Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**RABC Information Related to FWA-PTP Interference Case**
Date Submitted	**2002-05-21**
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Re:	As mentioned at the last TG2 meeting (#18), I am providing RABC information related to FWA/point-to-point interference case for high frequency systems. This information was already in IEEE 802.16.2 and can still be useful in the FWA/PTP interference case.
Abstract	The part of interest is Section 3.2. It is covering the derivation of the interference level acceptable into a point-to-point system.
Purpose	To be used by TG2 for discussion and to help preparing the draft document.
Notice	
Release	
Patent Policy and Procedures	

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RABC Publication 99.2

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1.0 Summary

This paper recommends a coordination process for point-to-multipoint fixed wireless access (FWA) systems operating between licensed areas in the 24, 28 and 38 GHz bands. Analysis is performed to provide a preliminary determination of spectral power flux-density (pfd) levels that can be used as a trigger point between licensed operators.
Distance is used as the first trigger mechanism. If the boundary of two service areas is within 60 km of each other, then the coordination process is invoked. Two spectral pfd levels are proposed for coordination. The first one, level A , represents a minimal interference scenario where either licensed operator does not require coordination. A second level, B , typically 20 dB higher than A , represents a trigger for two possible categories: if the interference is above A but below B, then coordination is required with existing systems only. If the interference is greater than level B, then coordination is required for both existing and planned systems. The table below summarises spectral pfd levels A and B for the three frequency bands.

Frequency Band (GHz)	spectral pfd Level A (dBW/m^2 in any 1 MHz)	spectral pfd Level B (dBW/m^2 in any 1 MHz)
24	-114	-94
28	-114	-94
38	-125	-105

2.0 Co-operation between Licensed Operators

The co-operation process is designed to encourage industry communications and minimize government(s) involvement, which may unnecessarily delay system deployment. Mutually acceptable arrangements between licensees are encouraged. The arrangements should ensure service in the boundary is available. In cases where the licence(s) is transferred, the arrangement(s) developed between licensees shall be in effect until superseded by a new arrangement. Under the circumstances where an arrangement does not exist, the following coordination process is proposed.

2.1 Coordination Process

The coordination process applies only if an arrangement between the licensees does not exist. The process is proposed as shown in Figure 1. Coordination will be necessary between licensees whose service areas are within 60 km of each other. Note that the 60 km is the derived radio horizon based on a BTS and RTS antenna height of 90 m above the local terrain with an average clutter height of 15 m, and assumes that the transmitter and receiver are 4 km within the service area boundary. In the event an operator uses sites of very high elevation, relative to local terrain, or relatively high power that could produce interference to service areas beyond 60 km, then this operator shall undertake the coordination process with the affected licensee(s).
The objective of the process is to minimize unnecessary coordination that may delay the deployment time, while at the same time protect the interest of existing systems and new systems. In this regard, two spectral pfd levels are proposed, which yield three categories of coordination as depicted below: i) *spectral pfd* $<$ *A* - no coordination required, ii) *A* $<$ *spectral pfd* $\leq$ *B* - coordination required for existing systems only, and iii) *spectral pfd* $>$ *B* - coordination required for both existing and planned systems. The spectral pfd levels are calculated at the adjacent licensee s service area boundary with free space propagation and atmospheric losses taken into account.

