Frequency Coordination Considerations
and
Operational Methodologies
for
Smart Spatially Adaptive Antennas with Distributed Elements

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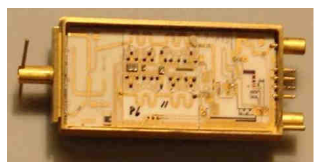
Introduction

A smart antenna is an antenna array with electronics and software which make it possible to transmit and receive in an adaptive, spatially sensitive manner. It is the emergence of low cost, very powerful integrated circuit electronics which make it possible to economically deploy smart antenna systems that can reuse frequencies around a licensed path without causing harmful interference.

The coordination requirements, procedures and methodologies for fixed services microwave paths using directional antennas -- as contained in Part 101 of the Federal Communications Commission rules and in TIA/EIA Telecommunications Systems Bulletin -- are the same for any type of directional antenna, including a dumb parabolic dish antenna with one non-active element or a smart multiple active element antenna.

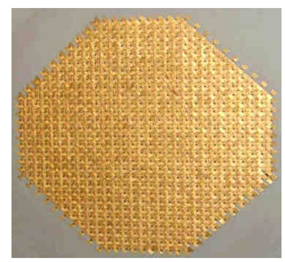
Dumb dish antenna

Figure 1



Active element

Figure 2



Smart antenna with hundreds of active elements

Figure 3

Examples

The subsequent examples follow the format given in TSB10-F, and the appropriate general comments of Section 3 apply.

Example 1. Digital Interferer into Victim Digital Receiver

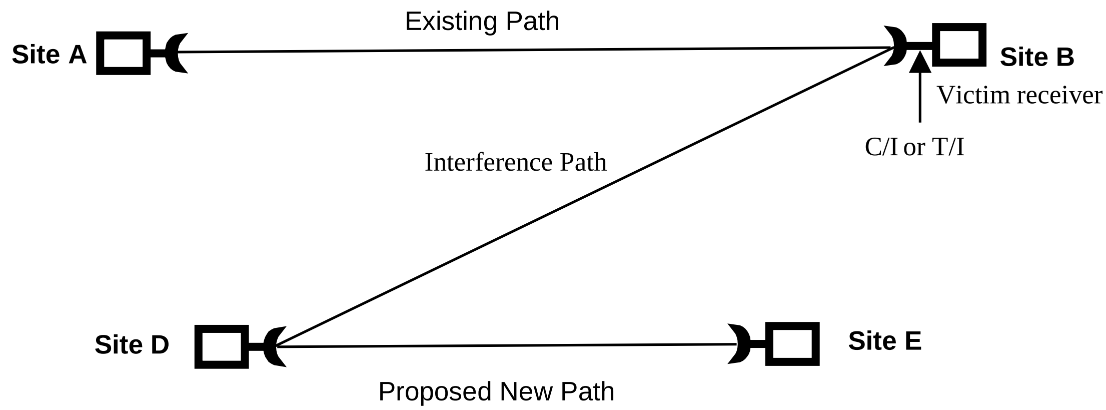


Figure 4

P_A	=	+30dBm	Desired transmit power
G_A	=	43dBi	Desired transmit antenna gain
W_A	=	2dB	Desired transmit transmission line loss
$EIRP_A$	=		$(P_A + G_A - W_A)$
	=		$(30 + 43 – 2) = 71$dBm
P_D	=	+33dBm	Interfering transmit power
G_D	=	38dBi	Interfering transmit antenna gain
W_D	=	2dB	Interfering transmit transmission line loss
$EIRP_D$	=		$(P_D + G_D – W_D)$
	=		$(33 + 38 – 2) = 69$dBm
G_B	=	43dBi	Victim receiver antenna gain
W_B	=	2dB	Victim receiver transmission line loss
L_{AB}	=	140dB	AB = 22 mile communications path free-space path loss
L_{DB}	=	146dB	DB = 44 mile interfering path free-space path loss
W_D	=	2dB	Interfering transmit transmission line loss
M_D	=	33dB	Interfering transmit antenna discrimination
M_B	=	36dB	Victim receive antenna discrimination
T	=	- 75dBm	Victim receiver threshold
I_T	=	-100dBm	Victim receiver thermal noise -6dB
C	=		Received carrier level in dBm at the victim receiver input
	=		$P_A + G_A – W_A + G_B – W_B - L_{AB}$, dBm ----------------------(1)
I	=		Interference level at the input of the victim receiver from the source antenna system, in dBm
	=		$P_D + G_D - W_D + G_B – W_B - L_{DB} – M_D – M_B$, dBm ------(2)

