Regulatory requirements for white space devices in the UHF TV band

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Contents

Section 1

Introduction

1.1 This document contains the proposed regulatory requirements that white space devices (WSDs) will have to meet in order to operate within the UHF TV band in the UK.

1.2 These requirements will form the basis for the drafting of regulatory instruments to enable the legal use of WSDs in the UK. These include the Statutory Instrument (SI), the Interface Regulation (IR), and the Voluntary National Specification (VNS).

Section 2

Terminology

2.1 UHF TV band – For the purposes of this document, this is defined as the frequency band 470 – 790 MHz (channels 21-60), but excluding 550 – 606 MHz[1] (channels 31-37) and 606 – 614MHz[2] (channel 38).

2.2 TV white space device (WSD) – A radio equipment that operates in the white spaces of the UHF TV band.

2.3 White space – Part of the spectrum, which is available for a radio-communication application (service, system) at a given time in a given geographical area on a non-interfering and non-protected basis with regard to other services with a higher priority on a national basis.

2.4 TV white space database (WSDB) – A database system that returns information to WSDs on the available frequencies and permitted power levels at specific geographic locations, based on white space data provided by Ofcom.

2.5 Geo-location capability – Capability of a WSD to determine its geographic latitude and longitude coordinates.

2.6 Master WSD – A WSD which directly communicates with a WSDB to obtain operating parameters specific to its geographic location.

2.7 Slave WSD – A WSD which does not directly communicate with a WSDB, and which obtains operating parameters specific to its geographic location from its serving master WSD.

2.8 Fixed WSD – A WSD whose antennas are permanently mounted on a non-moving platform (e.g., fixed base station, fixed consumer premises equipment, home router[3]). A fixed WSD can be a master or a slave device.

2.9 Portable/mobile WSD – A WSD whose antennas are mounted on a portable/mobile platform (e.g., mobile user equipment, laptop dongle, home router[3]). A portable/mobile WSD can be a master or a slave device.

2.10 Indoor WSD – A WSD whose antennas are located within a building.

2.11 Outdoor WSD – A WSD whose antennas are not located within a building.

2.12 Electronic communications network[4] (ECN) – 1) a transmission system for the conveyance, by the use of electrical, magnetic or electro-magnetic energy, of signals

[1] This is the so-called 600 MHz band, and has been cleared in the UK.
[2] This channel is used for shared (uncoordinated) licensed programme making and special events (PMSE) usage in the UK.
[3] A home router may be a fixed or portable device; i.e., the antennas of a home router may or may not be permanently mounted on a non-moving platform. However, it is unlikely that the movements of a home router within the home will be significant in the context of interference to licensed services (small separations between victim and interferer are handled via reference geometries).
[4] As defined in Section 32(1) of the Communications Act.

of any description; and 2) such of the following as are used, by the person providing the system and in association with it, for the conveyance of signals: a) apparatus comprised in the system, b) apparatus used for the switching and routing of the signals, and c) software and stored data.

2.13 Electronic communications service[5] (ECS) – A service consisting in, or having as its principal feature, the conveyance by means of an ECN of signals except insofar as it is a content service.

2.14 Communications providers (CP) – These are defined[6] as providers of ECSs and ECNs and therefore would not include members of the public."

2.15 Consumer premises equipment (CPE) – A UE which is located at a user's premises and, in conjunction with an ECN, provides services to a user.

2.16 In-block emissions – Emissions corresponding to those segments of a radiated signal's frequency spectrum which carry information intended for a receiver. The width of the in-block segment of the frequency spectrum is the nominal bandwidth of the signal. Emissions are specified here as equivalent isotropic radiated power (EIRP).

2.17 Out-of-block emissions – Emissions corresponding to those segments of a radiated signal's frequency spectrum (outside the in-block segment) which correspond to unintended radiations. Emissions are specified here as equivalent isotropic radiated power (EIRP).

[5] As defined in Section 32(2) of the Communications Act.
[6] As defined in Section 23(4) of the Communications Act.

Section 3

Requirements for master WSDs

Overview

3.1 In order to be authorised to radiate within the UHF TV band, a master WSD **must**

a) discover one or more approved WSDBs,

b) communicate specific information to one or more approved WSDBs,

c) receive specific information from one or more approved WSDBs,

d) operate subject to the specific instructions and parameters received from an approved WSDB, and

3.2 Where appropriate, a master WSD **must** also communicate appropriate information to served slave WSDs so that the slave WSDs are able to operate subject to the specific instructions and parameters received by the master WSD from an approved WSDB.

3.3 The specific information in 3.1(b) above can be either determined automatically by the master WSD, or, in special circumstances[7], be determined by a communications provider. See Figure (1).

3.4 Where the specific information in 3.1(b) above is determined automatically by the master WSD, it is the responsibility of the master WSD to communicate this information to one or more approved WSDBs.

3.5 Where the specific information in 3.1(b) above is determined by a communications provider, it is the responsibility of the communications provider (and not the master WSD) to communicate this information to one or more approved WSDBs. This will be subject to special arrangements between the communications provider, the WSDB provider, and Ofcom. Note that information determined by a communications provider shall not be input into the master WSD itself[8].

3.6 Communication between a master WSD and a WSDB **must** not occur within the UHF TV band, unless the master WSD has already been authorised by the WSDB to radiate within the UHF TV band.

[7] Special circumstances apply to fixed master WSDs which, in order to benefit from increased white space availability, are geo-located by a communications provider (for increased geo-location accuracy), or use judicious antenna characteristics to mitigate interference to DTT and PMSE services.

[8] This is to mitigate the risk of inaccurate information being manually input into devices by users (whether unintentionally, or in an attempt to benefit from increased white space availability).

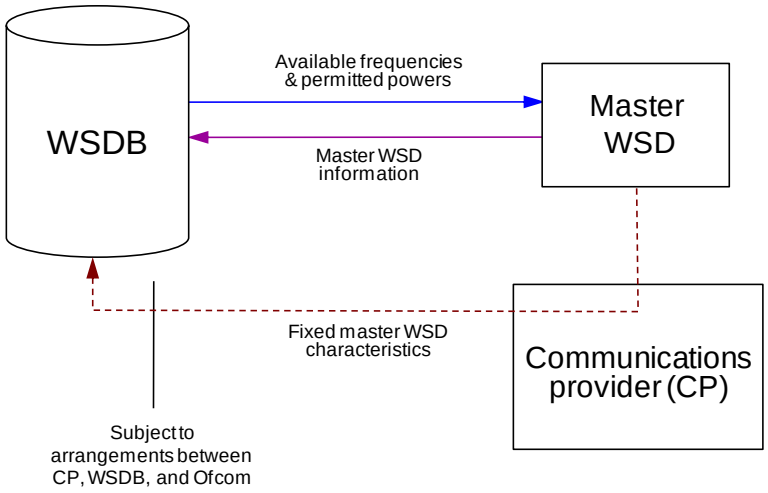


Figure (1). Master WSD and communications with a WSDB.

Database discovery

3.7 When operating in the territories of the United Kingdom, a master WSD **must** discover approved WSDBs by consulting a website maintained by (or on behalf of) Ofcom which holds a list of approved WSDBs. A master WSD **must** cease communications within the UHF TV band if more than 24 hours have elapsed since it previously successfully discovered an approved WSDB.

