Project	IEEE 802.16 Broadband Wireless Access Working Group
Title	Requirement on STS antenna Side Lobe Level (SLL) and Front-to-Back Ratio (FBR) from Coexistence point-of-view
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Re:	Call for contributions on antenna requirements for Broadband Wireless Access systems.
Abstract	This document derives the requirement on Side Lobe Level and Front-to-Back Ratio of STS antennas by taking into consideration the minimum required C/I, a system level parameter. A co-channel interference scenario at service boundary is used to find the antenna parameters that guarantee acceptable operation in presence of rain.
Purpose	It is proposed that 802.16.2 (Coexistence Task Group) adopt the criteria contained in this document as requirement on Side Lobe Level and Front-to-Back ratio of STS antennas.
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Requirement on STS antenna Front-to-Back Ratio and Side Lobe Level from Coexistence Point-of-View

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Introduction

Coexistence issues throughout the deployment of BWA systems create certain interference scenarios. Since interference problems should not be completely left to coordination efforts, it is Coexistence Task Group's responsibility to recommend certain requirements for the equipment- and network-level parameters in BWA systems.

By considering coexistence scenarios, one can distinguish the following cases.

Case1: Same market, adjacent bands- coexistence of two or more BWA operators within the same market, but in adjacent bands.

Case 2: Adjacent markets, same or adjacent bands- coexistence of two or more BWA operators across BTA boundaries in the same or adjacent bands.

Case 3: Adjacent countries, same or adjacent bands- coexistence of two or more BWA operators across international boundaries in the same or adjacent bands.

Case 4: Multiple systems, same or adjacent bands- coexistence of BWA systems with non-BWA systems in the same or adjacent bands.

Case 5: Multiple systems, different bands- coexistence of BWA systems with non-BWA systems in distant bands.

Case 6: Multiple technologies, same or adjacent bands- coexistence of multiple technologies or brands of radios within an operator's market.

There may be other coexistence scenarios. The above list, however, contains the scenarios that cause known interference problems.

This contribution deals with co-channel interference that occurs in cases 2 and 3. Consideration of worst case scenarios leads to derivation of requirements on Side Lobe Level (SLL) and Front-to-Back ratio (FBR) of STS antenna.

Side Lobe Level (SLL)

Figure 1 depicts the case of co-channel interference across service boundaries of two BWA systems operating in adjacent markets or across international boundaries. To picture the worst case scenario, it is assumed that the STS in network 1 is located at the cell boundary at the edge of a sector so that BTS antenna looks at it with its Half-Power Beam Width (HPBW) gain. At the same time nearby interfering BTS in network 2 looks at the victim STS with its maximum gain. It is also assumed that the radio link to the victim (path length=R_1) is suffering from a rain cell, while the interferer's link (path length=R_2) is clear.

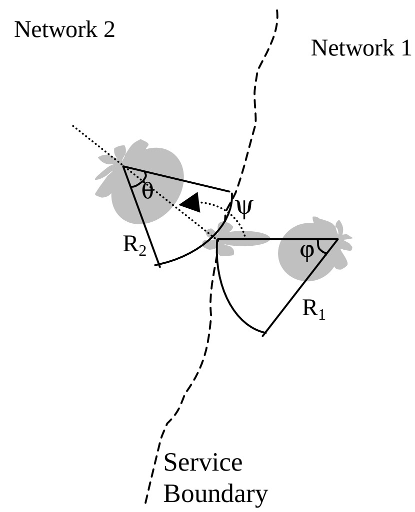

Figure 1. Interference case

The wanted signal (in dBm) at the victim STS antenna port is given by Equation 1 below.

$$C = P_{1,t} + G_{HPBW} - PL_{R1} - L_{Rain} + G_{S,\max}$$ Equation 1

$P_{1,t}$ = BTS Transmit Power of Network 1, dBm

$G_{HPBW} = G_{1,\max} - \alpha$ = HPBW Gain of Network 1 BTS Antenna, dBi

$G_{1,\max}$ = Network 1 BTS Antenna Maximum Gain, dBi

α = dB down at HPBW, dB (Typically 3 dB)

PL_{R1} = Path Loss at Distance R_1, dB

L_{Rain} = Rain Attenuation, dB

$G_{S,\max}$ = Maximum Gain of STS Antenna, dBi

To address the worst case, it is assumed that Network 2 is using the same polarization as Network 1. The unwanted signal (in dBm) at the victim STS antenna port is given by Equation 2 below.