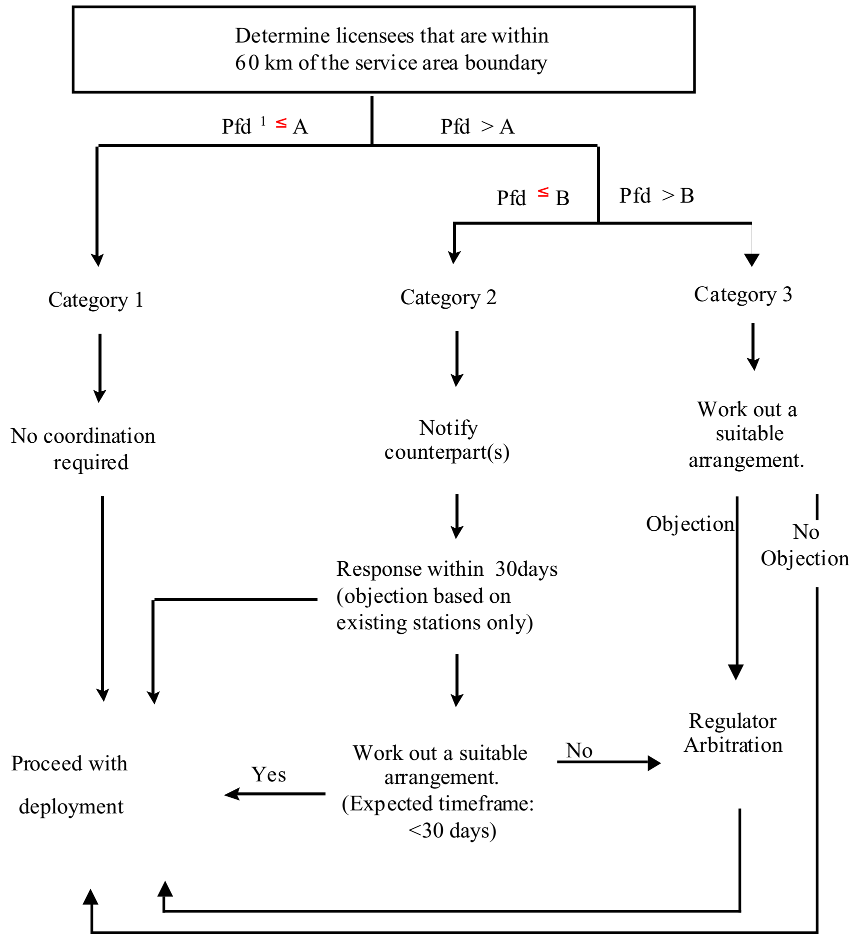
The following provides an elaboration of the chart shown in Figure 1.

Category 1 — Less than or equal to spectral pfd A:

This category represents a very low probability of interference in which case coordination is not required. This level should be set based on appropriately conservative technical assumptions to protect the interest of all affected parties. Deployment of systems can be carried out quickly.

Category 2 — Greater than spectral pfd A, but less than or equal to spectral pfd B:

While spectral pfd A allows for quick deployment, it is based on fairly conservative assumptions that may unnecessarily limit system performance. The spectral pfd level B is 20 dB higher than spectral pfd level A, and allows operators to use practical mitigation and siting measures to avoid any potential for interference. Examples of mitigating techniques include using cross-polarization, placing BTS transmitter at the same frequency as interfering BTS transmitter, etc. If the spectral pfd level is greater than A but is less than or equal to spectral pfd B at the service area boundary of the neighbouring service area(s), the following coordination process is required:



Note: 1. Pfd is calculated at the service area boundary of the respective counterpart(s).

Figure 1 Coordination Process.

The licensee will be required to notify the neighbouring licensee(s) of its intention to deploy the new facility along with the appropriate data necessary to conduct an analysis. The neighbouring licensee(s) must respond within thirty days upon receipt of such notice and may object to such deployment on the basis of harmful interference to its **existing facilities only**. Objections based on non-existing systems, such as planned facilities, will not be valid. It is assumed that practical mitigation measures can be taken to avoid interference from this facility.

If no objection is raised, then the facility can then be deployed.

If objection is raised, there are two options: 1) employ whatever means necessary to lower the spectral pfd level to below level 'A' in which case, the facility can be deployed immediately without coordination, or 2) come to a mutually beneficial arrangement/understanding with the respective licensees. (This can be viewed as a triggering point for communications resulting in some arrangement that benefits both licensees.) It is expected that the time frame for the completion of such an arrangement/understanding would be less than thirty days, as all system parameters are known.

This allows for a relatively quick deployment of a facility without unnecessarily limiting system performance, while at the same time protecting the interest of the related parties.

<u>Category 3</u> —Greater than spectral pfd B:

A spectral pfd level greater than 'B' represents a higher probability of interference between systems in which case coordination is required before deployment.