Information communicated from a master WSD to a WSDB

Master WSD antenna latitude and longitude

3.8 The latitude and longitude coordinates (in WGS84 format) of a master WSD's transmitting antennas **must** be communicated to a WSDB. Specifically, the following requirements apply:

3.8.1 A master WSD **must** have the capability to automatically determine the latitude and longitude coordinates of its antennas, unless the device falls under the category of master WSDs described in 3.8.2.

3.8.2 Where a fixed master WSD is used by (or on behalf of) a communications provider, the master WSD **may** have the capability to automatically determine the latitude and longitude coordinates of its antennas. If the device does not have such a capability, the antenna latitude and longitude coordinates of the fixed master WSD **must** be determined by the communications provider.

3.8.3 The accuracy of the determined latitude and longitude coordinates of an antenna **must** be specified as $\pm\Delta x$ and $\pm\Delta y$ metres respectively, corresponding to a 95% confidence level. If Δx or Δy is greater than 50 metres, then the values of Δx and Δy **must** be communicated to a WSDB.

Other master WSD antenna characteristics

3.9 The antenna height above ground level of a master WSD **may**[9] be communicated to a WSDB, unless the device falls under the category of WSDs described in 3.10.

3.10 Where the antenna latitude and longitude coordinates of a fixed master WSD are determined and communicated by a communications provider, the antenna heights above ground level of the fixed master WSD **must** also be communicated to a WSDB.

3.11 Where the antenna height above ground level of a master WSD is communicated to a WSDB, the following requirements apply:

3.11.1 A master WSD **must** have the capability to automatically determine the heights of its antennas, unless the device falls under the category of master WSDs described in 3.11.2.

3.11.2 Where a fixed master WSD is used by (or on behalf of) a communications provider, the master WSD **may** have the capability to automatically determine the heights of its antennas. If the device does not have such a capability, the antenna heights of the fixed master WSD **must** be determined by the communications provider.

3.12 The following information relating to a fixed master WSD **may**[10] additionally be communicated to a WSDB:

3.12.1 Antenna angular discrimination (directionality and orientation) – This **must** be specified[11] as relative gain (in dB) at intervals of 10 degrees in absolute[12] azimuth and elevation. Where multiple antennas are involved, the angular discrimination must apply to the combined emissions from the antennas.

3.12.2 Antenna polarisation – This **must** be specified as either horizontal polarisation, vertical polarisation, slant (±45 degrees), or mixed polarisation.

3.12.3 Antenna position – This **must** be specified as either indoor or outdoor.

3.13 Where any of the fixed master WSD antenna characteristics outlined in 3.12 are communicated to a WSDB, the following requirements apply:

3.13.1 A fixed master WSD **must** have the capability to automatically determine these characteristics, unless the device falls under the category of fixed master WSDs described in 3.13.2.

[9] If this information is not communicated, then default values will be used by the WSDB.
[10] If this information is not communicated, then default values will be used by the WSDB.
[11] We are also considering an alternative approach. Here the angular discrimination will be specified via a horizontal radiation "pattern identifier", a vertical radiation "pattern identifier", an absolute azimuth pointing angle (0° to 360°, with a resolution of 10°), and an absolute elevation pointing angle (-90° to +90°, with a resolution of 10°). The pattern identifiers would relate to angular discrimination *templates* maintained by Ofcom and shared with WSDBs. This approach would significantly reduce the amount of information that needs to be communicated to the WSDB.
[12] Azimuth values are between 0° and 360°, where 0° points North, and 90° points East. Elevation values are between -90° and +90°, where 0° points to the horizon, and +90° points vertically up.

3.13.2 Where a fixed master WSD is used by (or on behalf of) a communications provider, the master WSD **may** have the capability to automatically determine these characteristics. If the device does not have such a capability, the antenna characteristics of the fixed master WSD **must** be determined by the communications provider.

Other parameters

3.14 A master WSD **must**[13] automatically communicate its unique device identifier[14] to a WSDB.

3.15 A master WSD **must**[13] automatically communicate to a WSDB the unique device identifiers[14] of its associated slave WSDs.

3.16 A master WSD **must**[13] automatically communicate its device class[15] to a WSDB.

3.17 A master WSD **must**[13] automatically communicate to a WSDB the device classes[15] of its associated slave WSDs, if these are different from that of the master WSD.

3.18 A master WSD **must**[13] automatically communicate its technology identifier[16] to a WSDB.

3.19 A master WSD **must**[13] automatically communicate to a WSDB the technology identifiers of its associated slave WSDs[17], if these are different from that of the master WSD.

3.20 A master WSD **must** automatically communicate to the WSDB the locations and antenna characteristics (see Section 4) of its associated slave WSDs, where such information is automatically determined by the slave WSDs and communicated from the slave WSDs to the master WSD.

3.21 After receiving instructions from a WSDB in relation to the maximum permitted EIRPs over the DTT channels, and prior to initiating transmissions within the UHF TV band, a master WSD **must** successfully communicate to the WSDB the following information:

[13] In the special circumstances outlined in 3.3, where the communications provider determines and communicates certain characteristics of a fixed WSD to a WSDB, the communications provider must at this stage also communicate the WSD's unique device identifier, device class, and technology identifier.

[14] The unique device identifier would enable the WSDB to instruct the master WSD and its associated slaves to cease transmission in the context of 3.23.8. The device identifier would need to be internationally harmonised.

[15] The device class would identify, among other things, the emission mask of the WSD, and would allow the WSDB to use the associated protection ratios. The device class would need to be internationally harmonised.

[16] The technology identifier would enable the WSDB to use technology-specific protection ratios, and would also be helpful in informing the WSDB with regards to the broad time-frequency structure of the WSD signals. This latter information could be used in the context of feedback from WSDs to WSDBs with regards to the used radio resource. For this latter reason, the reporting of the technology identifier is mandatory. The technology identifier would need to be internationally harmonised.

[17] This accounts for cases where the master and slave use different technologies (e.g., where the slave is involved in slave-to-slave communications via one technology, and communicates with the master WSD via a different technology).

3.21.1 The intended lower and upper frequency boundaries[18] of the in-block emissions of the master WSD. A lower frequency will be specified as (470 + 8k + 0.1n) MHz, with the corresponding upper frequency specified as (470 + 8k + 0.1m) MHz, where $0 \leq k \leq 39$, $0 \leq n \leq 79$, $1 \leq m \leq 80$, and $n < m$.

3.21.2 The maximum in-block EIRP spectral density, specified in units of dBm/(0.1 MHz), that the master WSD intends to radiate between each reported lower frequency boundary and its corresponding upper frequency boundary.

3.22 After a slave WSD associates[19] with a master WSD, and prior to the slave WSD initiating further transmissions within the UHF TV band, a master WSD **must** successfully communicate to the WSDB the following information:

3.22.1 The intended lower and upper frequency boundaries[18] of the in-block emissions of the slave WSD. A lower frequency will be specified as (470 + 8k + 0.1n) MHz, with the corresponding upper frequency specified as (470 + 8k + 0.1m) MHz, where $0 \leq k \leq 39$, $0 \leq n \leq 79$, $1 \leq m \leq 80$, and $n < m$.