$$I = P_{2,t} + G_{2,\max} - PL_{R2} + G_{S,s}$$ Equation 2

$P_{2,t}$ = BTS Transmit Power of Network 2, dBm

$G_{2,\max}$ = Network 2 BTS Antenna Maximum Gain, dBi

PL_{R2} = Path Loss at Distance R_2, dB

$G_{S,s} = G_{S,\max} - SLL$ = Gain of STS Antenna at angle ψ, dBi

SLL = Side Lobe Level of STS Antenna

It is reasonable to assume that the interference (*I*) calculated above is the strongest co-channel interference and, given the path loss and practical reuse schemes, contribution of other co-channel interference sources can be ignored.

C/I in dB, thus, can be calculated by using Equation 3 below.

$$\frac{C}{I} = \left(P_{1,t} - P_{2,t}\right) + \left(G_{HPBW} - G_{2,\max}\right) + \left(PL_{R2} - PL_{R1}\right) + \left(G_{S,\max} - G_{S,s}\right) - L_{Rain} \qquad \text{Equation 3}$$

Assuming free space path loss, Equation 3 can be written as follows.

$$\frac{C}{I} = \left(P_{1,t} - P_{2,t}\right) + \left(G_{HPBW} - G_{2,\max}\right) + 20\log\left(\frac{R_2}{R_1}\right) + SLL - L_{Rain} \qquad \text{Equation 4}$$

The required C/I value is a function of factors such as target Bit Error Rate (BER) and the modulation being used. By keeping C/I at least at its required level, the requirement on minimum SLL of the STS antenna can be derived by rearranging Equation 4.

$$(SLL)_{\mathrm{Re}q.} \geq \left(\frac{C}{I}\right)_{\mathrm{Re}q.} + \left(P_{2,t} - P_{1,t}\right) + \left(G_{2,\max} - G_{HPBW}\right) - 20\log\left(\frac{R_2}{R_1}\right) + L_{Rain} \qquad \text{Equation 5}$$

Given the fact that adjacent markets usually provide service to a similar customer base, it is reasonable to make the following simplifying assumptions.

$P_{1,t} = P_{2,t}$

$G_{1,\max} = G_{2,\max}$

$R_1 = R_2$

Applying the above assumptions reduces Equation 5 to the following:

$$(SLL)_{\mathrm{Re}q.} \geq \left(\frac{C}{I}\right)_{\mathrm{Re}q.} + \alpha + L_{Rain} \qquad \text{Equation 6}$$

Figure 2 depicts $(SLL)_{Req.}$ versus $(C/I)_{Req.}$ for rain regions D2, D3, E, and F at 38 GHz with vertical polarization and target availability of 99.999% using typical data for a 64QAM radio.

