Electronic Communications Committee (ECC)
within the European Conference of Postal and Telecommunications Administrations (CEPT)

# TECHNICAL REQUIREMENTS FOR UWB DAA (DETECT AND AVOID) DEVICES TO ENSURE THE PROTECTION OF RADIOLOCATION SERVICES IN THE BANDS 3.1 - 3.4 GHz AND 8.5 - 9 GHz AND BWA TERMINALS IN THE BAND 3.4 - 4.2 GHz

**Kristiansand, June 2008**

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# 0 ABBREVIATION

| Abbreviation | Explanation |
|---|---|
| **AMC** | Asymmetrical Modulation and Coding Scheme |
| **BS** | Base Station |
| **BWA** | Broadband Wireless Access |
| **CS** | Central Station |
| **DAA** | Detect And Avoid |
| **DL** | Downlink |
| **CEPT** | European Conference of Postal and Telecommunications Administrations |
| **ECC** | Electronic Communications Committee |
| **EU** | European Union |
| **LOS** | Line of Sight |
| **MCL** | Minimum Coupling Loss |
| **MWA** | Mobile Wireless Access |
| **NF** | Noise Figure |
| **NLOS** | Non Line of Sight |
| **NWA** | Nomadic Wireless Access |
| **RSSI** | Received Signal Strength Indication |
| **SNR** | Signal to Noise Ratio |
| **TPC** | Transmit Power Control |
| **TS** | Terminal Station |
| **UL** | Uplink |
| **UWB** | Ultra Wide Band |

# 1 INTRODUCTION

This draft Report defines a specific 'detect and avoid' (DAA) based interference mitigation architecture for UWB devices to protect BWA application such as WiMax systems operating in the band 3.4 - 4.2 GHz and radiolocation services operating in the band 3.1 - 3.4 GHz and 8.5 – 9 GHz. The report describes the main technical requirements for the DAA mechanism, and it presents results of some measurements performed to characterise and study the effects of DAA on BWA.

It has to be noted that these conclusions are relevant for radars in the band 3.1 - 3.4 GHz and 8.5 – 9 GHz but cannot be expanded to the band 2.7 - 3.1 GHz band in which different radar types are operated (aeronautical and meteorological radars in particular).

The flexible DAA proposal is based on the definition of different zones for which an appropriate UWB emission power level is authorised. Therefore, each zone corresponds to a minimum isolation between the potential victim system and the potential UWB interferer. In each zone a specific protection level is defined for the UWB transmission for the different systems. These protection levels in conjunction with the given minimum isolation are intended not to cause interference to the operation of the potential victim system based on the definition of the equivalent protection included in the generic UWB Decision ECC/DEC/(06)04.

Three zones (zone 1, 2 and 3) are defined for the frequency band 3.4 - 4.2 GHz and only two (Zone A and B) for 3.1 - 3.4 GHz and 8.5 - 9 GHz.

The report is structured as follows:

- Section 2.1– Definition of DAA parameters
- Section 2.2 and 2.3 – Description of DAA mechanism
- Section 3 – Conclusion for the proposed values for regulation
- Annexes – Technical studies

As existing systems are subject to technological change and other systems may be deployed or developed in the future within e.g. IMT, it should however be noted that these requirements on DAA provided in this Report are application specific and may need to be revisited in the future taking into account, amongst others, 3GPP systems which may in the future operate in the band 3.4 - 4.2 GHz. In particular, the WRC-07 identified the band 3.4 - 3.6 GHz for IMT applications. In addition, it has to be noted that the protection of future broadcast services without uplink feedback and passive radar systems has not been studied.

It has furthermore to be emphasized that especially for radiolocation services DAA technical parameters alone given in this report do not ensure protection of radio services by themselves. This has to be completed with adequate DAA measurement procedures and test pattern in the related ETSI standard.

This Report does not address protection of outdoor services in the band 3.4 – 4.2 GHz such as FS and FSS earth stations since the DAA technique are not designed to mitigate interference into such services.

It has to be noted this ECC report is a follow-up of the existing reports about compatibility issues for UWB devices. In that context and in addition to ECC Report 64, it is recalled that complementary technical studies developed in response to the second mandate from the EC to CEPT on the Harmonise radio spectrum use for Ultra-wideband Systems in the European Union concluded that some level of confidence regarding the protection of the outdoor Fixed Service and the Fixed Satellite Service with a UWB maximum mean e.i.r.p. spectral density level of -41.3 dBm/MHz can be provided (using different propagation models and assuming 100% of UWB devices operating indoor with an average 1% activity factor). However, it should be noted that, in any case, a PSD level of less than −80 dBm/MHz should be regulated for protecting indoor BFWA applications, unless suitable mitigation techniques are enforced.

## 2 DETECT AND AVOID PARAMETERS

Detect and Avoid parameters are primarily defined for the three victim systems identified to be protected by DAA mechanisms:

- BWA Indoor terminals in 3.4 – 4.2 GHz
- Radiolocation systems in 3.1 – 3.4 GHz
- Radiolocation systems in 8.5 – 9 GHz

Similar to ECC Report 94, the IEEE802.16 WiMAX system has been assumed to be representative of BWA systems in the 3.4 – 3.8 GHz band.

### 2.1 DAA Operation Description

The flexible "DAA" approach is based on the definition of different DAA zones for which an appropriate UWB emission power level is authorised. Therefore, each DAA zone corresponds to a minimum isolation between the potential victim system and the potential UWB interferer. In each zone, in conjunction with the given minimum isolation, a specific protection level is defined allowing for a specific UWB transmission level for the different victim systems in order not to cause interference to the operation of the potential victim system.

Three zones (Zone 1, 2 and 3) are defined for the BWA in the frequency band 3.4 – 4.2 GHz and only two zones (Zone A and B) are defined for Radiolocation systems in the bands 3.1 – 3.4 GHz and 8.5 – 9 GHz.

Before initiating UWB communications, the UWB device shall perform a monitoring of the RF environment during a minimum time to detect any actively operating victim signal (initial availability channel check time). Based on the result of this detection process, the UWB device has to determine the corresponding zone it occupies and react accordingly.

The **DAA UWB** devices shall be able to detect any change of the RF configuration (e.g. modification of operating zone) and switch to the corresponding emission level in a maximum time according to the victim service and procedural tests which will be defined in revised ETSI EN 302 065**.**

### 2.2 DAA Parameters Definition

In this section, the parameters used to specify the DAA properties are described. Some parameters may be specific to one or the other victim system.

- **Minimum Initial Channel Availability Check Time, $T_{avail}$**

The minimum time the UWB device spends searching for victim signals after power on, Parameter: $T_{avail}$

- **Signal Detection Threshold, $D_{thresh}$**

The power of the received victim signal by the UWB device which defines the transition between adjacent protection zones, Parameter: $D_{thresh}$

This detection threshold is specified at the antenna connector assuming a 0dBi antenna gain for each detection operation and may be based on multiple levels. This detection threshold can alternatively be expressed as a field strength limit.

- **Avoidance Level (*UWB Maximum Tx Power density*)**

The maximum Tx power density to which the UWB transmit power is set for the relevant protection zone

- **Default Avoidance Bandwidth**

The minimum portion of the victim service bandwidth requiring protection

- **Maximum Detect and Avoid Time, $T_{avoid}$**

Maximum time duration between a change of the external RF environmental conditions and adaptation of the corresponding UWB operational parameters (as defined in ETSI EN 302065).

- **Detection Probability**

The probability for the DAA enabled UWB device to make a correct decision either due to the presence of a victim signal before starting transmission or due to any change of the RF configuration during UWB device operation.

### 2.3 Description of Detect and Avoid operation in the frequency bands 3.1-3.4 GHz and 8.5-9 GHz

The "Detect and Avoid" sequences are described in this section, in order to understand the required Detect and Avoid parameters to be defined for each DAA operating zone.

An overview of the flow chart of the flexible DAA proposal is depicted in Figure 1 below for the protection of radiolocation systems operated in these frequency bands. This is based on detection of the radiolocation emission signal.

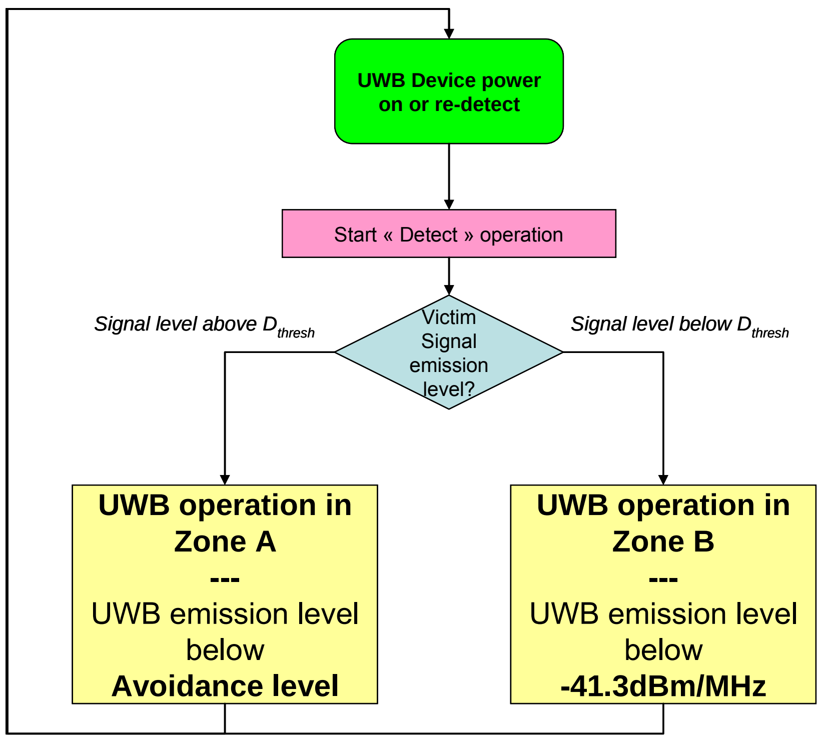


**Figure 1: DAA flow chart revision for radiolocation systems**

The proposed DAA approach is based on the detection of radiolocation system signal with one detection threshold $D_{thresh}$ (Zone A/ZoneB). Depending on the measured signal level, the UWB emission level is limited to the avoidance level (when the measured signal level is above the Threshold) in Zone A, and to -41.3 dBm/MHz in Zone B.

If a UWB device detects a radiolocation system signal above the detection threshold, the default avoidance bandwidth is the full band (300 MHz for 3.1 to 3.4 GHz band, and 500 MHz for 8.5 to 9 GHz band).

**<u>Detect and avoid operation for radiolocation systems in 3.1 to 3.4GHz band:</u>**

**<u>Initial Detect Operation</u>**

- Start by a "listen before talk" mode before establishing any communication
    - No transmit operation : Inherent Avoid mode
    - Check Initial channel availability:

        - Parameter: *Minimum Initial Channel Availability Check Time, $T_{avail}$*
        - Parameter: *Detection Probability*
    - React according to detected level
        - If victim systems are detected (Signal level ≥ $D_{thresh}$): Transmit operation can start in Avoid mode (Zone A).
        - If victim systems are not detected (Signal level < $D_{thres}$): Start in normal operation mode (Zone B).

**<u>Continuous Detect Operation</u>**

- During operation in Zone A, UWB operation with "Avoid" mode
    - Start from UWB operation with "Avoid" mode
    - Maintain continuous detect operation
        - Parameter: *Detection Probability*
    - React according to detected level
        - If victim systems are detected: Transmit operation should continue with "Avoid" mode (Zone A).
        - If victim systems are not detected: Switch to normal operation (Zone B).
- During operation in Zone B, normal UWB operation
    - Start from normal operational mode (without avoid)
    - Maintain continuous detect operation
        - Parameter: Maximum Detect and *Avoid Time, $T_{avoid}$*
        - Parameter: *Detection Probability*
    - React according to detected level
        - If victim systems are detected: Transmit operation should switch to "Avoid" mode (Zone A).
        - If victim systems are not detected: Continue in normal operation (Zone B).