3.22.2 The maximum in-block EIRP spectral density, specified in units of dBm/(0.1 MHz), that the slave WSD intends to radiate between each reported lower frequency boundary and its corresponding upper frequency boundary.

Information received by a master WSD from a WSDB

3.23 A master WSD **must** be able to receive the following information[20] from a WSDB:

3.23.1 Lists of lower and upper frequency boundaries[21] within which the master WSD and each of its served slave WSDs are authorised to operate. A lower frequency will be specified as (470 + 8k + 0.1n) MHz, with the corresponding upper frequency specified as (470 + 8k + 0.1m) MHz, where $0 \leq k \leq 39$, $0 \leq n \leq 79$, $1 \leq m \leq 80$, and $n < m$.

3.23.2 A maximum permitted master WSD EIRP spectral density, P_0, specified in units of dBm/(0.1 MHz), and a maximum permitted master WSD EIRP spectral density, P_1, specified in units of dBm/(8 MHz), between each lower frequency boundary and its corresponding upper frequency boundary as described in 3.23.1.

[18] The use of upper and lower frequency boundaries (defined over a 100 kHz raster) allows a WSDB to collect more granular information with regards to the usage of the frequency resource by narrowband WSD technologies. The upper and lower frequencies of a boundary pair do not straddle a DTT channel boundary. Note that a WSD may transmit over multiple, non-contiguous, whole DTT channels or fractions of DTT channels.
[19] See also 4.6.
[20] While the communication of some of this information from a WSDB to a master WSD is optional, master WSDs must be able to receive and interpret these.
[21] The upper and lower frequencies of a boundary pair do not straddle a DTT channel boundary. Note that a WSD may transmit over multiple, non-contiguous, whole DTT channels or fractions of DTT channels.

3.23.3 For each served slave WSD, a maximum permitted EIRP spectral density, P_0, specified in units of dBm/(0.1 MHz), and a maximum permitted EIRP spectral density, P_1, specified in units of dBm/(8 MHz), between each lower frequency boundary and its corresponding upper frequency boundary as described in 3.23.1.

3.23.4 Limits on the maximum contiguous and maximum non-contiguous instantaneous bandwidths of master WSDs (and their served slave WSDs) specified as n×0.1 MHz, where n > 0.

3.23.5 A sensing level[22] (optional) for the detection of DTT use of spectrum, specified in units of dBm/(8 MHz).

3.23.6 A sensing level[22] (optional) for the detection of PMSE use of spectrum, specified in units of dBm/(0.1 MHz).

3.23.7 A single time validity for the parameters communicated by the WSDB as described in 3.23.1 to 3.23.6.

3.23.8 Instruction for the master WSD and its served slave WSDs to cease[23] transmission within 60 seconds when instructed by the WSDB.

3.23.9 An acknowledgement from the WSDB, in the context of 3.21 and 3.22, that the reported information on the DTT channels and EIRP spectral densities intended to be used by the master and slave WSDs were received successfully[24] by the WSDB.

Operation of a master WSD

3.24 Prior to transmission in the UHF TV band, a master WSD **must** request from an approved WSDB the relevant instructions and parameters outlined in 3.23 pertaining to itself, and where appropriate, to its served slave WSDs.

3.25 A master WSD **must** only transmit within the UHF TV band in accordance with the relevant instructions and parameters in 3.23, provided by an approved WSDB, and for a time period which does not exceed the time validity of those instructions and parameters.

3.26 A master WSD which wishes to simultaneously transmit over multiple DTT channels **must** a) comply with the maximum permitted master EIRP spectral densities in each of the DTT channels to be used, and b) radiate with a total EIRP which does not exceed the smallest maximum permitted master EIRP specified over each of the DTT channels to be used.

3.27 A master WSD that services slave WSDs **must** ensure that it communicates specific information to those slave WSDs, so that the slave WSDs are able to transmit within the UHF TV band in accordance with the relevant instructions and parameters in

[22] The sensing function itself is not mandatory for the WSDs.
[23] This requirement implements a so-called WSDB “kill switch” to disable WSDs in the event of interference to licensees. The time validity parameter as described in 3.23.7 is an alternative tool for disabling the WSDs.
[24] Via a handshake protocol.

3.23, provided by an approved WSDB, and for a time period which does not exceed the time validity of those instructions and parameters.

3.28 A master WSD **must** ensure that it has access to valid instructions and parameters from a WSDB whenever the determined latitude or longitude coordinates of its antennas (or those of its served slave antennas) change by more than 50 metres with respect to those determined at the time of its previous consultation with a WSDB.

Additional requirements for master WSDs

3.29 The out-of-block EIRP spectral density, P_{OOB}, of a master WSD **must** satisfy the following requirement:

$$P_{OOB\ (dBm/(100\ kHz))} \leq \max\{ P_{IB\ (dBm/(8\ MHz))} - AFLR\ (dB), -84 \}$$

where P_{IB} is the WSD's in-block EIRP spectral density, and AFLR is the WSD's adjacent frequency leakage ratio outlined in the table below for different device classes.

Table 1. Master WSD adjacent frequency leakage ratios for different device classes.

Where P_{OOB} falls within the n^{th} adjacent DTT channel	AFLR (dB)			
	Class 1	Class 2	Class 3	Class 4
n = ±1	74	74	64	54
n = ±2	79	74	74	64
n ≥ ±3	84	74	84	74

3.30 A master WSD **must** only transmit using the minimum EIRP necessary to achieve its required quality of service.

3.31 A master WSD **must** only transmit subject to specific constraints on the time structure of its signals[25].

Security requirements

3.32 Communications between a master WSD and a WSDB **must** be performed using secure protocols[26] that avoid malicious corruption or unauthorized modification of the data.

3.33 Communications between a master WSD and a slave WSD for purposes of relaying WSDB-related instructions and parameters **must** be performed using secure protocols[27] that avoid malicious corruption or unauthorized modification of the data.

[25] These constraints are yet to be defined, and are subject to the timely availability of evidence which can identify specific WSD time structures that lead to excessively high DTT protection ratio values.
[26] We expect these security protocols to be internationally standardised by bodies such as the IETF.
[27] We expect these security protocols to be specified within technology standards.

Section 4

Requirements for slave WSDs

4.1 In order to be authorised to radiate within the UHF TV band, a slave WSD **must**

a) receive specific information from its serving master WSD, and

b) operate subject to the specific instructions and parameters received from its serving master WSD.

4.2 Specific information relating to a slave WSD **must** be communicated to one or more approved WSDBs. Additional information relating to a slave WSD **may** be communicated to one or more WSDBs if the device wishes to benefit from increased white space availability.

4.3 The specific information in 4.2 above can be either determined automatically by the slave WSD, or, in special circumstances[28], be determined by a communications provider. See Figure (2).

4.4 Where the specific information in 4.2 above is determined automatically by the slave WSD, it is the responsibility of the slave WSD to communicate this information to its serving master WSD, to be subsequently forwarded to one or more approved WSDBs.