On Page 3 – 13, Section 3 of TSB10-F it states: "The only calculation required is to determine the interfering signal level at the victim receiver's input," therefore:

I = 33 + 38 – 2 + 43 - 2 – 146 - 33 – 36 = -105 dBm

This interference case will clear by 5dB (-100dBm – (-105dBm)).

The above calculation and result apply to all antenna types including a dumb parabolic dish antenna system with a single passive element or a smart antenna system with multiple active elements, because the interference (I) is the highest level of interference at the victim receiver's input from the source antenna system. Interference from the source antenna's individual element or elements is never greater than the highest level of interference (I) at the victim receiver's input or the victim receiver's thermal noise -6dB (I_T).

As all the coordination information for all paths -- licensed or pending -- is known, a smart antenna with distributed radiators can ensure that the interference from any distributed element (I_{DRE}) of the source antenna system arriving at the input of any victim receiver is always less than the source antenna system's highest level of interference (I) arriving at the victim receiver's input or below the victim receiver's thermal noise -6dB (I_T).

Figure 4a shows a smart antenna at Site D with a distributed radiating element (DRE1) located one mile in front of Site D in-line with Site E. The smart antenna knows the characteristics of its DRE's (all adaptive) and that in this example, the desired EIRP toward Site D from DRE1 is 5dBm with an EIRP toward Site B of -40dBm.

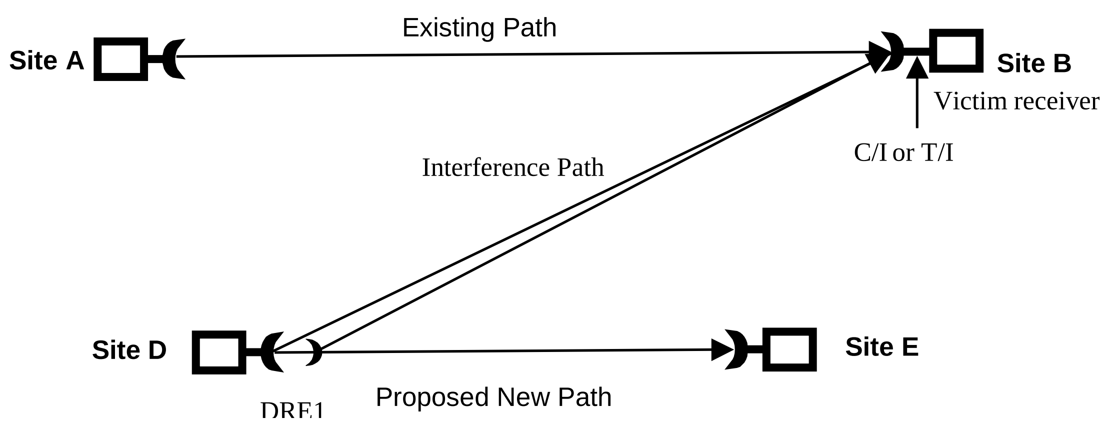


Figure 4a

Because the smart antenna at Site D has all the coordination data loaded into the system, it knows the differential gain of the antenna at Site B and all the other information to calculate the interference at the victim receiver from any DRE. In the case of DRE1,

$I_{DRE1} = -40 + G_B – W_B – L_{DB} – M_B =$

$= -40 + 43 – 2 – 146 – 36 = -181dBm$

This meets the requirement that $I_{DRE} <$ I (-181 – (-105)) = -76dB

Therefore, the frequency of the proposed path can be reused between Site D and DRE1 without having any effect on path coordination results.

