COMMUNICATIONS AUTHORITY OF KENYA

Dynamic Spectrum Access Framework

for

Authorisation of the Use of TV White Spaces

May 2021

Overview

The Communications Authority of Kenya is the regulatory authority for the ICT sector in Kenya with responsibilities in telecommunications, e-commerce, broadcasting, postal/courier services and cybersecurity. The Authority is responsible for managing the numbering and frequency spectrum resources for the country as well as safeguarding consumers of ICT services.

The Authority is committed to discharging its mandate to ensure that the ICT sector contributes to the socio-economic growth of Kenya, in line with its vision of a digitally transformed nation. The Authority is adopting methods beyond the traditional model of dedicated spectrum licensing to individual operators to meet the rapidly increasing demand. To achieve this, one of the objectives of the Authority's Strategic Plan (2018-2023) is to develop a framework for Dynamic Spectrum Access (DSA). Implementation of spectrum sharing is a key regulatory intervention that the Authority intends to adopt to accommodate varying levels of spectrum demand and over time, this approach shall be a key strategy of spectrum management.

Effective implementation of a spectrum sharing approach will enable efficient utilisation of the spectrum while protecting existing primary users from harmful interference. Spectrum sharing can increase capacity as it makes the fallow spectrum available without displacing incumbent users. The Authority envisions that this will be an important way to unlock maximum value from radiocommunication services and serve as a flexible way to reduce artificial spectrum scarcity.

The Authority authorises the use of TV white spaces (TVWS), in the 470-694 MHz UHF Spectrum band, currently allocated to the broadcasting service on a primary basis. White Space Devices (WSDs) shall be authorised to operate in areas where specific channels are unused for Digital Terrestrial Television (DTT) broadcasting. The Authority shall assess every model of WSD to ensure it meets the Type Approval requirements before installation. The operation of the WSDs shall be managed by geolocation database(s) qualified by the Authority, which will hold details on the location and operation of DTT transmitters. The communication between TVWS devices and geolocation databases will be performed following the 'Procedure for Qualification of Geolocation Databases'.

This framework follows previous consultations with stakeholders and trials conducted between 2013 and 2019 on TVWS applications. By this action, the Authority demonstrates its commitment to addressing radio frequency spectrum efficiency challenges through innovation and provision of an enabling regulatory environment, which allows optimal use of spectrum for universal access to ICT services. The Authority conducted a validation exercise to determine the viability of the framework, before implementation.

The Authority, therefore, adopts the framework set out in this document, including the definitions, rules and procedures defining TVWS availability and associated power levels to be controlled by the geolocation databases. The primary reference standard for WSDs, ETSI 301 598, describes compliance assessment for Wireless Access Systems operating in the UHF band. The Authority shall maintain control over the effective implementation of the regulatory framework allowing TVWS operation, subject to market demand and periodic feasibility assessment of costs and benefits for efficient operation.

ACKNOWLEDGEMENT

The Communications Authority of Kenya acknowledges exceptional support from the following organisations in developing and validating this framework.

The University of Strathclyde is a leading technological university in Glasgow, Scotland, UK whose Software-Defined Radio Lab is researching and trialling agile radio network solutions featuring 4G/5G, Xilinx RFSoC, OpenRAN, Neutral Hosting, Shared Spectrum, Dynamic Spectrum Access and MultiUser MIMO technologies. It is leading an Engineering & Physical Sciences Research Council project on 'Enabling affordable Internet access with dynamic spectrum management & software-defined radio'. Under the project, researchers from Malawi, Kenya, Zambia & Ghana are guiding the adoption of dynamic spectrum management and supporting the development of appropriate regulatory policies in their respective countries.

@iLabAfrica is a Centre of Excellence in ICT Innovation and Development at Strathmore University. The centre spearheads Research and Innovation in Information Communication Technology for the Development (ICT4D) of ecosystems towards the attainment of the United Nations Sustainable Development Goals (SDGs) and to contribute toward Kenya's Vision 2030. The research centre is involved in interdisciplinary research, students' engagement, collaboration with government, industry and other agencies.

The Dynamic Spectrum Alliance (DSA) is a cross-industry, not for profit organization advocating for laws, regulations and economic best practices that will lead to more efficient utilization of spectrum and foster innovation and affordable connectivity for all. The DSA is focused on promoting spectrum sharing innovation to get the most out of wireless resources by advocating for policies that promote unlicensed and dynamic access to spectrum to unleash economic growth and innovation. Their focus is to ensure that regulatory frameworks to support a diversity of technologies are adopted.

The UK Prosperity Fund 'Digital Access Programme' is a Foreign & Commonwealth Development Office initiative that aims to catalyse more inclusive, affordable and secure digital access for excluded and underserved communities in Kenya, Nigeria, South Africa, Brazil and Indonesia. Increased digital inclusion in the programme countries will form the basis for more thriving digital ecosystems that generate high-skilled jobs, opportunities for local digital entrepreneurship focused on development challenges, as well as potential partnerships with international and UK business aimed at mutual prosperity.

Abbreviations

BSD	Broadcast Signal Distributor
DSA	Dynamic Spectrum Access, Dynamic Spectrum Alliance
DTT	Digital Terrestrial Television
ETSI	European Telecommunications Standards Institute
GE06	ITU GE06 Agreement for Digital Broadcasting
IEEE	Institute for Electrical and Electronics Engineers
IoT	Internet of Things
ITU	International Telecommunications Union
PAWS	Protocol to Access White Space Database
RF	Radio Frequency
WLANs	Wireless Local Area Networks
WSD	White Space Device
TVWS	Television White Spaces
WRC	ITU World Radiocommunication Conference

Definition of Terms

Term	Definition
Dynamic Spectrum Access	A technique by which a radio system actively adapts to the local radio spectrum environment to identify and then access available channels at specific locations.
White Space	A portion of the radiofrequency spectrum, available for radiocommunication applications (services, systems) at a given time in a given geographical area on a non-interfering / non-protected basis concerning other services with a higher priority on the Table of Frequency Allocations
TV White Space (TVWS)	White Space in the UHF TV broadcast band 470-694 MHz
White Space Device (WSD)	A radiocommunication device that operates in the white space frequency bands using dynamic spectrum access techniques.
TV White Space Device (TVWSD)	A WSD designed to operate on an unlicensed basis on available channels in the Digital Terrestrial Television broadcasting band 470-694 MHz.
Coordinated use of white spaces	A group of WSDs use available white space resources obtained with parameters from the geolocation database(s) and knowledge of the spectrum usage by other WSDs.
Uncoordinated use of white spaces	Each WSD independently uses available white space resources obtained with the help of the geo-location database without any additional information about the spectrum usage of other WSDs
Geolocation Database (GDB)	A third-party database recognized by the Authority that maintains records of all licensed services and systems approved to operate in a specified frequency band available for WSDs. The GDB identifies available frequencies at a specific time and geographic location and provides lists of these frequencies to WSDs in response to queries.
Master WSD	A WSD that communicates directly with a WSDB & with client WSDs.
Client WSD	A WSD that is only able to communicate with other WSDs, when under the control of a master WSD.
Geolocation Capability	The ability of a WSD to determine its geographic coordinates within a required level of accuracy.

Table of Contents

1. Background

The increase in radiocommunication devices and services has resulted in greater demand for access to the radio frequency spectrum. A new spectrum management paradigm is required for some services to balance spectrum utilisation by incumbents and the growing demand from the new services. Dynamic spectrum access (DSA) is a spectrum sharing concept that allows secondary users to access spectrum in licensed spectrum bands on the condition that they do not cause harmful interference to incumbent users. DSA may alleviate spectrum scarcity and increase spectrum utilisation, especially in rural underserved areas. The authority authorises dynamic access of the UHF band 470-694 MHz on a non-protected, non-interference basis by white space devices (WSDs). In establishing the regulatory requirements for TVWS in Kenya, the Authority sets limits that will offer the protection required to prevent harmful interference to the DTT broadcasting service.