4.5 Where the specific information in 4.2 above is determined by a communications provider, it is the responsibility of the communications provider (and not the slave WSD) to communicate this information to one or more approved WSDBs. This will be subject to special arrangements between the communications provider, the WSDB provider, and Ofcom. Note that information determined by a communications provider shall not be input into the slave WSD itself[29].

4.6 Once a master WSD is authorised (see 3.1) to radiate within the UHF TV band, the master WSD can broadcast to the slave devices within its coverage area, the identity of the available DTT channels, and the maximum permitted slave EIRP spectral densities. These EIRP spectral densities are specified by the relevant approved WSDB, and are calculated based on default slave WSD characteristics. Upon receipt of the identity of the available DTT channels, and the maximum permitted slave EIRP spectral densities, a slave WSD may commence radiation within the UHF TV band. The slave WSD **must** then communicate[30] specific information to its serving master WSD, so that these can be forwarded to an approved WSDB. Subsequently, the slave WSD **may** communicate additional information regarding its characteristics to its serving master WSD, again to be forwarded to an approved WSDB (see also 4.3,

[28] These special circumstances apply to fixed slave WSDs which, in order to benefit from increased white space availability, are geo-located by a communications provider (for increased geo-location accuracy), or use judicious antenna characteristics to mitigate interference to DTT and PMSE services.
[29] This is to mitigate the risk of inaccurate information being manually input into devices by users (whether unintentionally, or in an attempt to benefit from increased white space availability).
[30] As part of the slave device's process of association with the serving master WSD.

4.4, and 4.5). The WSDB can then calculate new slave EIRP spectral density limits based on the specific slave WSD characteristics reported. The new limits can then be communicated to the relevant master WSD, and subsequently communicated to the relevant slave WSD.

4.7 Communication between a slave WSD and a master WSD **must** not occur within the UHF TV band, unless the WSDs have already been authorised by a WSDB to radiate within the UHF TV band.

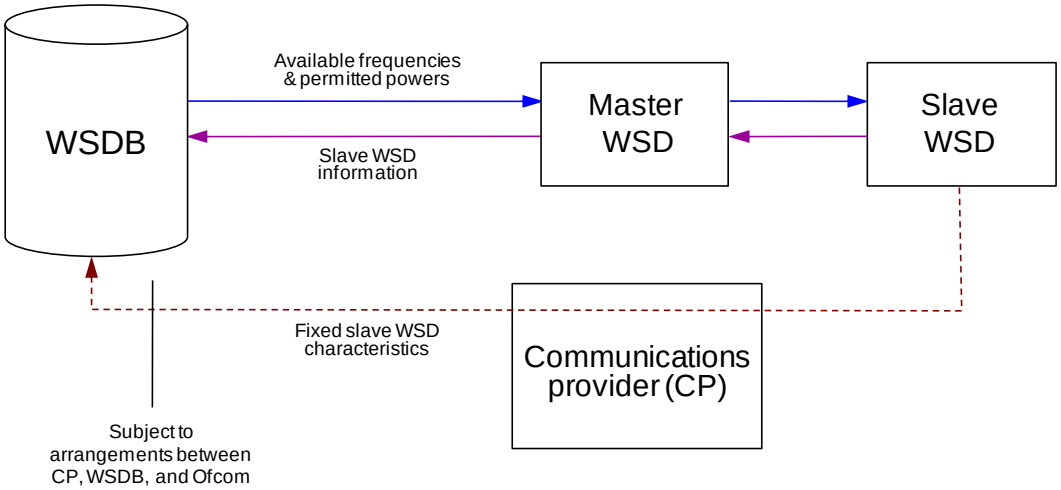


Figure (2). Slave WSD and communications with a WSDB.

Information communicated from a slave WSD to a master WSD

Slave WSD antenna latitude and longitude

4.8 The latitude and longitude coordinates of a slave WSD's transmitting antennas **may**[31] be communicated to a WSDB.

4.9 Where the latitude and longitude coordinates of a slave WSD's transmitting antennas are communicated to a WSDB, the following requirements apply:

4.9.1 A slave WSD, **must** have the capability to automatically determine the latitude and longitude coordinates of its antennas, unless the device falls under the category of slave WSDs described in 4.9.2.

4.9.2 Where a fixed slave WSD is used by (or on behalf of) a communications provider, the slave WSD **may** have the capability to automatically determine the latitude and longitude coordinates of its antennas. If the device does not have such a capability, the antenna latitude and longitude coordinates of the fixed slave WSD **must** be determined by the communications provider.

4.9.3 The accuracy of the determined latitude and longitude coordinates of an antenna **must** be specified as $\pm\Delta x$ and $\pm\Delta y$ metres respectively,

[31] If this information is not communicated, then default values will be used by the WSDB.

corresponding to a 95% confidence level. If Δx or Δy is greater than 50 metres, then the values of Δx and Δy must be communicated to a WSDB.

Other slave WSD antenna characteristics

4.10 The antenna heights above ground level of a slave WSD **may**[32] be communicated to a WSDB, unless the device falls under the category of WSDs described in 4.11.

4.11 Where the antenna latitude and longitude coordinates of a fixed slave WSD are determined and communicated by a communications provider, the antenna heights above ground level of the fixed slave WSD **must** also be communicated to a WSDB.

4.12 Where the antenna heights above ground level of a slave WSD are communicated to a WSDB, the following requirements apply:

4.12.1 A slave WSD **must** have the capability to automatically determine the heights of its antennas, unless the device falls under the category of slave WSDs described in 4.12.2.

4.12.2 Where a fixed slave WSD is used by (or on behalf of) a communications provider, the fixed slave WSD **may** have the capability to automatically determine the heights of its antennas. If the device does not have such a capability, the antenna heights of the fixed slave WSD **must** be determined by the communications provider.

4.13 Where the latitude and longitude coordinates of a fixed slave WSD are communicated to a WSDB, the following information **may**[33] additionally be communicated to the WSDB:

4.13.1 Antenna angular discrimination (directionality and orientation) – This **must** be specified[34] as relative gain (in dB) at intervals of 10 degrees in absolute[35] azimuth and elevation. Where multiple antennas are involved, the angular discrimination **must** apply to the combined emissions from the antennas.

4.13.2 Antenna polarisation – This **must** be specified as either horizontal polarisation, vertical polarisation, slant ($\pm$45 degrees), or mixed polarisation.

4.13.3 Antenna position – This **must** be specified as either indoor or outdoor.

4.14 Where any of the fixed slave WSD antenna characteristics outlined in 4.13 are communicated to a WSDB, the following requirements apply:

[32] If this information is not communicated, then default values will be used by the WSDB.
[33] If this information is not communicated, then default values will be used by the WSDB.
[34] We are also considering an alternative approach. Here the angular discrimination will be specified via a horizontal radiation "pattern identifier", a vertical radiation "pattern identifier", an absolute azimuth pointing angle (0° to 360°, with a resolution of 10°), and an absolute elevation pointing angle (-90° to +90°, with a resolution of 10°). The pattern identifiers would relate to angular discrimination *templates* maintained by Ofcom and shared with WSDBs. This approach would significantly reduce the amount of information that needs to be communicated to the WSDB.
[35] Azimuth values are between 0° and 360°, where 0° points North, and 90° points East. Elevation values are between -90° and +90°, where 0° points to the horizon, and +90° points vertically up.

