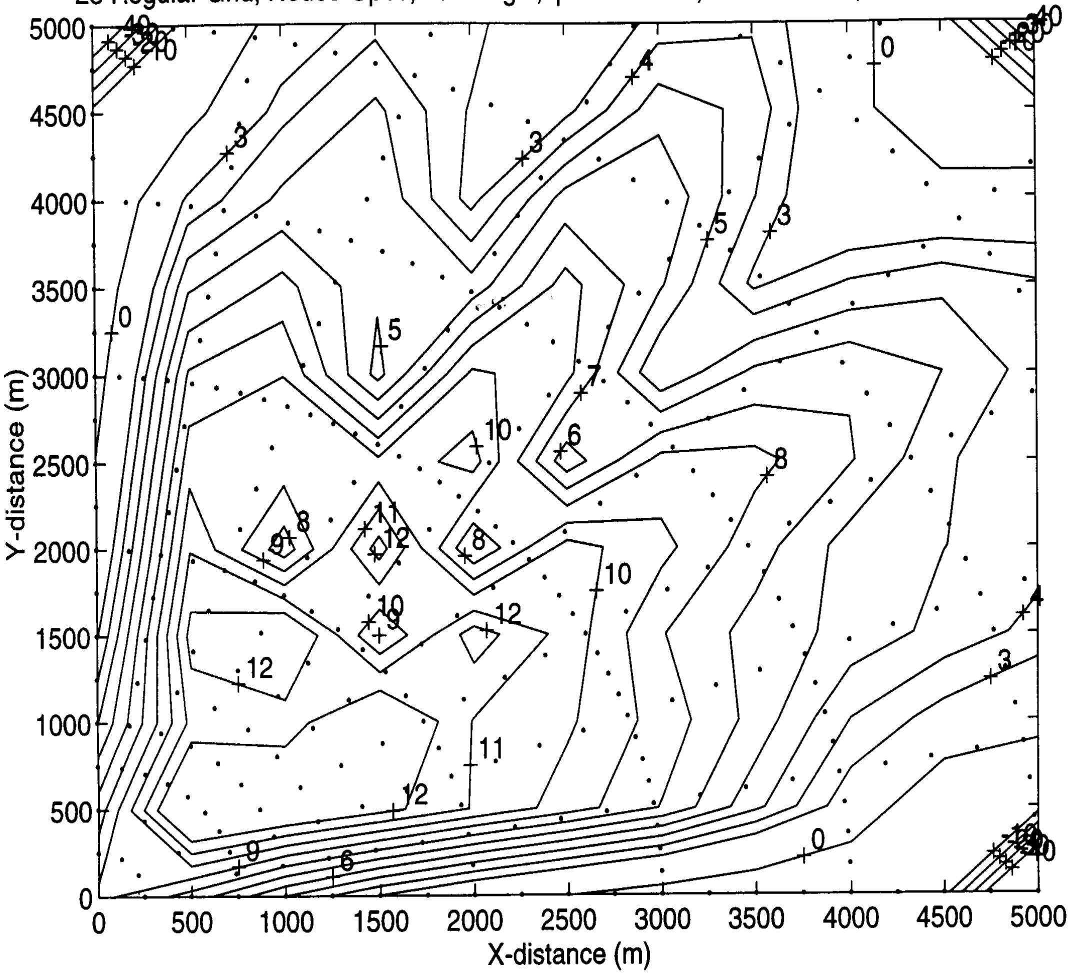
P-MP Radio System: Array of Cells



- Fixed antenna polarization management enables frequency re-use between sectors.
- If a hub sector transmits vertically, remote terminals (RTs) in the same sector transmit horizontally.
- ~4x re-use: QPSK, x-Pol < -25 dB, $r_2/r_1 > \sim d/2$.

