# Antenna Placement and Isolation Guideline

March 2015

Document Reference: 4-3-2-001

## Related Policies and Documents

| Report Reference Number | Issuer | Reference | Document Name |
|---|---|---|---|
| [1] | Telecommunications Industry Association (TIA) | TSB-88.3 | Wireless Communications Systems Performance in Noise and Interference Limited Situations Part 3: Recommended Methods for Technology Independent Performance Verification |
| [2] | ITU-R | ITU-R M.2244 | Isolation between antennas of IMT base stations in the land mobile service |
| [3] | ITU-R | ITU-R M.2141 | Study of the isolation between VHF land mobile radio antennas in close proximity |
| [4] | Ericsson | 14/100 56-HSD 101 02/5 Rev A | Guideline for Interference Considerations in Co-Existence |
| [5] | Telstra | Trunk Radio Tech Rept 125-TR | Mt Budawang : Co-Siting of Police and GRN |
| [6] | Motorola Solutions | Report | Mt. Gibraltar - Interference Investigation Report |
| [7] | Bird Technologies | Application Notes | Antenna Location is not an Architectural Decision |
| [8] | RFI | Presentation | Passive Intermodulation PIM and Peak Instantaneous Power PIP |
| [9] | Rodhe & Schwarz | 11356Cat | VHF/UHF Filters/Multicouplers – Overview |

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# 1 Introduction

## 1.1 Overview

The NSW Telco Authority (TA) and its Board are responsible for the strategic direction of wireless operational voice and data telecommunications in NSW. This includes determining a whole-of-Government telecommunications strategy, prioritising investment decisions, and developing and implementing state wide policy affecting planning development, operations and maintenance.

Part of the TA's mandate includes establishing a set of standards, guidelines policies and procedures that can be utilised "cross sector" covering the design, installation, commission and operation of the operational telecommunications infrastructure.

This document forms part of the overall guidelines, specifically the isolation required between antennas for radio communication.

## 1.2 Purpose

The purpose of this document is to define the required isolation between systems for co-located antennas and to establish a set of guidelines that can be used to design the Land Mobile Radio (LMR) systems (VHF and UHF). It will address the physical separation of antennas required to meet the isolation criteria and ensure minimal interference between systems sharing the same tower infrastructure. This will ensure that Government Radio Network (GRN) and other LMR networks will operate in an optimal manner. This guideline is not intended to replace the requirements for a detailed design for the antenna and filter systems on a site by site basis.

## 1.3 Scope

The scope of this document applies to LMR radio communications systems operating in the VHF and UHF bands. The application of this guideline does not extend to other bands for mobile radio or other radio systems (broadcast, mobile etc.).

The document addresses physical methods (vertical and horizontal separation) for achieving the required isolation but does not cover other aspects (filtering, polarisation, radiation patterns or consideration of the effects of the tower/structure).

The recommendations are based on results of ITU-R's studies conducted specifically in the UHF and VHF bands and other documents listed in the related documents section.

## 1.4 Audience

The intended audience for this document are designers responsible for radio planning and associated activities specifically in the VHF and UHF bands. It is expected that this guideline will be applied by the intended audience for new sites and existing sites undergoing upgrades.

# 2 Guideline

## 2.1 Antenna Isolation

Antenna isolation is a key consideration in the design of any radio communications system. Sufficient isolation is required to ensure that interference between systems is kept within acceptable levels (levels at which the equipment can operate effectively). A number of techniques for achieving isolation between two antennas/ systems exist including but not limited to:

- Physical separation
- Polarisation
- Optimisation of antenna patterns
- Filtering

A lack of sufficient isolation can lead to a number of undesirable effects:

- Intermodulation issues
- Receiver desensitization
- Transmitter noise; or
- Adjacent channel interference.

Antenna isolation is a measure of power transfer from one antenna to another (Transmit Tx to Receive Rx), generally represented as a loss in dB. As a general rule, the antenna isolation should be as large as possible to minimize interference between systems and can be maximised by:

- Increasing the physical separation between the antennas
- Using filters to reduce the received power of unwanted frequency (for systems operating on separate frequencies)
- Reducing the correlation coefficient between the antenna's radiation patterns - that is, have the antenna's peak radiation in different or opposite directions (azimuth and tilt changes can be used to achieve this along with antennas that meet specific design criteria)
- Using different polarizations

The GRN and most other LMR systems used by NSW Government agencies typically uses omni directional antennas with vertical polarization, as a result of this architecture physical separation and filtering will be the main methods used to achieve the required isolation.