In any event, the licensees are expected to take full advantage of interference mitigation techniques such as antenna discrimination, polarization, frequency offset, shielding, site selection, or power control to facilitate co-existence with other systems.

3.0 Analysis Assumptions

This section analyses typical radio parameters associated with broadband FWA systems to establish the appropriate coordination spectral pfd levels discussed above. The analysis considers the following interference scenarios:

i) BTS to BTS,
ii) BTS to Remote Terminal Station (RTS),
iii) RTS to BTS, and
iv) RTS to RTS.

Aggregate levels are included in the analysis based on certain assumptions described below. Interference between like entities (BTS-BTS or RTS-RTS) will occur if the frequency plans between both systems are dissimilar, i.e. like systems operating co-channel. Co-channel interference is most prevalent between base stations, primarily because base stations a) are installed on relatively high buildings (typically 70-100 m) and hence have clear LOS to many other licensed base stations, b) transmit constantly, and c) typically operate over 360 degrees in azimuth.

RTS systems, on the other hand, have relatively narrow antenna beamwidths, which reduces the interference scenario considerably. Furthermore, the effects of aggregation are considered to be negligible since there is a very low probability of two or more RTSs transmitting at precisely the same time, towards the exact same direction, within the same channel, and operating co-polarized. Additionally, RTSs tend to be installed on lower buildings, and hence, have significantly reduced radio horizon ranges due to other buildings and natural obstacles. One such major obstacle is the actual BTS building serving the RTS.

3.1 Analysis at 24/28 GHz

This section provides a sample analysis of spectral pfd levels for the 28 GHz band. It is assumed that the parameters and derived spectral pfd levels are applicable to 24 GHz.

The following assumptions have been made for the 24/28 GHz band;

- Base stations are evenly distributed in a square grid fashion
- Cell radii are ~ 4 km
- The central interference mechanism is base station to base station co-channel
- No line-of-sight obstructions exist
- No diffraction losses are present

Using the following typical hardware related assumptions:

- transmitter BTS antenna gain: +18 dBi (+21 dBi 90 deg azimuth BW antenna with -1 deg downtilt)
- transmitter power: -12 dBW power per 40 MHz or -28 dBW/MHz
- victim receiver antenna gain: +18 dBi (+21 dBi 90 deg azimuth BW antenna with -1 deg downtilt)
- victim receiver noise floor: -128 dBW per 10 MHz or -138 dBW/MHz (assuming NF=6 dB)
- Interference Objective = 8 dB below noise floor (-146 dBW/MHz)

The following formula defines the spectral pfd:

$$pfd = \frac{Pr}{Ae} = \frac{Pr}{\lambda^2 \frac{G}{4\pi}}$$

where:

Pr = interference power level at receiver input
Ae = effective antenna aperture
λ = wavelength
G = antenna gain.

To create an interference signal of -146 dBW/MHz at the input of the receiver, the power flux density would be:

$$PFD = \frac{Pr}{Ae} = \frac{10^{-146/10}}{.01072^2 * \left(\frac{10^{(18/10)}}{4\pi}\right)} = \frac{2.51x10^{-15}}{0.00057}$$

$= 4.407 \times 10^{-12}$
$= -114$ dBW/m² in any 1 MHz

3.1.1 BTS to BTS Interference

The following steps are undertaken to determine if the above spectral pfd level can be met for a very large LMCS/LMDS deployment located directly across a lake from a victim base station receiver, typical to the Greater Toronto Area scenario.

The power level at the victim receiver is calculated as follows:

$P_{victim} = P_{TX} + 10\log(N) + G_{TX} + G_{RX} - 20\log(F) - 20\log¤ - 32.4 - A_{losses}$

where;