Example 2. Digital Interferer into Victim Digital Receiver

In this example the path Site D to Site E is the existing path operating Time Division Duplex (TDD). Figure 5 shows a proposed path Site F to Site G where Site F is located nine miles from Site D intersecting the existing path at a right angle one mile from Site D. The Site F antenna has a gain of 46dBi and the P_F is 33dBm.

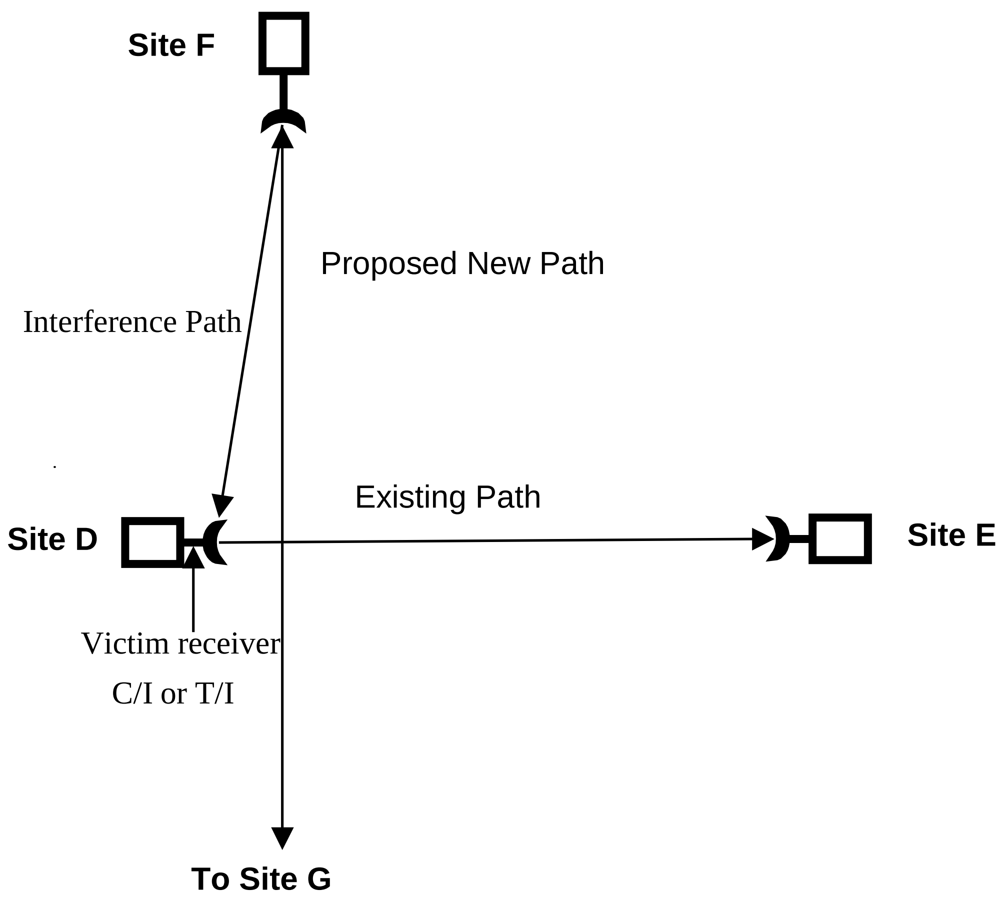


Figure 5

P_D	=	+33dBm	Desired transmit power
G_D	=	38dBi	Desired transmit antenna gain
W_D	=	2dB	Desired transmit transmission line loss
$EIRP_D$	=		$(P_D + G_D – W_D)$
	=		(33 + 38 – 2) = 69dBm
P_F	=	+33dBm	Interfering transmit power
G_F	=	46dBi	Interfering transmit antenna gain
W_F	=	2dB	Interfering transmit transmission line loss
$EIRP_F$	=		$(P_F + G_F – W_F)$
	=		(33 + 46 – 2) = 77dBm
G_D	=	38dBi	Victim receiver antenna gain
W_D	=	2dB	Victim receiver transmission line loss
L_{FD}	=	132dB	FD = 9 mile interfering path free-space path loss
W_D	=	2dB	Interfering transmit transmission line loss
M_F	=	26dB	Interfering transmit antenna discrimination
M_D	=	42dB	Victim receive antenna discrimination
T	=	-75dBm	Victim receiver threshold