### 2.4 Description of Detect and Avoid operation in the frequency band 3.4 – 4.2 GHz

The "Detect and Avoid" sequences are described in this section in order to understand the required Detect and Avoid parameters to be defined for each DAA operating zone.

An overview of the flow chart of the flexible DAA proposal is depicted in Figure 2 below for the protection of BWA systems operated in this frequency band. This is based on detection of the BWA TS uplink emission by UWB device.

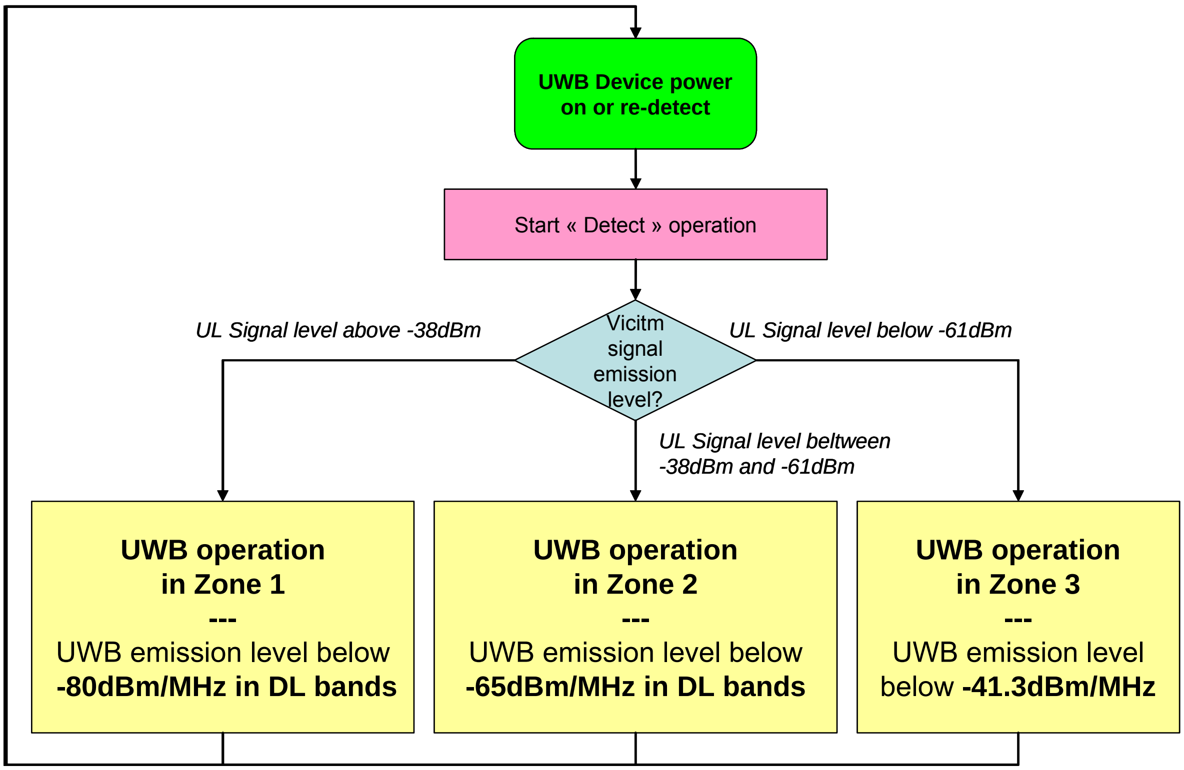


**Figure 2: DAA flow chart revision in the frequency band 3.4-4.2 GHz**

The proposed DAA approach is based on the UL detection with two thresholds of -38dBm (Zone 1/Zone2) and -61dBm (Zone 3/Zone 2). Depending on the measured signal level the UWB emission level is limited to -80dBm/MHz (signal level > -38dBm) in Zone 1 and -65dBm/MHz (-38dBm > signal level > -61dBm) in Zone 2, and -41.3 dBm/MHz otherwise.

If a UWB device detects an uplink signal in the band 3.4-3.6GHz or 3.6-3.8GHz above the detection thresholds, the default avoidance bandwidth is the full 200MHz band.
If a downlink detection mechanism is developed and tested to meet overall protection levels for BWA services, the avoidance bandwidth can be reduced to a minimum of 20MHz around the DL carrier frequency.. The correct downlink identification need to take into account the different duplex modes (TDD versus FDD) and duplex spacings.

The combination of detection threshold, initial channel availability check time and detection probability should safeguard the protection of BWA TS for more than 99.75% of the time.

The Detect and Avoid time shall be achievable by any individual UWB device and must be achieved during the operation of a UWB network. During actual operation, since at least two devices are needed to form a network, it's possible for the devices to negotiate detection capability between them and share detection information. For example, if one device is sending a large file to another device, it's possible for the receiving device to be the primary detecting device. In addition, it might be desired to have powered devices be the primary detecting device in order to save battery life in mobile devices. For all devices, it is recommended that continuous detection is employed when receiving data.

**<u>Detect and avoid operation for the frequency band 3.4-4.2 GHz:</u>**

**<u>Initial Detect Operation</u>**

- Start by a "listen before talk" mode before establishing any communication
  - No transmit operation : Inherent "Avoid" mode
  - Check Initial channel availability:
    - Parameter: *Minimum Initial Channel Availability Check Time,* $T_{avail}$

        - Parameter: *Detection Probability*
    - React according to detected level
        - If victim systems are detected:
            - with Signal level ≥ $D_{thresh\ 1}$ :Transmit operation can start with "Avoid" mode in Zone 1
            - with Signal level < $D_{thresh\ 1}$ and Signal level ≥ $D_{thresh\ 2}$ :Transmit operation can start with "Avoid" mode in Zone 2 with Signal level < $D_{thresh\ 2}$ :Transmit operation can start with normal operation mode in Zone 3

**Continuous Detect Operation**

- During operation in Zone 1 or Zone 2, UWB operation with "Avoid" mode
    - Start from UWB operation with "Avoid" mode
    - Maintain continuous detect operation
        - Parameter: Maximum Detect and *Avoid Time*, $T_{avoid}$
        - Parameter: *Detection Probability*
    - React according to detected level
        - If victim systems are detected: Transmit operation should continue with "Avoid" mode (Zone 1 or Zone 2).
        - If victim systems are not detected: Switch to normal operation (Zone 3).
- During operation in Zone 3, normal UWB operation
    - Start from normal operational mode (without avoid)
    - Maintain continuous detect operation
        - Parameter: Maximum Detect and *Avoid Time*, $T_{avoid}$
        - Parameter: *Detection Probability*
    - React according to detected level
        - If victim systems are detected: Transmit operation should switch to "Avoid" mode (Zone 1 or Zone 2).
        - If victim systems are not detected: Continue in normal operation (Zone 3).

## 3 CONCLUSION - PROPOSED VALUES FOR REGULATION

It is noted that *DAA* technical parameters alone do not ensure protection of radio services. This has to be completed with adequate DAA measurement procedures and test pattern in the related ETSI standard (ETSI EN302065)

As existing systems are subject to technological change and other systems may be deployed or developed in the future, it should be noted that these requirements on DAA provided in this Report may need to be revisited in the future.

### 3.1 Frequency range 3.1-3.4 GHz

Table 1 show the technical requirements for DAA in the 3.1 – 3.4 GHz band. These results are derived from studies in Annex 2 of this document.

| **Parameter** | | **Zone A** | **Zone B** |
|---|---|---|---|
| *Minimum Initial Channel Availability Check Time* | $T_{avail}$ | 14 sec | |
| *Maximum detect and avoid time* | $T_{avoid}$ | 150sec | |
| *Detection probability during 'listen before talk' mode with the test pattern given in ETSI EN 302065* | | 99% | |
| *Detection probability in Continuous detection operation during UWB device operation with the test pattern given in ETSI EN302065* | | 97% | |
| *Signal Detection Threshold (peak detector)* | $D_{thresh}$ | -38 dBm | -38 dBm |
| *Avoidance Level (UWB Maximum Tx Power density)* | | -*70* dBm/MHz | -41.3 dBm/MHz |
| *Default Avoidance Bandwidth* | | *300 MHz* | |

**Table 1:**

Detection probability in continuous detection mode during UWB device operation in DAA zones refers to environment conditions changes (moving UWB devices). The ETSI test procedures for continuous detection operation shall include mechanisms for evaluating the given detection probability in a reliable way.

### 3.2 Frequency range 3.4 - 4.2 GHz

Tables 2 and 3 show the technical requirements for DAA in the 3.4 – 4.2GHz band. These results are derived from studies in Annex 1 of this document.

| **Parameter** | | **Zone 1** | **Zone 2** | **Zone 3** |
|---|---|---|---|---|
| *Minimum Initial Channel Availability Check Time* | $T_{avail}$ | 5.1s | | |
| *Detection Probability for initial detect operation after UWB device power ON.* | | 99% | | |
| *Signal Detection Threshold (UL)* | $D_{thresh\ (UL)}$ | ≥ -38 dBm ($D_{thresh\ 1}$) | < -38dBm ($D_{thresh\ 1}$)<br>≥ -61 dBm ($D_{thresh\ 2}$) | < -61 dBm ($D_{thresh\ 2}$) |
| *Avoidance Level (UWB Maximum Tx Power density))* | | -80 dBm/MHz | -65dBm/MHz | -41.3 dBm/MHz |
| *Default avoidance bandwidth* | | 3.4 – 3.6GHz or 3.6 – 3.8GHz | | |

**Table 2**

In addition to the above, UWB network during the continuous detection operation shall also meet the requirement defined in the table below.

| **BWA system test mode** | *Detect and Avoid Time* | *Detection Probability*<br>(for continuous detect operation) |
|---|---|---|
| VoIP | 2s | 95% |
| Web surfing | 15s | 95% |
| Sleep mode | 60s | 95% |
| Multimedia broadcasting | 15s | 95% |

**Table 3**

Taking into account moving devices, the detect and avoid parameters in the table above shall provide an equivalent protection of the potential victim device. These test modes must be verified in the corresponding test setup for the harmonized ETSI standard.

### 3.3 Frequency range 8.5-9 GHz

The frequency band 8.5 to 9.0 GHz is used by different radiolocation, surveillance and reconnaissance applications. The DAA mechanism has been studied for monostatic radars (transmitter and receiver at the same place).

The impact of interference has not been studied for the following radars:

- bistatic radars (one transmitter and one receiver at different places),
- multistatic radars (one or more transmitter and one or more receivers at different places) and
- passive radars.

In order to assess the impact of interference on these radars, further studies may be required.

In the absence of these studies, Table 4 shows the technical requirements for DAA in the 8.5 – 9GHz band. These results are derived from studies in Annex 3 of this document. The table contains DAA requirements only for a monostatic radar system.
.

| **Parameter** | | **Zone A** | **Zone B** |
|---|---|---|---|
| *Minimum Initial Channel Availability Check Time* | $T_{avail,}$ | 14 sec | |
| *Detect and Avoid time* | | 150 sec | |
| *Detection probability during' listen before talk' mode with the test pattern given in ETSI EN 302065* | | 99% | |
| *Detection probability in Continuous detection operation during UWB device operation with the test pattern given in ETSI EN 302065* | | 97% | |
| *Signal Detection Threshold (Peak detector)* | $D_{thresh}$ | -61dBm | -61dBm] |
| *Avoidance Level (UWB Maximum Tx Power density))* | | -*65* dBm/MHz | -41.3 dBm/MHz |
| *Default Avoidance Bandwidth* | | 500 MHz | |

**Table 4**

Detection probability in continuous detection mode during UWB device operation in DAA zones refers to environment conditions changes (moving UWB devices). The ETSI test procedures for continuous detection operation shall include mechanisms for evaluating the given detection probability in a reliable way.

