COEXISTENCE ANALYSIS AT 26 & 28 GHz

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Purpose: For information on some inputs to the process of developing frequency assignment recommendations for the 24.5 - 29.5 GHz bands in Europe.

COEXISTENCE ANALYSIS AT 26 & 28 GHz

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BACKGROUND

- Working with Harris Systems Ltd. And Wavtrace Inc. on coexistence issues for TDD and FDD
- Inputs to European fora - ETSI and SE19
- Complementary results to inputs to IEEE 802.16

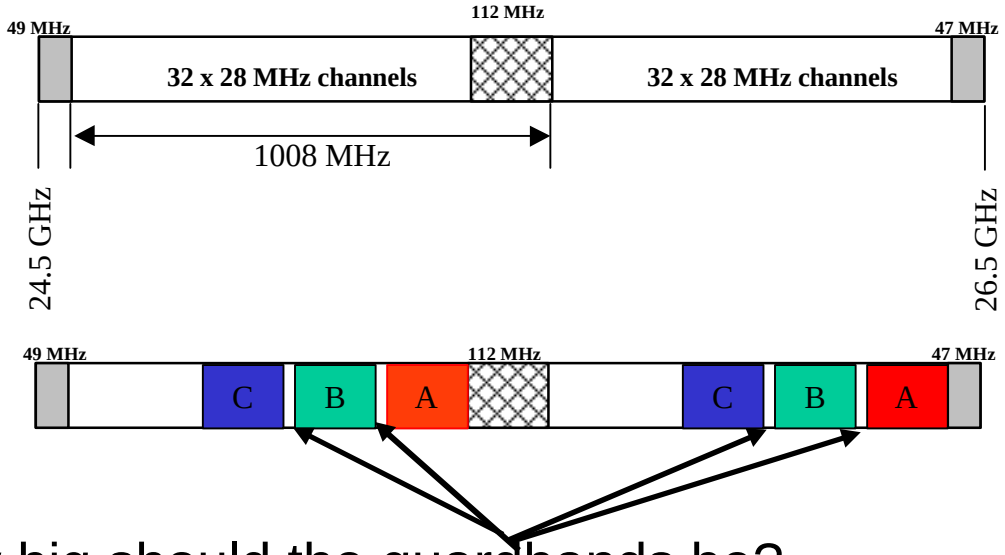
AGENDA

- Problem statement
- General assumptions
- Same area, adjacent frequency block interference (“adjacent channel”)
- Same frequency block, adjacent area interference (“co-channel”)
- Concluding remarks

FREQUENCY BANDS

- 26 GHz now licensed in several European counties for FWA
- 28 GHz to be licensed (e.g. UK auctions this fall)
- New 32 GHz band
- Questions arise about guidelines for frequency assignment to ensure that operators can “coexist”
- Mainly addressed in CEPT/ERC/SE19, based on equipment parameters specified by ETSI TM4

26 GHZ BAND & TYPICAL ALLOCATION

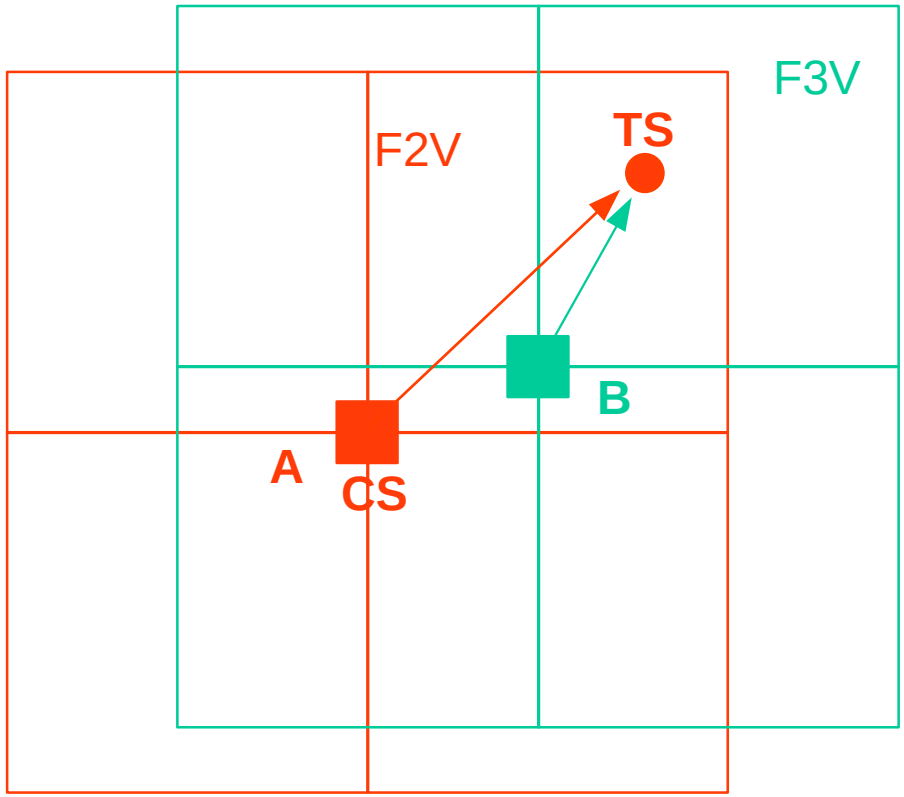


- How big should the guardbands be?
- How far apart should co-channel systems be?

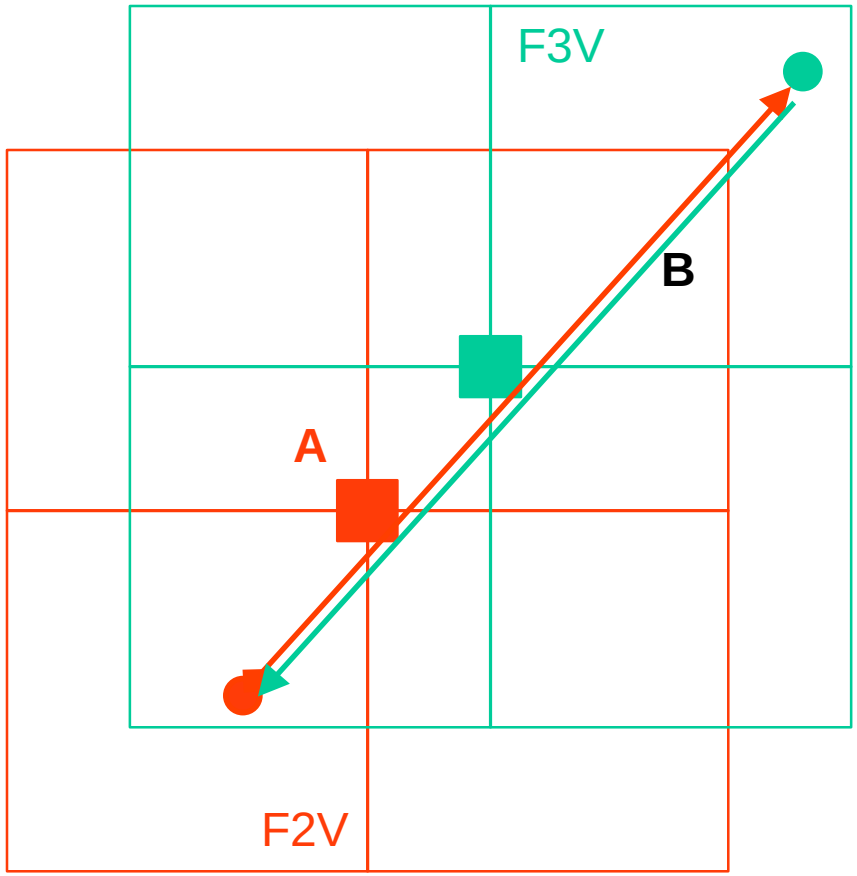
SYSTEMS OF INTEREST

- Point-to-Multipoint systems conforming to ETSI EN 301-213, parts 1 - 3
- Only Quaternary modulation systems considered in coexistence analysis so far
- Frequency and Time Division duplexing
- Various TS antennas