The lowest recommended antenna isolation for co-sited (co-located) antennas is 30 dB (Interferer port to victim port). This is valid for equipment on the same site, belonging to the same system as well as for all systems sharing the same site. This isolation can be achieved through the application of the following rules:

| Victim<br><br>Rx Antenna | Interferer<br><br>Tx Antenna | Horizontal Separation – dh (m) | Vertical Separation – dv(m) |
|---|---|---|---|
| UHF | VHF | 4.5 | 3 |
| UHF | UHF | 2 | 1 |

Table 1: Recommended Antenna Separation [2] [4]

## 2.2 Antenna Separation

### 2.2.1 Horizontal Antenna Separation

As antennas are separated the amount of signal coupled from one antenna to another is reduced as a function of the distance. One way of achieving this isolation is through antenna separation in the horizontal plane. Horizontal separation tends to follow the inverse square law, which states that signal level will drop by 6 dB (75%) every time you double the distance. If the distance between the antennas is doubled, the signal levels will drop by 6 dB and any intermodulation products produced by those fundamental signals can drop up to 18 dB ([7]).

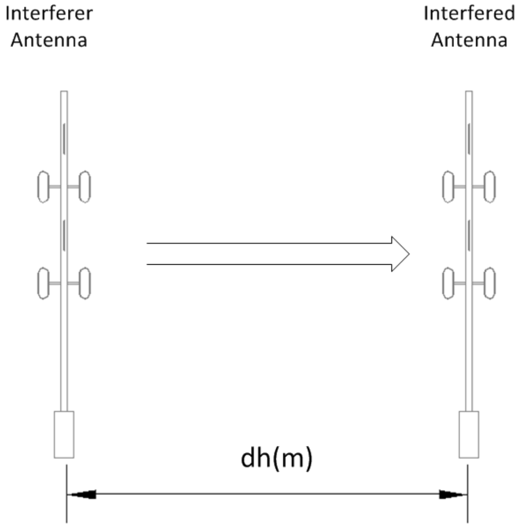


Figure 1: Horizontal Separation

The table below shows isolation measurement results and the horizontal separation required to achieve specific isolation requirements for UHF and VHF. As can be seen, relatively large horizontal antenna spacing are required to achieve the required isolation values, in instances where this is not practicable other techniques for achieving isolation will need to be investigated.

| Victim<br><br>Rx Antenna | Interferer<br><br>Tx Antenna | Horizontal Separation<br>– dh (m) | Isolation(dB) |
|---|---|---|---|
| UHF | VHF(High)<br><br>VHF (low) | 4.5<br><br>7.6 | 30 |
| UHF | UHF | 1.62<br><br>9.11 | 30<br><br>45 |

Table 2: Horizontal separation vs Isolation [2] [3]

It is recommended that a minimum horizontal separation of 2m and 4.5m is achieved for UHF to UHF and UHF to VHF installations respectively. On building roof tops where greater horizontal separation is possible 10m is recommended.

### 2.2.2 Vertical Antenna Separation

Vertical antenna separation is a more efficient method of achieving the required isolation in space constrained environments (i.e. towers). Vertical separation provides significantly more isolation than horizontal separation. Based on industry standard isolation charts, spacing two VHF antennas 3m apart vertically will provide approximately 35 dB of isolation while 3m of horizontal spacing will provide less than 20 dB.

Inverted mounting of antennas is another method often used to conserve tower space or to provide RF isolation (typically utilised for omni directional whip antennas). Some antennas are designed for in-field changes between upright and inverted mounting.

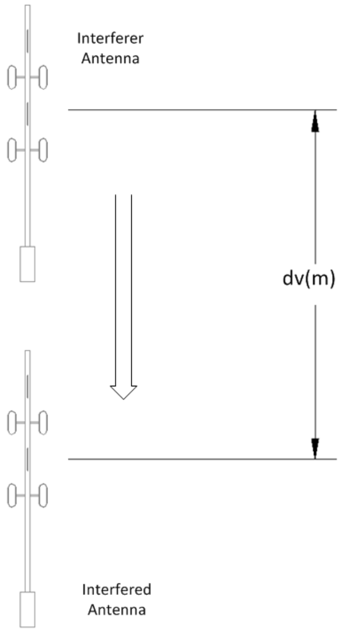


Figure 2: Vertical Separation

The table below shows isolation measurement results for vertical separation for UHF and VHF:

| Interfered<br><br>GRN Rx Antenna | Interferer<br><br>Tx Antenna | Vertical Spearation – dv (m) | Isolation(dB) |
|---|---|---|---|
| UHF | VHF | 3 | 35 |
| UHF | UHF | 0.72<br><br>1.72 | 30<br><br>45 |