4.14.1 A fixed slave WSD **must** have the capability to automatically determine these characteristics, unless the device falls under the category of slave WSDs described in 4.14.2.

4.14.2 Where a fixed slave WSD is used by (or on behalf of) a communications provider, the slave WSD **may** have the capability to automatically determine these characteristics. If the device does not have such a capability, the antenna characteristics of the fixed slave WSD **must** be determined by the communications provider.

Other parameters

4.15 A slave WSD **must**[36] automatically communicate its unique device identifier[37] to its serving master WSD.

4.16 A slave WSD **must**[36] automatically communicate its device class[38] to its serving master WSD.

4.17 A slave WSD **must**[36] automatically communicate its technology identifier[39,40] to its serving master WSD.

Information received by a slave WSD from a master WSD

4.18 A slave WSD **must** be able to receive the following information[41] from its serving master WSD:

4.18.1 A list of the lower and upper frequency boundaries[21] within which the slave WSD is authorised to operate.

4.18.2 A maximum permitted slave WSD EIRP spectral density, P_0, specified in units of dBm/(0.1 MHz), and a maximum permitted slave WSD EIRP spectral density, P_1, specified in units of dBm/(8 MHz), between each lower frequency boundary and its corresponding upper frequency boundary as described in 4.18.1.

[36] In the special circumstances outlined in 4.3, where the communications provider determines and communicates certain characteristics of a fixed WSD to a WSDB, the communications provider must at this stage also communicate the WSD's unique device identifier, device class, and technology identifier.
[37] The unique device identifier would enable the WSDB to instruct the master WSD and its associated slaves to cease transmission in the context of 4.18.6. The device identifier would need to be internationally harmonised.
[38] The device class would identify, among other things, the emission mask of the WSD, and would allow the WSDB to use the associated protection ratios. The device class would need to be internationally harmonised.
[39] The technology identifier would enable the WSDB to use technology-specific protection ratios, and would also be helpful in informing the WSDB with regards to the broad time-frequency structure of the WSD signals. This latter information could be used in the context of feedback from WSDs to WSDBs with regards to the used radio resource. For this latter reason, the reporting of the technology identifier is mandatory. The technology identifier would need to be internationally harmonised.
[40] This accounts for cases where the master and slave use different technologies (e.g., where the slave is involved in slave-to-slave communications via one technology, and communicates with the master WSD via a different technology).
[41] While the communication of some of this information from a master WSD to its slave WSDs is optional, slave WSDs must be able to receive and interpret these.

4.18.3 A sensing level[22] (optional) for the detection of DTT use of spectrum specified in units of dBm/(8 MHz).

4.18.4 A sensing level[22] (optional) for the detection of PMSE use of spectrum, specified in units of dBm/(0.1 MHz).

4.18.5 A single time validity for the parameters communicated by the serving master WSD as described in 4.18.1 to 4.18.4.

4.18.6 Instruction for the slave WSD to cease[42] transmission within 1 second when instructed by a master WSD.

4.18.7 Limits on the maximum contiguous and maximum non-contiguous instantaneous bandwidths of slave WSDs specified as n×0.1 MHz, where n > 0.

Operation of a slave WSD

4.19 A slave WSD **must** only transmit within the UHF TV band in accordance with the instructions and parameters in 4.18 provided by its serving master WSD, and for a time period which does not exceed the time validity of those instructions and parameters.

4.20 A slave WSD which wishes to simultaneously transmit over multiple DTT channels **must** a) comply with the maximum permitted slave EIRP spectral densities in each of the DTT channels to be used, and b) radiate with a total EIRP which does not exceed the smallest maximum permitted slave EIRP specified over each of the DTT channels to be used.

4.21 A slave WSD **must** cease transmission within 1 second when instructed so by its serving master WSD or within 5 seconds of losing communications[43] with its serving master WSD.

4.22 A slave WSD **may** communicate with another slave WSD provided that each is controlled via communication over the UHF TV band[44] by its serving master WSD.

Additional requirements for slave WSDs

4.23 The out-of-block EIRP spectral density, P_{OOB}, of a slave WSD **must** satisfy the following requirement:

$$P_{OOB\ (dBm/(100\ kHz))} \leq \max\{ P_{IB\ (dBm/(8\ MHz))} - AFLR\ (dB), -84 \}$$

[42] This requirement implements a so-called WSDB "kill switch" to disable WSDs in the event of interference to licensees. The time validity parameter as described in 4.18.5 is an alternative tool for disabling the WSDs.
[43] This is to mitigate circumstances where the slave moves outside the coverage area of its associated master.
[44] This is to ensure that the slave WSDs are within the expected UHF coverage areas of their respective master WSDs.

where P_{IB} is the WSD's in-block EIRP spectral density, and AFLR is the WSD's adjacent frequency leakage ratio outlined in the table below for different device classes.

Table 2. Slave WSD adjacent frequency leakage ratios for different device classes.

Where P_{OOB} falls within the n^{th} adjacent DTT channel	AFLR (dB)			
	Class 1	Class 2	Class 3	Class 4
n = ±1	74	74	64	54
n = ±2	79	74	74	64
n ≥ ±3	84	74	84	74

4.24 Portable/mobile slave WSDs, and non-geolocated fixed slave WSDs, **must** have antennas with gain not exceeding 2.15 dBi[45].

4.25 A slave WSD **must** only transmit using the minimum EIRP necessary to achieve its required quality of service.

4.26 A slave WSD **must** only transmit subject to specific constraints on the time structure of its signals[46].

[45] A WSDB needs to estimate the possible locations of a portable/mobile slave WSD (or a non-geolocated fixed slave WSD) based on the expected coverage areas of its associated master WSD. To do so, the WSDB will assume a 2.15 dBi slave antenna gain, corresponding to an integral dipole.
[46] These constraints are yet to be defined and are subject to the timely availability of evidence which can identify specific WSD time structures that lead to excessively high DTT protection ratio values.

Section 5

Examples of exchanged information

5.1 In this section we present, for information, examples of sequences of message exchanges between master WSDs, slave WSDs, WSDBs, and where relevant, communications providers.

5.2 We specifically address the following three cases:

5.2.1 Case 1 – This relates to scenarios where information pertaining to the master and slave WSDs is determined automatically by the devices, and subsequently communicated to an approved WSDB.

5.2.2 Case 2 – This is similar to Case 1, except that here the initial association between a slave WSD and its master WSD is not performed via the UHF TV band.

5.2.3 Case 3 – This relates to scenarios where certain information pertaining to fixed master and slave WSDs is determined by a communications provider, and is subsequently communicated, by the provider, to an approved WSDB.

5.3 The examples presented in this section are not intended to be exhaustive.

Table 2. Case 1 – All device information is determined automatically by the master WSD and slave WSD.