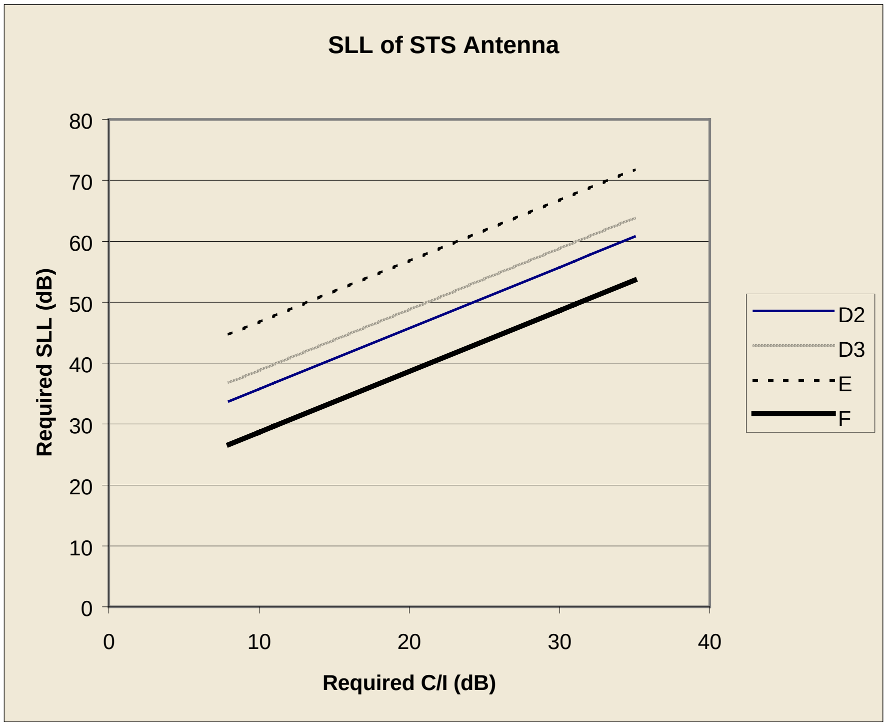

Figure 2. Minimum SLL Required for STS Antenna

Front-to-Back Ratio

Figure 3 depicts the worst case scenario for interference through the back lobe of STS antenna. This is basically the same problem as SLL with angle ψ=180^o.

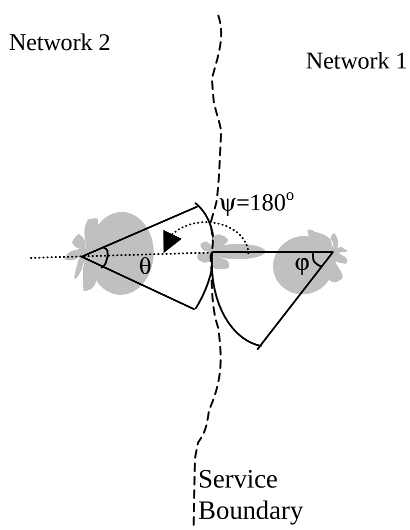

Figure 3. Case for Front-to-Back ratio

Therefore, the same criteria proposed for SLL could be applied to FBR.

$$(FBR)_{\mathrm{Re}q.} \geq \left(\frac{C}{I}\right)_{\mathrm{Re}q.} + \alpha + L_{Rain} \qquad \text{Equation 7}$$

Effect of Orthogonal Polarization

An effective coordination process in service boundary areas should include polarization planning so that adjacent cells/sectors use orthogonal polarization. If Network 1 and Network 2 co-channels use orthogonal polarization (vertical and horizontal), the situation will be improved due to Cross-Polarization Discrimination (XPD) of antennas. The effects of both interfering and victim antenna XPD, however, needs to be considered. This is done with the concept of combined XPD, known as XPD_{min} [1]. While XPD in the direction of maximum gain should be used for the interfering BTS antenna, the XPD of interest for the victim STS is the one at angle ψ. Equation 8 is then used to calculate XPD_{min}.

$$XPD_{\min} = \left[(XPD_t)^{-1/2} + (XPD_r)^{-1/2}\right]^{-2}$$

$$XPD_t = \text{XPD of Interfering BTS Antenna, Linear} \qquad \text{Equation 8}$$

$$\text{XPD}_\text{r} = \text{XPD of the victim STS Antenna at angle } \psi\text{, Linear}$$

Although XPD_{min} is smaller than any one of the contributing XPDs, it will loosen the requirement on SLL and FBR as shown in Equation 9 below.

$$(SLL)_{\mathrm{Re}q.} \geq \left(\frac{C}{I}\right)_{\mathrm{Re}q.} + \alpha + L_{Rain} - XPD_{\min} \qquad \text{Equation 9}$$

Effect of Dynamic Power Control

Implementation of dynamic power control for the purpose of increasing the transmit power to compensate for rain attenuation improves the situation even further, at least for short periods of time. It is not clear at this point, however, whether this feature appears as “recommended” or “required” in 802.16 standard. Moreover, the coexistence-oriented criteria should provide sufficient margin even if the dynamic power control is not in place or is unavailable temporarily due to equipment malfunction. It is suggested, therefore, that the effect of dynamic power control not be taken into consideration in derivation of SLL and FBR requirements.

Conclusion

The worst case scenario in terms of co-channel interference between two adjacent networks along the market boundary area was discussed. The requirement on antenna SLL and FBR was then derived as a function of minimum required C/I and presented graphically for a few rain regions. Also, the effect of using orthogonal polarization on co-channel radios was discussed and its effect on the SLL and FBR requirement formulated.

References

[1] Stutzman, W. L., *Polarization in Electromagnetic Systems*, Artech House, Boston, 1993, pp. 170-172.