## 4 LIST OF REFERENCES

[1] ECC Report 100, 'Compatibility studies in the band 3400 - 3800 MHz between Broadband Wireless Access (BWA) systems and other services', February 2007, www.ero.dk

[2] ITU-R M.1465 – 05/2000: Characteristics of and Protection Criteria for Radars operating in the radiodetermination service in the frequency band 3 100-3 700 MHz

[3] ITU-R M.1796 (2007): Characteristics of and protection criteria for terrestrial radars operating in the radiodetermination service in the frequency band 8 500-10 500 MHz

## ANNEX 1: COMPATIBILITY STUDIES FOR BWA SYSTEMS IN 3.4 - 4.2 GHz

Similar to ECC Report 94, the IEEE802.16 WiMAX system is assumed to be representative of BWA systems in the 3.4-3.8 GHz band. The studies and measurements should give confidence that DAA is able to protect IEEE 802.16 WiMax systems, operating today or in the near future.

Other technologies, such as TD-CDMA systems, could be used which have different features including higher sensitivity level. However, the assumptions used in this report are consistent with those adopted in previous ECC reports on UWB and BWA.

Two approaches were studied in defining the uplink detection thresholds
- Scenario 1 – Baseline assumptions based on ECC Report 100[1] and WiMAX Forum contributions
- Scenario 2 - Revised assumptions based on WiMax Forum contributions

### A.1.1 Identification of uplink detection thresholds based on scenario 1

#### A.1.1.1 BWA Characteristics and Baseline assumptions

BWA parameters selection is based on ECC Report 100 [1] and on WiMAX Forum contributions specification for nomadic (NWA) and mobile (MWA) use in the bands 3.4-4.2 GHz. The references are given for each parameter selection. For the calculations, we took the presented SNR figures and added an implementation loss and a noise figure.

Table 5 shows the Central Station (CS) parameters for NWA and MWA

| **Parameter** | **Value** | **Operating conditions** |
|---|---|---|
| Max Tx Power Level (in dBm) | 35 | BWA, NWA & MWA coverage |
| Antenna gain ( in dBi) | 9 | NWA & MWA CS |
| Min Required SNR (in dB) | 2.9 | Modulation in receive mode: QPSK ½, PUSC |
| BS Receiver sensitivity [dBm]<br>For AWGN, 7MHz RX bandwidth | - 89.9 | Modulation in receive mode: QPSK ½, PUSC |
| Implementation loss (dB) | 2.5 | |
| Noise figure (dB) | 6 | CS |

**Table 5: CS Parameters**

Table 6 shows the Terminal Station (TS) parameters for indoor NWA and MWA

| **Parameter** | **Value** | **Operating conditions** |
|---|---|---|
| Max Tx Power Level (in dBm) [1] | 20 | NWA & MWA Terminals |
| Omnidirectional antenna gain ( in dBi) 0dB is used as worst case [1] | 0 | Mobile TS |
| | 5 | Nomadic TS |
| Implementation loss (dB) | 2.5 | |
| Noise figure (dB) | 7 | |
| Minimum Required SNR (dB) for each AMC case | 2.9 | QPSK rate-1/2 PUSC |
| | 6.3 | QPSK rate-3/4 PUSC |
| | 8.6 | 16QAM rate-1/2 PUSC |
| | 12.7 | 16QAM rate-3/4 PUSC |
| | 13.8 | 64QAM rate-1/2 PUSC |
| | 16.9 | 64QAM rate-2/3 PUSC |
| | 18 | 64QAM rate-3/4 PUSC |
| | 19.9 | 64QAM rate-5/6 PUSC |

**Table 6: TS Parameters**

### A.1.1.2 UL detection threshold values

For the definition of these detection thresholds, BWA deployment scenario considering realistic trade off is investigated between:

- BWA base station and clients operating distances (cell edge or within the cell)
- Multiple modulation/coding schemes scenario
- BWA client Transmit power control operation in realistic deployment scenario
- Potential fading margin effect

The evaluation of this trade-off will allow the definition of potential complementary assumptions.

#### A.1.1.2.1 Determination of the UL detection thresholds values

Table 7 provides the theoretical study assumptions that allowed the definition of the DAA Zone borders and that led to the DAA detection thresholds for the zones differentiation. The maximum allowable UWB Tx power ($4^{th}$ column) is determined according to a maximum allowable interference level about -115dBm/MHz (which leads to the isolation figure in the first column) After that, this isolation figure can be substracted to the UWB emission level to determine the Wimx UL received power on UWB device ($5^{th}$ column).

| Isolation between WiMax & UWB (dB) | D LOS (m) | D NLOS (m) | Max Allowed UWB Tx in WiMax DL band (dBm/MHz) | WiMax UL signal power at UWB device receiver (20dBm WiMax TX power) | Flexible DAA Zones<br><br>UWB operating In each Zone |
|---|---|---|---|---|---|
| < 35 | 0.36 | < 0.36 | -80 (Note 1) | > -15dBm | **Zone 1:**<br>**UWB TX level < - 80dBm/MHz** |
| 35 to 44 | 1 | < 1 | -80 | < - 15 dBm<br>> -24dBm | |
| 44 to 55 | 3.5 | 1 | -70 | **> - 35dBm (Level 1)** | |
| 55 to 64 | 3.5 to 11 | 1 to 4 | -60 | > -45dBm | **Zone 2:**<br>**UWB TX level < - 65dBm/MHz** |
| 64 to 75 | 11 to 35 | 4 to 7 | -50 | **> - 55dBm (Level 2)** | |
| > 75 | > 35 | > 7 | -41 | < -55dBm | **Zone 3:**<br>**UWB TX level < - 41dBm/MHz** |

**Table 7**

Note 1: The maximum mean e.i.r.p. spectral density limit of -80 dBm/MHz at 3.5 GHz is based on single interference analysis on BWA services assuming a minimum separation distance of 36 cm and receiver sensitivity;

The conclusion is that the UWB device can estimate the TS location according to two threshold values (-35 and -55 dBm)

- if the received power is greater than -35 dBm (on a measurement bandwidth equal to the BWA communication channel), therefore UWB device is at least in zone 2 and probably in zone 1 depending on the cell coverage. UWB emission power has to be limited to -80dBm/MHz
- if the received power is within the range [-35,-55]dBm (on the same measurement bandwidth), therefore, the UWB device is at least in zone 3 and maybe in zone 2. UWB emission power has to be limited to -65 dBm/MHz.
- if the received power by the UWB device is below -55dBm, therefore, the UWB device is far from TS and BS. Emission can be allowed at -41.3 dBm/MHz.

### A.1.1.2.2 Estimation of TS TPC range at the cell edge

A theoretical study has been conducted according to the assumptions defined in section A.1.1.1 for BWA parameters selections to assess TPC values according to BWA deployments. This study aims also to identify some relationships between TPC, DL and UL AMC.

The link budget calculations lead to the results in the Table 8 below, considering the following scenario:

- The UL QPSK Rate ½ case
- Each DL AMC case
- LOS for the ranges
- Fading margin 8dB for range and isolation calculation

| | DL AMC | 64QAM 5/6 | 64QAM ¾ | 64QAM 2/3 | 64QAM ½ | 16QAM ¾ | 16QAM 2/3 | QPSK ¾ | QPSK ½ |
|---|---|---|---|---|---|---|---|---|---|
| **CS to TS DL** | **CS to TS isolation [dB]** | 110.15 | 112.05 | 113.15 | 116.25 | 117.35 | 121.45 | 123.75 | 127.15 |
| | **CS to TS range [m]** | 2194 | 2730 | 3099 | 4428 | 5026 | 8059 | 10502 | 15534 |
| | | **DL limited** | | | **UL limited** | | | | |
| **TS to CS UL** | **Max. UL power control range for QPSK R = ½ @ 20dBm** | 3.0dB | 1.1dB | 0.0dB | -3.0dB | -4.0dB | -8.0dB | -10dB | -14dB |
| | | **TPC Applicable** | | | **TPC Not Applicable** | | | | |

**Table 8: Study results of link budget analysis between UL QPSK R=1/2, and all possible DL AMC scenario**

These first results are indicating that only three DL AMC cases are DL limited when using an UL with QPSK Rate ½, modulation and rate coding. These three DL limited cases are DL 64QAM Rate 5/6, DL 64QAM Rate ¾ and DL 64QAM Rate 2/3.
For these three DL limited cases we calculate a theoretical UL TPC range at each "DL AMC cell edge" of:

- 3.0dB at the "cell edge" of the DL 64QAM Rate 5/6,
- 1.1dB at the "cell edge" of the DL 64QAM Rate ¾
- And 0.0dB at the "cell edge" of the DL 64QAM Rate 2/3 (TPC just at the initial operating range)

In addition, these theoretical results have been validated by measurements where it is observed that the TPC range is less than 3 dB at the DL cell edge under worst case situation (DL limited case for 64 QAM 5/6).

For the investigation of the maximum TPC range operation, Figure 3 below represents the test results for the DL 64QAM 5/6 rate as the theoretical study identifies this scenario as the case where the most TPC power reduction would be made.

Referring to the plot TX_PWR Figure 3, it can be seen that the TS (red line) reaches full power just at the edge of the cell. Operating with at target RSSI of -99dBm thus provide the lowest possible TS transmit power without reducing the coverage of the cell for the worst case of DL limited possibilities (64QAM5/6) (purple line).

For this campaign, it was concluded that using -99dBm UL RSSI target is valid, if not conservative, for use in the following measurement campaigns. This means that the results of this report are obtained at the lowest possible transmit power of the TS.

Operators may choose less extreme TPC settings, thus, as they relate to the establishment of DAA zone thresholds, these results should be considered conservative and generally protective of the BWA system.

These measurement results reported here show that for this worst case DL limited scenario (64QAM 5/6) a 3dB TPC range, or perhaps less, is sufficient to account for the case where the TS is operating at the absolute minimum transmit power.

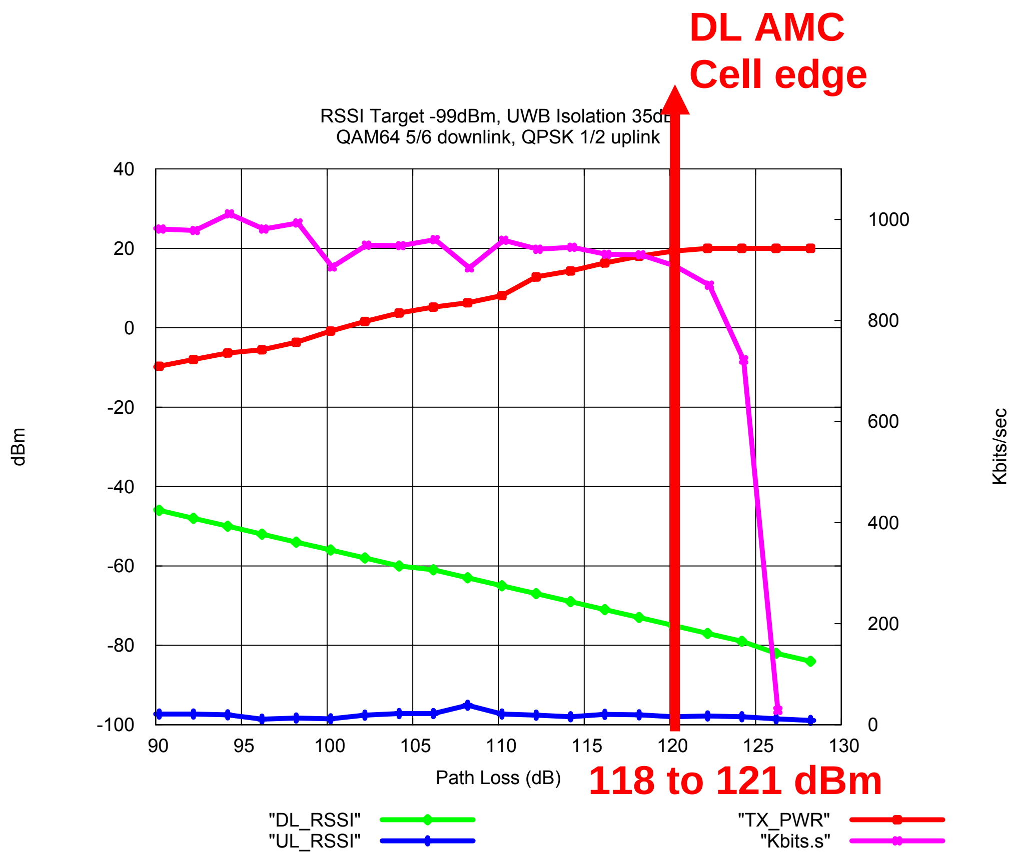


**Figure 3**

Legend:

- kbit.s: Data throughput in DL (purple line),
- TX_PWR: TS UL TX power (red line)
- DL_RSSI: DL signal received by TS & by UWB device (green one)
- UL_RSSI: TS UL signal received by CS (blue line)

#### A.1.1.2.3 UL Detection Thresholds Safety Margin

##### A.1.1.2.3.1 At the cell edge

**Zone1/Zone2 Border safety margin: 15 dB**

Figure 4 shows some measurements of the potential BWA performance degradation, by decreasing the UWB isolation to 35dB in order to simulate a Zone 1 operation when the UWB device is located at 36cm of the BWA client. The effect when the UWB interference is active was also measured. The measurement data UWB-41, UWB-65 represent the cell coverage reduction when UWB interference power is increased up to -41.3dBm/MHz (brown line) or -65dBm/MHz (blue-green line).