Margin at RT from Multi-Hub Interference

- Arrayed (4-sector) Hub Simulation
- 5 km Hub spacing, 25x25 Hub grid
- Clear Air, Balanced Hub EIRP
- Actual antenna pattern data (ITU-R Doc. JRG7d-9d/11)
- Margin, dB, is amount > 8 dB Eb/(No+Io) Threshold for QPSK

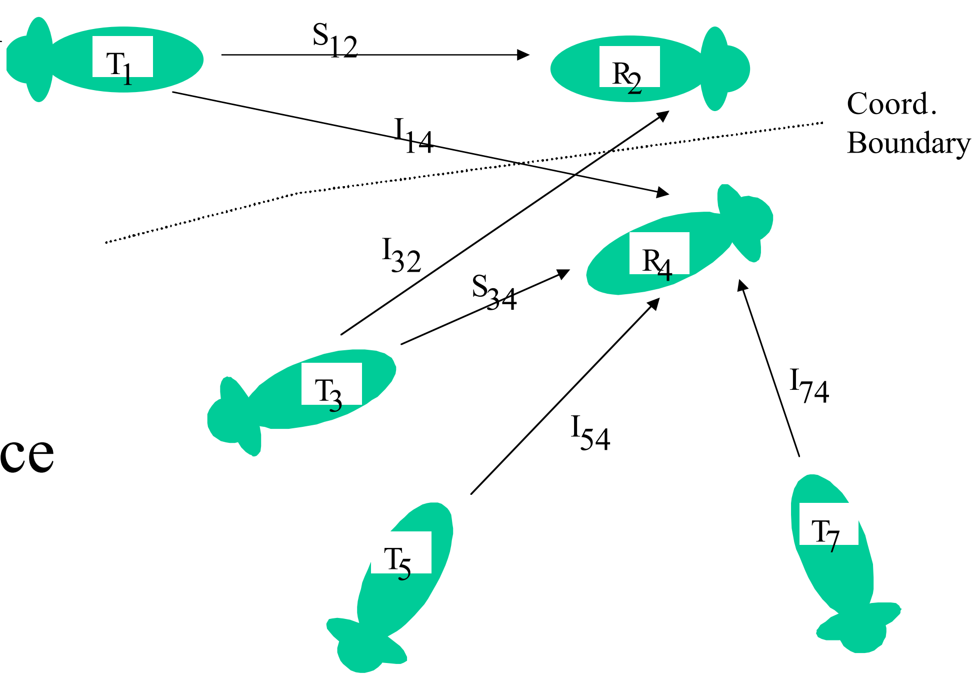

Margin (dB) at RT over Hub Sector

25 Regular Grid, Nodes-Cpes,DS Margin,space=500 m,Area "0" Rain, V CPE Rcvr Pol

- **100 % coverage within the sector, no margin at 2.5 km on sector boundary**

Interference Scenarios

- All emitters are potential interferers
- S/(N+I) trade-off
- Noise limited system objective
- Cross-coupled interference potential
- $N_t = kTB = -144$ dB(W/MHz)
- $N = N_t + NF$, dB
- For I/N < -10 dB @ 8 dB NF, I < -146 dB(W/MHz)



I/N, dB	SNIR Degradation, dB
-30	0.004
-20	0.043
-10	0.414
0	3.010
10	10.414

Transmitted PFD versus EIRP

$$\mathbf{PFD_{tx} = P_t\, G_t / (}\, 4\, \pi\, d^2) = \mathrm{EIRP} / \mathbf{(}\, 4\, \pi\, d^2)$$

Power Flux Density dB(W/MHz-m^2)	EIRP Spectral Density, dB(W/MHz)					
	Distance, km					
	1	5	10	20	50	100
-115	-44	-30	-24	-18	-10	-4
-110	-39	-25	-19	-13	-5	1
-105	-34	-20	-14	-8	0	6
-100	-29	-15	-9	-3	5	11
-90	-19	-5	1	7	15	21
-80	-9	5	11	17	25	31
-70	1	15	21	27	35	41
-60	11	25	31	37	45	51

- Transmitting an effective isotropic radiated power (EIRP) of -5 dB(W/MHz) produces a power flux density (PFD) of -90 dB(W/MHz-m^2) at 5 km.