Strathmore University and the Communications Authority of Kenya entered into a memorandum of understanding (MoU) to investigate the viability of radiofrequency spectrum sharing in Kenya. The collaborative study invited other researchers and stakeholders to participate in shaping the strategy for DSA implementation in Kenya. CA envisions that TV white spaces will enable enhanced Internet access in rural Kenya. The adopted framework is advised by technical trials, due diligence, research activities and ongoing consultations. The primary focus for the trials was to evaluate spectrum usage in the UHF band based on international best practices and investigate the opportunity for spectrum sharing to enhance Internet access for rural Kenya.

The Authority authorises the operation of geolocation databases in the country which will receive periodic updates from the Authority's spectrum management database, perform coexistence calculations and provide transmission parameters to the WSDs for non-interference operation. The WSDs must meet the minimum technical specifications and be Type Approved before installation and use, they shall be authorised to operate at specific locations and times determined by the geolocation database. The Authority conducted a validation exercise on the framework and a formal consultation from March – April 2020 to obtain views from relevant stakeholders and the general public concerning the implementation of a sustainable model for TVWS under the DSA Framework. The initial studies of the DSA framework focusing on TVWS in the UHF band were concluded in May 2020 and technical research and consultations will continue to expand the scope of DSA to other bands and radiocommunication services by 2023. The consultation was an opportunity for stakeholders to examine the framework and propose improvements to enable shared access to the under-utilised radio frequency spectrum as part of a wider strategy to enable accessible communications services to all in Kenya.

1.1. Communications Authority of Kenya Legal and Regulatory Framework

This section describes the role of the Authority in determining the requirements for spectrum management and as pertains to spectrum sharing. The Communications Authority of Kenya is the regulatory authority for the ICT industry in Kenya with responsibilities in telecommunications, e-commerce, broadcasting, postal & courier services and cybersecurity. The Authority is responsible for managing the country's numbering and frequency spectrum resources as well as safeguarding the interests of consumers of ICT services. Established in 1999 by the Kenya Information and Communications Act, 1998, the Authority is responsible for facilitating the development of the information and communications sectors including broadcasting, cybersecurity, multimedia, telecommunications, electronic commerce, postal and courier services.

1.2. Key Responsibilities

The key responsibilities of the Authority include:

a) Licensing all systems and services in the communications industry.
b) Managing the country's frequency spectrum and numbering resources.
c) Type approving and accepting communications equipment for use in Kenya.
d) Protecting consumer rights within the communications environment.
e) Managing competition to ensure a level playing ground for all operators.
f) Regulating retail and wholesale tariffs for communications services.
g) Monitoring the activities of licensees to enforce compliance with license conditions.

1.3. Spectrum Management Responsibilities

The increasing use of wireless technologies, and opportunities for development that these technologies provide, highlight the importance of radio-frequency spectrum management processes. Increased demand requires that spectrum be used efficiently and that effective spectrum management processes and systems are implemented to facilitate the deployment of radio systems and ensure minimum interference. Under article 3 of the Kenya Information and Communications (Radio Communications and Frequency Spectrum) Regulations, 2010, the Authority is required to:

a) Promote and support the orderly development and efficient operation of radio communication systems and services to meet the country's socio-economic, security and cultural needs;
b) Ensure proper planning and management of the spectrum resource under the Act, Government policy objectives and international agreements;
c) Promote the efficient use of frequency spectrum resource through the adoption of technological advances and efficient spectrum allocation and management technology based on operational requirements and technical viability;
d) Ensure the equitable and fair allocation and assignment of spectrum to benefit the maximum number of users.

1.4. Telecommunications Equipment Type Approval

The Communications Authority of Kenya is responsible for the type approval and acceptance of telecommunications equipment for use in Kenya. Duly licensed vendors and contractors are authorised to market telecommunication equipment and are required to obtain type approval from the Authority for each model of equipment they intend to sell. Entities wishing to use telecommunication equipment on their networks must have the requisite authority to operate the communication network under article 3 of the Kenya Information and Communications (Importation, Type Approval and Distribution of Communications Equipment) Regulations, 2010. All communications equipment to be used to access public communication networks and radio communications equipment intended to be connected directly or to interwork with a communications network in Kenya to send, process or receive information shall, before their use, be submitted for type approval or type acceptance by the Authority.

1.5. Importance of International Approach to Spectrum Management

Spectrum use must be coordinated and regulated under the Kenya Information and Communications Regulation and the Radio Regulations of the International Telecommunication Union (ITU), a specialised United Nations (UN) agency for information and communication services. The international approach to spectrum management enables efficient and effective use of radio frequency spectrum and harmonised use regionally stimulates socio-economic progress.

Spectrum management provides an orderly method for allocating and assigning frequency bands, authorising and recording frequency assignments and establishing regulations and standards. Regulations can specify technical factors, establish licensing criteria, and set priorities that will be used to determine who will be authorised to access a frequency band, and for what purpose it will be used. Policy statements are a link between government agenda and regulatory perspective to ensure alignment of objectives.

Frequency coordination, notification and registration are essential tasks for administrations so that their radiocommunication services obtain international protection. This activity is performed by correspondence with the ITU and other administrations, or in bilateral or negotiations. The primary objective of ITU-R in spectrum management is to ensure interference-free operations of systems. This is ensured through the implementation of the radio regulations and regional agreements, and the efficient and timely update of these instruments through the rigorous processes of World and Regional Radiocommunication Conferences. Radiocommunication standardisation establishes 'recommendations' intended to assure the necessary performance and quality in operating radio systems by conserving spectrum and ensuring flexibility for future expansion and technological developments.

1.6. Application of the Authority’s Mandate to TV White Spaces

The Authority’s approach to spectrum sharing is determined by the observance of the regulatory framework and it expects the authorisation of the use of TV white spaces to deliver on the following:

a) Facilitation of access to unused spectrum: There are important benefits to consumers by making TVWS available for use, including improved access to broadband Internet services by the rural areas and optimising the innovative use of the spectrum.

b) Protection of licensed spectrum users: DTT is the main platform for providing television broadcast services in Kenya and delivers significant value for consumers. DTT broadcasting performs a critical public policy role in providing affordable access to broadcasting content and providing consumers with a wide variety of channels.

c) Deployment of WSDs presents a low risk of interference to DTT receivers. The coexistence calculations defined under the framework shall ensure the protection of DTT receivers from WSDs emissions

d) Minimisation of regulatory hurdles. A level of regulation is necessary to permit access to white spaces while protecting primary users. The Authority has made this as versatile as possible, consistent with the need to prevent harmful interference and maintain flexibility for future applications of spectrum sharing.

2. Spectrum Sharing Opportunity for TVWS Applications

This document describes the Authority's framework to enable dynamic spectrum access to white spaces in the UHF band 470 to 694 MHz. The framework was developed following trials, due diligence and extensive consultations conducted to formulate a suitable approach to achieve the first stage of dynamic spectrum access for Kenya. Adequate measures are adopted to guarantee a low probability of harmful interference to DTT reception. The Authority sought the support of international administrations to ensure that this framework is consistent with best practices and in line with technical standards and markets.