I_T	=	-100dBm	Victim receiver thermal noise level -6dB
I	=		Interference level at the input of the victim receiver from the source antenna system, in dBm
	=		$P_F + G_F - W_F + G_D – W_D - L_{FD} – M_F – M_D$, dBm -------(3)

On Page 3 – 13, Section 3 of TSB10-F it states, "The only calculation required is to determine the interfering signal level at the victim receiver's input. Therefore:

I = 33 + 46 – 2 + 38 - 2 – 132 - 26 – 42 = -87 dBm

Missing the interference margin by 13dBm (-100dBm – (- 87dBm)).

However, the new applicant advises the licensee, or their coordination service provider, that there is a 14dB obstruction loss between Site F and Site D, therefore the interference case will clear by 1dB.

As previously stated, this calculation applies for any type of antenna system at Site D, dumb or smart.

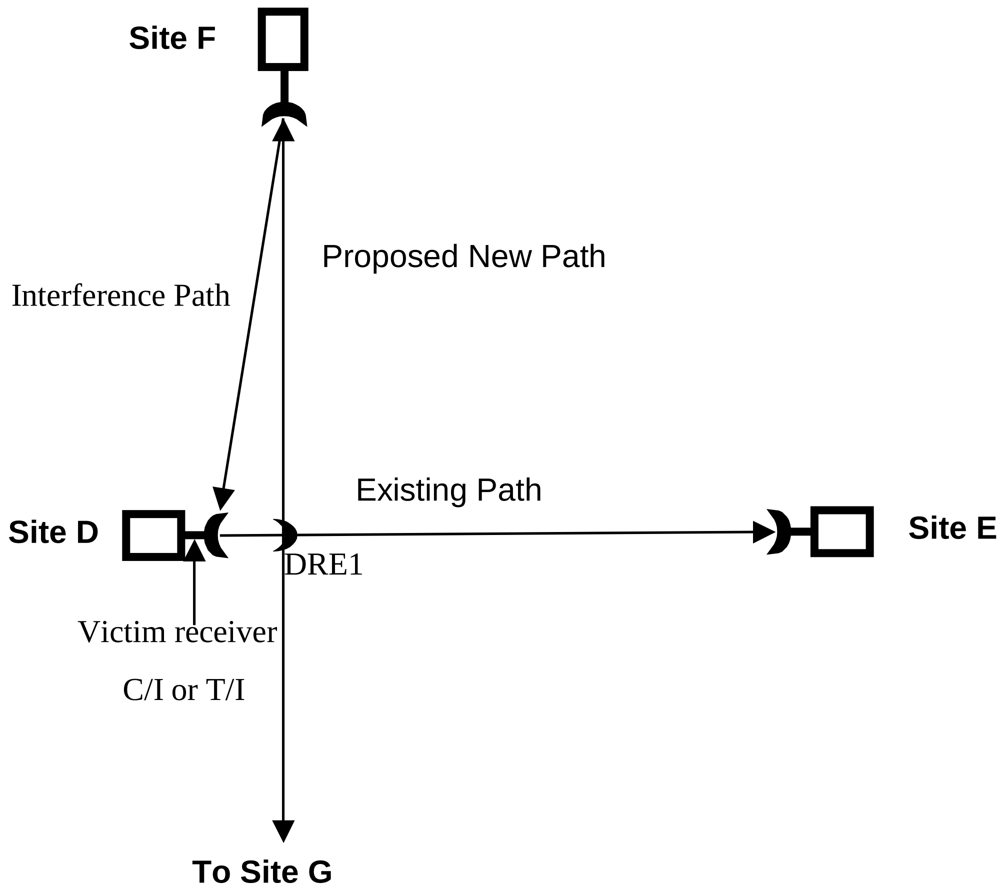


Figure 5a

Figure 5a shows the system using a smart antenna with an element, DRE1, at the path intersect. The smart antenna knows the characteristics of all of its fully adaptive DRE's, including DRE1, and that in this example, the desired EIRP toward Site D from DRE1 is 5dBm with an EIRP toward Site F of -37dBm.