Received PFD to Received Signal Level (RSL)

$$\mathbf{PFD_{rx} = 4\,\pi\,P_r\ /\ (\ G_r\,\lambda^2)}$$

RSL, Pr dB(W/MHz)	Comments	Power Flux Density, dB(W/MHz-m^2), at 27.5 GHz					
		Receiver Antenna Gain, dBi					
		36	16	6	0	-4	-14
-93	RSL @ 5km & 8 dB(W/MHz) EIRP	-79	-59	-49	-43	-39	-29
-106	RSL @ 5km & -5 dB(W/MHz) EIRP	-92	-72	-62	-56	-52	-42
-127	RSL Thres., BER=10^{-6}, Eb/No = 8 dB	-113	-93	-83	-77	-73	-63
-136	Noise floor, 8 dB NF	-122	-102	-92	-86	-82	-72
-146	Max interference for I/N < -10 dB	-132	-112	-102	-96	-92	-82

- A received PFD of -92 dB(W/MHz-m^2) with a 36 dBi receiver antenna produces an RSL of -106 dB(W/MHz).
- An I/N goal up to -10 dB requires a PFD from interference less than -112 dB(W/MHz-m^2) with a 16 dBi antenna and -132 dB(W/MHz-m^2) with 36 dBi antenna.

Free-Space Separation Distance for I/N < -10 dB

$$d = \left(\mathrm{EIRP}/(4\pi\, \mathrm{PFD}_{rx}) \right)^{0.5}$$

- Simple Antenna: Hub: front (180°) 16 dBi, other -10 dBi, RT: front (4°) 36 dBi, other -10 dBi

Path	Orientation	EIRP, dB(W/MHz)	PFD_{rx}, dB(W/MHz-m^2)	d, km	Approx. Probability	Comments
Hub-to-Hub	Back-to-Back	-31	-86	0.2	0.25	
	Back-to-Front	-31	-112	3.2	0.25	
	Front-to-Back	-5	-86	3.2	0.25	
	Front-to-Front	-5	-112	63.2	0.25	Problem: long range, Likely
RT-to-Hub	Back-to-Back	-51	-86	0.0	0.494	
	Back-to-Front	-51	-112	0.3	0.494	
	Front-to-Back	-5	-86	3.2	0.006	
	Front-to-Front	-5	-112	63.2	0.006	Low probability, ATPC Mitigates
Hub-to-RT	Back-to-Back	-31	-86	0.2	0.494	
	Back-to-Front	-31	-132	31.7	0.006	Desired Hub Dominates
	Front-to-Back	-5	-86	3.2	0.494	Reduces fade margin slightly
	Front-to-Front	-5	-132	631.5	0.006	Desired Hub Dominates
RT-to-RT	Back-to-Back	-51	-86	0.0	0.9779	
	Back-to-Front	-51	-132	3.2	0.0110	
	Front-to-Back	-5	-86	3.2	0.0110	
	Front-to-Front	-5	-132	631.5	0.0001	Low probability, likely over horiz

- Hub-to-Hub Front-to-Front coupling requires >60 km separation at -5 dB(W/MHz) Hub EIRP

Comments on Coordination Triggers

- Suggested trigger: coordinate if the PFD at a boundary exceeds a threshold of about -115 dB(W/MHz-m^2).
- Such a level protects (I/N < -10 dB) hubs (with antenna gains less than 18 dBi) and RTs assuming a clear air received signal level of receiver threshold plus fade margin.
- A PFD trigger of -132 dB(W/MHz-m^2) is needed to protect RTs (with gains up to 36 dBi) that operate at receiver threshold.
- A coordination boundary of 20 km (US LMDS Part 101 rule) is sufficient for off-beam interference scenarios, but is not sufficient for main-beam coupling scenarios.
- A coordination threshold should be based on a PFD value rather than (or in addition to) a coordination distance.

Potential Separation Distance from Spurious Emissions

- Per ITU Radio Regulation, Spurious Emissions for Fixed Service Stations above 15 GHz limited to a maximum of -43 dBW/MHz.