WSDB	Master WSD	Slave WSD
START		
Request for master WSD operating parameters. Master WSD unique device identifier, device class & technology identifier. Master WSD antenna latitude and longitude coordinates & accuracy. *Master WSD antenna height (optional).* *Fixed master WSD antenna angular discrimination, polarization & position (optional).*	←	
A list of lower and upper frequency boundaries for master WSD. A list of maximum permitted master WSD EIRP spectral densities. Limits on maximum contiguous and non-contiguous bandwidths for master WSD. *Sensing level for detection of DTT (optional).* *Sensing level for detection of PMSE (optional).* Time validity of parameters.	→	
Master WSD intended lower and upper frequency boundaries of in-block emissions. Master WSD intended maximum in-block EIRP spectral densities for each frequency boundary. Request for slave WSD operating parameters within coverage area of master WSD.	←	
Acknowledgement that reported information was received successfully. A list of lower and upper frequency boundaries for slave WSD within coverage area of master WSD. A list of maximum permitted slave WSD EIRP spectral densities. Limits on maximum contiguous and non-contiguous bandwidths for slave WSD. Time validity of parameters.	→	

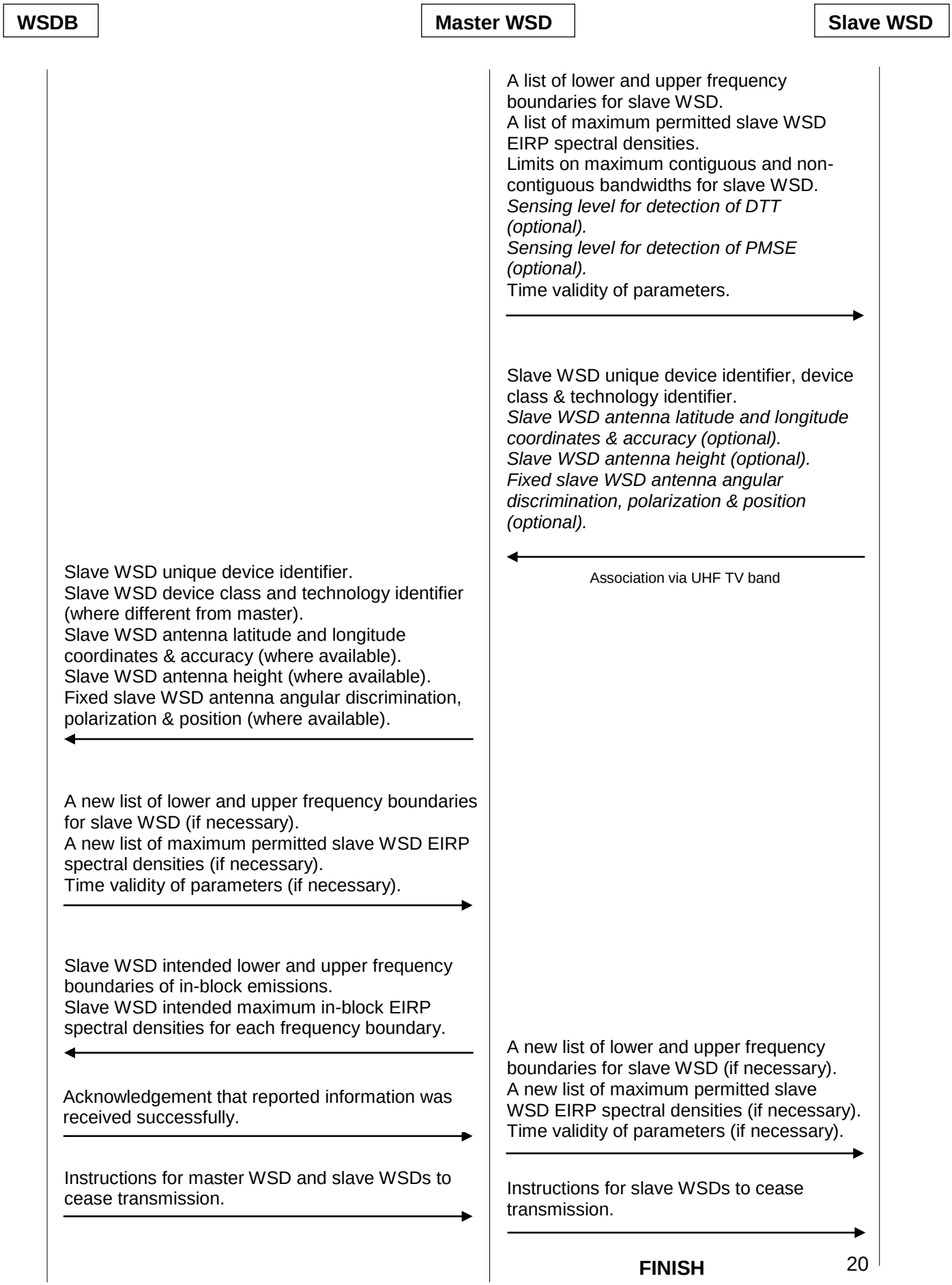

WSDB
Master WSD
Slave WSD
A list of lower and upper frequency boundaries for slave WSD.
A list of maximum permitted slave WSD EIRP spectral densities.
Limits on maximum contiguous and non-contiguous bandwidths for slave WSD.
Sensing level for detection of DTT (optional).
Sensing level for detection of PMSE (optional).
Time validity of parameters.
Slave WSD unique device identifier, device class & technology identifier.
Slave WSD antenna latitude and longitude coordinates & accuracy (optional).
Slave WSD antenna height (optional).
Fixed slave WSD antenna angular discrimination, polarization & position (optional).
Association via UHF TV band
Slave WSD unique device identifier.
Slave WSD device class and technology identifier (where different from master).
Slave WSD antenna latitude and longitude coordinates & accuracy (where available).
Slave WSD antenna height (where available).
Fixed slave WSD antenna angular discrimination, polarization & position (where available).
A new list of lower and upper frequency boundaries for slave WSD (if necessary).
A new list of maximum permitted slave WSD EIRP spectral densities (if necessary).
Time validity of parameters (if necessary).
Slave WSD intended lower and upper frequency boundaries of in-block emissions.
Slave WSD intended maximum in-block EIRP spectral densities for each frequency boundary.
A new list of lower and upper frequency boundaries for slave WSD (if necessary).
A new list of maximum permitted slave WSD EIRP spectral densities (if necessary).
Time validity of parameters (if necessary).
Acknowledgement that reported information was received successfully.
Instructions for master WSD and slave WSDs to cease transmission.
Instructions for slave WSDs to cease transmission.
FINISH

Table 3. Case 2 – Similar to Case 1, but where initial association between the master WSD and slave WSD is not performed via the UHF TV band.