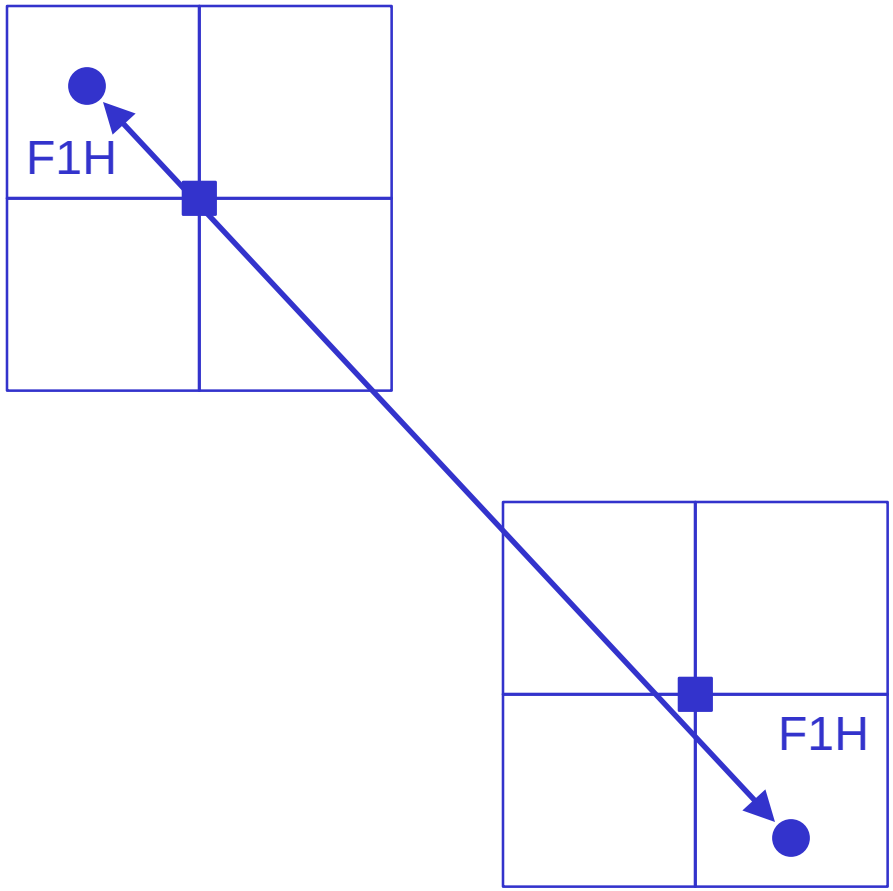
CS-TS ADJACENT CHANNEL INTERFERENCE - FDD/TDD



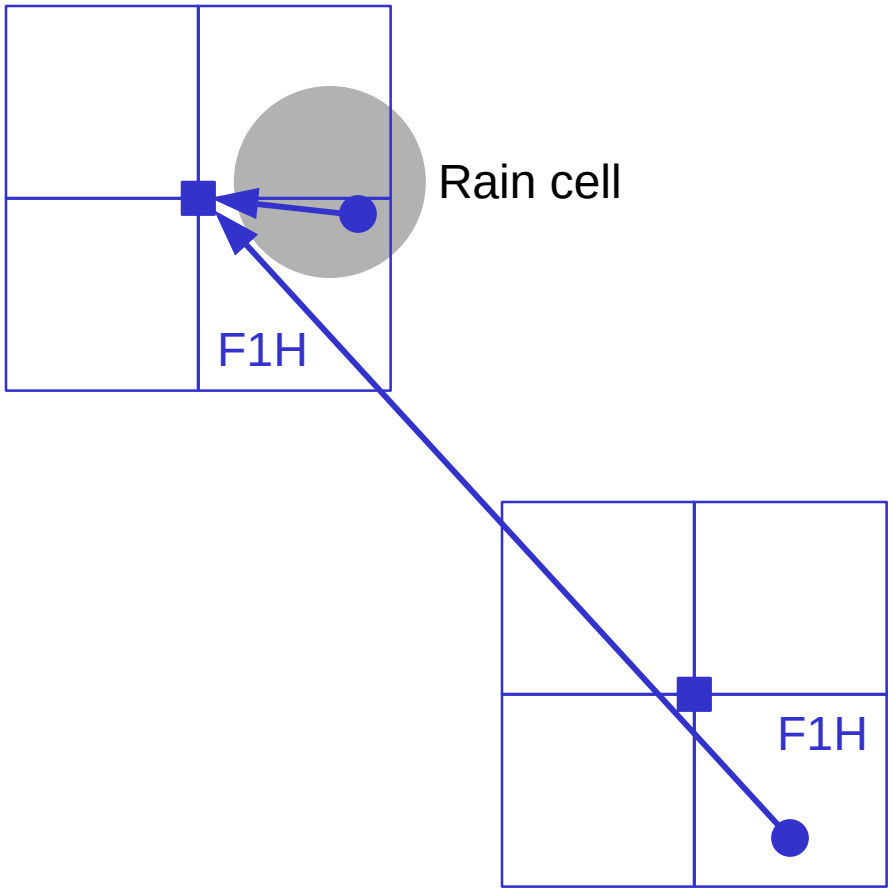
TS-TS ADJACENT CHANNEL - TDD ONLY



TS-TS CO-CHANNEL - TDD ONLY



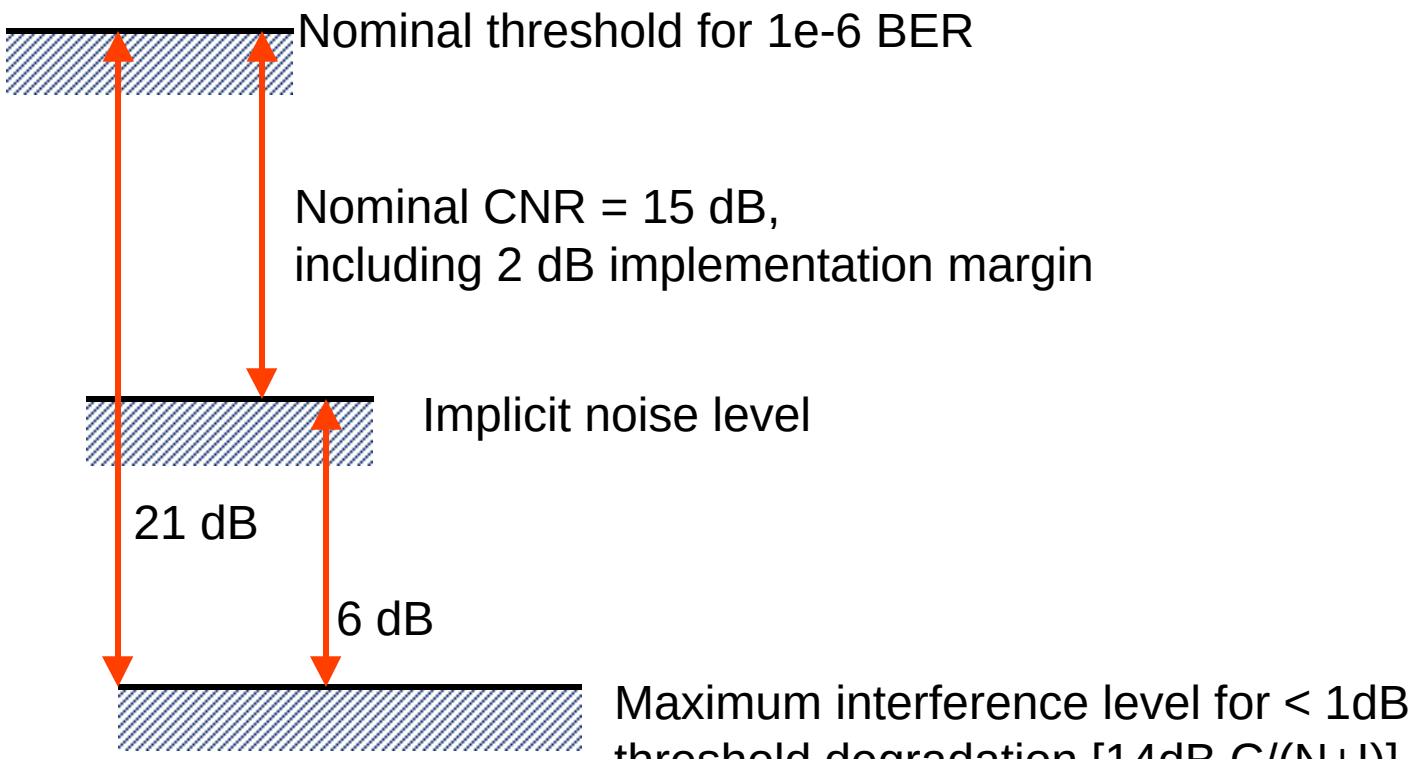
TS-CS CO-CHANNEL - TDD/FDD



GENERAL FORMULA

$$Pr = P_t + G_t + G_r - 20\log(D) - 20\log(F) - 92.4 - [\text{Net Filter Discrimination}] - [\text{Atmospheric attenuation}*(D)] \quad \text{dBm}$$