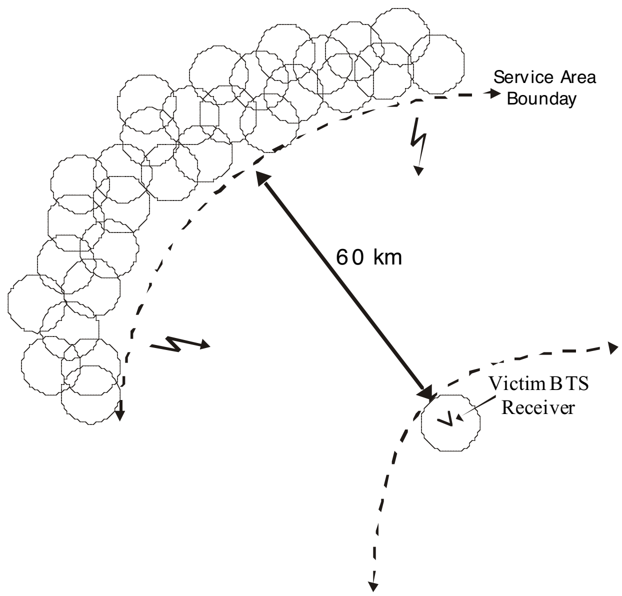
P_{TX} = transmitter power
N = number of transmitter sources with unobstructed LOS to victim receiver (co-channel)
G_{TX} = transmitter antenna gain in the direction of the victim receiver
G_{RX} = victim receiver gain in the direction of the source transmitter(s)
F = frequency, MHz
R = range, km
A_{losses} = atmospheric losses, ~ 0.1 dB/km

A large network is assumed to be generating the interference based on the following assumptions:

- 4 sectored cells
- 52 cells in the network
- 1 co-channel TX per sector
- only one of the sector TXs per BTS oriented toward victim receiver (1/4 or 25%)
- 50% of properly oriented TXs have unobstructed LOS to victim receiver
- frequency reuse of 80%
- 50% of transmitters are cross-polarized

The total number of co-channel transmitters is therefore:

52 cells x 4 sectors x 25% directed towards victim x 50% blocked x 80% reuse x 50 % x-pol = 10 TX sources



Therefore assuming 60km range (60 km + 4 km distance from BTS to service boundary),

P_{victim} = P_{TX} + 10log(N) + G_{TX} + G_{RX} - 20log(F) - 20log¤ - 32.4 - A_{losses}
= -28 dBW/MHz + 10log(10) + 18 +18 - 20log(28000) - 20log(64) - 32.4 — 64(.1)
= -146dBW/MHz

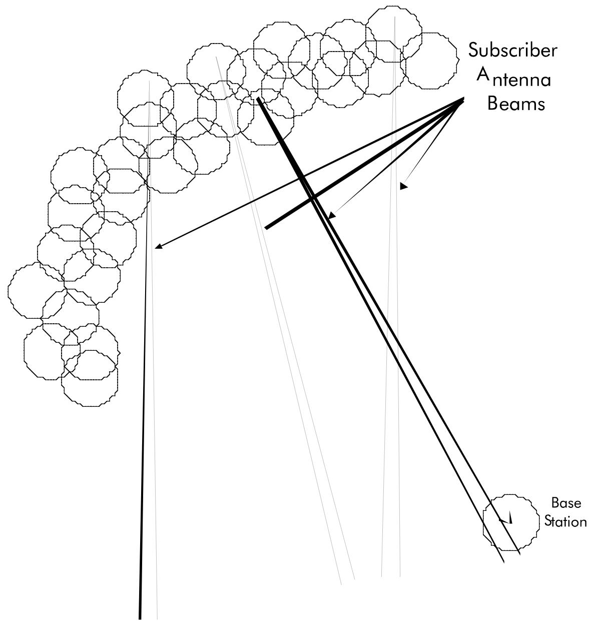
This is consistent with the interference objective of —-146 dBW/MHz.
The spectral pfd at the victim receiver is calculated as follows:

pfd_{victim} = P_{TX} + 10log(N) + G_{TX} - 10log(4π) - 20log¤ - A_{losses}
= -28 dBW/MHz +10 + 18 - 11 - 96 - 64(.1)
≅ -114 dBW/m^2 in any 1 MHz

This is approximately equivalent to the spectral pfd level derived earlier to meet the interference objective. The spectral pfd value of —114 dBW/MHz is based on the aggregate effects of 10 base stations, which equates to -124 dBW/m^2 in any 1 MHz on a per transmitter basis. Assuming up to 10 dB of losses from manmade or natural obstacles are present, then a per transmitter spectral pfd limit of -114 dBW//m^2 in any 1 MHz (-124 + 10log10) would meet the interference objective stated earlier.