As all the coordination information for all paths -- licensed or pending -- is known, the smart antenna can ensure that the interference from any distributed element (I_{DRE}) of the source antenna system arriving at the input of any victim receiver is always less than the source antenna's highest level of interference (I) arriving at the victim receiver's input or below the victim receiver's thermal noise -6dB (I_T).

Also, the smart antenna knows that the accepted interference level at Site F from Site D, after the obstruction loss of 14 dB, is -101dBm. Assuming a worst-case scenario of no obstruction loss from DRE1 toward Site F, then I_{DRE1} at the input of the receiver at Site F is given by equation 4:

$I_{DRE1} = -37 + G_F - W_F - M_F - L_{FDRE1}$ --(4)

$= -37 + 46 – 2 – 0 - 132 = -125$dBm

This meets the requirement that $I_{DRE} < I$ by 24dB (-125dBm – (-101dBm))

Therefore, the reused frequency of the existing path will have no effect on path coordination results and conclusions.

Example 3. Digital Interferer into Victim Digital Receiver

In this example Site D to Site E is the existing path operating TDD. Figure 6 shows a proposed path Site H to Site J where Site H is located one hundred and twenty miles from Site D and is pointed into the rear of the Site D antenna at an angle off the existing path of 95 degrees. The Site H antenna has a gain of 38dBi and the P_H is 20dBm.