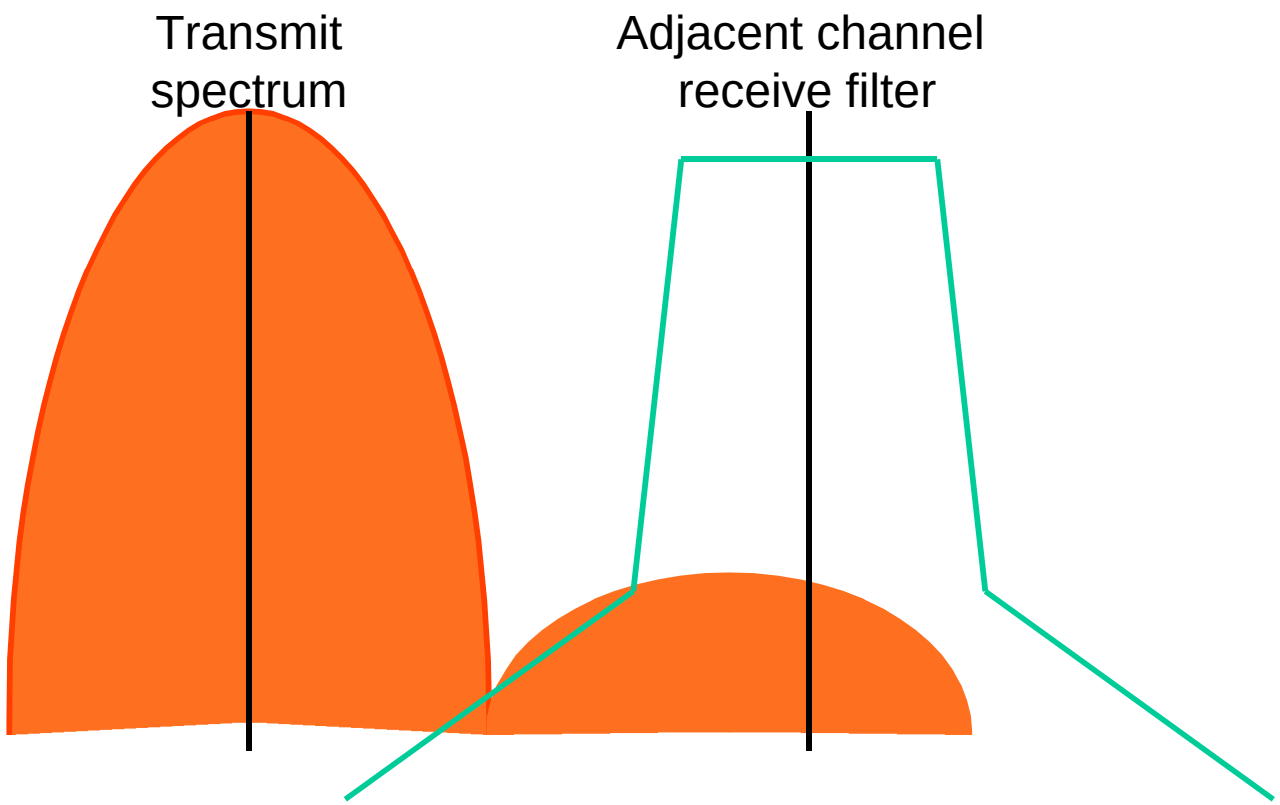
TARGET INTERFERENCE LEVEL



SYSTEM THRESHOLDS - QUATERNARY MODULATION

System BW (Mbit/s/MHz)	ETSI threshold (dBm)	Interference target - dBm
4/3.5	-86	-107
8/7	-83	-104
16/14	-80	-101
34/28	-77	-98

SYSTEM SELECTIVITY



MEASURING SYSTEM SELECTIVITY

- Characterised by “Net Filter Discrimination” (NFD)
- NFD found by:
  - system measurements, or
  - inference from published standards, or
  - extrapolation of measurements
- Tables given in document SE19(99)195 for “typical” systems, based on measurement and extrapolation

NFD DEFINITION

$$NFD = 10\log_{10}\left(\frac{\int_{-\infty}^{+\infty} S_V(f)\cdot\left|H_v(f)\right|^2\cdot df}{\int_{-\infty}^{+\infty} S_I(f)\cdot\left|H_v(f)\right|^2\cdot df}\cdot\left(P_I/P_V\right)\right)$$

- *"The carrier to interference ratio at the receiver filter output, divided by the carrier to interference ratio at the receiver input"*

NFD TABLE EXAMPLE - 1

Victim Interferer dF(MHz)	4Mb/s 4Mb/s	4Mb/s 8Mb/s	4Mb/s 16Mb/s	4Mb/s 34Mb/s	8Mb/s 4Mb/s
0	0	0	0	0	0
1,75	2	1	0	0	0
3,5	20	8	3	1	1
5,25	37	21	8	2	22
7	56	33	14	3	43
8,75	66	45	21	5	56
10,5	74	51	28	8	64
12,25	81	55	34	11	69
14	84	61	39	15	74
15,75		66	44	18	79
…..	…..	…..	…..	…..	…..
40,25				52	
42				54	
43,75				56	
45,5				58	

28 MHz guard

NFD TABLE EXAMPLE - 2

Victim	16Mb/s	16Mb/s	34Mb/s	34Mb/s	34Mb/s	34Mb/s
Interferer	16Mb/s	34Mb/s	4Mb/s	8Mb/s	16Mb/s	34Mb/s
dF(MHz)						
0	0	0	0	0	0	0
…..	…..	……	…..	…..	…..	…..
49	75	56			70	47
50,75	77	57			71	49
52,5		58			72	51
54,25		59			73	53
56		60			74	54
57,75		61				56
59,5		62				58
61,25		63				60
63		64				61
64,75		65				62

28 MHz guard

TRANSMIT POWER

- Maximum CS and TS transmit power = 24 dBm
- TSs have ATPC
- Nominal ATPC back-off 15 dB at cell edge

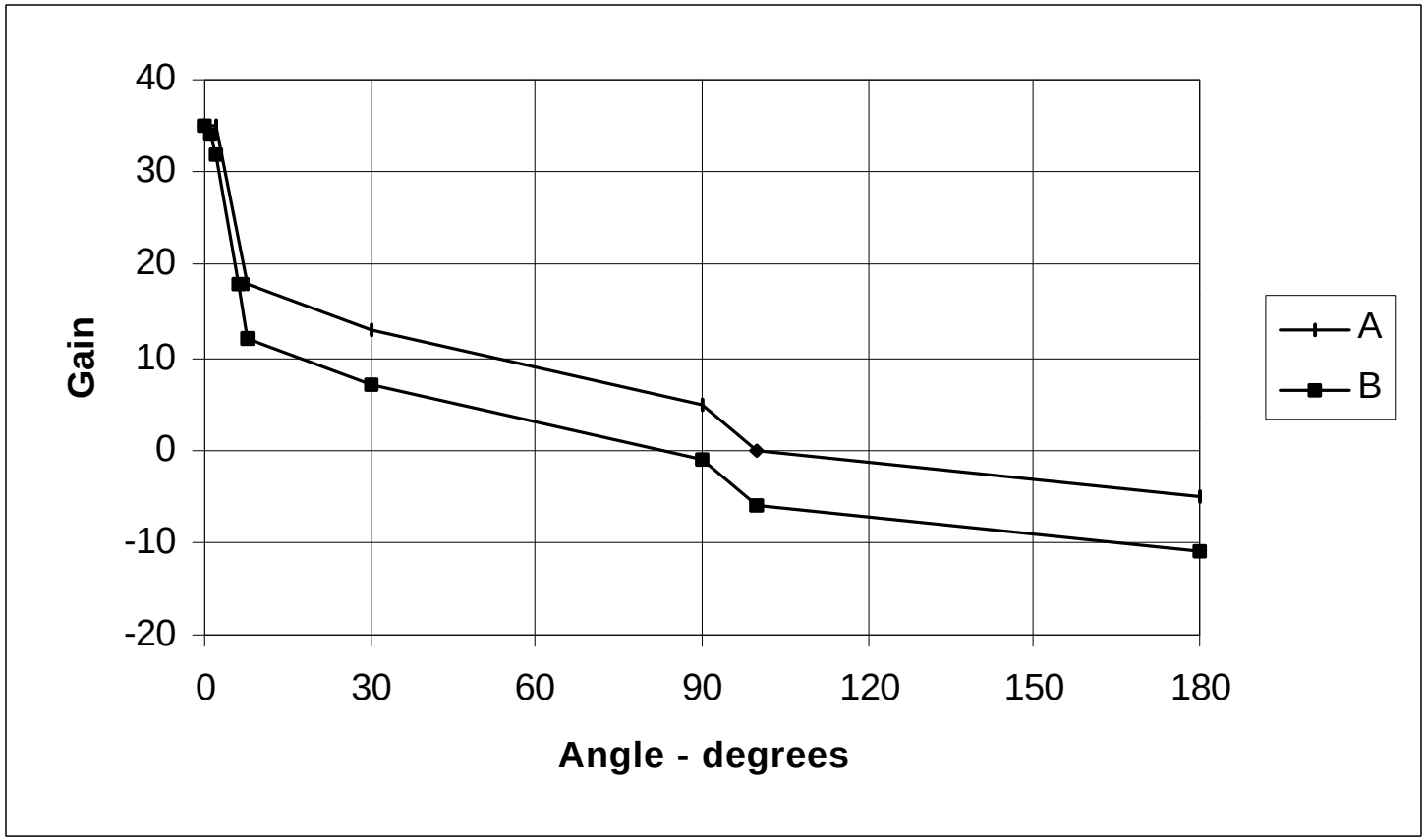
ANTENNA GAINS

- CS antenna 19 dBi, uniform in 90° sector
- TS antenna gain 34 - 35 dB max
- Patterns assumed follow ETSI and IEEE masks
- Several types.....