2.1. Definition of TV White Spaces

TV white spaces are "portions of spectrum left unused by TV broadcasting services", in the UHF band. The UHF band between 470 MHz – 694 MHz is allocated, on a primary basis, to the broadcasting service for Digital Terrestrial Television (DTT) transmissions in ITU region 1 which includes Africa. Each multiplex requires an 8 MHz channel and the multiplexes are transmitted on various frequency channels at designated broadcast sites.

There are 28 channels of 8 MHz bandwidth (from CH21 to CH48) that are available for DTT broadcasting in Kenya, though not all 28 channels are activated at each transmission site due to varying signal coverage areas and irregular terrain. High-power TV transmissions on the same frequency channel require geographic separation between their coverage areas to avoid interference in multi-frequency networks (MFNs). Channels that are not activated for DTT transmissions at a given location, at a particular time may be available for use by low power WSDs on a dynamic basis.

Radiofrequency spectrum in the UHF band has highly desirable propagation characteristics and TV white spaces are particularly suitable for delivering Internet access in rural and underserved semi-urban areas. Possible applications include the provision of fixed wireless broadband connectivity to homes, businesses, public services like education and health facilities as well as Internet of Things (IoT) applications.

2.2. Authorisation of White Space Device Operation

The Authority has adopted a framework for authorisation of TV white space applications that includes specific device requirements, operational parameters, channel usage parameters, coexistence calculations and procedure for qualification of geolocation databases. The Authority acknowledges that there is room for further development and refinement of certain aspects of the framework and considers that additional consultation and research work is required in partnership with industry and academia to improve the framework and its possible application to other spectrum bands in the future.

Under the coexistence calculations adopted for this framework, the operating parameters have been set to ensure the protection of services above and below the band 470 – 694 MHz and DTT receivers within the band. Through arrangements with databases, to be adopted under the procedure for qualification of geolocation database providers, the Authority will have mechanisms to control the operation of WSDs.

The Authority shall qualify geolocation database (GDB) providers who can demonstrate that their database solutions meet the minimum requirements to reliably provide information on the availability of TV white spaces to the WSDs. The Authority will regularly monitor the deployment of WSDs and the performance of geolocation databases to determine possible ways of improving the framework.

The Authority shall periodically update the adopted technical standards, specifications and parameters necessary for the seamless operation of the TV white spaces ecosystem. WSDs shall require registration authentication by a geolocation database before they operate. The qualified database shall provide device management functionality for the identification of non-conforming WSDs for their immediate deactivation. With time, the operation of a large number of WSDs may require multiple geolocation databases with open standards to ensure interoperability so that network operators can select a qualified geolocation database of their preference.

2.3. Risks associated with TV White Spaces

a) Availability of TVWS can be unreliable

A frequency channel that has been available for WSDs could, at any time, be assigned by the Authority to a broadcast signal distributor (BSD) for DTT transmission. The availability of TV white spaces is therefore not guaranteed at specific locations and this unpredictability may preclude some services that must have guaranteed access to spectrum.

b) TVWS spectrum may not be available indefinitely

In the UHF band, the possibility of increased demand for high definition transmissions shall require additional spectrum assignments to broadcast signal distributors and therefore a reduction in available TV white space channels. The combined effect of increased demand for mobile spectrum and DTT requirements could result in a significant change to white space availability.

c) TVWS spectrum may not be authorised by neighbouring countries

Most countries that have authorised TV white spaces access are relying on a geolocation database providing WSDs with the information of the channels to use. However, for neighbouring East African countries, their local circumstances may lead to different regulatory approaches and implementations. As a result, TV white spaces may not be available in the region in a harmonised way, which could lead to challenges in border areas.

2.4. Possible Licensing Models for TVWS

While permitting TVWS operation will improve spectrum efficiency, it is vital to protect the broadcasting service reception from harmful interference, this shall be achieved by adopting a suitable licensing model from the following options;

a) License-exempt

In this model, no regulatory record is kept of which devices are using RF channels and this poses a risk of interference to broadcasting services. It is not possible to identify and locate a device if it causes interference and no protection is provided between TVWS devices.

b) Lightly-licensed

In a lightly licensed regime, every master WSD is registered and fully controlled by the geolocation database(s). In the event of detecting interference to the primary licensee, the offending devices can be instructed to cease transmitting on a particular channel. The network operator requires annual authorisation to operate and pays for the geolocation database service and a nominal fee for the use of the radiofrequency spectrum.

c) Fully licensed

In this model, a TVWS device is charged a fee as a function of the area covered and the duration of usage, the parameters are calculated by a geolocation database, populated with technical data. In such a model, protection is provided between TVWS devices. Thus, if one TVWS device causes interference to another licensed device, the interfering device may be instructed to change channels or to cease transmission.

2.5. Adopted Licensing Models for TVWS

The Authority has adopted a lightly licensed model of service for TVWS applications. Under such a model, a master TV white space device shall consult any geolocation database qualified by the Authority and submit parameters describing its location, operational and device parameters. The database would then supply details of the frequency channels and power levels the WSD is allowed to use. Figure 2.1 illustrates how access to white spaces based on geolocation would work in practice.

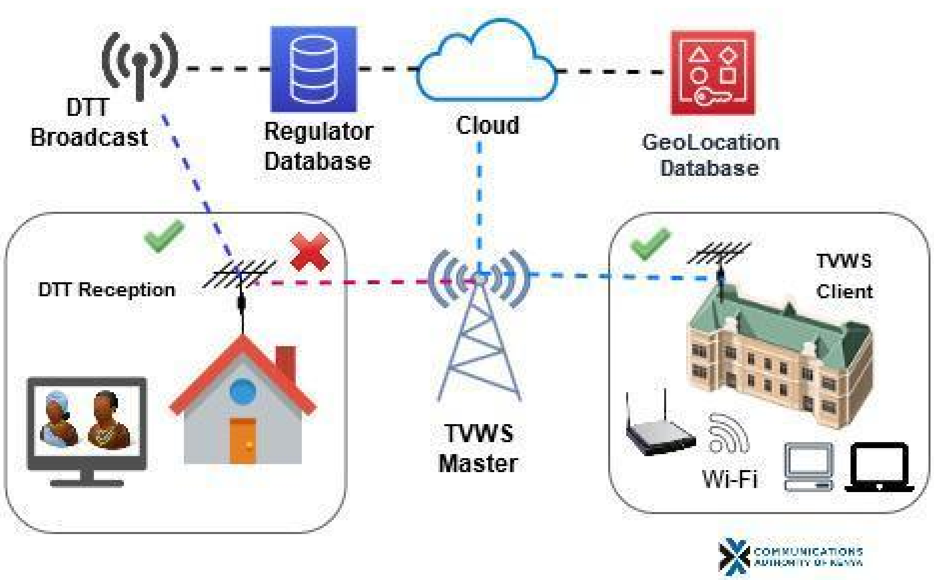

Figure 2.1: Simple diagram of TV White Space Network

The topology is a point to multipoint with a Base Station (BS) and several clients, the Consumer Premise Equipment (CPEs). The BS can serve fixed or portable CPE units equipped with outdoor directional antennas. Target service capacity is to deliver to a CPE at the edge of coverage a minimum throughput, 1.5 Mbit/s downlink and 354 kb/s in the uplink. The total capacity of the Base Station is up to 22 Mbit/s per channel.

The TVWS technology is capable of providing fixed broadband coverage over a 50 km range if sufficient transmitted power is permitted and propagation characteristics are exceptional. Practically, with an EIRP of 4W, the achievable range is about 30 km with a reasonable CPE antenna gain of about 11dB. This enhanced coverage range offers unique technical challenges regarding interference as well as opportunities for offering broadband services in sparsely populated rural areas. The advanced radio capability features necessary for dynamic spectrum access include accurate geolocation techniques, regulatory domain-dependent policies and coexistence calculations for optimal use of available spectrum.