3.1.2. RTS to BTS Interference

This section considers the interference problem arising from multiple RTSs to a victim BTS located 60 km away in an adjacent licensed service area. The figure below illustrates the typical distribution of RTS antenna pointing positions within a service area. Only one co-channel RTS can be active at any time in each sector. The antenna beams are drawn to scale, based on a typical 2 degree HPBW. The cell radius is 4 km. As shown in the figure, the antenna beam spread at 60 km is narrow (~2 km); hence, the likelihood of multiple RTSs simultaneously pointing their antennas towards the same victim receiver operating co-channel and co-polarized is minute. Additionally, since RTS antennas tend to be situated at low altitudes, LOS will be severely affected. Assuming the height of the BTS building is higher than that of the RTS, then the BTS building alone will introduce significant blockage, not to mention other buildings and natural obstacles preventing LOS to a distant receiver.



Therefore, based on the assumptions above, the effects of aggregation will be negligible. For an absolute worst case analysis, assume three RTSs have clear LOS to a victim receiver.
Assumptions:

- RTS transmitter antenna gain: +36 dBi
- transmitter power: -12 dBW per 10 MHz
- power control: 25 dB to counter rain fade
- transmitted power with power control: -37 dBW per 10 MHz (-47 dBW/MHz)
- victim BTS receiver antenna gain: +18 dBi (+21 dBi 90 deg azimuth BW antenna with -1 deg downtilt)
- victim BTS receiver noise floor: -138 dBW/MHz (assuming NF=6)
- Interference Objective: 8 dB below noise floor (-146 dBW/MHz)

The calculated power level from RTS to victim base station receiver is:

P_{victim} = $P_{TX} + 10\log(N) + G_{TX} + G_{RX} - 20\log(F) - 20\log$¤ $- 32.4 - A_{losses}$
= -47 dBW/MHz +10log(3) + 36 + 18 -20log (28000) - 20 log(64)
¥ 32.4 - 64(.1)
= -151 dBW/MHz

The —151 dBW/MHz is well below the interference objective of —146 dBW/MHz. Hence, interference from RTS to BTS is considered negligible.

The corresponding power flux-density (spectral pfd) at the victim receiver is calculated as follows:

pfd_{victim} = $P_{TX} + 10\log(N) + G_{TX} - 10\log(4\pi) - 20\log$¤ $- A_{losses}$
= -47 dBW/MHz +10log(3) +36 -10log(4π) - 20log(64000) - 6

$= -118.8$ dBW/m^2 in any 1 MHz
$\cong -119$ dBW/m^2 in any 1 MHz

3.1.3 Base Station to RTS Interference

The BTS to RTS interference scenario is similar to the previous one, in that the likelihood of a direct beam coupling between both radio entities is considered minute. Assuming a worst case coupling of three base stations to a single RTS, then the following analysis applies:
Given that the base station transmits at full power during clear skies, the RTS operates well above the receiver noise floor. More precisely, the interference objective of the RTS is simply the modem s C/(N+I) requirement. For QPSK modulation, this value is typically 10 dB, while for 16 QAM, it is 20 dB. Therefore, the interference from a distant base station must be either 10 or 20 dB below the desired signal.
The power level of the desired signal at 4 km is:

$P_{desired} = P_{TX} + G_{TX} + G_{RX} - 20\log(F) - 20\log¤ - 32.4 - A_{losses}$
$= -28$ dBW/MHz $+ 18 + 36 - 20\log(28000) - 20\log(4) - 32.4 - 4(.1)$
$= -107.4$ dB/MHz

Therefore, the interference signal must be either -117.4 dBW/MHz (-107.4 — 10) for QPSK, or —127.4 dBW/MHz (-107.4 — 20) for 16 QAM operation.
The received power level at the victim RTS receiver is calculated as:

$P_{victim} = P_{TX} + 10\log(N) + G_{TX} + G_{RX} - 20\log(F) - 20\log¤ - 32.4 - A_{losses}$
$= -28$ dBW/MHz $+10\log(3) + 18 + 36 - 20\log(28000) - 20\log(64)$
¥ 32.4 - 64(.1)
$= -132$ dBW/MHz

This value meets the interference objective of the receiver operating at both QPSK and 16 QAM.
The equivalent spectral pfd is:

$pfd_{victim} = P_{TX} + 10\log(N) + G_{TX} - 10\log(4\pi) - 20\log¤ - A_{losses}$
$= -28$ dBW/MHz $+10\log(3) +18 - 10\log(4\pi) - 20\log(64000) - 6$
$= -117$ dBW/m^2 in any 1 MHz.

3.1.4. RTS to RTS Interference

The probability of direct coupling occurring between two RTSs is considered extremely low, given the high directivity of the antenna patterns involved and the limited clear LOS that can exist between any two RTSs. For the sake of analysis, assume a single RTS interferes with another licensed RTS. The interference level is calculated as:

$P_{victim} = P_{TX}$ - Power Control $+10\log(N) + G_{TX} + G_{RX} - 20\log(F) - 20\log¤$ —
$32.4 - A_{losses}$
$= -47$ dBW/MHz $+10\log(1) + 36 + 36 - 20\log(28000) - 20\log(64)$
¥ 32.4 - 64(.1)
$= -138$ dBW/MHz

This is well below the 16 QAM interference objective of -127.4 dBW/MHz described above. Therefore, interference between RTS is considered negligible.

The equivalent spectral pfd is:

pfd_{victim} = $P_{TX} + 10\log(N) + G_{TX} - 10\log(4\pi) - 20\log$¤ $- A_{losses}$

= -47 dBW/MHz +10log(1) +36 - 10log(4π) - 20log(64000) - 6

= - 124 dBW/m^2 in any 1 MHz.

3.1.5 Summary of 24/28 GHz Analyses

The table below summarizes the aggregate interference levels calculated above for each simplified scenario.

Scenario	Aggregate interference (dBW/MHz-m^2)
BTS to BTS	-114
RTS to BTS	-119
BTS to RTS	-117
RTS to RTS	-124

Based on the summary table above, the worst case spectral pfd interference level is between two base stations (BTS-BTS). Therefore, the recommended spectral pfd level at the service area border is -114 dBW/m^2 in any 1 MHz.

3.2 Analysis for 38 GHz

At 38 GHz, the interference analysis considers not only the BTS and RTS radios, but also point-to-point systems. The following assumptions apply:

BTS

- Gtx = Grx = 14 dBi

RTS

- Gtx = Grx = 38 dBi

Point-to-Point

- Grx = 44 dBi
- Receiver noise floor = -138 dBW/MHz.

The interference objective for the point-to-point radio is assumed to be 6 dB below the noise floor, which is equivalent to -144 dBW/MHz. However, in order to minimize the frequency of coordination, and given the low probability of main-beam to main-beam coupling, the risk associated with a further 10 dB of interference can be tolerated. This brings the objective to —134 dBW/MHz.

The following formula is used to calculate spectral pfd at the antenna aperture:

$$pfd = \frac{Pr}{Ae} = \frac{Pr}{\lambda^2 \frac{Gr}{4\pi}}$$

where,

λ = c/f = $3x10^8$ /$38x10^9$
= .00789 m

Pr = interference objective
= -134 dBW/MHz

Gr = receive antenna gain

The following is a sample calculation for a point-to-point receiver with an antenna gain of 44 dBi:

Pfd = Pr + 10 log (4π) — 20 log (λ) — Gr
= - 134 + 11 + 42 — 44
= - 125 dBW/m^2 in any 1 MHz.

The table below summarizes the interference objective for each radio entity:

Radio Entity	Spectral pfd Level A (dBW/m^2 in any 1 MHz)	Spectral pfd Level B (dBW/m^2 in any 1 MHz)
BTS	- 105	- 85
RTS	- 129	- 109
Point to Point	- 125	- 105

From the above table, the worst-case interference criterion is —125 (A level) and —105 (B level) dBW/m^2 in any 1 MHz associated with the point-to-point radio.