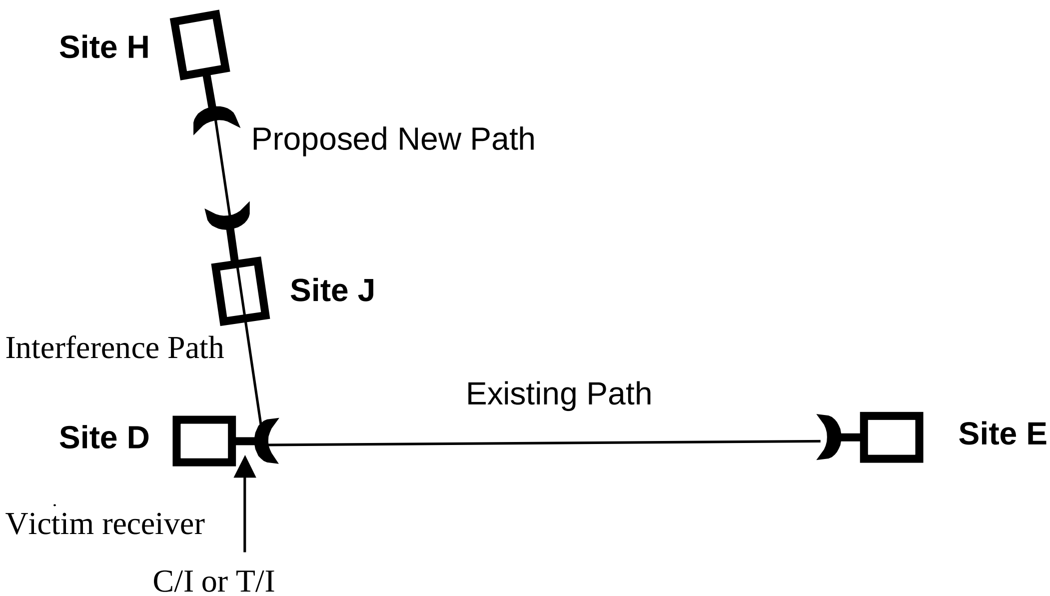


Figure 6

P_D	=	33dBm	Desired transmit power
G_D	=	38dBi	Desired transmit antenna gain
W_D	=	2dB	Desired transmit transmission line loss
$EIRP_D$	=		$(P_D + G_D – W_D)$
	=		(33 + 38 – 2) = 69dBm
P_H	=	20dBm	Interfering transmit power
G_H	=	38dBi	Interfering transmit antenna gain
W_H	=	2dB	Interfering transmit transmission line loss
$EIRP_H$	=		$(P_H + G_H – W_H)$
	=		(20 + 38 – 2) = 56dBm

G_D	=	38dBi	Victim receiver antenna gain
W_D	=	2dB	Victim receiver transmission line loss
L_{DH}	=	154dB	FD = 120 mile interfering path free-space path loss
W_H	=	2dB	Interfering transmit transmission line loss
M_H	=	0dB	Interfering transmit antenna discrimination
M_D	=	42dB	Victim receive antenna discrimination
T	=	-75dBm	Victim receiver threshold
I_T	=	-100dBm	Victim receiver thermal noise level -6dB
I	=		Interference level at the input of the victim receiver from the source antenna system, in dBm
	=		$P_H + G_H - W_H + G_D - W_D - L_{DH} - M_H - M_D$, dBm -----(5)

On Page 3 – 13, Section 3 of TSB10-F it states, “The only calculation required is to determine the interfering signal level at the victim receiver’s input. Therefore:

I = 20 + 38 – 2 + 38 - 2 – 154 - 0 – 42 = -104 dBm

The interference case will clear by 4dB (100- (-104)).

As previously stated, this calculation applies for any type of antenna system at Site D, dumb or smart.