- Protection Level (I/N < -10 dB) is -146 dBW/MHz with 8 dB Noise Figure.

$$d = (\lambda/4\pi)(P_tG_tG_r/P_r)^{0.5}$$

Transmitted Interference Power, Pt	-43	dBW/MHz
Received Interference Power, Pr	-146	dBW/MHz
Frequency	28	GHz

	Free-Space Separation Distance (d), m			
	Receiver Antenna Gain (Gr), dBi			
Transmitter Antenna Gain (Gt), dBi	-10	0	15	36
-10	12	38	214	2,403
0	38	120	677	7,599
15	214	677	3,808	42,732
36	2,403	7,599	42,732	479,461

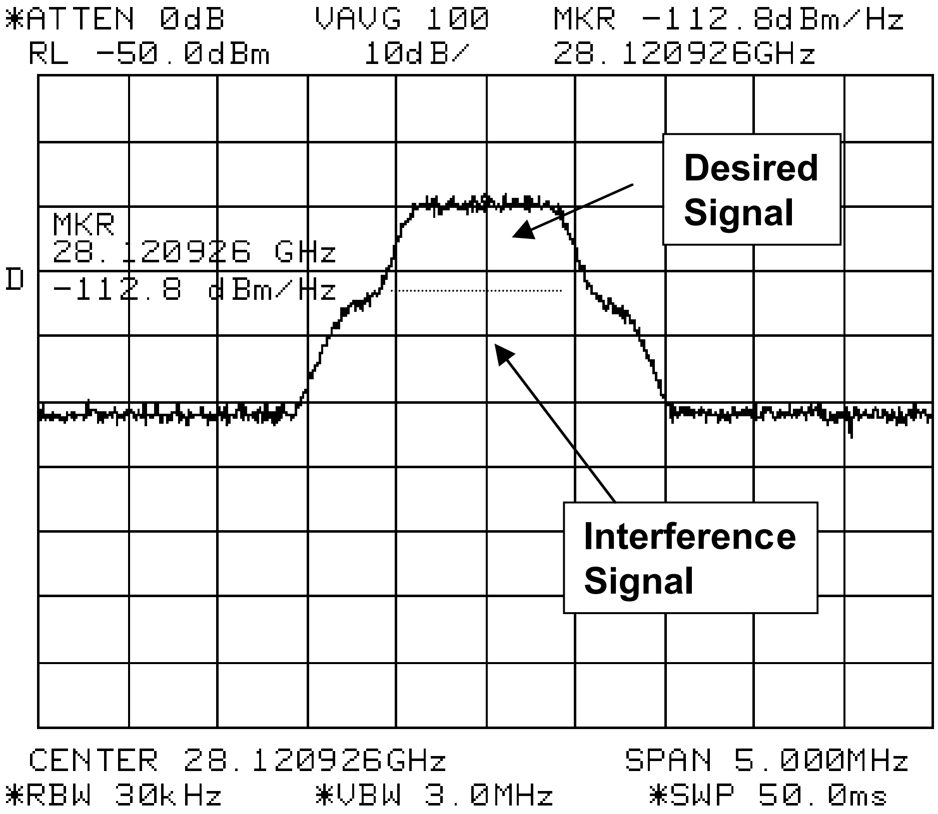
- Several kilometer separation distance if main-beam coupling.

ATPC in P-MP Radios

- Upstream Automatic Transmit Power Control (ATPC) useful, practical, and necessary (at least 15 dB range).
- Downstream ATPC difficult to stabilize. Reduces frequency re-use.
- Interference must be calculated during faded (max power) conditions and consider path (attenuation and antennas gains) between transmitter and receiver.

Automatic Power Control

- ATPC algorithms increase power to offset path fades but usually also increase power to overcome interference.
- Example shows: Rate 7/8 QPSK signal at 6 dB Eb/No on top of Rate 1/2 QPSK interference.
- System stability concern for allowing unconstrained power increase to overcome interference.
- For maximum stability and lowest cost, inter-system coordination levels should be noise and not interference limited.



Interference Relationships -- Summary

- The propagation equation allows signal and interference determination.
- An interference-to-noise comparison allows an interference acceptability determination.
- Separation-distance and power-flux-density are two key interference management terms.