Table 3: Vertical separation vs Isolation [2] [3]

To obtain maximum vertical isolation, the antennas must be located exactly above and below each other. Any offset will reduce the isolation. It is recommended that a minimum vertical separation of 1m and 3m is achieved for UHF to UHF and UHF to VHF installations respectively. On towers where greater vertical separation is possible a minimum of 2 m is recommended.

### 2.2.3 Antenna separation from infrastructure

Transmitted energy coupled into other structures such as the tower or the rooftop antenna grid can be conducted along the structure and coupled into other antenna(s), thereby reducing the isolation.

In many cases, depending on the coverage requirements a directional antenna array can be used to reduce the impact of installing below the tower by minimising the amount of power that is radiated in the direction of the tower (minimising the coupling affect).

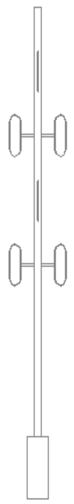

Figure 3: Omni Array

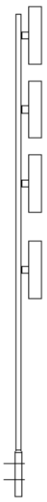

Figure 4: Directional Array

The following figures show examples of the predicted antenna pattern distortion caused by close proximity with a steel tower.

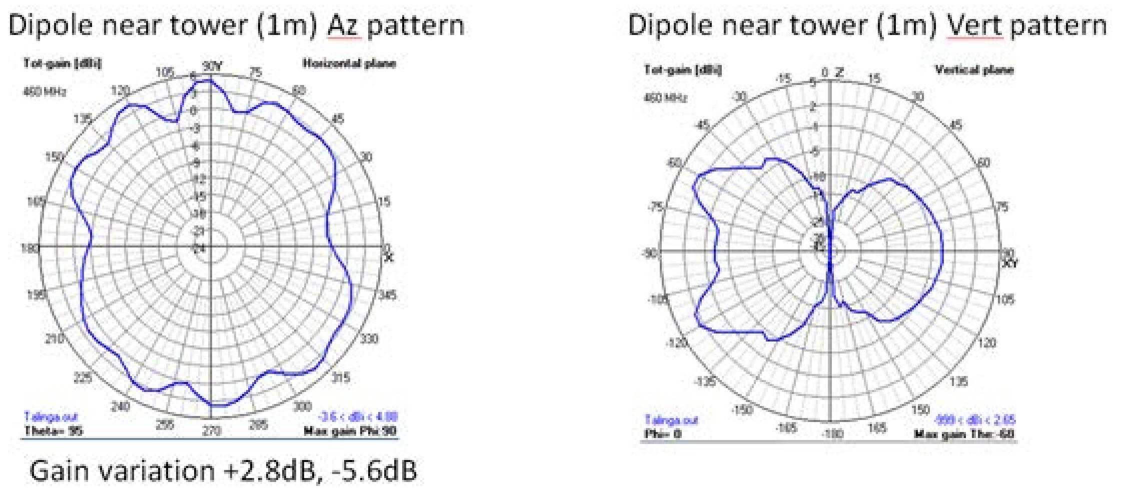


Figure 5: Simulated Antenna Pattern distortion at 1m from the tower

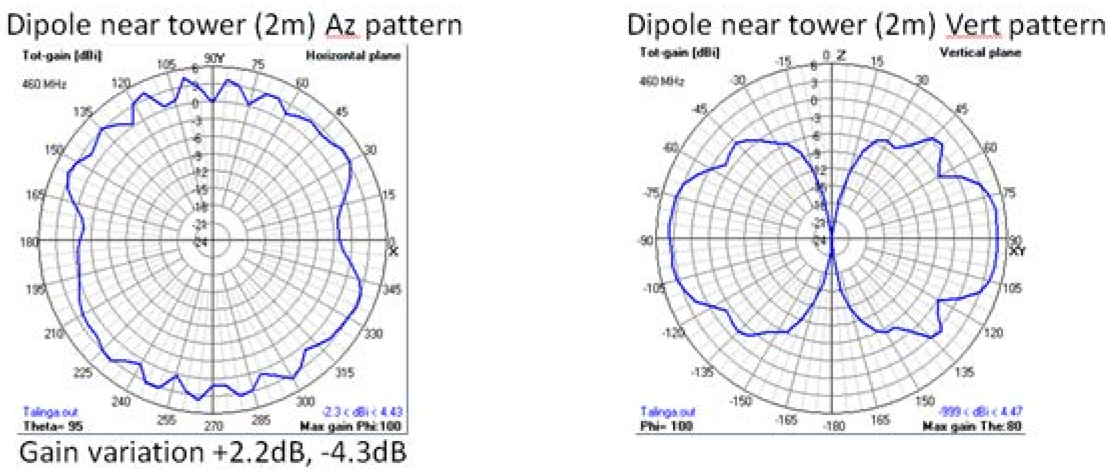


Figure 6: Simulated Antenna Pattern distortion at 2m from the steel tower

As general rule, separation distances are chosen as a multiple of wave lengths. UHF separation distance is shown in the following table, based on a wavelength of 0.75m at 400MHz.

| Wavelength | Separation |
|---|---|
| 3 | 2.25 m |
| 2 | 1.50 m |
| 1 | 0.75 m |

Table 4: UHF Separation from Infrastructure

If the antenna cannot be installed on the top, it is recommended to place antennas at least 1.5 m from the tower for a omni array and 0.75m for a directional array.

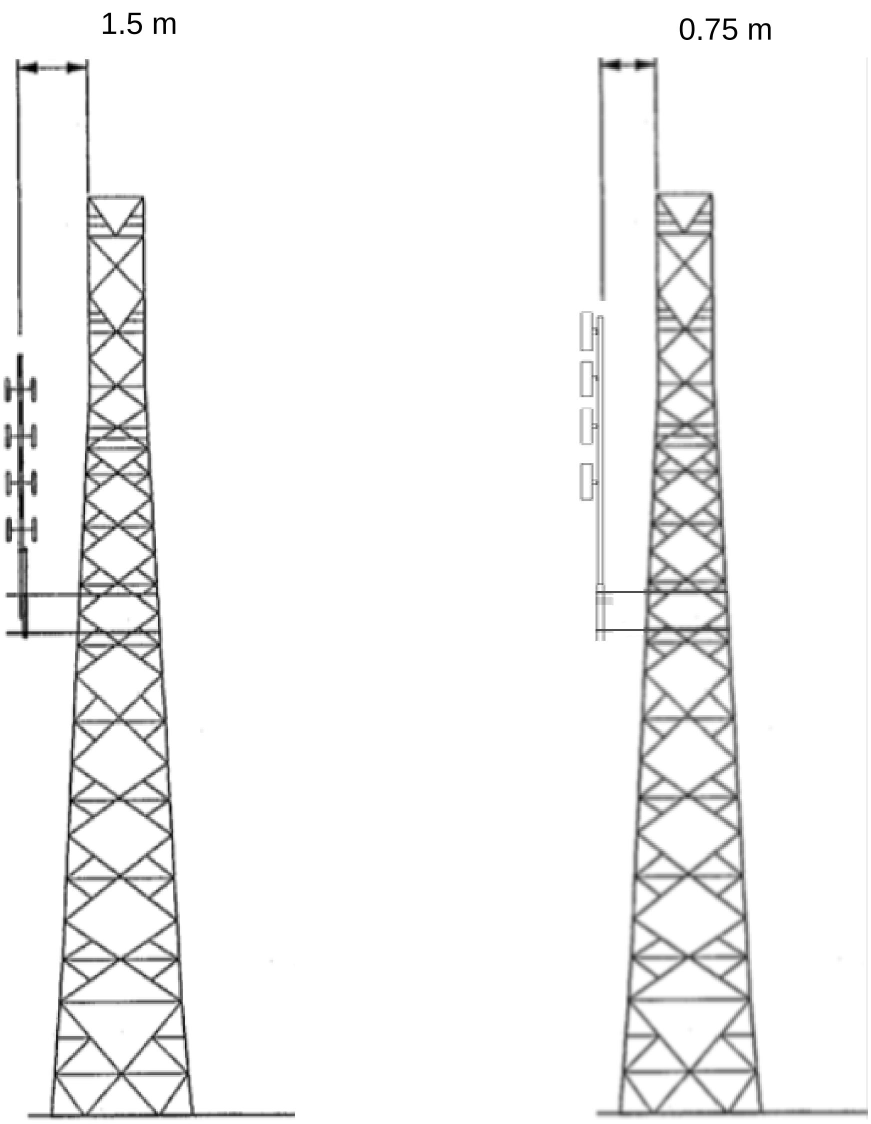


Figure 7: Tower separation for omni array and Directional array

Note that this recommendation only applies if the tower is steel or metalic. For concrete poles the effect of shadowing by the tower should be taken in consideration.