Under these conditions:

- It is observed that at the isolation level of 121dB between the CS and the TS, which is defined as the “Cell Edge” for the DL 64QAM5/6, no UL TPC operation is yet active (red line) and that the measured UL signal received at the UWB location is -15 dBm (black line).
- With a 35dB isolation between the BWA client and the UWB device, the UWB may still operate at -65dBm/MHz (DAA Zone 2 operation) until a CS to TS isolation level (path loss and antenna gains) of 116dB, without impacting the BWA system.
- With a CS to TS isolation of 116dB, the UL TPC is operating, and the measured UL signal received at the UWB location is -20dBm (black line). This -20 dBm level indicates that there is a 15dB safety margin (35 – 20= 15), for the proposed DAA detection threshold for the Zone1/Zone2 border.

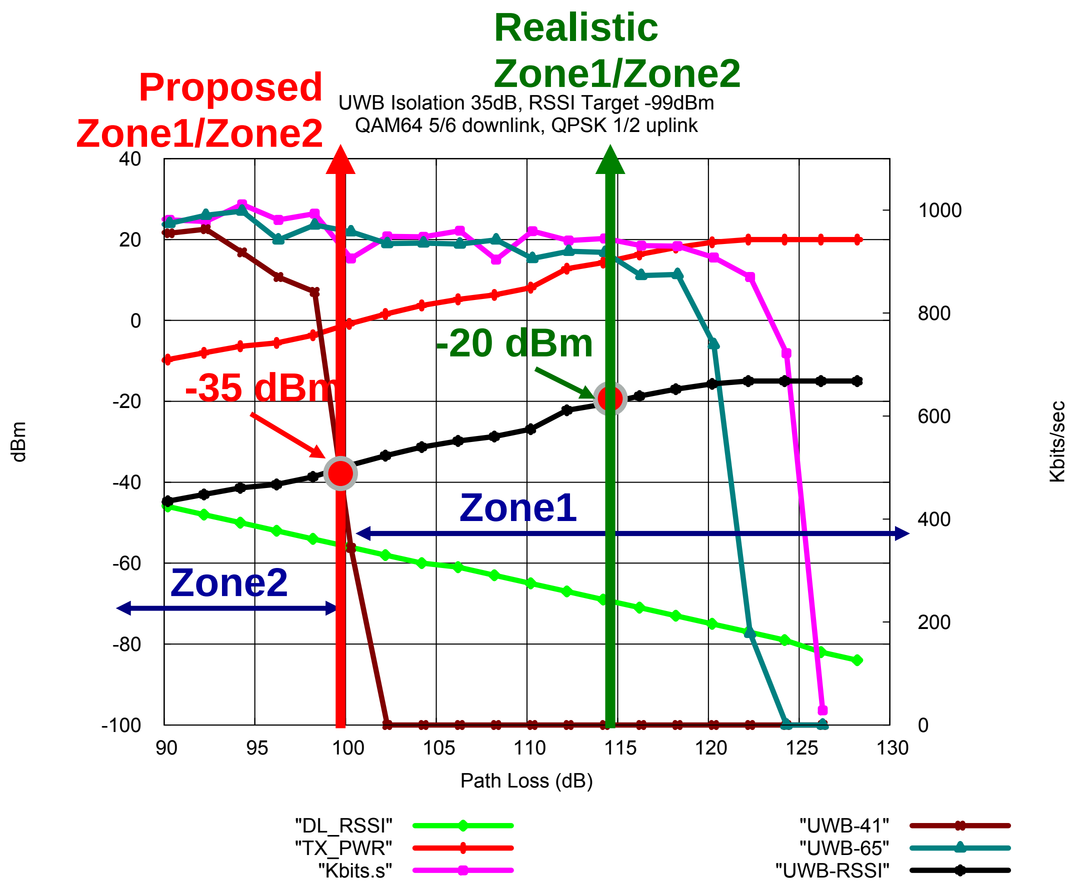


**Figure 4**

Legend:

- kbit.s: Data throughput in DL (purple line),
- TX_PWR: TS UL TX power (red line)
- DL_RSSI: DL signal received by TS & by UWB device (green line)
- UWB_RSSI: TS UL signal received by UWB device (black line)
- UWB-41: Data throughput in DL (brown line) with -41dBm/MHz UWB emission level
- UWB-65: Data throughput in DL (blue-green line) with -65dBm/MHz UWB emission level

<u>The conclusion of this section is that the threshold value of -35dBm include a 15 dB safety margin to protect BWA operation when UWB device is operating in zone 1</u>

**Zone2/Zone3 Border safety margin: 13 dB**

Figure 5 shows some measurements of the potential BWA performance degradation by increasing UWB isolation up to 55dB in order to simulate a Zone 2 operation when the UWB device is located just at the Zone1/Zone2 border. The measurement data UWB-41, UWB-65 and UWB-NONE represent the cell coverage reduction when UWB interference power is increased up to -41.3dBm/MHz (brown line), -65dBm/MHz (blue-green line) and without UWB interference respectively (purple line).

Under these conditions:

- It can be seen, that with a 55dB isolation for the Zone1/Zone2 border definition for DAA operation, an UWB TX power at -65dBm/MHz emission in Zone 2 is adequate for any path loss between the CS and the TS (blue-green line similar to the purple one).
- It is also observed that at the isolation level of 121dB between the CS and the TS, which is defined as the "Cell Edge" for the DL 64QAM5/6, no UL TPC operation is yet active (red line) and that the measured UL signal received at the UWB location is -35 dBm, which is the proposed Detection threshold for Zone1/Zone2 border.

- With a 55dB isolation between the BWA client and the UWB device, the UWB may still operate at -41.3dBm/MHz (DAA Zone 3 operation) until a CS to TS isolation level of 112dB, without impacting the BWA system (brown line).
- With a CS to TS isolation of 112dB, the UL TPC is operating, and the measured UL signal received at the UWB location is -42dBm (black line). This -42 dBm level indicates that there is a 13dB safety margin (55 – 42= 13), for the proposed DAA detection threshold for the Zone2/Zone3 border.

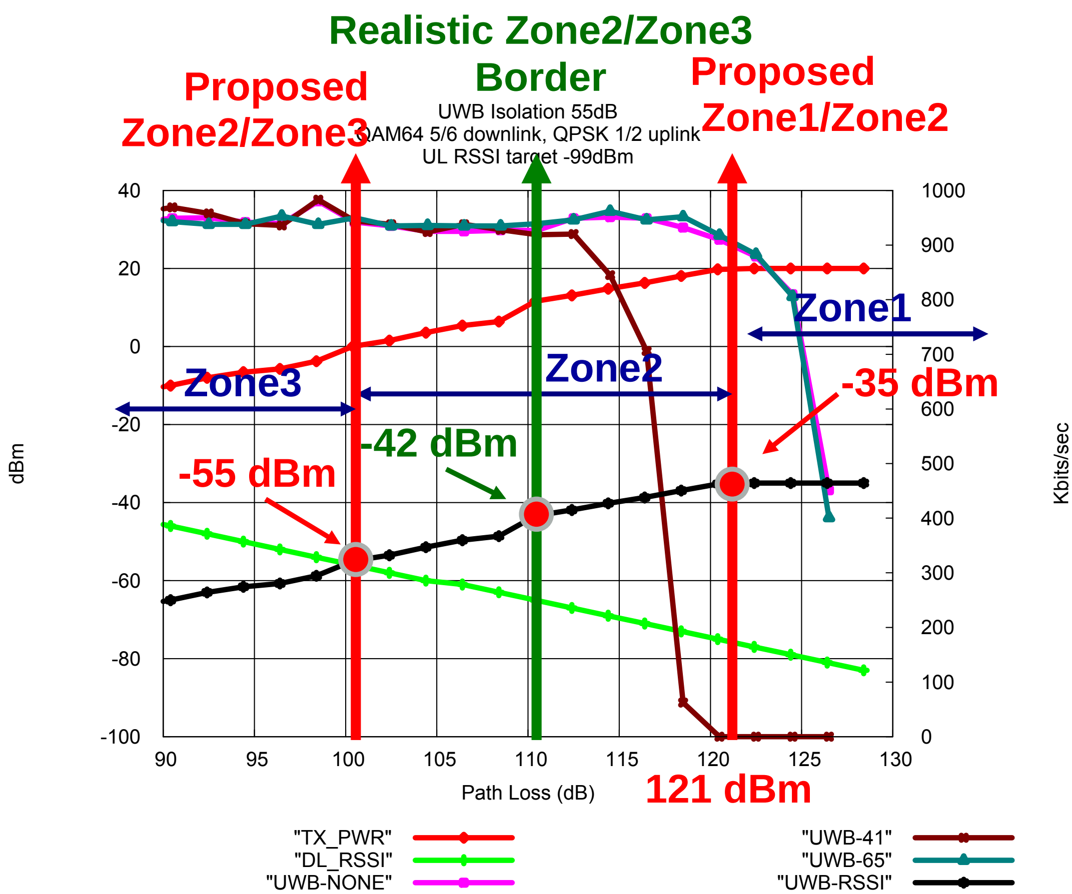


**Figure 5**

Legend:

- UWB-NONE: Data throughput in DL (purple line) ,
- UWB-41: Data throughput in DL (brown line) with -41dBm/MHz UWB emission level
- UWB-65: Data throughput in DL (blue-green line) with -65dBm/MHz UWB emission level
- TX_PWR: TS UL TX power (red line)
- DL_RSSI: DL signal received by TS & by UWB device (green line)
- UWB_RSSI: TS UL signal received by UWB device (black line)

The conclusion of this section is that the threshold value of -55dBm include a 13 dB safety margin to protect BWA operation when UWB device is operating in zone 2.

**Zone3 Operation Validation**

Figure 6 shows some measurements of the potential of BWA performance degradation by increasing the UWB isolation to 75dB in order to simulate a Zone 3 operation when the UWB device is located just at the Zone2/Zone3 border. The measurement data UWB-41, UWB-65 and UWB-NONE represent the cell coverage reduction when UWB is operating with an emission level of -41.3dBm/MHz, -65dBm/MHz and without UWB.