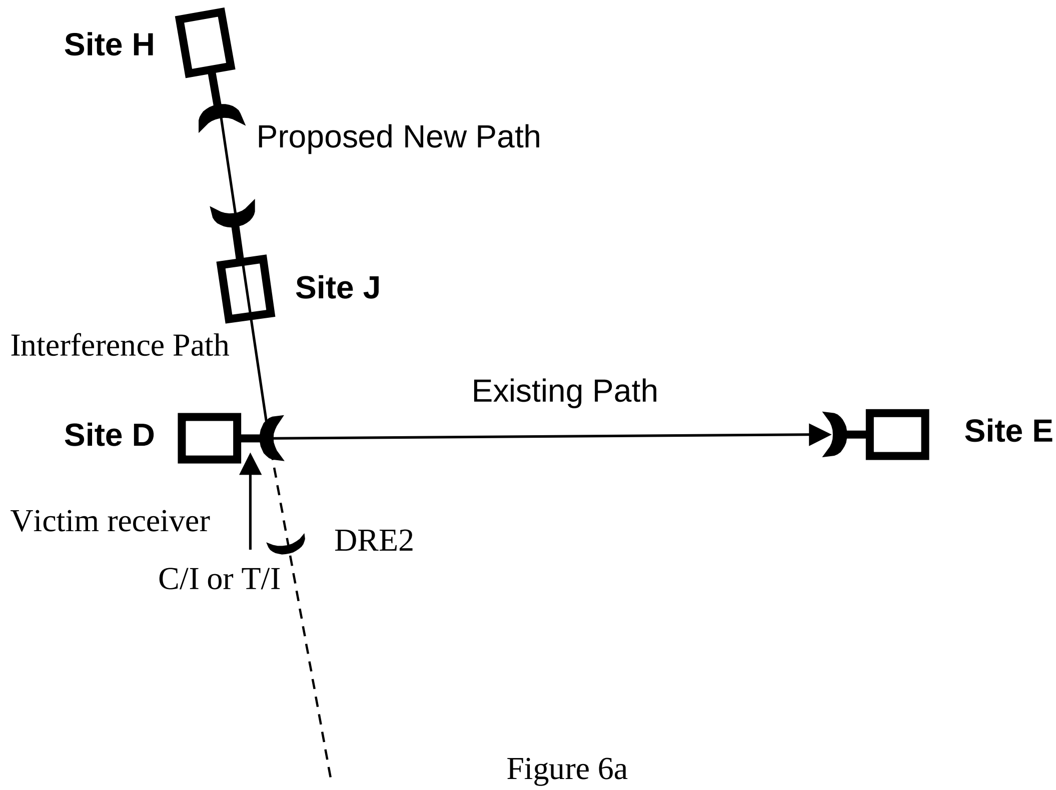


Figure 6a

Figure 6a shows a system with DRE2 one thousand feet from Site D at an angle of 265 degrees off of the existing path (pointing directly at Site H). The smart antenna knows the characteristics of its DRE's (all adaptive) and that in this example, the desired EIRP toward Site D from DRE2 is 13dBm.

As all the coordination information for all paths -- licensed or pending -- is known, the smart antenna can ensure that the interference from any distributed element (I_{DRE}) of the source antenna system arriving at the input of any victim receiver is always less than the source antenna's highest level of interference (I) arriving at the victim receiver's input or below the victim receiver's thermal noise -6dB (I_T).

Also, the smart antenna knows that the accepted interference level at Site H from Site D is:

$I = P_D + G_D - W_D + H_D - W_H - L_{DH} - M_H - M_D$ --(6)

$= 33 + 38 - 2 + 38 - 2 - 154 - 0 - 42 = -91$dBm

The interference level (I_{DRE2}) at the input of the receiver at Site H is given by equation 7:

$I_{DRE1} = 13 + G_H - W_H - M_H - L_{FDRE1}$---------------- --(7)

$= 13 + 38 - 2 - 0 - 154 = -105$dBm

Exceeding the requirement $I_{DRE} < I$ by 14dB (-105dBm – (-91dBm)).

Therefore, the reused frequency of the existing path will have no effect on path coordination results and conclusions.

Example 4. Digital Interferer into Victim Digital Receiver

In this example the path Site D to Site E is the existing path operating TDD. Figure 7 shows a proposed path Site K to Site M where Site K is located sixty miles from Site D directly facing the back of the Site D antenna. The Site K antenna has a gain of 38dBi and the P_K is 30dBm.

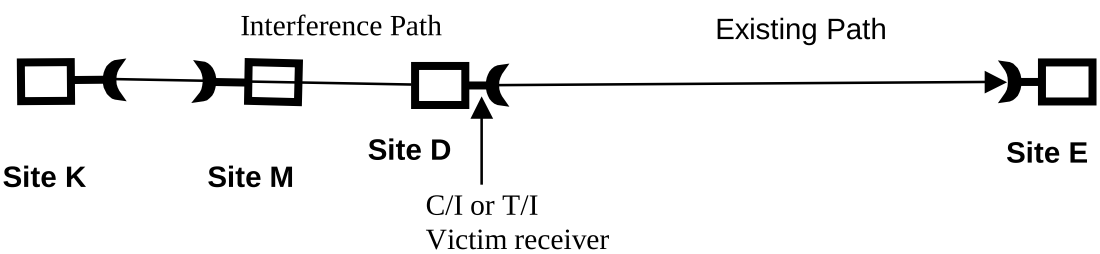


Figure 7

P_D	=	+33dBm	Desired transmit power
G_D	=	38dBi	Desired transmit antenna gain
W_D	=	2dB	Desired transmit transmission line loss
$EIRP_D$	=		$(P_D + G_D – W_D)$
	=		(33 + 38 – 2) = 69dBm
P_K	=	+30dBm	Interfering transmit power
G_K	=	38dBi	Interfering transmit antenna gain
W_K	=	2dB	Interfering transmit transmission line loss
$EIRP_K$	=		$(P_K + G_K – W_K)$
	=		(30 + 38 – 2) = 66dBm
G_D	=	38dBi	Victim receiver antenna gain
W_D	=	2dB	Victim receiver transmission line loss
L_{DK}	=	148dB	FD = 60mile interfering path free-space path loss
W_K	=	2dB	Interfering transmit transmission line loss
M_K	=	0dB	Interfering transmit antenna discrimination
M_D	=	55dB	Victim receive antenna discrimination
T	=	-75dBm	Victim receiver threshold
I_T	=	-100dBm	Victim receiver thermal noise level -6dB