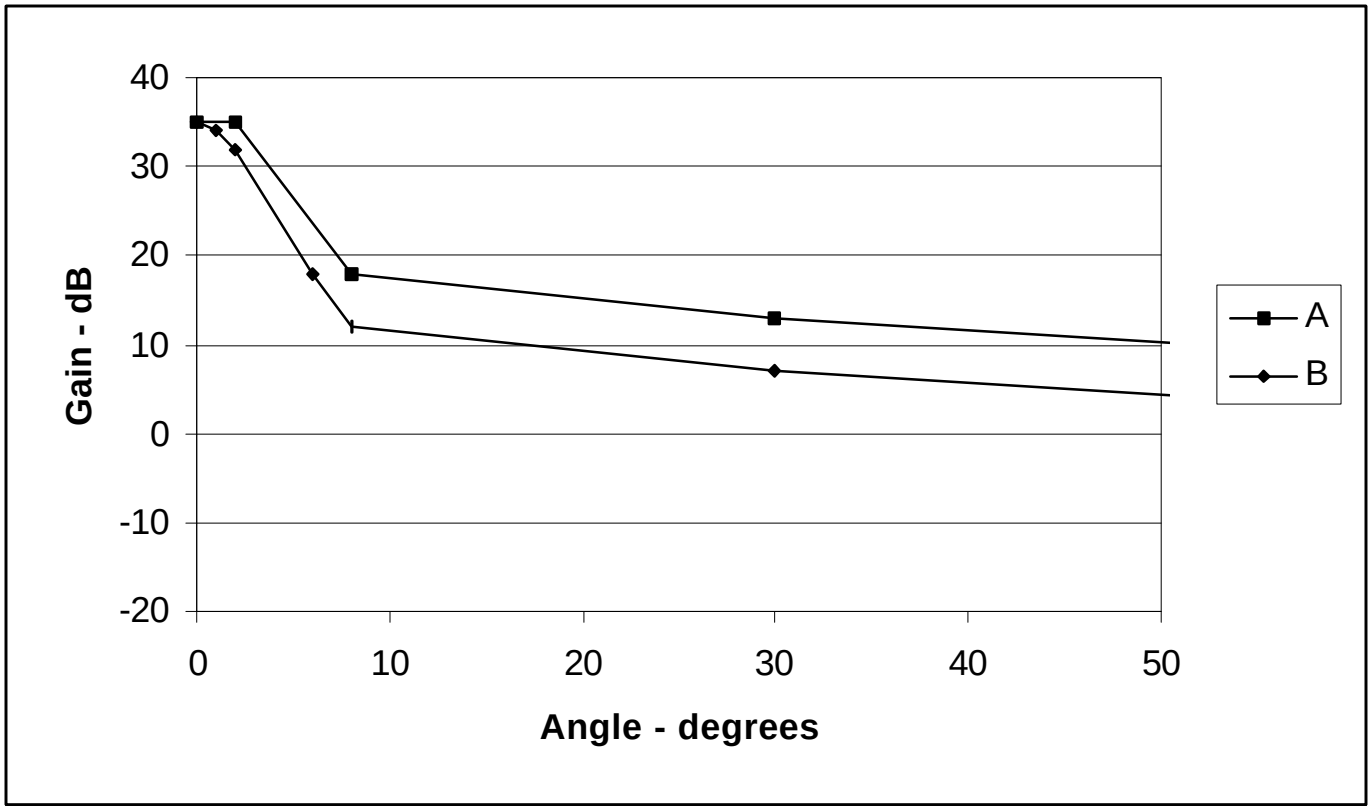
ANTENNA TYPES

Type	Comments
A	ETSI TS1 antenna described in EN 301 215-2, but with 35 dB assumed gain.
B	Hypothetical antenna based on A with improved side-lobe performance and more realistic nose shape
C	TDMA antenna assumed in TM04069
D	Idealised “rectangular” antenna of 4° beamwidth
E	IEEE 802.16 directivity Class 2 26 GHz antenna