Under these conditions:

- It can be seen, that with a 75dB protection distance for the Zone2/Zone3 border definition for DAA operation, an UWB TX power at -41.3dBm/MHz emission in Zone 3 is adequate for any path loss between the CS and the TS (brown, blue-green and purple line similar).
- It is also observed that at the isolation level of 121dB between the CS and the TS, which is defined as the "Cell Edge" for the DL 64QAM5/6, no UL TPC operation is yet active (red line) and that the measured UL signal received at the UWB location is -55 dBm (black line), which is the proposed Detection threshold for flexible DAA.

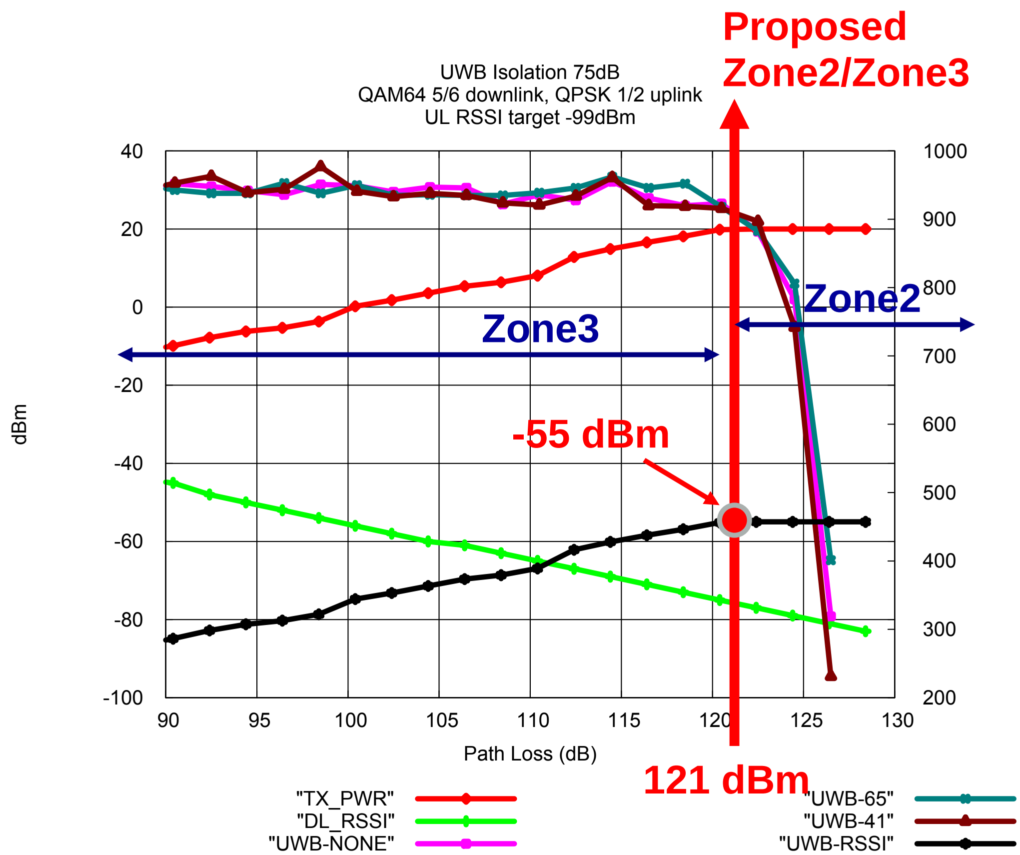


**Figure 6**

Legend:

- UWB-NONE: Data throughput in DL (purple line),
- UWB-41: Data throughput in DL (brown line) with -41dBm/MHz UWB emission level
- UWB-65: Data throughput in DL (blue-green line) with -65dBm/MHz UWB emission level
- TX_PWR: TS UL TX power (red line)
- DL_RSSI: DL signal received by TS & by UWB device (green line)
- UWB_RSSI: TS UL signal received by UWB device (black line)

<u>The conclusion of this section is that under the test configurations setup emulating the BWA characteristics assumptions defined in section A.1.1.1, the impact of TPC has already been accounted for within the safety margin included in the proposed detection threshold levels.</u>

#### A.1.1.2.3.2 Inside the cell

The purpose of this section is to assess the impact of a reduced TS emission level which means an increased TPC value (since it is deployed inside the cell).

The red line in Figure 7 stands for the maximum allowable UWB emission power level for a given isolation between BWA TS and UWB device in order to maintain the same interference power level on TS (-115dBm/MHz).
The three green boxes show the allowable UWB emission level according to the isolation between TS and UWB (and consequently operating zone). Therefore, the gap between this red line and borders of the different boxes stands for the additional margin to protect BWA TS device.

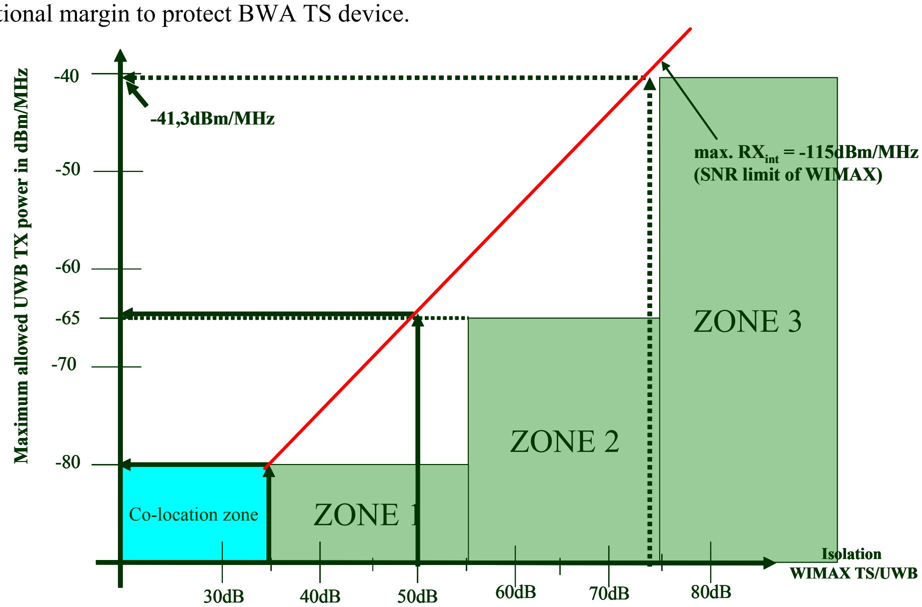


**Figure 7: Maximum UWB Tx Power at Downlink AMC Cell Edge**

When the BWA TS is operating inside the downlink AMC cell, any reduced TS emission power will lead to a reduction of the isolation figure between TS and UWB device. Therefore, a translation on the left side of the different boxes can be observed (5dB in the example in Figure 8).

But it means also that the received DL power is increased also by this value (which leads to this reduced TS emission power). Therefore, the red line has also to be translated on the upper side by 5 dB.

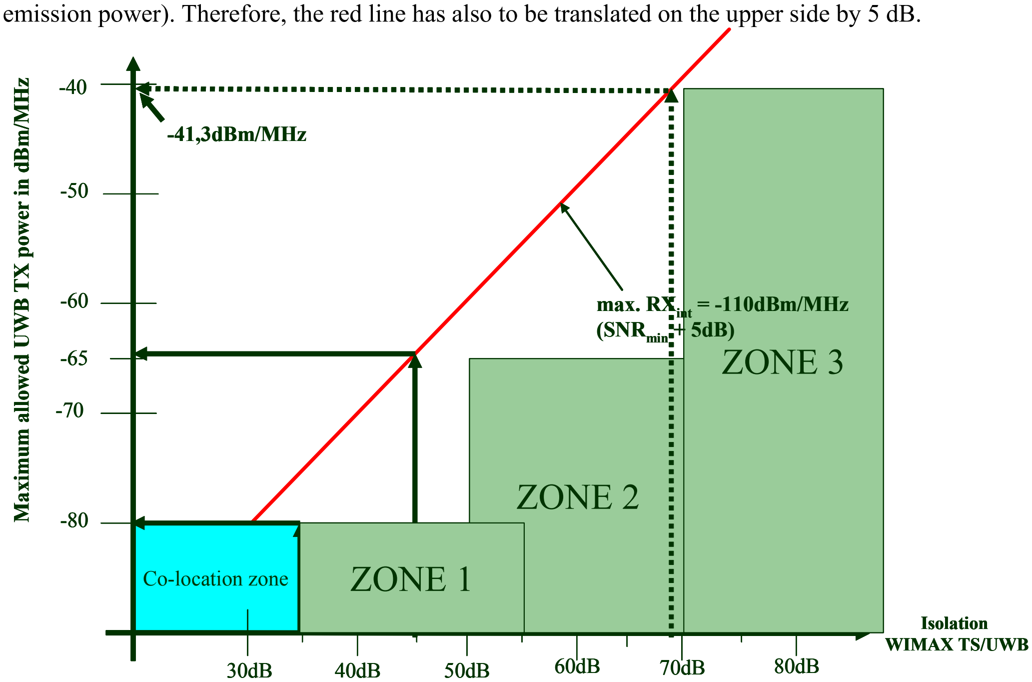


**Figure 8: Maximum UWB Tx Power at Downlink AMC Inside Cell**

The conclusion is that the TPC range induced by the isolation reduction is compensated by the corresponding increase of the SNR value on the TS.

The overall conclusion of section A.1.1.2 is that the worst case is given by the downlink transmission in 64QAM and uplink transmission in QPSK.

### A.1.2 Identification of uplink detection thresholds based on scenario 2

Report 100 identifies an asymmetric network configuration in which the downlink capacity is designed to be significantly greater on the downlink. Such networks are uplink limited and the downlink signal strength at the cell edge can be high. The WiMAX Forum has identified that many operators will operate their networks in a more symmetric configuration, for example using BPSK with sub-channelisation on the uplink. Indeed, future pico and femto cells are likely to be designed to achieve symmetric capacity on the up and downlinks. In this situation the safety margins on the uplink threshold detection levels reduces to zero.

The acceptable level of UWB interference at a BWA terminal is -80dBm/MHz at a 36cm from a BWA terminal. It was accepted that the probability of the two devices being in closer proximity than this was small enough to be ignored. Therefore, at distances greater than 36cm, the maximum acceptable level of UWB interference at a BWA terminal antenna is -114.7dBm/MHz. Thus the objective of the DAA scheme is to ensure, with high probability, that this level is not exceeded.

The basis of the DAA proposal is that UWB devices listen for BWA signals and use the level of the detected signal to estimate the distance to any nearby BWA terminal. The UWB device then adjusts its transmitted power so as to ensure that its signals will be less than -114.7dBm/MHz at the BWA terminal. Since up and downlink frequencies are unknown, any signal received by a UWB device is interpreted as a BWA uplink signal, and the largest received signal strength is used to determine the UWB transmit power.

#### A.1.2.1 Threshold levels for Zones 1 and 2

The UWB device uses the detected signal strength to estimate the path loss between it and the nearest BWA terminal. On the basis of this it then determines in which of the three zones it is located. Three factors need to be taken into account in determining the appropriate threshold levels. They are:

- The BWA terminal maximum transmit power;
- The operation of BWA terminal transmit power control. If this results in a lower level than is assumed in the DAA algorithm, the BWA to UWB path loss estimate will be too high;
- Differential fading between the path from the BWA terminal to UWB device (on the uplink frequency) and the UWB to BWA path (on the downlink frequency)[1]. If the fade level on the BWA to UWB path is higher, the UWB to BWA path loss estimate will be too high.

##### A.1.2.1.1 BWA terminal transmit power

The maximum BWA terminal transmit power will vary with the class of the device. A value representative of expected fixed and nomadic devices is 20dBm.

##### A.1.2.1.2 Transmit power control

A BWA terminal makes use of transmit power control to keep the radiated power to the minimum needed to ensure satisfactory reception at the base station, and the signal detected by the UWB device will be reduced as the terminal comes closer to its base station. The UWB algorithm will interpret the reduced signal strength as an increase in the isolation between it and the BWA terminal leading to the possibility that the UWB device could switch to its next higher transmit power before the path loss justified it.