I = Interference level at the input of the victim receiver from the source antenna system, in dBm

= $P_K + G_K - W_K + G_D - W_D - L_{DK} - M_K - M_D$, dBm -----(8)

On Page 3 – 13, Section 3 of TSB10-F it states, "The only calculation required is to determine the interfering signal level at the victim receiver's input. Therefore:

I = 30 + 38 – 2 + 38 - 2 – 148 - 0 – 55 = -101 dBm

Clearing the interference case by 1dB (- 100 – (-101)).

As previously stated, this calculation applies for any type of antenna system at Site D, dumb or smart.

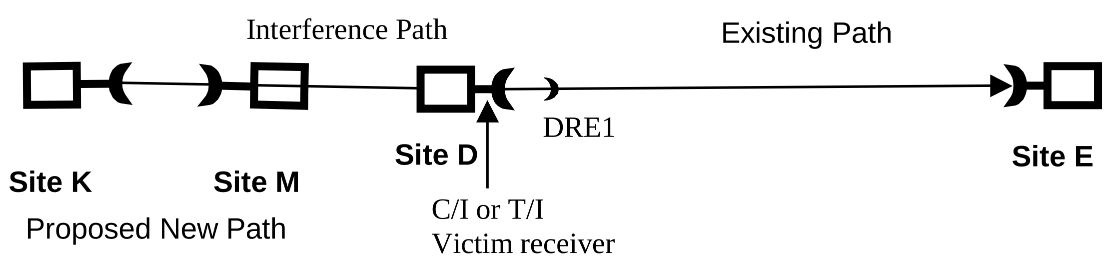


Figure 7a

Figure 7a shows a system with DRE1 one mile from Site D pointing directly at Site K. The smart antenna knows the characteristics of its DRE's (all adaptive) and that in this example, the desired EIRP toward Site D from DRE1 is 5dBm.

As all the coordination information for all paths -- licensed or pending -- is known, the smart antenna can ensure that the interference from any distributed element (I_{DRE}) of the source antenna system arriving at the input of any victim receiver is always less than the source antenna's highest level of interference (I) arriving at the victim receiver's input or below the victim receiver's thermal noise -6dB (I_T).

Also, the smart antenna knows that the accepted interference level at Site K from Site D is:

$I = P_D + G_D - W_D + G_K - W_K - L_{DK} - M_K - M_D$ ---(9)

= 33 + 38 – 2 + 38 – 2 – 148 – 0 – 55 = -98dBm

The interference level (I_{DRE2}) at the input of the receiver at Site K is given by equation 10:

$I_{DRE1} = 5 + G_K – W_K – L_{KDRE1} – M_K$ ---(10)

$= 5 + 38 – 2 – 148 - 0 = -107$dBm

Exceeding the requirement $I_{DRE} < I$ by 9dB (-98dBm – (-107dBm)).

Therefore, the reused frequency of the existing path will have no effect on path coordination results and conclusions.

Conclusion

In the last century, fixed microwave links used dumb antenna systems, such as a parabolic dish, with a continuously-on carrier operating Frequency Division Duplex (FDD). This resulted in a static, non-optimized, non-adaptive set of operating parameters. Emerging technologies make possible smart antenna systems operating Time Division Duplex (TDD) to be totally adaptive, and therefore capable of optimizing the operating parameters to increase the effective use of spectrum. The examples above have shown that all frequency coordination equations and procedures apply equally to paths designed with dumb and smart antenna systems because interference at the input of an existing or proposed receiver from a smart antenna’s distributed radiating element or elements will have no effect on path coordination results or conclusions. This allows for licensed frequencies to be reused by the licensee without causing harmful interference, making it possible for the licensee to make more effective use of the authorized spectrum.