WSDB	Master WSD	Slave WSD
		START
		Slave WSD technology identifier, unique device identifier & device class. *Slave WSD antenna latitude and longitude coordinates & accuracy (optional).* *Slave WSD antenna height (optional).* *Fixed slave WSD antenna angular discrimination, polarization & position (optional).*
		◄- Association is not performed via UHF TV band
Request for master WSD operating parameters. Master WSD unique device identifier, device class & technology identifier. Master WSD antenna latitude and longitude coordinates & accuracy. *Master WSD antenna height (optional).* *Fixed master WSD antenna angular discrimination, polarization & position (optional).* Request for slave WSD operating parameters. Slave WSD unique device identifier. Slave WSD device class and technology identifier (where different from master). Slave WSD antenna latitude and longitude coordinates & accuracy (where available). Slave WSD antenna height (where available). Fixed slave WSD antenna angular discrimination, polarization & position (where available).		
◄———		
A list of lower and upper frequency boundaries for master WSD. A list of maximum permitted master WSD EIRP spectral densities. Limits on maximum contiguous and non-contiguous bandwidths for master WSD. A list of lower and upper frequency boundaries for slave WSD. A list of maximum permitted slave WSD EIRP spectral densities. Limits on maximum contiguous and non-contiguous bandwidths for slave WSD. *Sensing level for detection of DTT (optional).* *Sensing level for detection of PMSE (optional).* Time validity of parameters.		
———►		

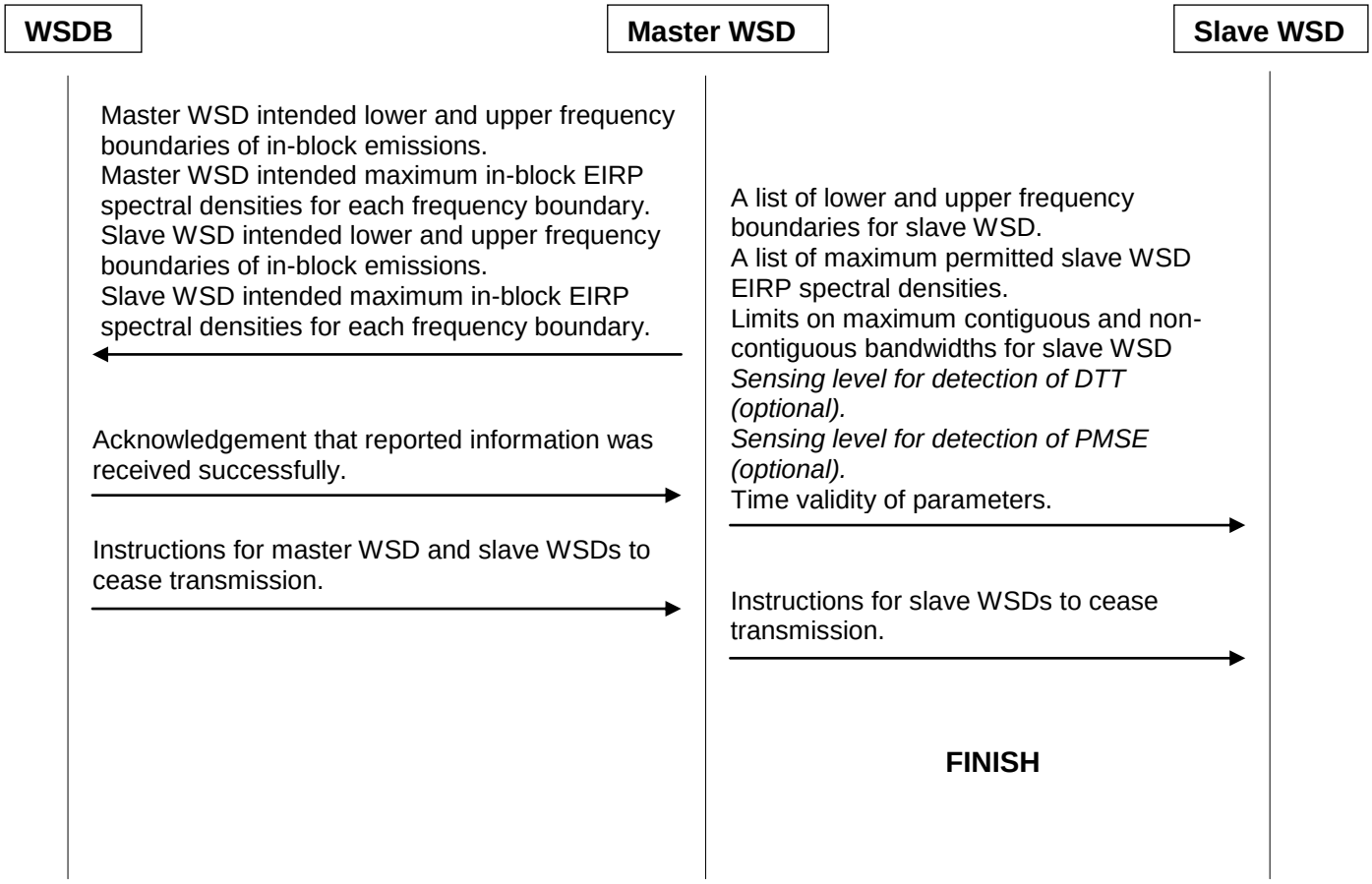
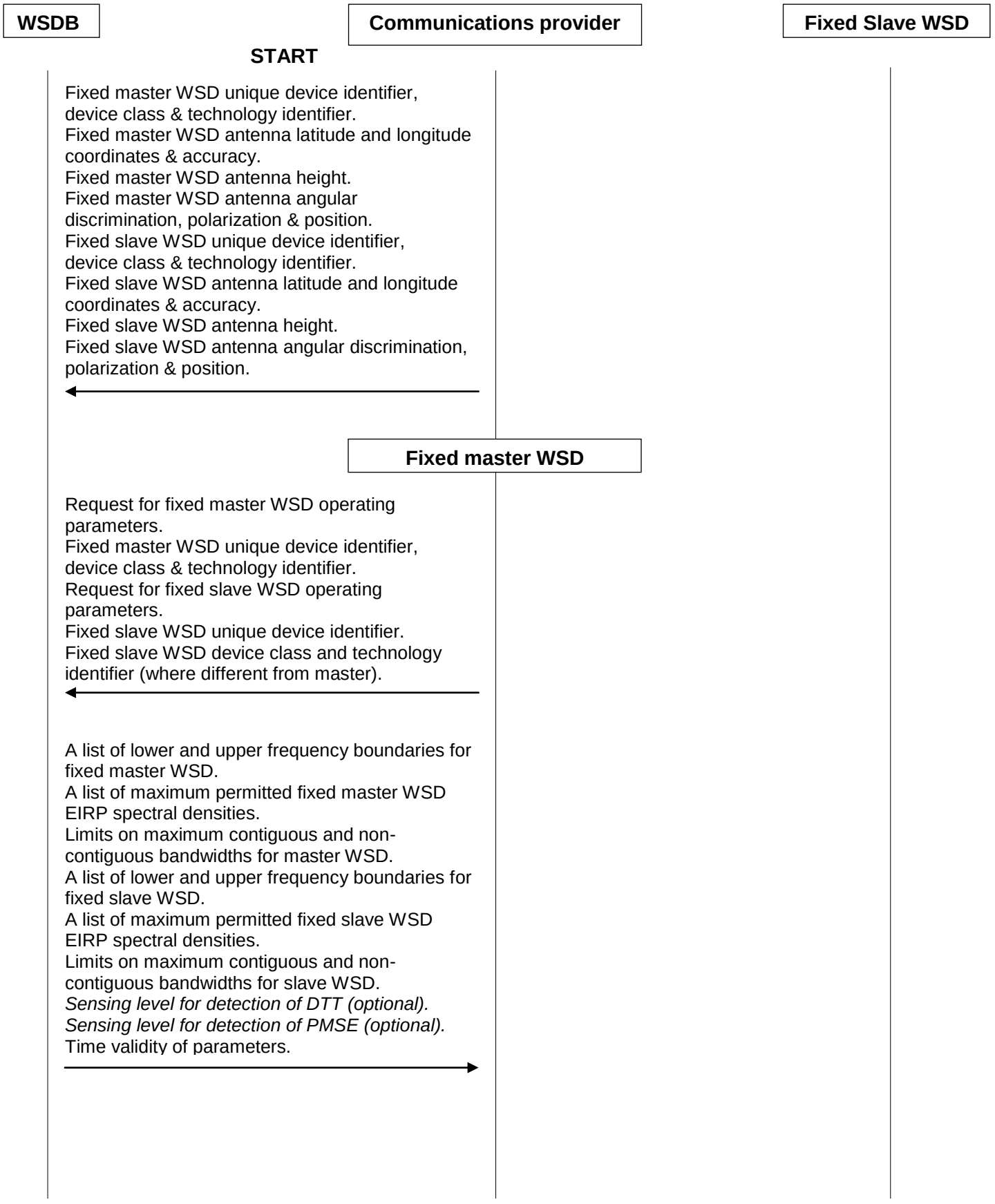
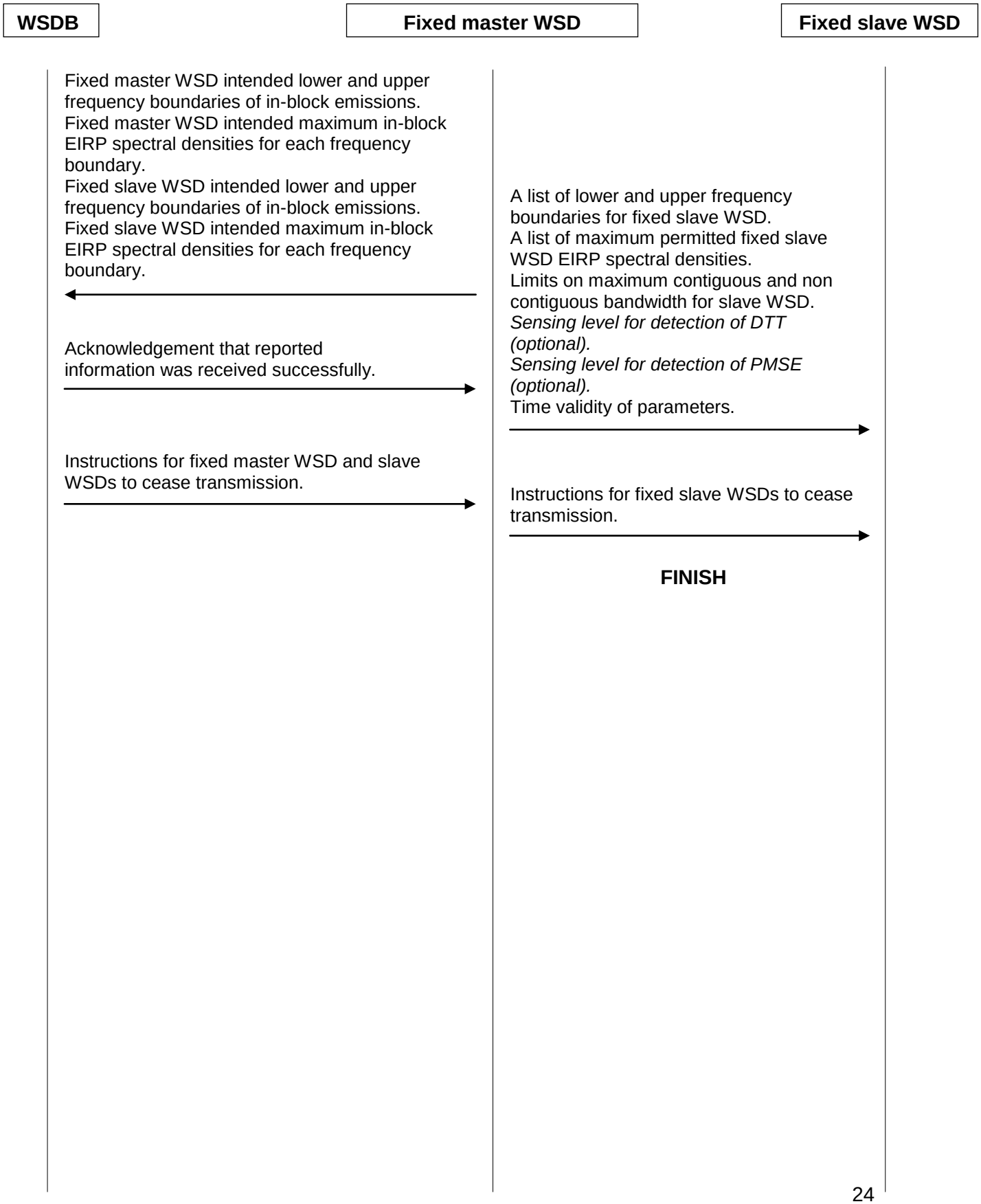