The effect will depend on the alignment of the up and downlink AMC switching points which in turn will depend on the degree of uplink/downlink asymmetry and will therefore vary between networks and between base stations within the same network. The central part of Figure 9 shows how the up and downlink AMCs align when the up and downlinks are made ~9dB more symmetric than in considered in Report 100.

Figure 9 also shows how the excess SNR on the downlink and the terminal transmit power vary in this case. Although the BWA terminal will reduce its radiated power as it comes closer to the base station and the received excess downlink SNR will increase at the same rate, the relative positions of the AMC switch points alter the extent to which these balance out. At point (b) for example the terminal transmit power is reduced by over 3dB at the point at which the downlink SNR is at its minimum. The worst case occurs when the downlink AMC switches to its next higher level just before the terminal transmit power control reaches its maximum. Once the downlink reaches its highest AMC level (64QAM 5/6) its SNR margin will continue to increase. Thus the worst case would be a 4.1dB error in the estimated UWB to BWA terminal path loss.

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[1] Differential fading can occur even with TDD operation when the up and down link sub-channels are separated by more than the coherence bandwidth (of around 5 MHz).

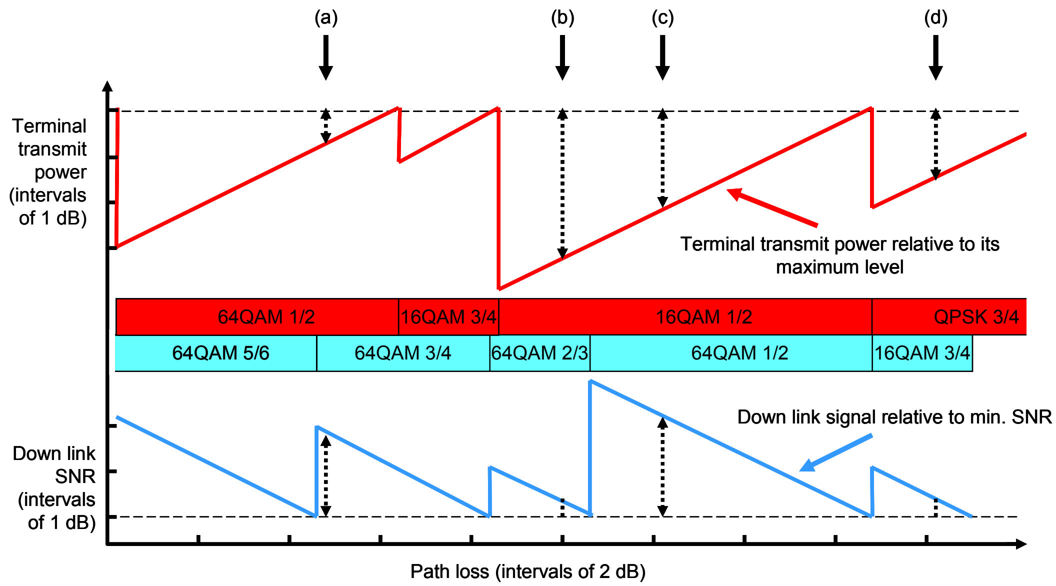



**Figure 9: This figure shows how the BWA terminal transmit power will adjust downwards (relative to its maximum transmit power) and how the SNR on the downlink changes (relative to the minimum SNR for each modulation scheme) as the path loss is reduced. At points (b) and (d) the reduction in transmit power is greater than the margin above the minimum SNR. At point (c) the two are equal, and point (a) shows an example in which the SNR margin exceeds the reduction in transmit power**

The relationship between AMC on the up and downlinks will depend upon the type of base station and on the link budgets implemented by individual operators. Clearly, the reduced terminal transmit power will be compensated by a higher SNR on the downlink some of time. Equally clearly it cannot be relied on to do so. To ensure a low probability that the UWB to terminal path loss will be under-estimated it is estimated that a TPC margin of 3.1dB is required, 25% less than the maximum possible.

#### A.1.2.1.3 Differential fading

The UWB device uses the estimated path loss on the BWA terminal to UWB device path whereas the UWB signal is affected by the path loss on the UWB to BWA terminal path. The frequency spread between the two paths can be greater than the coherence bandwidth even with TDD systems leading to uncorrelated fading on the two paths. Thus a margin may be required to ensure that the probability that the UWB to BWA terminal path loss is under-estimated is kept small.

Simulations show that with a 10 MHz frequency difference (which can occur with 10 MHz and larger channels), there is a 5% probability that the terminal to UWB path loss will exceed that on the reverse path by 8dB or more. Measurements confirm the simulation results. Measurements were performed for frequency differences of 20, 50 and 100 MHz. For the 95% confidence level, the differential fade depth for a 20 MHz frequency difference was found to range from 8 to 10 dB for BWA to UWB separation distances ranging from 2 to 3m. To ensure that the probability of path loss under-estimation is less than 5% a margin of about ~10dB is therefore required. Taking into account that in normal circumstances, at least two UWB devices are involved, taking independent measurements, to reach a 5% confidence level, a 6dB margin seems appropriate.

**Differential fading measurements**

Measurements of the path loss difference on the paths between a BWA terminal victim terminal and a potential UWB interferer were made in a laboratory environment. A range of LOS and NLOS situations were considered. An example is shown in the following figure.

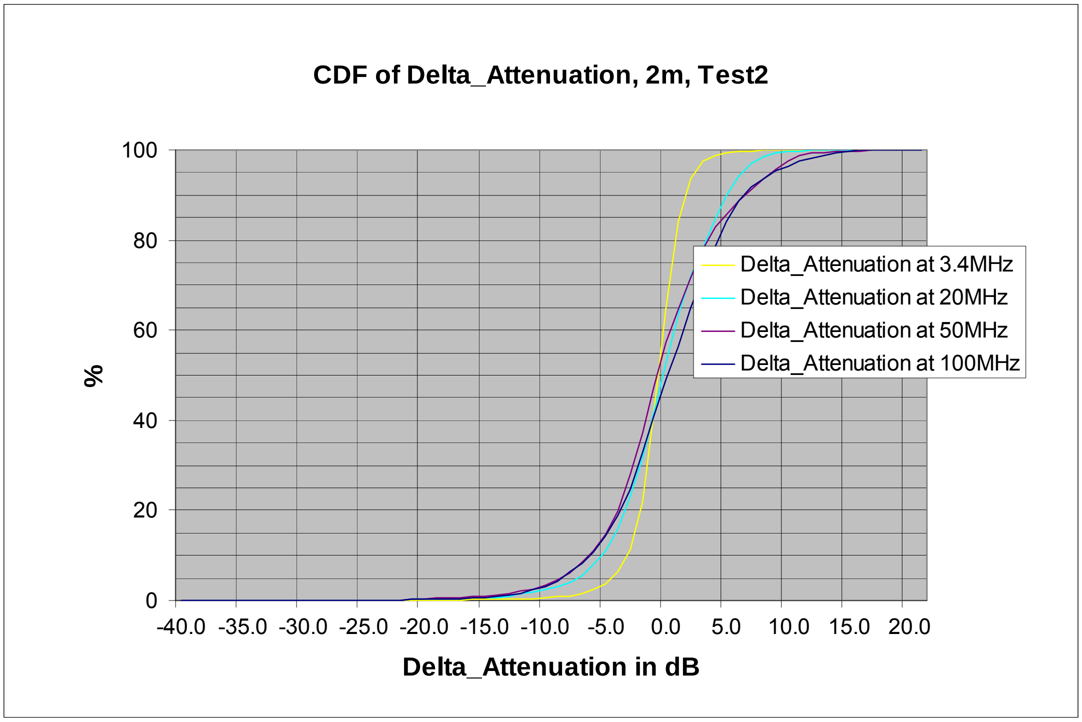



**Figure 10: Example of measured CDF of path loss differences for different frequency offsets, 2m distance**

Some of the results are summarized in the following table.

| | | Δf = 20 MHz | | Δf = 50 MHz | | Δf = 100 MHz | |
|---|---|---|---|---|---|---|---|
| | Scenario (1m) | Threshold 50% in dB | Threshold 95% in dB | Threshold 50% in dB | Threshold 95% in dB | Threshold 50% in dB | Threshold 95% in dB |
| | | | | | | | |
| d=1m | Lab1 | -0,2981 | 6,7019 | -0,2981 | 6,7019 | 0,7019 | 8,7019 |
| | Lab2 LOS | 0,974 | 4,9774 | -1,0266 | 4,9774 | -0,0226 | 3,9774 |
| | Hall LOS | -0.4245 | 2,5755 | -1,4245 | 2,5755 | -0,425 | 2,5755 |
| | Office | 0,1724 | 3,1724 | -0,8276 | 2,1724 | -0,8276 | 3,1724 |
| d=2m | Lab1 | -0,686 | 8,9314 | 1,9314 | 8,9314 | 0,9314 | 8,9314 |
| | Lab2 LOS | -0.4109 | 8,5891 | -1,4109 | 6,5891 | -0,4109 | 7,5891 |
| | Hall LOS | 0.8855 | 7,8855 | 1,8855 | 9,8855 | 0.8855 | 6,8855 |
| | Office | -0.7629 | 5.2371 | -0.7629 | 4.2371 | -0.7629 | 5.2371 |
| d=3m | Lab1 | 0,4587 | 6,4587 | 0,4587 | 9,4587 | 1,4587 | 11,4587 |
| | Lab2 LOS | -1,7936 | 7,2064 | -1,7936 | 7,2064 | 2,7936 | 7,2064 |
| | Hall LOS | -1.7534 | 6.2466 | -1.7534 | 9,2466 | 0,7534 | 6.2466 |
| | Office | -0.4216 | 7.5784 | -0.4216 | 7.5784 | -0.4216 | 7.5784 |

**Table 9: Measurement results for the needed margin in the different environments**

Focusing on the case of 20 MHz bandwidth and the 95% threshold shows that margins of up to 9dB are required.

### A.1.2.2 Threshold level L1

The path loss between the UWB device and the BWA terminal needs to exceed 49.7dB before the UWB device may transmit at -65dBm/MHz. The threshold can be calculated from the margins discussed above. Table 10 gives the calculation.

| **Threshold level L1 – calculation** | **Value** |
|---|---|
| BWA terminal transmit power<br>Required path loss<br>TPC margin<br>Fading allowance | 20dBm<br>49.7dB<br>3.1dB<br>6dB |
| ***Threshold L1*** | ***-38 dBm*** |

**Table 10: Calculation of threshold level L1**

#### A.1.2.3 Threshold level L2

The calculation of threshold level L2 is the same as for L1 with the required path loss increased to 73.4dB.

| **Threshold level L2 - calculation method** | **Value** |
|---|---|
| BWA terminal transmit power<br>Required path loss<br>TPC margin<br>Fading allowance | 20dBm<br>73.4dB<br>3.1dB<br>6dB |
| ***Threshold L2*** | ***-61dBm*** |

**Table 11: Calculation of threshold L2**

### A.1.3 Conclusion for uplink detection thresholds

Two scenarios have been presented on the detection threshold. The differences between both scenarios are:

First scenario
Theoretical study validated by measurement based on the identification of the worst case situation which is TS at cell edge with 64QAM downlink transmission and QPSK uplink transmission (asymmetric).

This result in
- Uplink detection threshold of -35dBm for L1 and -55dBm for L2

Second scenario
Based on typical less asymmetrical BWA system able to utilize subchannelize BPSK modulation in the uplink, and inclusion of specific fading margin and TPC of impact throughout the cell and the cell edge.

This result in
- Uplink detection threshold of -38dBm for L1 and -61dBm for L2

It was agreed to use the detection thresholds based on the result of the second scenario.