3. Framework for the Use of TV White Spaces

3.1. Introduction and Overview

The framework aims to allow WSDs to use spectrum in the UHF band at particular locations and times on a shared basis subject to ensuring that there would be no harmful interference to other spectrum users in the band or adjacent to the band. The Authority intends to make sharing as simple as possible and the overall approach is summarised in Figure 3.1.

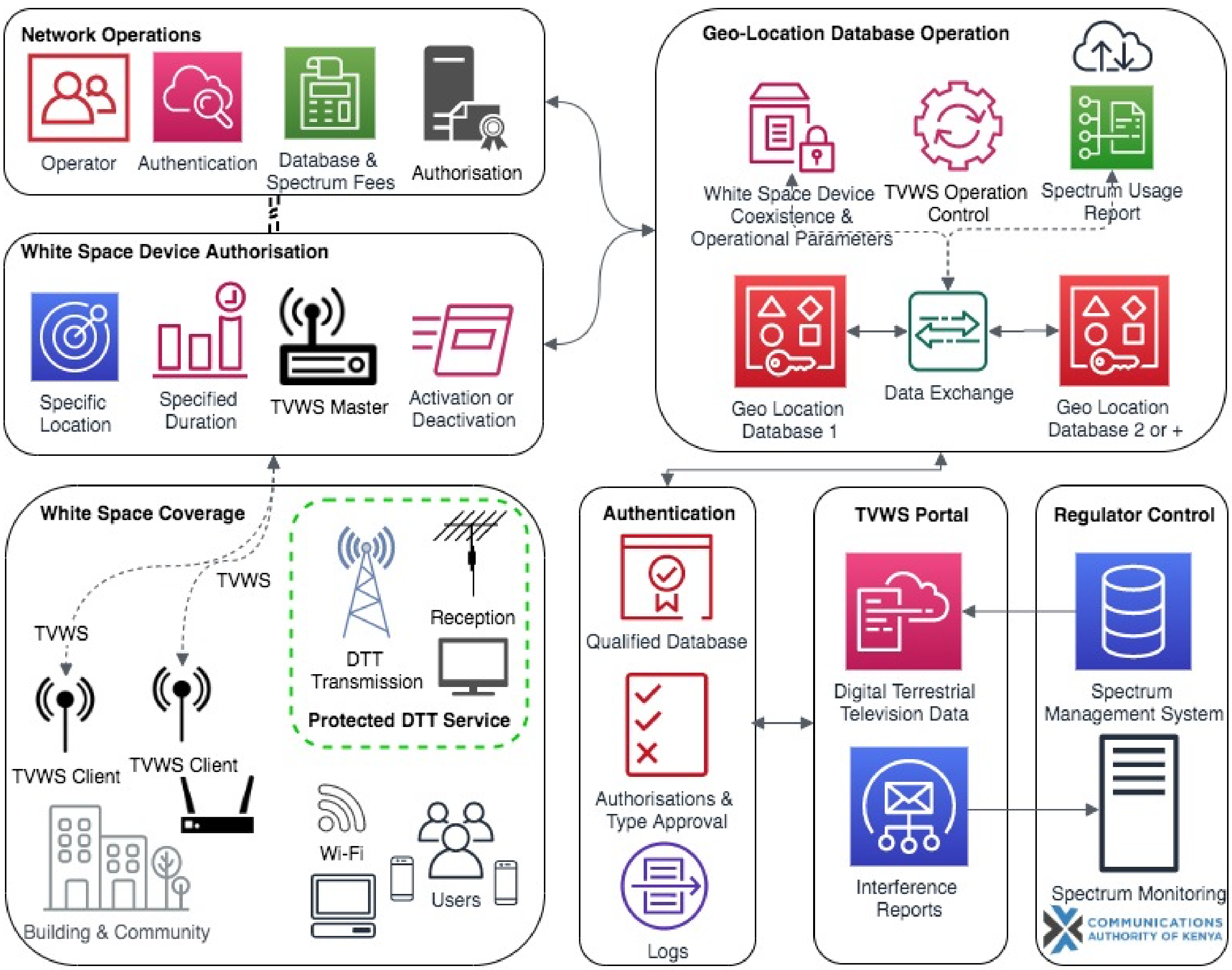

Figure 3.1: Illustration of the framework for the use of TV white spaces

A master WSD will provide its location and operational characteristics to a geolocation database that has information on licensed DTT transmissions. The geolocation database will then use the information to determine the channels available for secondary use by the WSD and the associated power levels. The database will perform calculations for the location and technical characteristics provided by a WSD and will communicate the available channels and powers to the master WSD to initiate transmission. The master WSDs shall use PAWS protocol to establish communication with a geolocation database during database discovery. They will be required to obtain the operational parameters over the Internet. The database provider shall have adequate security features to restrict access to the geolocation database and the available channels.

3.2. Key Provisions of the TVWS Framework

For the implementation of the framework, the following are key provisions:

a. **Eligible Operators**: The Authority shall permit interested service providers who hold either a Network Facilities Provider License (Tiers 1, 2 and 3), a Broadcasting Signal Distributor License or a Self-Provisioning Broadcasting License to use the TVWS spectrum.
b. **Device authorisation**: Every white space device model must meet the minimum technical requirements for equipment type approval before deployment
c. **Coexistence framework**: The use of TV white spaces shall be controlled following the rules, conditions, and calculations stipulated in the framework.
d. **Database Service Providers:** The Authority shall qualify 3rd party databases that would be capable of taking the data provided by the Authority and providing responses to WSDs that accurately identify available channels and acceptable power levels.

3.3. Primary Reference Standards

The primary documents referenced in the formulation of the TVWS framework are;

a. ETSI EN 301 598 v2.1.1: Harmonised Standard for White Space Devices (WSD); Wireless Access Systems operating in the 470 MHz to 790 MHz frequency band;
b. ETSI TS 102 946: System requirements for Operation in UHF TV Band White Spaces
c. ETSI TS 103 145: System Architecture and High-Level Procedures for Coordinated & Uncoordinated Use of TV White Spaces
d. ETSI TS 103 143: System architecture for information Exchange between different Geo-Location databases enabling the operation of White Space Devices
e. Model Rules & Regulations for the use of Television White Spaces - Dynamic Spectrum Alliance.
f. IEEE 802.11af: Standard for Information Technology - Telecommunications & Information Exchange Between Systems
g. IETF PAWS RFC 7545: IETF Protocol to Access White Space Databases

3.4. Qualification of Geolocation Databases

The operation of white space devices will be controlled by databases qualified by the Authority. A master WSD will need to contact a database, which will respond to the WSD with a set of operational parameters including the frequencies and maximum powers at which the WSD can transmit. The Authority's arrangements with geolocation database providers will include a detailed methodology to calculate coexistence parameters that meet the Authority's objective of ensuring a low probability of harmful interference to primary users of the target band and services adjacent to the band.

The database providers will undergo a qualification process through which the Authority will determine their compliance with rules for the operation of geolocation databases for spectrum sharing. The main objective of the qualification process is to test whether the database is capable of implementing the Authority's coexistence rules. To perform the necessary calculations that result in a set of operational parameters for a particular WSD, the Authority will provide a database with data on active DTT Transmissions.

These data will include designated DTT transmitter locations, active channels, maximum radiated power and other parameters described in the rules. The database will compute transmission parameters for use by WSDs that will ensure a low probability of harmful interference to DTT reception and guarantee adherence to Kenya's international obligations regarding neighbouring countries use of the UHF band.