## 2.3 Stacked Antenna configurations

Typical Isolation between stacked antennas is shown below:

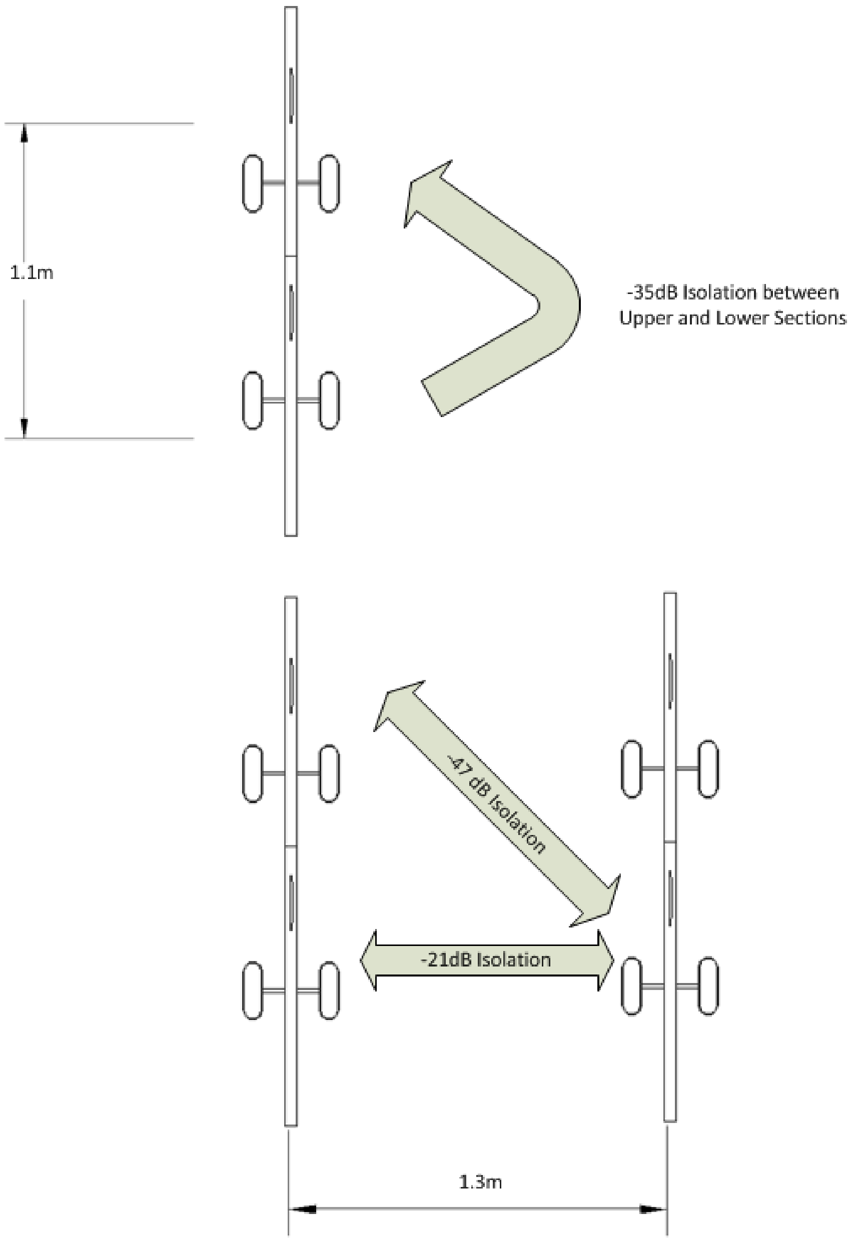


Figure 7: Antenna Isolation for dual stacked antenna configurations [5]

The dual stacked antenna configuration should comply with the minimum vertical antenna isolation requirement of 30dB.