### A.1.4 Assessment of other DAA Parameters

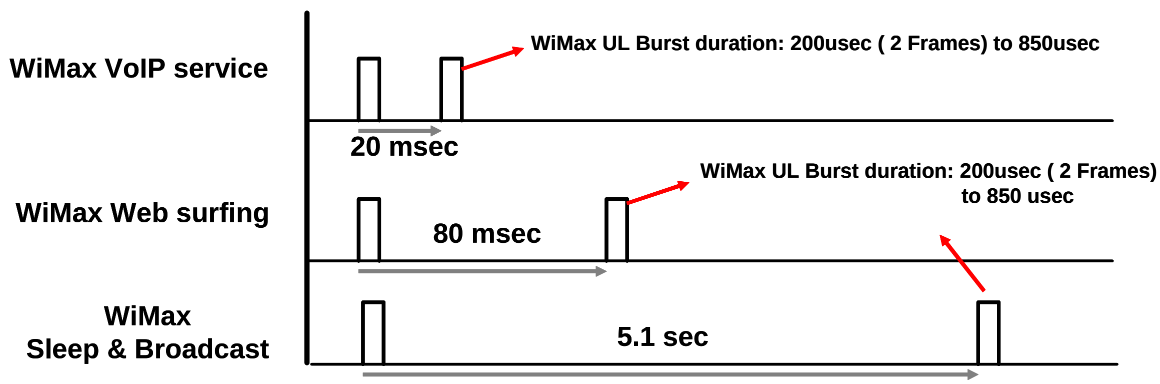
The combination of detection threshold, initial channel availability check time and detection probability is intended to provide protection to BWA TS for more than 99.75% of the time.

In addition to the flow chart presented in section 2.3, there is a need to define additional DAA parameters.
These parameters need to be defined taking into account typical BWA activity information. BWA subscribers will make use of a wide range of services including VoIP, web surfing and multimedia broadcasting, see Table 8. The multimedia broadcasting service is taken as the representative service as it is expected to be widely used. In this case there is very infrequent uplink traffic. However, every BWA terminal will send a periodic ranging signal which the UWB can detect.

| BWA service / mode | Relevant characteristics of the service | Uplink tx interval | Typical minimum period to receive at least one UL transmission | Representative duration of individual transmissions |
|---|---|---|---|---|
| VoIP | An uplink signal typically sent every 4th frame. | 20 - 80ms | 20ms | 300µs |
| Web surfing | An uplink signal typically every 16th frame. | 80 – 320ms | 80ms | 300µs |
| Sleep mode | Wake up periods likely to vary widely but terminal will send regular ranging signals with a minimum interval of 5s. | 5 – 35s | 5.1s | 300µs |
| Multimedia broadcasting | Downlink requiring continuous capacity (effectively real time). No uplink transmissions other than ranging signal. | 5 – 35s | 5.1s | 300µs |

**Table 12: The characteristics of the representative BWA services**

Typical BWA pattern uses are given in the figure below.




The idle mode has not been included here as idle periods can last for much longer periods (hours) and it would be impractical to detect terminals in this mode.

The DAA parameters are defined for two cases described below:

- During UWB startup process ( listen before talk)
- During UWB operation/communication (to monitor changes in the interference environment)

### A.1.4.1 Initial detection operation

The channel availability check time 'Minimum ***Initial Channel Availability Check Time'*** $T_{avail,\,Time}$ is defined based on typical minimum period to receive at least one UL transmission for multimedia broadcasting operation. This worst case situation leads to a minimum time of 5.1s.

Procedural tests shall ensure in Zone 1 and 2 FWA TS transmission is successfully detected by UWB device for more than 99% of cases.

### A.1.4.2 Continuous Detect Operation

Once a UWB device has established the mode in which it is to operate (Zone 1, 2 or 3) it will be necessary to regularly check for any change that could affect the level at which it transmissions are received by the nearby BWA terminal. This may come about as a result of movement by either or both devices, changes in the local propagation environment, change of channel, etc. Changing from Zone 3 to Zone 2 or Zone 2 to Zone 1 increases the protection of the BWA terminal and does not need to be specified from the BWA perspective. Changes in the other direction need to be detected reliably and quickly.

The time taken to detect and correctly respond to a change is the period during which normal BWA operation can be disrupted. This process will not be entirely deterministic so the protection level is expressed in terms of the detection probability and the associated detect and avoid respond time as given in Table 13. This level of protection is applicable irrespective of which zone the UWB device is operating in.

| BWA service / mode | Detect and Avoid Time | Detection Probability |
|---|---|---|
| VoIP | 2s | 95% |
| Web surfing | 15s | 95% |
| Sleep mode | 60s | 95% |
| Multimedia broadcasting | 2s | 95% |

**Table 13: Protection requirements for an active BWA terminal.**

### A.1.4.1 Assessment impact to delay in BWA startup process

Measurement results show that significant startup delays may occur under worst case conditions. Data in Figure 11 was collected over two weeks of tests represented by hundreds of measurements points taken. Using this chart the probability that a startup will be delayed longer than a given time can be found. For example, at 70% duty cycle, the probability that startup will be delayed more than 100 seconds is approximately 56%

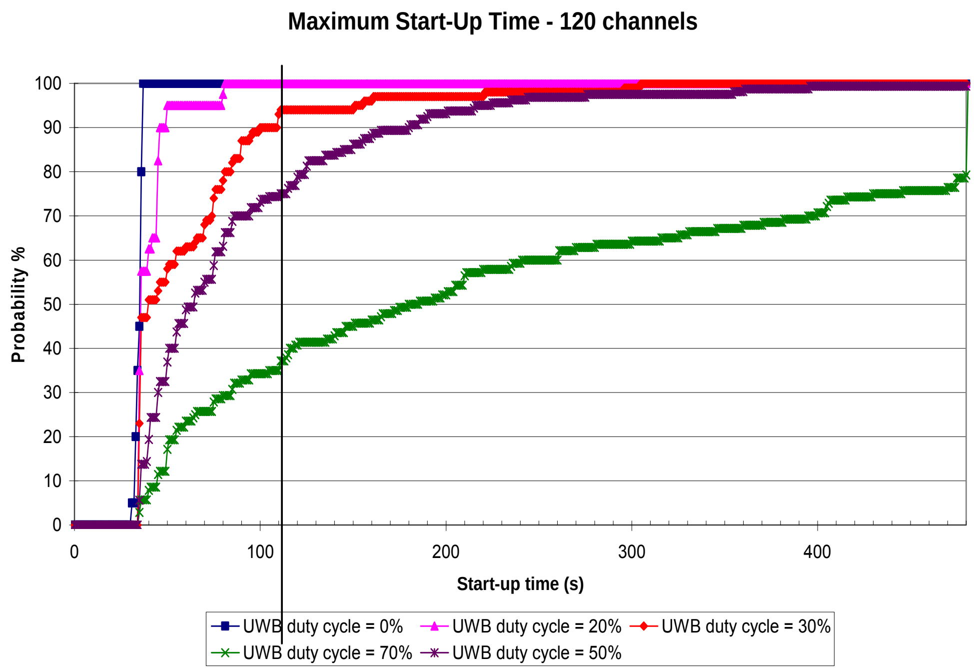



**Figure 11: Probability of delayed start**

In order to evaluate the potential UWB interference risk on BWA clients during the startup operation, we shall also take into consideration BWA and UWB populations deployment scenario. For this reason, we provide also a complementary theoretical study on the probability that this delay impact may occur in the grade of service section below

| | Parameter | Value | Units | Source |
|---|---|---|---|---|
| 1 | BWA BTS range (RBTS) | 1000.00 | m | 1km Base station covg range |
| 2 | BWA BTS coverage area (approximated to circular area) | 3.14 | km2 | |
| 3 | Max distance from BS where BWA client's start up time is not affected (Rdegradation-free) | 600.00 | m | WiMedia test bed measurements, Erceg C model |
| 4 | Max degradation-free area | 1.13 | km2 | |
| 5 | Total area susceptible to start up time degradation | 2.01 | km2 | |
| 6 | UWB device density (Active + Inactive) | 10000 | devices/km2 | Spreadsheet prepared for aggregation studies (ITU) - Worksheet 'Act factors' |
| 7 | Activity factor | 5.00% | | Upper activity factor figure from ITU studies. |
| 8 | Total number of active UWB devices in area susceptible to start up time degradation (5 * 6 * 7) | 1006 | devices | WiMedia test bed measurements derived from 100% duty cycle results tabulated in table 4 of TG3#21_08R0[3] |
| 9 | Max distance from UWB device where BWA start up is affected(raffected) | 2.00 | m | |
| 10 | Area around active UWB device where BWA start time is affected | 0.000013 | km2 | |
| 11 | Total possible affected area (7 * 9) | 0.01 | km2 | |
| 12 | %Area affected by UWB int when all active UWB devices transmit at 100%duty cycle (11 / 2) | 0.40% | | |
| 13 | Prob of interference when a single UWB device is operating at 70% duty cycle | 55.00% | | For 70% duty cycle, the prob of start up time delayed by 100secs is 55% |
| 14 | Probability of UWB devices affecting start up operation in a BWA cell (12 * 13) | 0.22% (note) | | This number assumes each active UWB device is affecting start up operation of any BWA client in its vicinity. |

**Table 14: Probability of any startup being delayed by 100 seconds**

Note: changing the assumptions from a 100 sec delay start-up to 0 sec delay would increase the probability and its associated impact to 0.38%. In some circumstances, a BWA customer terminal may not be able to access the network.

The probability of impacting BWA client during its startup operation, of 0.22% is achieved using conservative assumptions such as:

⇒ The definition of the harmful interference for the Startup operation, is defined as a startup delay larger than 100sec.

⇒ All BWA client located within 2m distance from the UWB device, are considered impacted with harmfull interference during the startup operation

⇒ The BWA client is performing 120 scans at each startup operation

⇒ Each active UWB device is considered operating independently, when in normal operation, several UWB devices may operate in the same area.

⇒ This study doesn't take into account the UWB / BWA co-located equipments, which introduce an additional mitigation factor.

This concluded that it is not necessary to mandate duty cycle limits for UWB devices to protect startup of BWA devices.

## ANNEX 2: COMPATIBILITY STUDIES FOR RADIOLOCATION SYSTEMS IN THE FREQUENCY BAND 3.1-3.4 GHz

### A.2.1 Radars characteristics and baseline assumptions

The radiolocation system characteristics are described in the table below. These characteristics are based on various sources (ITU-R M1465 [2] , and national administrations information (France, Germany and UK).

| Radar Systems Deployments in 3100 – 3400 MHz | | | |
|---|---|---|---|
| **System Mobility** | **Fixed and Mobile systems** | | |
| **Radar system deployment: One single radar per area** | **Yes** | | |
| **Radars Systems Characteristics in 3100 – 3400 MHz** | | | |
| | **Min** | **Typ.** | **Max** |
| **Pe: Radar transmitter emission power Peak power in [dBm]** | **55** | **80** | **95** |
| **Ge: Antenna gain in [dBi] In the antenna main beam (for 0° elevation and azimuth)** | **25** | **35** | **45** |
| **Pe + Ge: Peak EIRP according to distance coverage in [dBm]** | **80** | **115** | **140** |
| **Antenna rotation duration. For rotating or periodic radars only, (typical) in [second]** | **1** | **6** | **12** |
| **Radar Receiver bandwidth (Typical) [In MHz]** | | **10** | |
| **Radar Signal characteristics** | | | |
| | **Min** | **Typ.** | **Max** |
| **Pulse duration in [µs]** | **0.2 µs** | **10 & 110 µs** | **110 µs** |
| **Pulses repetition frequency in [Hz]** | **300 Hz** | **4 kHz** | **7 kHz** |
| | | | |

**Table 15**

The signal characteristics of radiolocation systems are classified. Therefore, the given figures may not be representative of deployed radar systems. Especially the signal characteristics of non pulse radar systems as for example FMCW or FH radars are not presented in table 15. However the test procedure to be described in the ETSI EN 302 065 has to reflect also those other radar types.