Once a database is qualified, it will be listed on the Authority's website (listing server) to be available for selection by a WSD. Under the framework, it is the master WSD that communicates with a geolocation database and such a device must only use transmission parameters provided by a qualified database. A master WSD will access the list of qualified databases from the Authority's website and select a database with which to exchange parameters as required. A master WSD must periodically reload the list of qualified databases, at least every 24 hours, in line with the ETSI Standard.

3.5. Master and Client WSDs

Under the TVWS framework, a distinction is made between master WSDs and client WSDs. A master WSD is a device that can communicate with and obtain parameters directly from a geolocation database and a client WSD is a device that is only able to operate when under the control of a master WSD. Deployments of WSDs would involve a master WSD as a base station or an access point, which controls several clients within its coverage area in point to multipoint mode.

3.6. Device Parameters

Once a master WSD has selected a qualified database, it will report to that database its "device parameters" which identify specific characteristics of the WSD, including its location and other information about the device. A master WSD shall also communicate to the geolocation database the device parameters of all client WSDs under its control. The harmonised ETSI standard describes the parameters required for the operation of WSDs, including the nature of the data exchanged between WSDs and the database. If the WSD setup is compatible with the standard, then the database shall initiate the determination of channel usage parameters.

3.7. Operational Parameters

The geolocation database will use device parameters together with DTT information provided by the Authority, to determine what frequencies are available for that particular device and at what powers it can transmit on a specific channel. This information is known as the "operational parameters" and will be communicated to the device. These operational parameters will only be valid for a short period so the device will have to query the database regularly to ensure that it can transmit using valid operational parameters.

3.8. Channel Usage Parameters

The channel usage parameters are reported by a WSD to inform a database of the actual frequencies and powers that it intends to use for transmission which will enable a database to log the information for spectrum management purposes. The channel usage parameters describe the radio resources (frequencies and powers) that a WSD intends to use which may be a subset of the resources indicated by the database in the operational parameters.

3.9. Exchange of Parameters between WSDs and Geolocation Databases

The exchange of parameters between WSDs and the databases could be as follows: Once a master WSD establishes a communications link with a qualifying database it will communicate its device parameters to that database. The database will then be able to calculate the operational parameters the master WSD may use. This set of operational parameters will include several channels and the maximum power allowed in each channel. The master WSD will select the channels and powers to use and report this to the geolocation database as the channel usage parameters.

If a master WSD is part of a network comprising client WSDs, it will now be able to obtain operational parameters for its clients as follows. First, the master WSD will request generic operational parameters from the geolocation database. These are the channels and powers to be used by a generic client device within the coverage area of the master. Generic operational parameters are quite restrictive, as they are calculated making cautious assumptions about the client devices. For instance, the master WSD will assume that the client WSD could be anywhere in the coverage area of the master. The geolocation database will estimate the coverage area of the master, and subsequently, calculate the generic operational parameters.

Secondly, the master WSD will broadcast generic operational parameters. Client WSDs must listen to the master's broadcast before transmitting and decode the generic operational parameter information. They will use it for their initial transmissions to the master, to report their unique device identifier and possibly other device parameters.

The client WSDs could continue using the generic operational parameters for transmissions or could provide the master with location information for the determination of operational parameters. The master will then relay this information to the geolocation database, which would calculate operational parameters specific for a particular client. These specific operational parameters are less restrictive than generic operational parameters.

Regardless of whether the client WSD operates according to generic or specific operational parameters, the master WSD serving it will also have to report the channel usage parameters of the client WSD to the geolocation database from which it has obtained operational parameters.

3.10. Interference Management

While the coexistence rules are sufficient to ensure a low probability of harmful interference, the implementation of this framework includes procedures to enable the Authority to manage any interference that could occur based on the key elements below:

1) The geolocation databases will avail information to the Authority for resolution of any interference cases. This information includes the frequencies and radiated power of WSDs in a particular location and time. The Authority shall identify WSDs potentially causing interference and act accordingly.
2) The Authority may instruct databases to shut down any WSD following the Kenya Information and Communications Regulations (1998) and DSA framework for the use of TV white spaces.
3) For some geolocation databases, a portal for regulator could provide real-time access for monitoring and possible deactivation of non-conforming WSDs.

3.11. Adjustments to Maximum Transmit Power

The Authority shall specify the maximum power limits for a particular location and channels to the geolocation databases. This may be used to implement changes required in a particular area as may be determined by the Authority, based on a review of the coexistence calculations.

3.12. Requirements to Cease Providing Geolocation Database Services

The Authority may instruct a geolocation database to cease providing services for a specified period to any or all WSDs. The Authority may remove any database from the list of qualified databases for failure to comply with the rules for the use of TV white spaces.

3.13. Transmission in Compliance with Parameters

a) Operational parameters

A WSD is considered to be transmitting using operational parameters if:

- The WSD only transmits in DTT channels that are in the list of available channels provided by the relevant geolocation database.
- The WSD RF EIRP in each DTT channel does not exceed the maximum specified by the relevant geolocation database.
- The WSD RF EIRP spectral density in each DTT channel does not exceed the maximum EIRP spectral density specified by the relevant geolocation database.
- The Nominal Channel Bandwidth of each WSD nominal channel does not exceed the Maximum

Nominal Channel Bandwidth specified by a geolocation database.

- The Total Nominal Channel Bandwidth used by the WSD does not exceed the Maximum Total Nominal Channel Bandwidth specified by a geolocation database.
- The WSD transmission time is between the time validity start ($T_{ValStart}$) and the time validity end (T_{ValEnd}) specified by the relevant geolocation database.
- The estimated WSD location is less than L_{Val} away from the location reported to the geolocation database at the time the operational parameters were obtained from the relevant geolocation database.

b) Channel Usage Parameters

A WSD is considered to be transmitting using channel usage parameters if:

- The WSD only transmits in DTT channels that are in the list of channels described by the said channel usage parameters.
- The RF EIRP in each DTT channel does not exceed the intended level declared in the channel usage parameters.
- The RF EIRP spectral density in each DTT channel does not exceed the intended level declared in the channel usage parameters.

General Requirements

- A master WSD shall not start transmissions in the UHF TV band unless it has received operational parameters from a geolocation database.
- A client WSD shall not start transmissions in the UHF TV band unless it has received operational parameters, either generic or specific, from a master WSD.
- A master WSD shall, at any point in time, only transmit using operational parameters that it has received from a geolocation database.
- A client WSD shall, at any point in time, only transmit using specific or generic operational parameters received from a master WSD.
- A master WSD shall, at any point in time, only transmit using the channel usage parameters that it has communicated to a geolocation database.
- If a client WSD's usage parameters have been communicated to the geolocation database, then the client WSD shall transmit using the said channel usage parameters.
- Communication between two client devices is permitted provided that each WSD is operating using operational parameters given by its serving master WSD.

4. TV White Spaces Trials

4.1. Introduction

Due to the innovative nature of dynamic spectrum access and the complexity of coexistence calculations, the Authority authorised several technical trials. The first TV white space trial in Kenya was permitted in September 2013, when Microsoft East Africa was authorised to test the technology with Indigo Telecom for one year. Mawingu Networks was later issued with a similar trial from November 2014 to December 2015. The initial trials were conducted in static channel mode, with no integration of WSDs with a geolocation database.

The Authority did not authorise commercial operation at the time because no effective framework had been formulated to regulate secondary access to TV white spaces. At the time, the Authority prioritised the digital switchover as a matter of great public interest and was involved in protracted litigation regarding the use of the UHF TV band spectrum. Nevertheless, the Authority has been monitoring international and regional approaches to the formulation of sustainable spectrum sharing models to improve broadband access.