Where separation of UHF and VHF antennas are not possible, UHF and VHF stacked antennas are recommended as shown in the following figure.

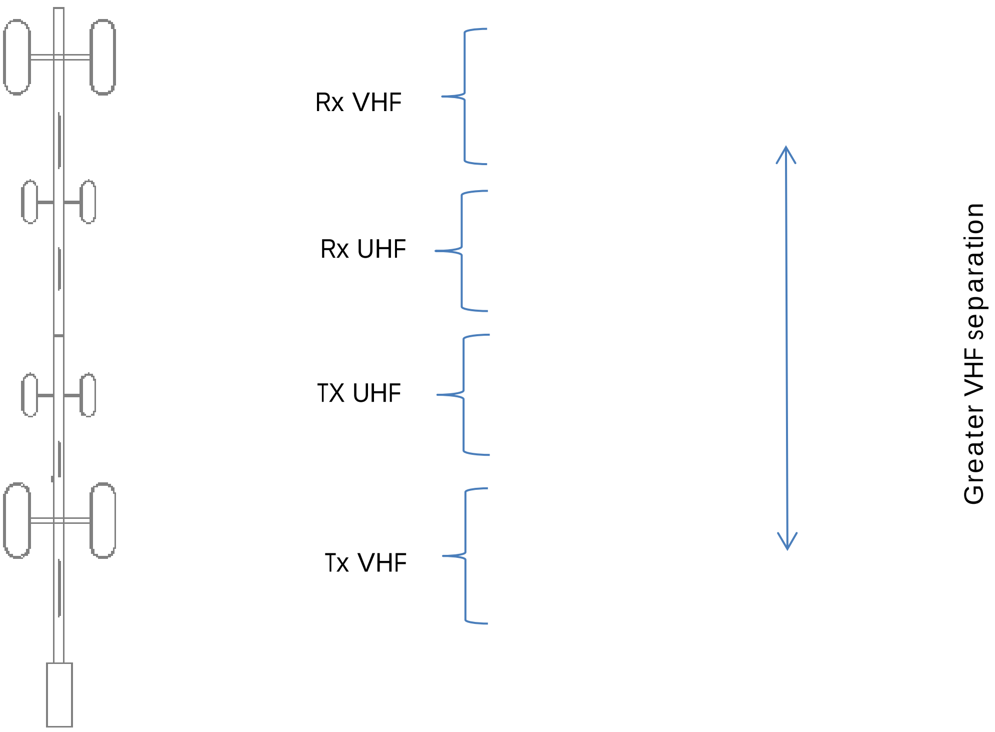


Figure 8: Dual band VHF and UHF stacked antenna configuration

## 2.4 General rules for antenna placement

The isolation between transmitting and receiving antennas should be maximised. On towers, the best separation can be achieved by grouping receive antennas together on one level and installing transmit antennas on another level.

Intermodulation of 3rd order products should be eliminated whenever possible. Where intermodulation (im) interference is detected or predicted, it is recommended that the frequency used by at least one transmitter is altered. Most systems utilise some amount of transmitter combination. Transmitters that produce IM must not be installed into the same combiner.

## 2.5 When Antenna Separation is not achievable

Whenever the recommended antenna separation cannot be achieved, calculation of the antenna isolation and additional filtering [9] need to be assessed to:

- Suppress out-of-band interference
- Suppress third-order cross-modulation (PIM)
- Prevent desensitization (reciprocal)
- Prevent blocking by the attenuation

## 2.6 Antenna Separation calculator

The Friis formula can be used to calculate isolation for any relative position and orientation of two antennas. If the antennas are located and oriented such that they are in the sidelobe region of each other, the peak gain level in the sidelobe regions can be used.

$Isolation = 22 + 20 \log(r/\lambda) - (G_{t,SL} + G_{r,SL})$ [2]

Here $G_{x,SL}$ = is the peak gain in the sidelobe region [2]

This formulation is implemented in the "Antenna Separation calculator.xlsx" in the appendix for antenna separation estimation. Note that taking antenna mounting imperfections into account, the gain values have been chosen conservatively.

# 3 Appendix

Calculation based on ITU-R M2244 [2]

Antenna_Separation
_calculatorv 1.0.xlsx

Available to download as a separate document – 4-3-2-001 Antenna Separation Calculator v1.0

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