WSDB
Master WSD
Slave WSD
Master WSD intended lower and upper frequency boundaries of in-block emissions.
Master WSD intended maximum in-block EIRP spectral densities for each frequency boundary.
Slave WSD intended lower and upper frequency boundaries of in-block emissions.
Slave WSD intended maximum in-block EIRP spectral densities for each frequency boundary.
A list of lower and upper frequency boundaries for slave WSD.
A list of maximum permitted slave WSD EIRP spectral densities.
Limits on maximum contiguous and non-contiguous bandwidths for slave WSD
Sensing level for detection of DTT (optional).
Sensing level for detection of PMSE (optional).
Time validity of parameters.
Acknowledgement that reported information was received successfully.
Instructions for master WSD and slave WSDs to cease transmission.
Instructions for slave WSDs to cease transmission.
FINISH

Table 4. Case 3 – Where certain information pertaining to fixed master and slave WSDs is determined by a communications provider.




WSDB
Fixed master WSD
Fixed slave WSD
Fixed master WSD intended lower and upper frequency boundaries of in-block emissions.
Fixed master WSD intended maximum in-block EIRP spectral densities for each frequency boundary.
Fixed slave WSD intended lower and upper frequency boundaries of in-block emissions.
Fixed slave WSD intended maximum in-block EIRP spectral densities for each frequency boundary.
A list of lower and upper frequency boundaries for fixed slave WSD.
A list of maximum permitted fixed slave WSD EIRP spectral densities.
Limits on maximum contiguous and non contiguous bandwidth for slave WSD.
Sensing level for detection of DTT (optional).
Sensing level for detection of PMSE (optional).
Time validity of parameters.
Acknowledgement that reported information was received successfully.
Instructions for fixed master WSD and slave WSDs to cease transmission.
Instructions for fixed slave WSDs to cease transmission.
FINISH