The Plan for VHF/UHF television broadcasting in the African broadcasting area and neighbouring countries was ratified in Geneva in 1989. This plan included technical criteria for the operation of analogue TV transmission in the UHF band 470 – 862 MHz. In 2006, the Geneva 2006 Plan was validated, paving the way for migration of terrestrial television broadcasting from analogue to digital format by 17th June 2015.

At the ITU-R WRC-15, a decision was made to maintain the primary allocation of the band 470-694 MHz to terrestrial TV broadcasting services until at least 2023 in ITU Region 1 on an exclusive basis (including Europe, the Middle East and Africa). The conference also rejected proposals to allocate the lower UHF band 470-694 MHz on a co-primary basis with mobile broadband services. This means that services other than broadcasting would be permitted to operate on a secondary basis in these bands.

The Authority received multiple requests to trial alternative deployments of TVWS networks within the DTT band. In November 2016, the Authority permitted the deployment of TV White Space networks by Broadcast Signal Distributors. Signet Signal Distributors and Pan Africa Networks Group were allowed to partner with telecommunications service providers to deploy TVWS networks.

Following initial trials, Signet Signal Distributors requested authorisation to carry out TV White Space trials using a different model. This alternative model entailed BSD's applying for assignment of unused/unassigned UHF TV spectrum in a given area, partner with a licensed operator to provide broadband services on a revenue share model over a fixed broadband wireless network on a non-protected and non-exclusive basis. Pan Africa Networks Group (PANG) were also issued trial authorisation to trial the same concept.

At the ITU level, no specific recommendations on the deployment of TV white space devices have been agreed and administrations are at liberty to determine a suitable approach for their jurisdiction while ensuring the protection of the primary service.

4.2. Trial Objectives

The Authority's objectives for the trials were:

a. To provide proof of concept, i.e. to understand whether the framework for implementing dynamic spectrum sharing using geolocation databases or spectrum sensing could be made to work in practice;

b. To undertake coexistence testing and ensure a low probability of harmful interference to DTT transmissions;

4.3. Trials Timeline

From 2013 to 2019, the Authority received multiple requests for authorisation of TV White Spaces technology. Initial proposals were analysed, and 4 licensees of the Authority were allowed to conduct TVWS trials under various models, with the Authority monitoring feedback and emerging challenges. Key components of the trials were:

a. **White Space Trials:** The first trial was issued in September 2013 and five more trials were authorised up until 2019.
b. **Framework Formulation:** Framework drafting began in June 2019 and will continue through the consultation phase and feasibility study being conducted until May 2020.

c. **Geolocation Database Qualification:** The Authority consulted several geolocation database providers who have been authorised to provide services by various administrations globally, they have been invited to participate in stakeholder consultations and two among them have supported trials and demonstrated capabilities and compliance to TVWS rules.

4.4. Geolocation Databases Verification

The trials provided the Authority with the opportunity to test the viability of third-party databases as a spectrum management tool, in controlled scenarios temporarily. Licensees who had been offered trial authorisations were open to engage geolocation database providers of their preference, whose databases comply with DSA rules, to demonstrate viability and performance of TVWS models. The approach is for licensees who have been authorised to deploy TVWS networks shall seek the services of any qualified database providers and pay for the use of services.

The database providers shall perform the necessary calculations based on data provided by the Authority to provide the relevant parameters to WSDs. The database providers shall also provide operational data to the Authority. A geolocation database shall be subjected to a qualification process before commencing operations. The objective of the qualification is to allow geolocation database providers to demonstrate that their geolocation databases meet the minimum requirements and rules for TVWS operation.

The Authority requires the following from the database providers:

a. **Declaration:** The database provider declares compliance with the requirements and provides relevant supporting documentation. This approach shall be used to verify the requirements such as security in the communications between the database and WSDs, record keeping and auditing, and data protection.

b. **Tests & Demonstration:** The database provider shall be required to run a series of test cases and demonstrate the results to the Authority. The database must receive and correctly incorporate DTT data and provide an interface for the Authority to query for operational parameters and logs.

4.5. White Space Trial Authorisations

Several operators were authorised to conduct renewable trials from September 2013. This has provided an opportunity for field tests to determine the interoperability of DTT, geolocation databases and WSDs in Kenya. These operators piloting TVWS technology were offered an opportunity to test their preferred use cases and test the technical capability and operational potential of their preferred WSDs. Trial scenarios were either a partnership between:

a. A Network Facilities Provider and a geolocation database provider, or
b. A Broadcast Signal Distributor and an NFP operator

The trials provided an opportunity for the Authority to determine a suitable framework and to better understand stakeholder interest in white space technology.

4.6. Operators, Databases and Device Partners during Trials

Table 4.1 summarizes the trials authorised in Kenya indicating operators and partners.

Table 4.1: Summary of White Space Trials

	Start (& Duration)	Operator	Affiliate Network Facilities Providers	Authorised Locations	Database Provider & Equipment Vendors	Outcome
1.	September 2013 (1 year)	Microsoft East Africa	Indigo Telecom	Kajiado and Laikipia	6Harmonics and Adaptrum	Trial Completed
2.	November 2014 (1 year)	Mawingu Networks	-	Laikipia	6Harmonics Adaptrum and Nominet	Trial Completed
3.	November 2016 (1 year)	Pan Africa Network Group Kenya	-	Countrywide	Static Model (No database)	Extension Requested
4.	November 2016 (1 year)	Signet Signal Distributors	Mawingu Networks	Countrywide	Static Model (No database)	Extension Requested
5.	March 2019 (6 Months)	Mawingu Networks	-	Embu	Adaptrum Redline and Fairspectrum	Trial Completed

The key considerations arising from the TVWS trials are:

a. The operation of geolocation databases,
b. The operation of WSDs, and interactions between WSDs and geolocation databases.

4.7. Trial Risks

Around the world, WSDs using TVWS are either license-exempt or lightly licensed, with varying requirements and rules of operation. The trial authorisations were similar to the unlicensed operation of WLAN systems on a temporary, non-protected and non-interference basis. The trials allowed operators to test various ways to determine the most appropriate framework while still limiting the risk of harmful interference. The primary risks during the trials were as follows:

a) **No regulatory framework**: TVWS standards for devices and databases were under formulation and the Authority had not determined a suitable framework.
b) **Risk of harmful interference**: There was a potential risk of harmful interference during trials though ultimately no incident of harmful interference by TVWS devices was detected or reported.

4.8. Geolocation Database Service Model

Two geolocation database providers supported the network operators conducting the trials and demonstrated their solutions. The database providers have submitted their views on the rules of database and WSD operation. Other stakeholders have also submitted their views on the qualification requirements for databases. White space network operators are allowed to select their preferred database service provider and meet their cost of operation. The option for the Authority to procure or develop a database during the trial was determined to be non-viable.

The requirements proved important in confirming that geolocation databases were able to provide services and manage the operation of WSDs with minimal risk of harmful interference to incumbent users. The two requirements for approaches to the qualification of Geolocation databases are:

a. **Declaration**: the geolocation database provider declares compliance with the requirements and provides relevant supporting documentation.
b. **Tests & Demonstration**: The geolocation database provider shall be required to run a series of test cases and demonstrate the results to the Authority and operator.

4.9. Transfer of data from the Authority to Geolocation Databases

The Authority implements a system that allows the transfer of data and notification of updates using a web-based platform. Geolocation databases shall be required to implement systems for data transfers using ETSI standard and PAWS protocol.