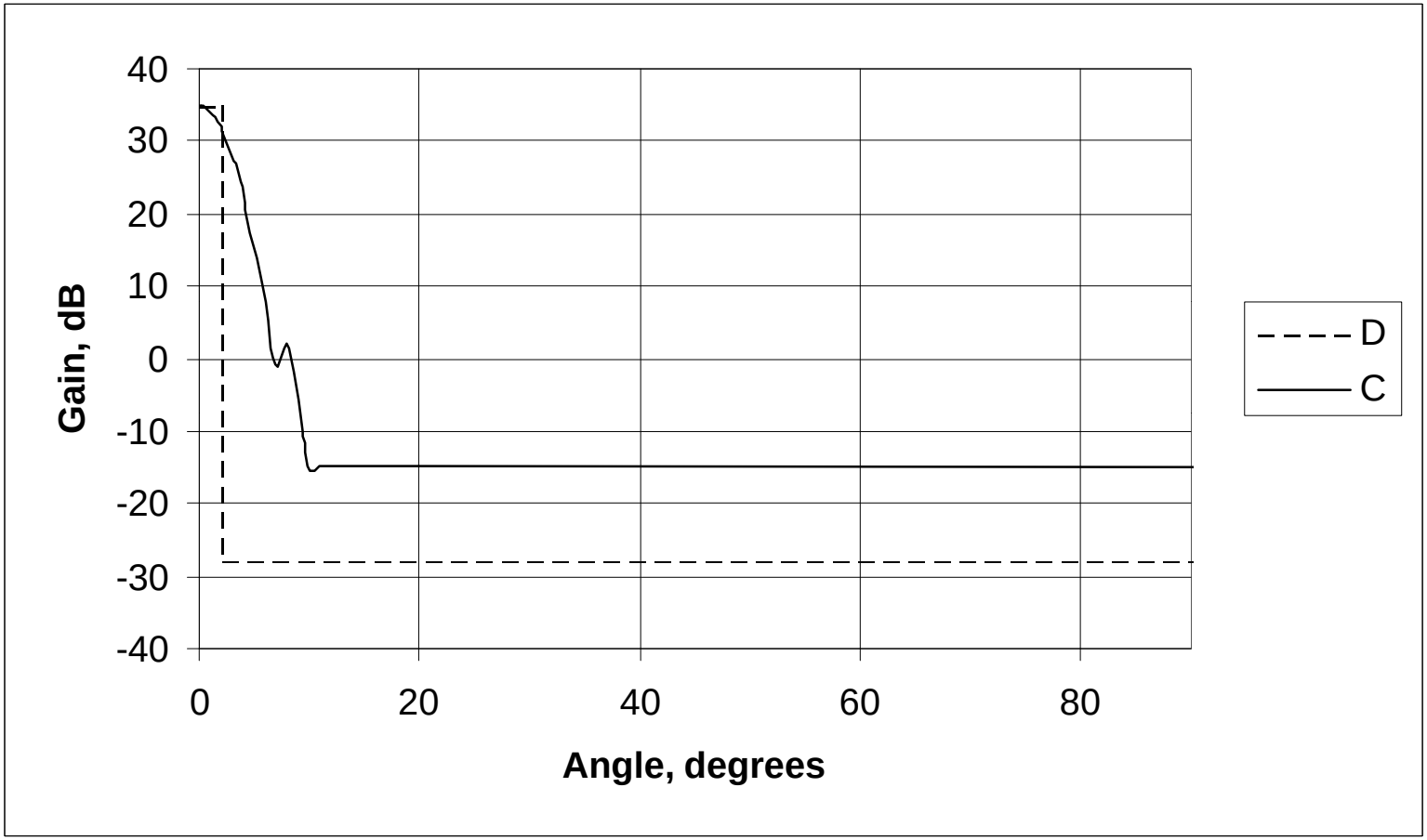
ETSI and modified ETSI



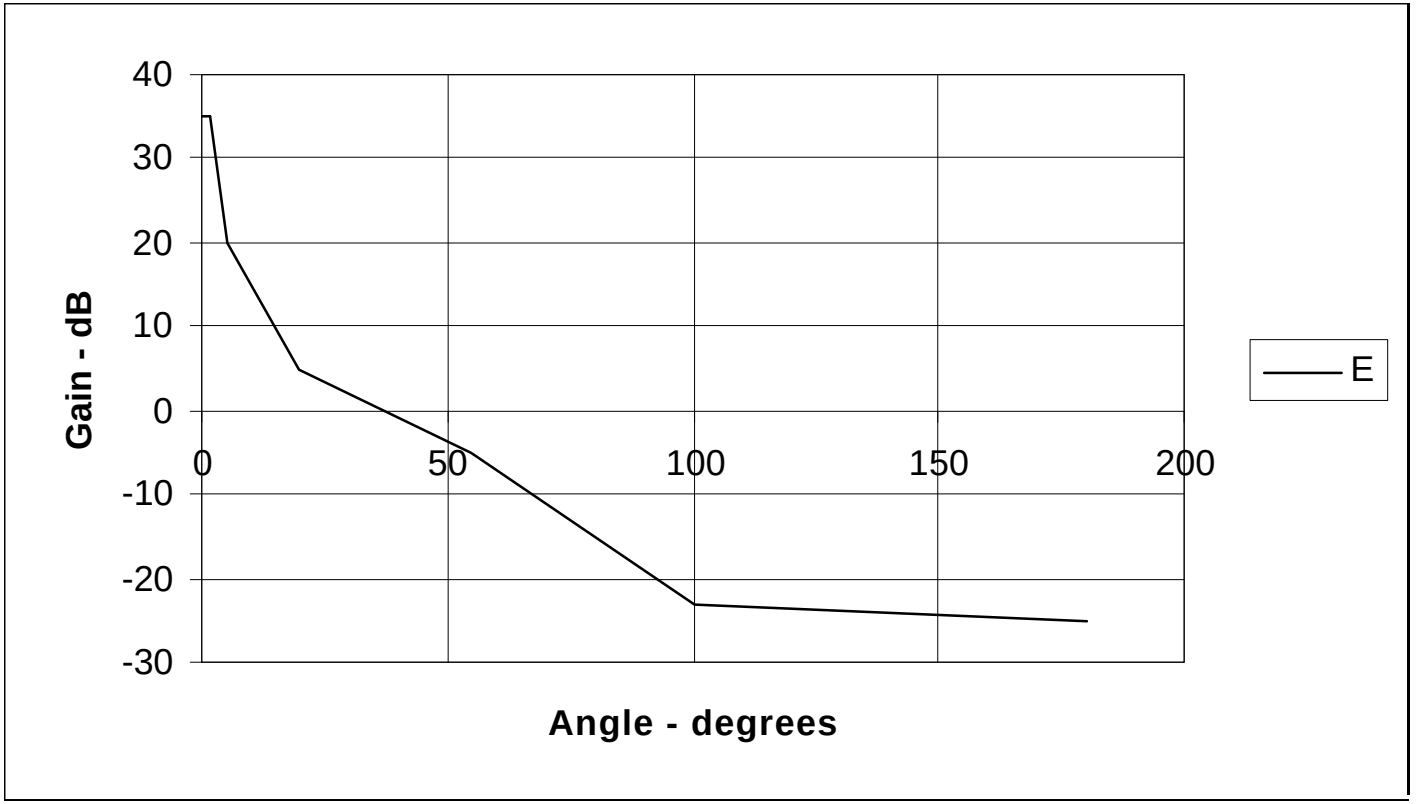
ETSI AND MODIFIED ETSI - EXPANDED



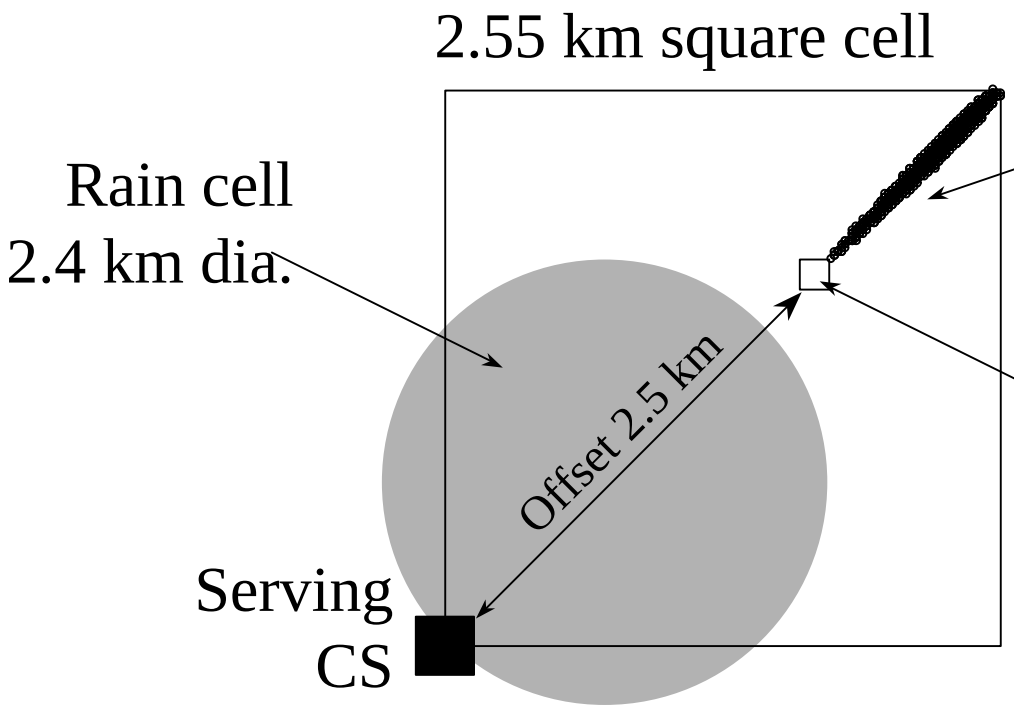
ETSI TM4069 TDMA EXAMPLE AND “IDEAL”



IEEE 802.16 26 GHz TYPE 2



GEOMETRY FOR CS-TS ADJACENT CHANNEL (FDD & TDD)



- Note that worst case interfering CS position is just outside rain cell

INTERFERENCE AREA

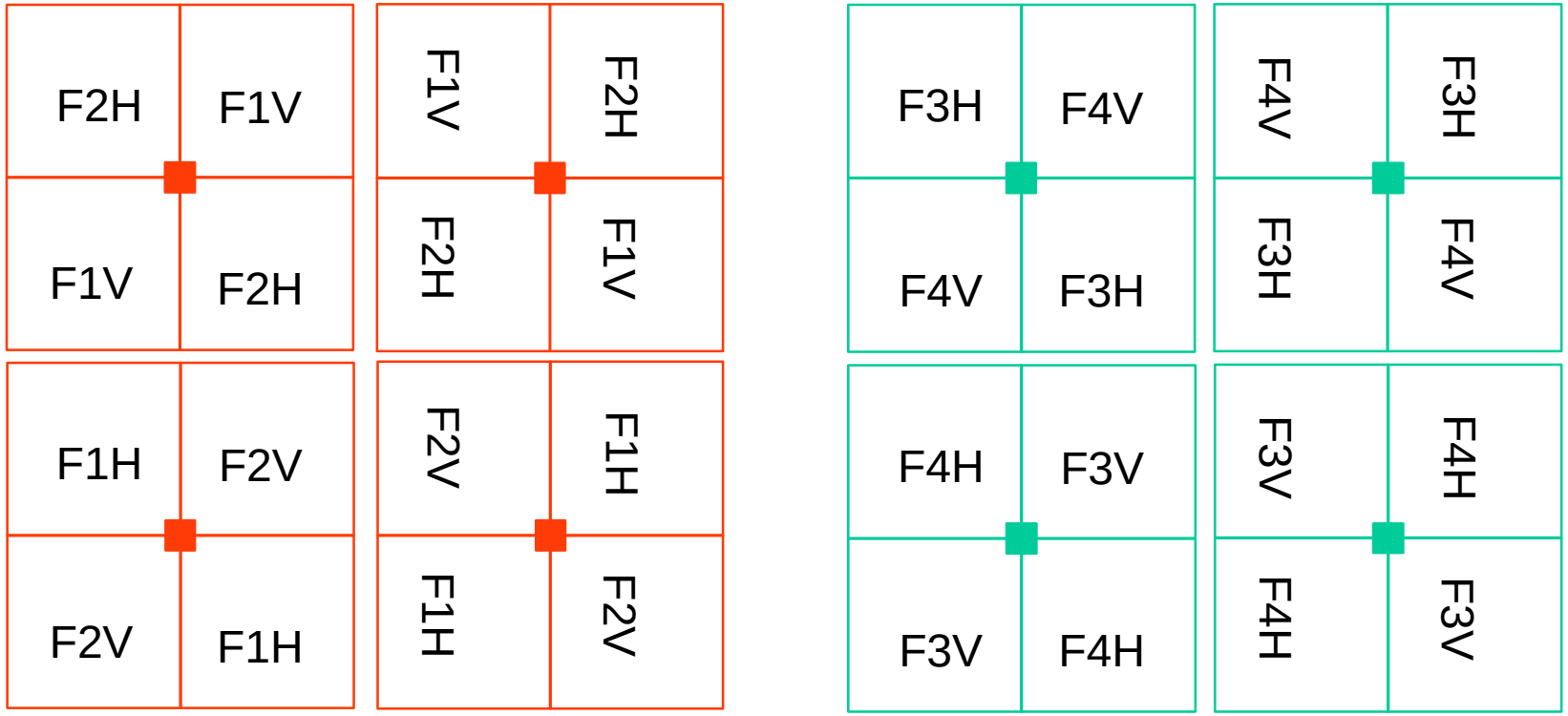
- Interference Area - IA - is *" the proportion of the sector area where interference is above target threshold"*
- Equivalent to *"the probability that any TS placed at random will experience interference above threshold*"

ISOP

- “Interference Scenario Occurrence Probability”
- Introduced in SE19(99)195 - draft of ERC technical report on 24.5 - 29.5 GHz FWA coexistence
- Defined as *“the probability that at least one of N_t terminals placed in the sector will be inside the IA”*
- Averaged across “all” the different frequency and polarisation assignment cases
- Significance for the adjacent channel case not clear, as ISOP is not a QoS measure
- Calculated for 15 TSs as a default

$$ISOP = P_x.(1 - [1 - IA]^{Nt})$$

EXAMPLE CELL TYPES



For 2-frequency 2-polarisation case, $P_x = 0.2446$

MONTE CARLO ANALYSIS

- Generate ~10,000 random TS locations in the cell
- For each, compute angle between boresight and interferer
- Look up antenna gain from mask
- Compute received interference power
- Subtract NFD
- Compare to threshold
- Increment interference counter if above threshold
- Compute IA
- Plot IA

RESULTS - 1

Antenna type	IA - %	ISOP - %
A	1.38	4.60
B	0.78	2.70
C	0.75	2.6
D	0.71	2.49
E	1.14	3.85

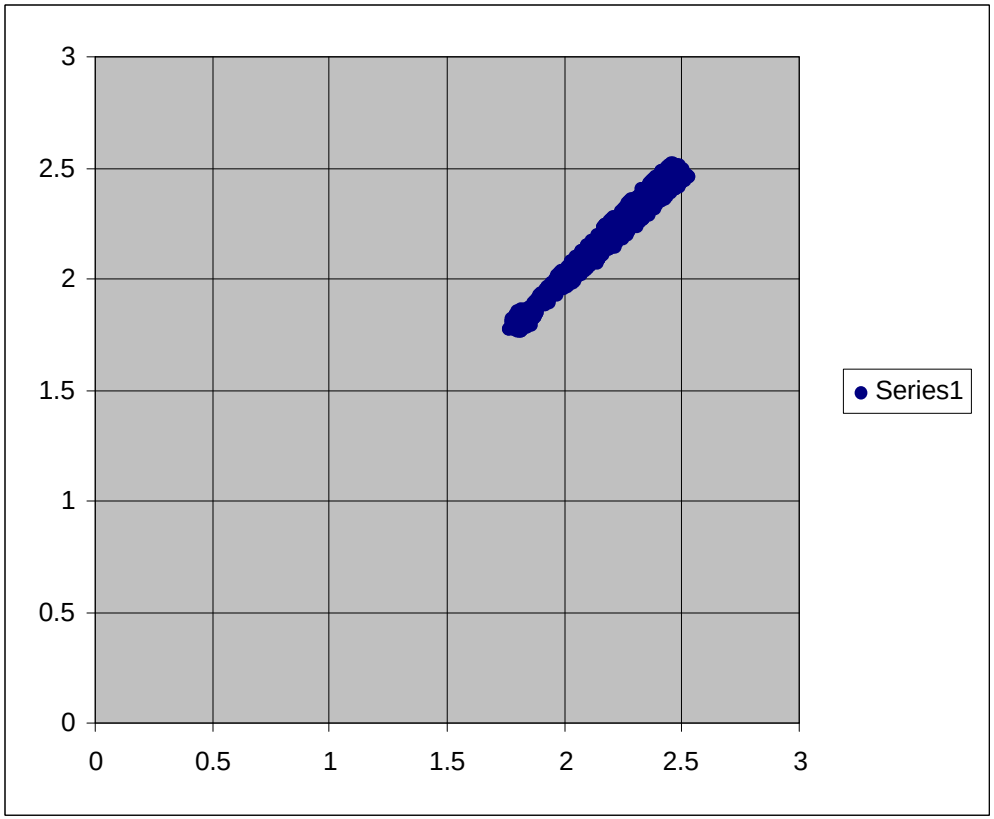
- 34 Mbit/s/28 MHz TDMA systems
- NFD = 54 dB - 56 MHz carrier spacing
- Threshold = -98 dBm
- CS Tx power 24 dBm
- Sector diagonal = 3.6 km