### A.2.2 Detection threshold values for S-band Radars

In this section, we will calculate the needed detection thresholds for the DAA detection process in order to guarantee an interference free operation of the potential victim radar device. The proposed TX power levels and antenna gains are based on the minimum values of Table 15.

In Table 16 below the calculation is depicted for different reference cases for the UWB TX powers from -41dBm/MHz e.i.r.p. down to -70dBm/MHz e.i.r.p.. In this table a radar TX power of 65dBm and an antenna gain of 40dBi have been assumed (Case A to Case D). In Case E, the worst case situation given in Table 16 is considered. For an UWB device operating at -41dBm/MHz e.i.r.p. a protection distance of 6.8km under LOS conditions can be observed (Case A). This LOS distance corresponds to a minimum needed isolation (or MCL) of 119dB (Case A: -41 + 40dBi –(-120)) or 104 (Case E: : -41 + 25dBi –(-120)). Under NLOS conditions with an attenuation exponent of 3.5 the needed isolation of 119dB in Case A corresponds to a distance of 150m and the needed isolation of 104dB in Case E to 58m.

| input fields are yellow | Case A | Case B | Case C | Case D | Case E |
|---|---|---|---|---|---|
| f/GHz | 3,10 | 3,10 | 3,10 | 3,10 | 3,10 |
| Victim thermal noise dBm/MHz | -114,00 | -114,00 | -114,00 | -114,00 | -114,00 |
| I/N dB | -6,00 | -6,00 | -6,00 | -6,00 | -6,00 |
| Imax/Victim dBm/MHz | -120,00 | -120,00 | -120,00 | -120,00 | -120,00 |
| **PSD_uwb dBm/MHz** | **-41,00** | **-50,00** | **-65,00** | **-70,00** | **-41,00** |
| **Antenna Gain UWB dBi** | **0** | **0** | **0** | **0** | **0** |
| PSD_uwb dBm/MHz e.i.r.p. | -41,00 | -50,00 | -65,00 | -70,00 | -41,00 |
| **Victim peak power dBm** | **65,00** | **65,00** | **65,00** | **65,00** | **55,00** |
| **Victim antenna gain dBi** | **40,00** | **40,00** | **40,00** | **40,00** | **25,00** |
| Victim peak power dBm e.i.r.p. | 105,00 | 105,00 | 105,00 | 105,00 | 80,00 |
| Victim power W e.i.r.p. | 3,16E+07 | 3,16E+07 | 3,16E+07 | 3,16E+07 | 1,00E+05 |
| **protection distance/m Free space loss** | **6817,71** | **2419,01** | **430,17** | **241,90** | **1212,38** |
| **protection distance/m NLOS exp 3.5** | **155,11** | **85,80** | **31,98** | **23,02** | **57,82** |
| Power flux density at the UWB device at the protection distance W/m^2 | 5,41E-02 | 4,30E-01 | 1,36E+01 | 4,30E+01 | 5,41E-03 |
| Power flux density at the UWB device at the protection distance dBm/m^2 | 17,34 | 26,34 | 41,34 | 46,34 | 7,34 |
| **Received peak power at the UWB Device at the protection distance dBm** | **-14,00** | **-5,00** | **10,00** | **15,00** | **-24,00** |

**Table 16: Calculation of radar detection threshold in the S-Band for different cases**

For an UWB device operating with -50dBm/MHz e.i.r.p. TX power (case B) the protection distance would be in the range of 2.4km under LOS conditions.
Based on the calculated mitigation distance and thus the corresponding minimum needed isolation, the radar signal strength at the mitigation distance can be calculated. In the case of the 6.8km mitigation distance for an UWB device using a TX power of -41dBm/MHz e.i.r.p., a radar peak power level of -14dBm in the over all radar operational bandwidth can be assumed.
Based on the worst case calculation (Case E) the detection threshold would need to be equal or smaller than -24dBm in the complete operational bandwidth. Thus if an UWB device with an operational TX power of -41dBm/MHz e.i.r.p. detects a radar with a peak power level of -24dBm or larger it shall switch to the corresponding avoid modus of -70dBm/MHz e.i.r.p. and thus avoiding any interference towards the potential victim system.

**The proposed peak detection threshold value to be defined in the regulation (-38dBm) was chosen to provide a harmonized value for radar and BWA. Therefore, a safety margin of 14dB (38-24) is sufficient to ensure the protection of any S-band radar. This detection threshold margin allows also to accommodate the potential aggregated UWB interference scenario.**

It has furthermore to be emphasized that DAA technical parameters alone do not ensure protection of radiolocation service by themselves. This has to be completed with adequate DAA measurement procedures in the related ETSI standard.

## ANNEX 3: COMPATIBILITY STUDIES FOR RADIOLOCATION SYSTEMS IN THE FREQUENCY BAND 8.5 - 9 GHz

### A.3.1 System characteristics for monostatic radiolocation systems

The radiolocation system characteristics are described in the table below for active radar systems only. These characteristics are based on national administrations information (France, Germany).

| **Radar Systems Deployments in 8500 – 9000 MHz** | | | |
|---|---|---|---|
| **System Mobility** | **Fixed and Mobile systems** | | |
| **Radar system deployment: One single radar per area** | **-** | | |
| **Radar Systems Characteristics in 8500 – 9000 MHz** | | | |
| | **Min** | **Typ.** | **Max** |
| **Radar transmitter emission power Peak power According to distance coverage in [dBm]** | **40** | **-** | **-** |
| **Antenna gain in [dBi]<br>In the antenna main beam** | **25** | **-** | **40** |
| **Peak EIRP according to distance coverage in [dBm]** | **65** | **-** | **-** |
| **Antenna rotation duration. For rotating or periodic radars only, (typical) in [second]** | **0.5 sec** | **1 sec** | **12 sec** |

**Table 17**

The signal characteristics of radiolocation systems are classified. Therefore, the given figures may not be representative of deployed radar systems. ITU-R M.1796 [3] may be used as guidance for the signal characteristics in this band, to be used when defining adequate test pattern for the ETSI Standard. In addition, it has to be noted that passive Radar systems may be deployed in the future and that DAA mechanism is not suitable for these radar systems. The impact of UWB devices on such passive radar systems has not been assessed.
Administrations should carefully consider the risk of interference taking into account possible future deployment of such systems.

### A.3.2 Detection threshold values for X-band monostatic active Radars

In this section we will calculate the needed detection thresholds for the DAA detection process in order to guarantee an interference free operation of the potential victim radar device.
The radiolocation systems considered for the TX power levels and antenna gains are based on the Table 17, which may not cover all radiolocation systems deployed in the X-band.
In this table a radar TX power of 40dBm and an antenna gain of 25dBi have been assumed.

And the calculation is depicted for the UWB TX powers values of -41dBm/MHz e.i.r.p. and -65dBm/MHz e.i.r.p related to the two operating Zones.

A calculation for the "Detect and Avoid Time" is given under the assumption of a threshold level of -61dBm.
It can be seen in the table below that under this assumption, a "Detect and Avoid Time" of 150s would give a significant security margin for all radiolocation systems with a detection threshold of -61 dBm.

## X-Band Radiolocations systems

| | Case A | Case B | Case C | Case D | Case E |
|---|---|---|---|---|---|
| f/GHz | 8.50 | 8.50 | 8.50 | 8.50 | 8.50 |
| Victim power dBm | 40.00 | 40.00 | 40.00 | 40.00 | 50.00 |
| max antenna gain dBi | 25.00 | 40.00 | 25.00 | 40.00 | 25.00 |
| p_eirp_Victim dBm | 65.00 | 80.00 | 65.00 | 80.00 | 75.00 |
| p_eirp max W | 3.16E+03 | 1.00E+05 | 3.16E+03 | 1.00E+05 | 3.16E+04 |
| Victim thermal noise dBm/MHz | -112.00 | -112.00 | -112.00 | -112.00 | -112.00 |
| I/N dB | -6.00 | -6.00 | -6.00 | -6.00 | -6.00 |
| Imax/Victim dBm/MHz | -118.00 | -118.00 | -118.00 | -118.00 | -118.00 |
| PSD_uwb dBm/MHz e.i.r.p. | -41.00 | -41.00 | -65.00 | -65.00 | -41.00 |
| protection distance/m Free space loss | 351.22 | 1975.06 | 22.16 | 124.62 | 351.22 |
| protection distance/m NLOSs (Exp 3.5) | 28.49 | 76.42 | 5.87 | 15.76 | 28.49 |
| Power flux density at the UWB device at the protection distance W/m^2 | 2.04E-03 | 2.04E-03 | 5.12E-01 | 5.12E-01 | 2.04E-02 |
| Power flux density at the UWB device at the protection distance dBm/m^2 | 3.10 | 3.10 | 27.10 | 27.10 | 13.10 |
| Antenna Gain UWB dBi | 0 | 0 | 0 | 0 | 0 |
| Received power at the UWB Device at the protection distance dBm | -37.00 | -37.00 | -13.00 | -13.00 | -27.00 |
| Detection Threshold at UWB device antenna in dBm | -61 | -61 | -61 | -61 | -61 |
| Distance to Radar victime device at threshold level in m | 5566.49 | 31302.65 | 5566.49 | 31302.65 | 17602.77 |
| Difference to needed minimum protection distance | 5215.26 | 29327.58 | 5544.32 | 31178.03 | 17251.55 |
| | | -24.77121255 | | | |

Assume a car with 100 km/h = 27.78 m/s

| | Detect and Avoid Time in sec |
|---|---|
| CASE A: | 200.39 |
| CASE B: | 1126.90 |
| CASE C: | 200.39 |
| CASE D: | 1126.90 |
| CASE E: | 633.70 |

**Table 18: Detect and Avoid Time calculation for the X-Band monostatic radiolocation services taking into account a detection threshold of -61dBm**

In this study we consider that the UWB device has a mobile speed of 100km/h in the direction towards the Radiolocation systems, and we calculate the maximum "Detect and Avoid Time" in order to maintain the UWB interferer level below the protection criteria when the UWB device is coming closer to the Radiolocation system.

It has furthermore to be emphasized that DAA technical parameters alone do not ensure protection of radiolocation service by themselves. This has to be completed with adequate DAA measurement procedures in the related ETSI standard.

### A.3.3 System characteristics for bi- / multistatic and passive radiolocation systems

**Bistatic radar** is the name given to a radar system which comprises a transmitter and receiver which are separated by a distance that is comparable to the expected target distance.

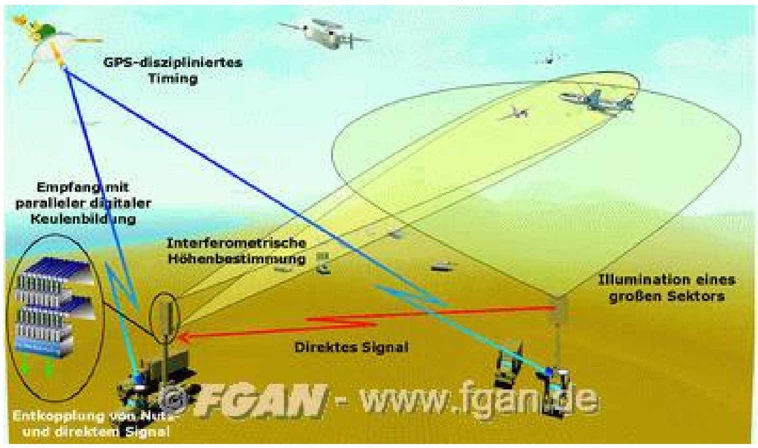



**Figure 12**

A **multistatic radar** system is one in which there are at least three components - for example, one receiver and two transmitters, or two receivers and one transmitter, or multiple receivers and multiple transmitters. It is a generalisation of the bistatic radar system, with one or more receivers processing returns from one or more geographically separated transmitters.

A bistatic or multistatic radar that exploits non-radar transmitters of opportunity is termed a **passive radar** or **passive coherent location** system or **passive covert radar**.