4.10. Geolocation of Devices

White Space devices (both master and client) shall be required to have geolocation functionality. Manually configurable master devices shall not be granted Type Approval, to limit the risk of harmful interference by transmissions from unauthorised devices, though client devices could be manually configurable.

4.11. Exchange of parameters between WSDs and Geolocation Databases

Master devices shall communicate their device parameters to the parent geolocation database and obtain operational parameters for their transmissions.

4.12. Interference Management

There were no reported or detected cases of harmful interference during any of the TVWS trials. While these trials were limited in scope and coverage, the Authority shall continue to conduct spectrum monitoring and resolve any future reported interference from the protected broadcasting service. The WSDs shall immediately cease transmissions upon reporting or detection of harmful interference as a result of their transmissions.

4.13. Objectives and Summary of Outcomes of TVWS Trials

The overall trial objectives were:

a. To provide a proof of concept for spectrum sharing viability in the UHF band.
b. To examine the possibility of coexistence between WSDs and DTT broadcasting services.
c. To allow operators, database providers and equipment vendors to test various models and use cases to support rural Internet access.

The trials provided insight towards the formulation of a framework for authorisation of the use of TV white spaces in Kenya. The trials further confirmed sufficient industry interest from network operators, supported by an ecosystem of database providers and equipment vendors, in using TV white spaces to improve rural broadband Internet access. Although the feasibility study is ongoing, the outcome of the completed trials was sufficient to develop the draft framework which shall be improved as relevant proposals are received.

4.14. Areas of Improvement of TVWS the Framework

The following areas of the framework may require further review:

a. **Database Qualification:** The testing of geolocation databases, including declarations, simulations and live testing against qualification is the most critical component in the pre-authorisation process to ensure optimal operation of WSDs.

b. **Device Compliance Testing:** As observed during the trials, the devices that have been granted type approval have demonstrated the capability to comply with the rules for the operation of WSDs. New models of the devices shall be evaluated under the equipment type approval regulations and follow a declaration, simulation and live-test procedure.

c. **Manual Configuration of Devices:** Some master devices require manual configuration to operate, including input of geographic coordinates and input of specific operational parameters. Such master devices are permitted under the TVWS framework.

d. **Data Transfer**: The aspects to be reviewed include data transfer procedures on the update of DTT activations, activation of WSD devices, RF spectrum utilisation and logs between:

- The Authority and geolocation database providers
- The Authority and network operators
- Geolocation database providers and network operators

5. Requirements for Devices Operating in TV White Spaces

5.1. Authorisation

Since 2013, the Authority has conducted assessments for possible authorisation of spectrum sharing in the UHF band for TVWS operation which has informed the formulation of technical and operational requirements described in section 3 of the framework. This section describes the operational and technical requirements for the use of WSDs in Kenya.

The Authority authorises lightly-licensed operation of WSDs in the UHF band on a secondary basis which permits the TVWS devices to operate on a non-protected and non-interference basis. The operation of Type Approved WSDs on a lightly licensed basis is unlikely to lead to harmful interference to DTT provided that the devices are controlled by a geolocation database approved by the Authority and comply with the technical and operational requirements.

5.2. Device Technical and Operational Requirements

Devices will need to comply with minimum technical and operational requirements to mitigate the risk of harmful interference under a license exemption regime. Compliance with the requirements in the ETSI Standard is the primary way of ensuring compliance with the regulatory requirements for license-exempt authorisation of WSDs.

5.3. Transmitter Unwanted Emissions

These are unwanted emissions from a WSD outside the nominal channels (out-of-block) within the 470 MHz to 694 MHz band when the WSD is in the transmit mode. The out-of-block EIRP spectral density, P_{OOB}, of a WSD shall satisfy the following limit:

P_{OOB} (dBm / (100 kHz)) ≤ max{ P_{IB} (dBm / (8 MHz)) - ACLR (dB), - 84 (dBm / (100 kHz)) }

where P_{IB} is the measured in-block EIRP spectral density over 8 MHz, and ACLR is the adjacent channel leakage ratio for different Device Emission Classes outlined in Table 5.1. Each out-of-block EIRP spectral density is examined in relation to P_{IB} in the nearest (in frequency) DTT channel used by the WSD. Where there are two nearest (in frequency) DTT channels used, the one with the lower P_{IB} shall be considered.

Table 5.1: Adjacent Channel Leakage Ratios (ACLR (dB)) for different Device Emission Classes

Δf	n= ±1	n= ±2	n= ±3	n= ±4
Class 1	55	60	65	68
Class 2	55	55	55	64
Class 3	45	55	65	68
Class 4	35	45	55	64
Class 5	24	34	45	55

Where P_{OOB} falls within the n^{th} adjacent DTT channel (based on 8 MHz channels)

5.4. Device Communication with a Geolocation Database

These devices communicate the information necessary for a database to be able to calculate the frequencies and powers at which a WSD may transmit to avoid harmful interference to other spectrum users and to ensure that the database obtains from devices the information necessary for interference management purposes. These requirements can be summarised as follows:

a. A master WSD shall only transmit using parameters that it has received from a geolocation database that has been qualified by the Authority.

b. A client WSD shall only transmit using parameters that it has received from a master WSD and shall not operate independently.

c. A master WSD or a client WSD that requires specific operational parameters from a geolocation database must report certain specific characteristics ('device parameters') to the geolocation database.

d. A client WSD that intends to use the generic operational parameters broadcasted by a master must report its unique identifier.

e. A WSD must report back to the database the actual channels and powers it intends to use (referred to as the 'channel usage parameters') and the WSD must only transmit using the channels and powers it reports to the database.

5.5. Device Characteristics and Parameters

Several parameters shall be required by a geolocation database to identify devices and determine the appropriate operational parameters consistent with the ETSI EN 301 598 v2.1.1 Standard. These parameters will be selected from a predefined set of values and shall be declared by the manufacturer:

a) Device Category

A master is a primary device able to communicate with a qualified geolocation database and obtain operational parameters. A client is a secondary device that can only operate under the control of a master WSD.

b) Device Type

Under the ETSI Standard, a type-A device is a WSD intended for fixed use only. This type of equipment can have integral/internal or external antennas. A type B WSD is not intended for fixed use and has an integral antenna or a dedicated antenna.

c) Unique Identifier

This identifies a specific WSD that will allow the database to log which devices are using particular channels and powers at any given time. The unique identifier shall be declared by the manufacturer and consist of the unique serial number of a WSD, the WSD's model number and the identifier of the device manufacturer.

d) Device Emission Class

Devices may report their emission class to a database for use in calculating operational parameters. For devices that do not report their emission class, the database will provide default operational parameters based on the ETSI EN 301 598 Standard. The characteristics of device operation are described in Table 5.2.