RESULTS - 2

Antenna type	IA - %	ISOP - %
D	1.55	5.11
E	2.07	6.60

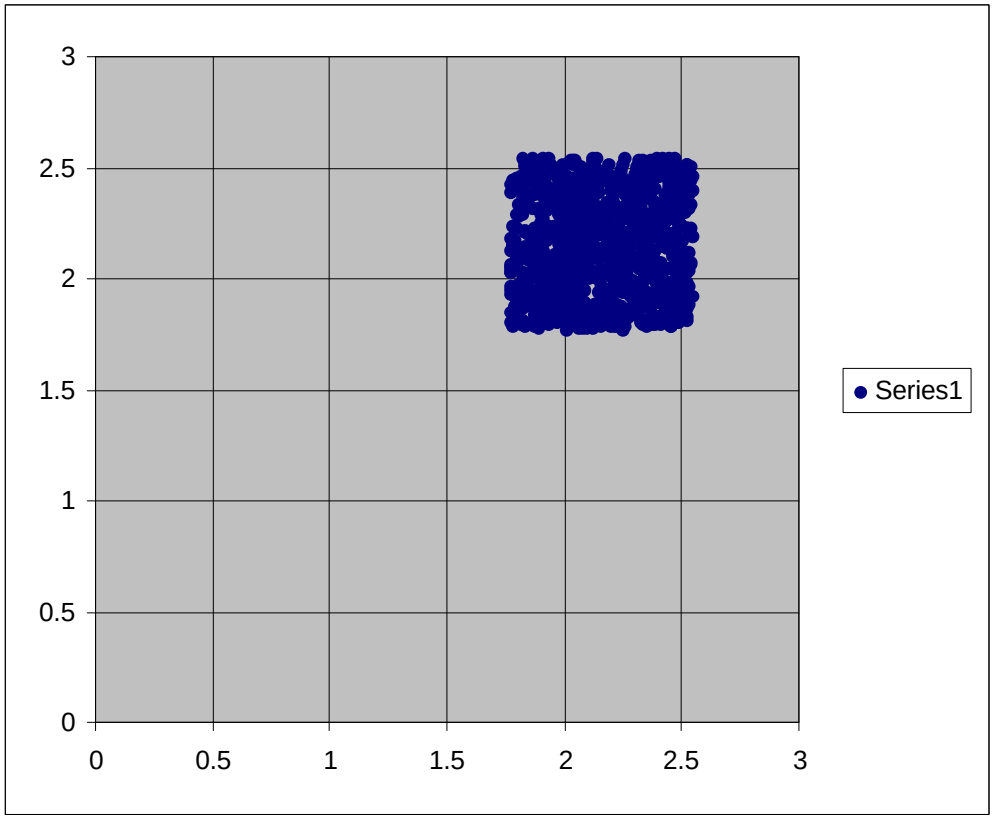
- 34 Mbit/s/28 MHz TDMA interferer; 4 Mbit/s/3.5 MHz victim
- NFD = 56 dB - 43.75 MHz carrier spacing
- Threshold = - 107 dBm
- CS Tx power 24 dBm
- Sector diagonal = 3.6 km

EXAMPLE OF IA PLOT FOR ETSI TS1 ANTENNA - 28 MHz guardband



IA FOR ADJACENT CHANNEL - no guardband

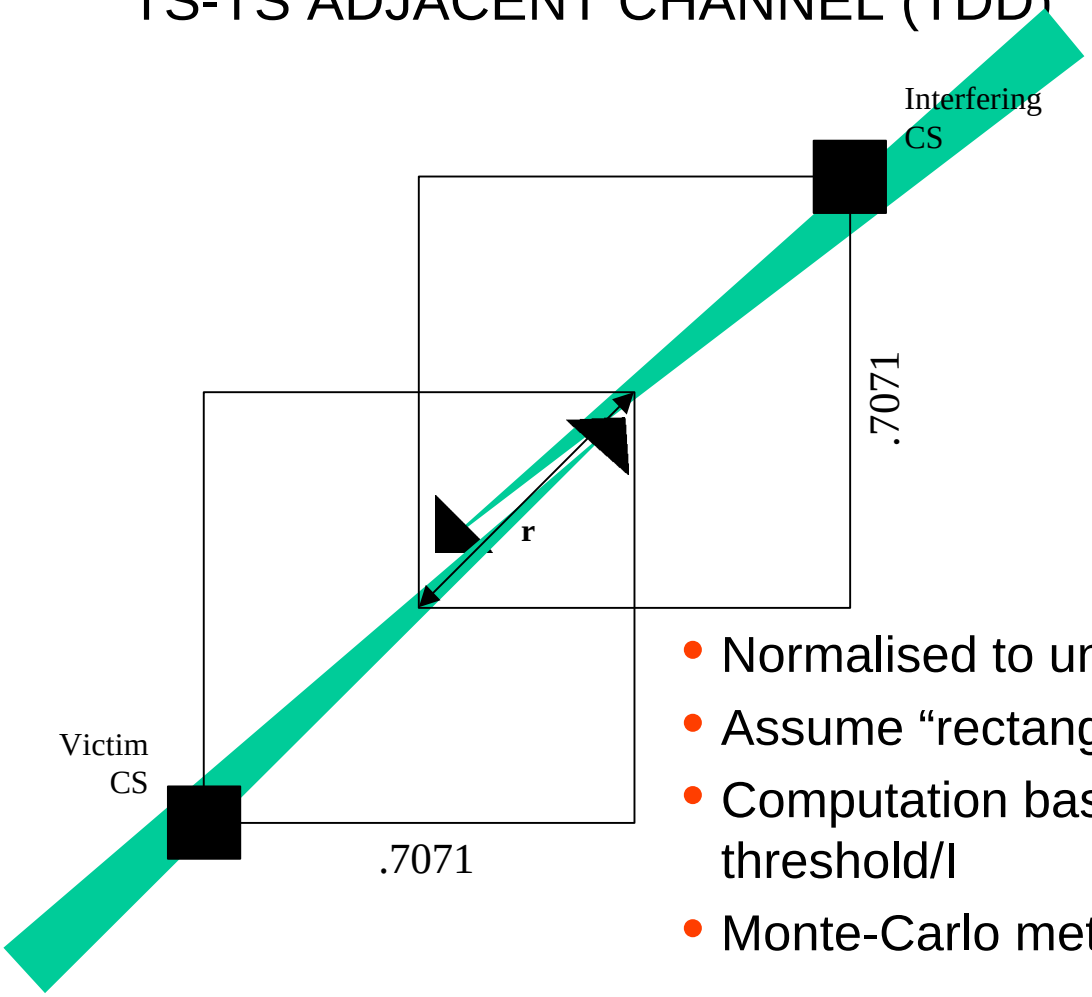
- TS1 antenna
- NFD = 23 dB
- IA = 9.2%



CS-TS ADJACENT CHANNEL - CONCLUSION

- 28 MHz guard band gives about 0.5 - 2% IA
- Sensitive to:
  - antenna pattern
  - CS Tx power
  - NFD
  - Threshold
  - Interferer location

TS-TS ADJACENT CHANNEL (TDD)

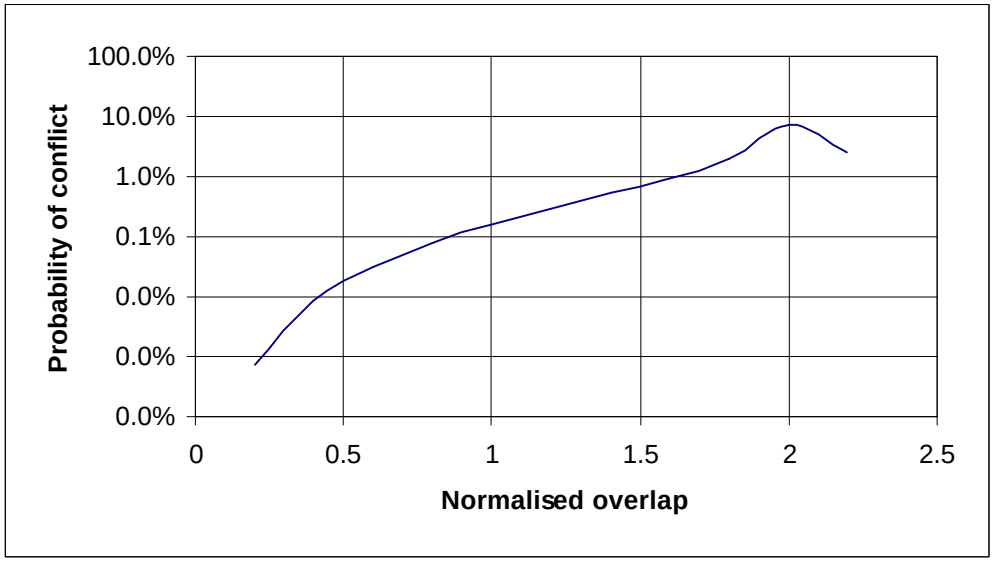


- Normalised to unity sector diagonal
- Assume “rectangular” antenna RPE
- Computation based on C/I, not threshold/I
- Monte-Carlo method

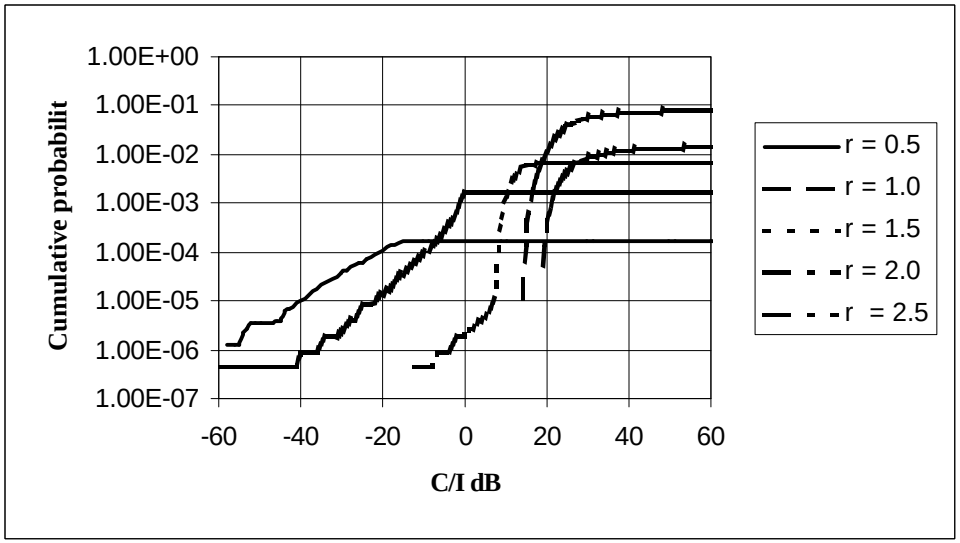
METHOD

- Position N terminals in each cell
- Check for mutual visibility between all pairs of terminals
- Where there is mutual visibility, calculate C/I allowing for uplink power control
- Update statistics
- Repeat!

PROBABILITY OF CONFLICT vs. OVERLAP



C/I DISTRIBUTIONS



- Correct C/I by:
  - TS/CS gain differential (16 dB typ.)
  - + ATPC cell-edge setting (15 dB typ.)
  - + NFD (54 dB typ.)
  - + X-POL (if applicable, 10 - 15 dB minimum)

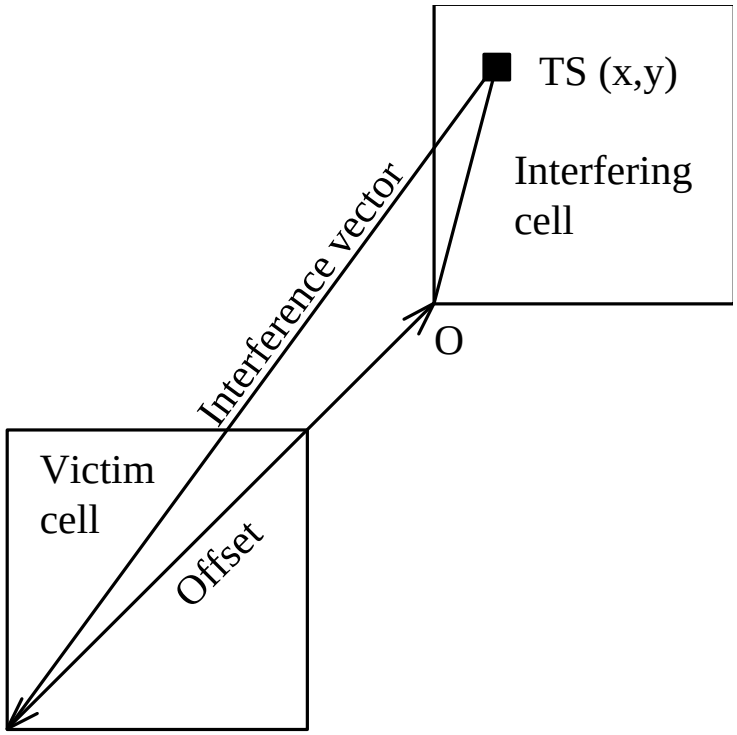
IMPLICATIONS

- For small overlaps, C/I can be very low, but probability also very low
- Maximum probability occurs for “co-sited” case
- But C/I then at acceptable level
- Rain fading is neutral or beneficial

OVERALL ADJACENT CHANNEL CONCLUSION

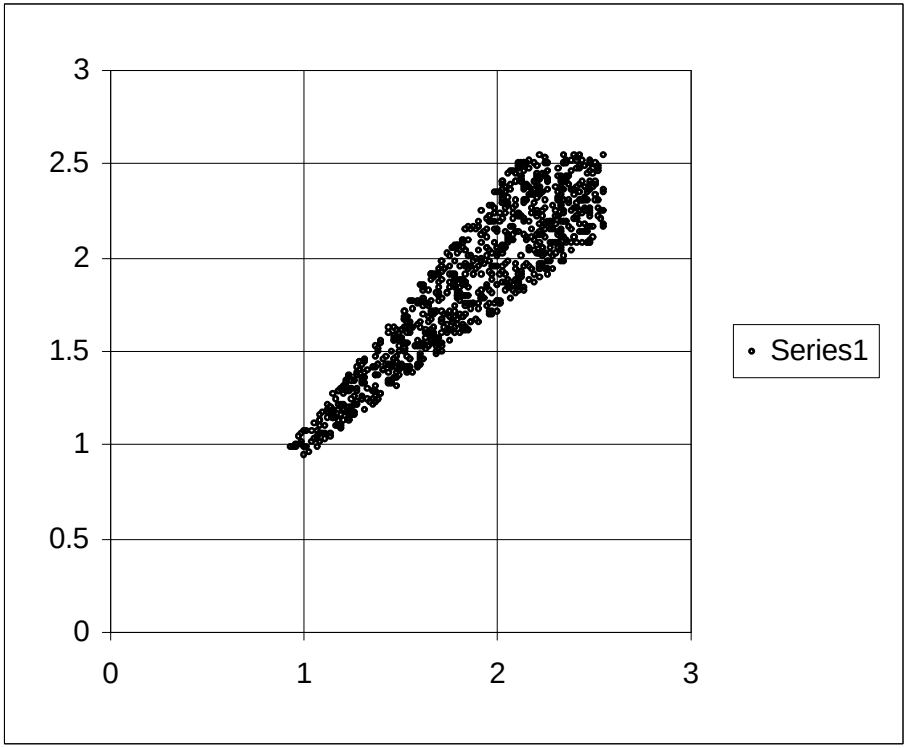
- 28 MHz guardband ensures 0.5 - 2% IA for CS-TS case
- Effect of interference is a small reduction in availability for most TSs in the IA
- TS-TS interference is not a limiting factor

TS-CS CO-CHANNEL (FDD and TDD)



- Limiting case for FDD cell spacing
- Based on adjacent channel Monte Carlo method
- Allows for atmospheric attenuation and uplink ATPC
- Atm = 0.21 dB/km
- ATPC = 15 dB reduction below full power at cell edge
- Antenna A: ETSI TS1
- Antenna C: TM4069

INTERFERENCE AREA - ANTENNA A - 20 km offset

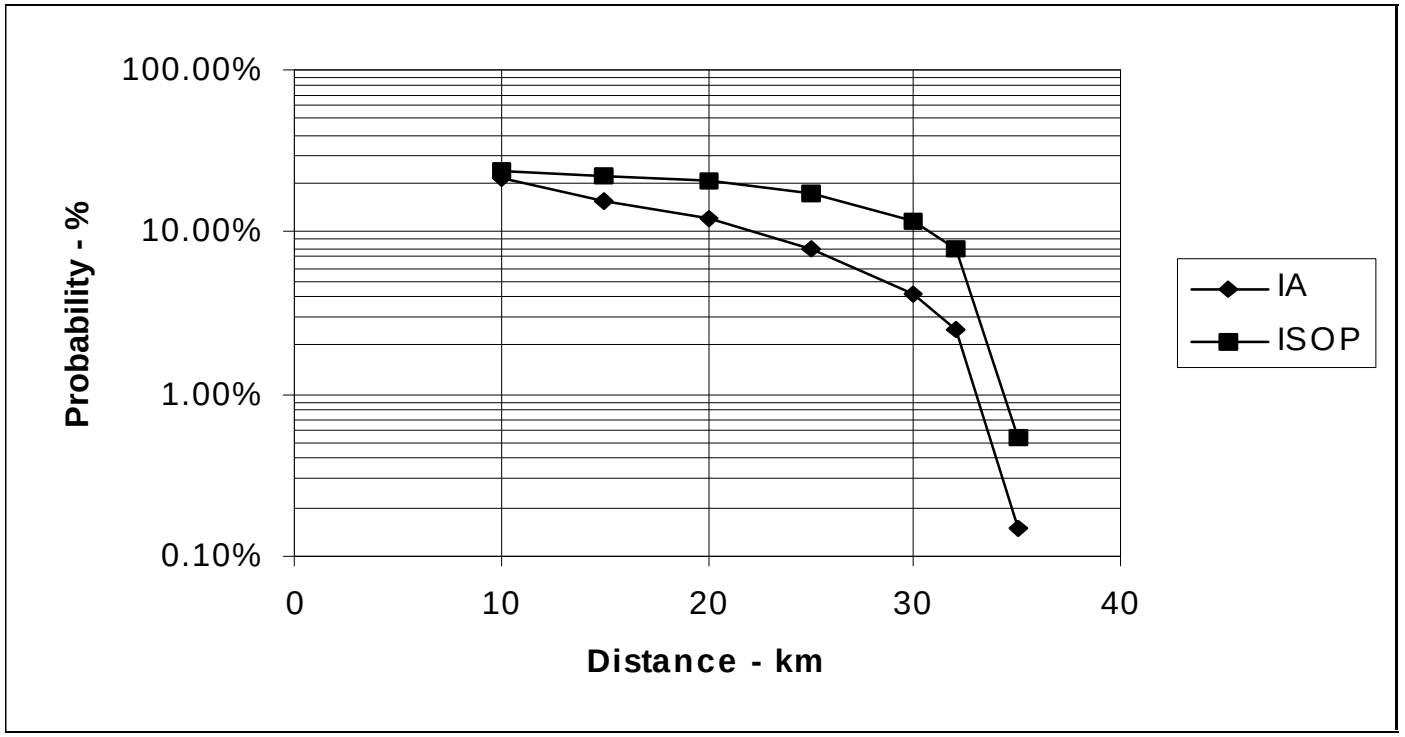


ISOP FOR CO-CHANNEL CASE

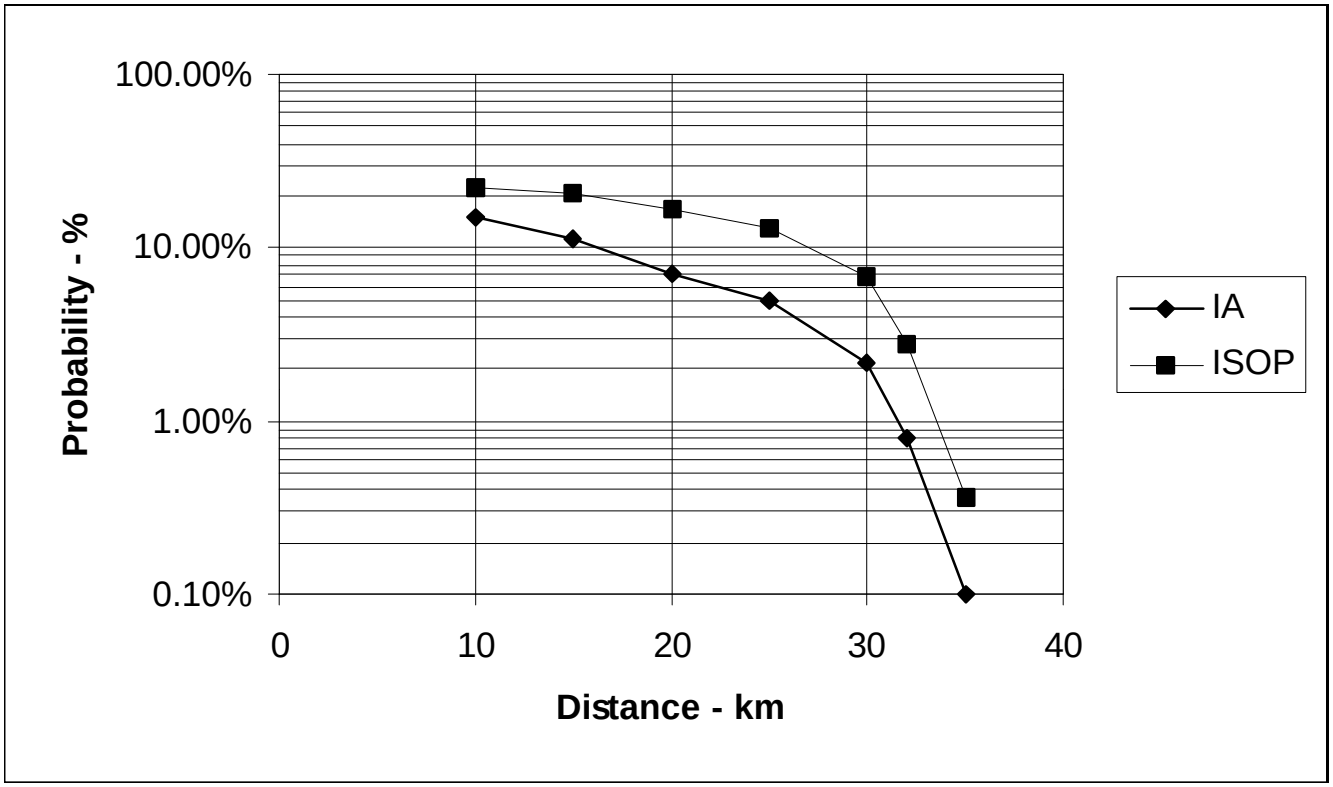
- Victim operator may suffer interference even if *only one* TS is placed in the critical area
- ISOP measures the probability of *at least one* terminal in the IA
- Interference outside the control of the victim operator
- ISOP is a useful measure for the co-channel case

$$ISOP = P_x.(1 - [1 - IA]^{Nt})$$

RESULTS - ANTENNA A



RESULTS - ANTENNA C



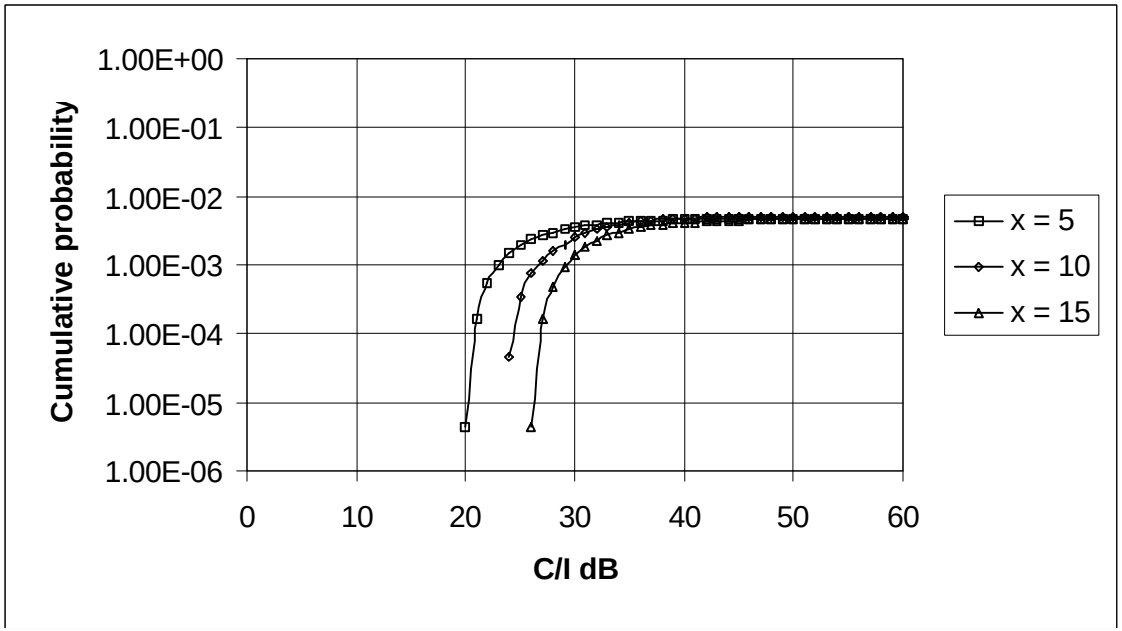
IMPLICATIONS

- IA quite high for low D
- IA drops sharply to zero as D approaches the “worst case” limit
- ISOP even sharper
- Worst case limit is probably safest - approx. 35 km

TS-TS CO-CHANNEL - TDD

- Same Monte-Carlo method as adjacent channel
- Larger values of cell offset
- Neglects atmospheric attenuation

TS-TS CO-CHANNEL - TDD - RESULTS



- Correct by:
  - TS/CS gain differential (16 dB typ.)
  + ATPC cell-edge setting (15 dB typ.)
  + X-POL (if applicable, 10 - 15 dB minimum)
- Probability and C/I level such that this interference mechanism is not the limiting case
- Rain neutral or beneficial

OVERALL CO-CHANNEL CONCLUSIONS: TDD and FDD

- Worst-case cell separations required for TS-CS interference (both)
- TS-TS is not a limiting case
- TS-CS: ~35 km
- Terrain and clutter probably also decrease coupling, so spacing could probably be reduced

CONCLUDING REMARKS - 1

GUARDBAND BETWEEN ADJACENT CHANNEL SYSTEMS

- 28 MHz guardband adequate for the systems considered for adjacent channel operation
- Effect on availability probably minimal - smaller guardband may be adequate
- TDD TS-TS interference is not a limiting issue

CONCLUDING REMARKS - 2

SEPARATION BETWEEN CO-CHANNEL SYSTEMS

- Minimum spacing of 35 km indicated by this analysis based on uplink analysis
- TS-TS interference alone would allow a smaller spacing - therefore TS-TS is not a limiting factor

CONCLUDING REMARKS - 3

PARAMETER SENSITIVITY

- IA is sensitive to virtually all system parameters
  - antenna pattern
  - NFD
  - Transmit power
  - etc
- Antenna pattern, Rx. threshold, and NFD can potentially be controlled through standardisation…..
- …but “coexistence” specifications have traditionally ignored coexistence issues!