Table 5.2: Device Parameters

Parameter Name	**Description**
Antenna location	Latitude and longitude coordinates and altitude, e.g. in WGS84 format [i.14].
Antenna location uncertainty	Latitude, longitude, and altitude uncertainties specified as ±Äx, ±Äy and ±Äz metres respectively, corresponding to a 95 % confidence level.
Device type	Type A or Type B.
Device category	Master or client.
Unique device identifier - Manufacturer identifier	A set of characters representing the IEEE™ Organisationally Unique Identifier (OUI) of the manufacturer, or the Universally Unique Identifier (UUID).
Unique device identifier - Model identifier	A set of characters representing the manufacturer's model number or some identifier to identify the product family.
Unique device identifier - Serial number	A set of characters representing an identifier unique to a device from a specific manufacturer.
Technology identifier	A set of characters that uniquely identifies the technology including: ● the organisation responsible for technical specifications; ● specification number, version and issue date.
Device Emission class	Class 1, Class 2, Class 3, Class 4 or Class 5. The device emission class number reported by the WSD to the geolocation database is the Class with which the device complies as specified in Table 5.1.
Spectral mask improvement	Improvement, $\Delta ACLR(n_{IB}, n_{OOB}) \geq 0$ dB, in adjacent channel leakage ratio, as a function of the out-of-block DTT channel index, n_{OOB} (21 to 48), and the nearest in-block DTT channel index, n_{IB} (21 to 60). The improvement is in relation to the ACLR of the device emission class (see Table 5.1) reported by the WSD. Where $\Delta ACLR$ is not reported for a certain (n_{IB}, n_{OOB}) combination, the geolocation database will assume that $\Delta ACLR = 0$ dB. Note that the ACLRs cannot be smaller than the values specified for the most relaxed device emission class.
Reverse intermodulation attenuation improvement	The reverse intermodulation attenuation improvement $\Delta RIM3(P_{IBk}) \geq 0$ dB, as well as PIBk where: $\Delta RIM3(P_{IBk}) = RIM3(P_{IBk})$ - 45 dB and for k different in-block power levels, P_{IBk} is a specific (k^{th}) in-block power level.

5.6. Operational Parameters

Operational parameters are generated by a geolocation database and provide operational instructions to a WSD, including the frequencies and powers that a WSD must use, that is:

a. The lower and upper-frequency boundaries within which a WSD may transmit.
b. The maximum permitted EIRP spectral density.
c. Limits on the maximum total number of DTT channels that may be used.
d. The period during which the operational parameters are valid.
e. The geographical area within which the operational parameters are valid.
f. The period within which a master device must check with a geolocation database that the operational parameters being used are still valid.

Operational parameters for client WSDs from the geolocation database are communicated via the serving master WSD. The operational parameters may be communicated to the client WSD by the master WSD either as a single set of parameters or a series of sets of parameters. Operational parameters are outlined in Table 5.3.

Specific operational parameters are operational parameters that a geolocation database calculates using the device parameters of a specific WSD as input. A geolocation database will only provide specific operational parameters for a WSD if it has received the device parameters of that WSD.

Generic operational parameters are the operational parameters that any client WSD in the coverage area of a serving master WSD can use. A geolocation database will provide generic operational parameters to a master WSD, and the master will broadcast these parameters for all client WSDs in its coverage area. The geolocation database will calculate generic operational parameters using, as input, the device parameters of the master WSD and a set of assumptions about the client WSDs.

NOTE: The algorithms to calculate operational parameters and the assumptions for these calculations are attached as an annex.

Table 5.3: Operational Parameters

Parameters	Description
Lists of DTT channel edge frequency pairs	This is the list of frequency blocks where the WSD is allowed to transmit. The ith lower channel edge frequency, f_L, i will be specified as (470 + 8ki) MHz, with the corresponding ith upper channel edge frequency, f_U, i specified as (470 + 8ki + 8) MHz, where 0 ≤ ki ≤ 39.
Maximum in-block RF EIRP spectral density for each DTT channel edge frequency pair	P_0, i (dBm / (0,1 MHz)) over the frequency interval f_L,i to f_U,i.
Maximum in-block RF EIRP for each DTT channel edge frequency pair	P_1, i (dBm) over the frequency interval f_L,i to f_U,i.
Maximum nominal channel bandwidth	Maximum contiguous bandwidth (in Hz) allowed.
Maximum total bandwidth	Maximum total bandwidth (in Hz) allowed which may or may not be contiguous.
Time validity start ($T_{ValStart}$)	The time when the operational parameters start being valid.
Time validity end (T_{ValEnd})	The time when the operational parameters stop being valid. Alternatively, for client WSDs, the serving master may indicate time validity by a permitted duration of operation, specified as T_{Dur} seconds instead of the pair $T_{ValStart}$ and T_{ValEnd}.
Location validity (L_{Val})	Radius (in metres) of the circle centred on the reported location of the WSD, outside of which the operational parameters are not valid.
Simultaneous channel operation power restriction (see note 2)	Can take values of 0 or 1. A value of 1 indicates the device that the power restriction applies, a value of 0 indicates that the power restriction does not apply. The default value is 0.
Update timer (T_{Update})	This timer indicates how often (in seconds) the master WSD shall check with the geolocation database that the operational parameters are still valid.
NOTE 1: The geolocation database specifies the maximum permitted in-block EIRP spectral density, P_0 (dBm in 0,1 MHz), and the maximum permitted RF EIRP, P_1 (dBm), that the WSD can use in each DTT channel.	

5.7. Channel Usage Parameters

A WSD shall report channel usage parameters to a geolocation database of the actual operating frequencies and powers, the parameters will include; location, the lower and upper-frequency boundaries and the maximum in-block EIRP spectral density. Table 5.4 outlines the channel usage parameters.

Table 5. 4: Channel usage parameters

Parameters	**Description**
List of lower and upper DTT channel edge frequencies within which a WSD intends to transmit	The i^{th} lower and upper edges shall be specified, respectively, as: f_L,i = (470 + 8ki) MHz, and f_U,i = (470 + 8ki + 8) MHz, where 0 ≤ ki ≤ 39.
In-block EIRP spectral density which a WSD intends to use within each DTT channel	Specified as P_0,i (dBm / 0,1 MHz) over the frequency interval f_L,i to f_U,i.
In-block EIRP which a WSD intends to use within each DTT channel	Specified as p1, i (dBm) over the frequency interval f_L,i to f_U,i.

The channel usage parameter p_0, i is the peak EIRP value in dBm that the WSD shall not exceed in any 100 kHz bandwidth within channel i.

5.8. The requirement to Cease Transmissions

In the event of harmful interference, the Authority shall request a geolocation database to instruct devices to cease transmissions, according to the conditions of database qualification. A master WSD will be required to verify with the serving geolocation database that its operational parameters are valid, within the period indicated by the geolocation database. If a master WSD is not able to verify that the operational parameters it is using are still valid, then the master WSD must cease transmission and instruct all client WSDs that it controls to stop transmissions. A client WSD must cease transmissions when instructed to do so by its master WSD.

6. TV White Spaces Spectrum Fees

6.1. Approach to Charging and Cost Recovery

A dynamic spectrum access framework requires regulatory infrastructure, unlike traditional spectrum sharing by WLANS and short-range devices in unlicensed bands. Several of the issues around the costs involved based on a model that requires the following data exchanges between participants:

a. The DTT BSDs submit requests for additional spectrum assignment and the Authority issues assignments with specific parameters.
b. The Authority updates the spectrum management system and the data is updated on a portal available to qualified geolocation databases.
c. The database executes algorithms to determine whether the available spectrum is suitable for TVWS applications.
d. The database instructs a WSD to transmit on updated parameters or cease transmissions.
e. The Authority receives any reports of interference for resolution.

The Authority shall engage in additional regulatory tasks including selection, qualification and regulation of databases, and update of DTT data on a portal to allow calculation of TVWS availability. Further, the Authority will review algorithms and monitor the accuracy of third-party geolocation databases. Although making spectrum available to WSDs shall not increase the risk of interference to DTT service if the coexistence framework is adhered to, there shall be an increase in the enforcement costs to the Authority of detecting and resolving interference.

The Authority shall determine an appropriate fee for spectrum utilisation by TVWS applications. Database providers will also incur costs in setting up their systems and responding to WSDs' requests. The prevailing frequency spectrum fee schedule is inadequate to cater for dynamic spectrum access and new concepts shall be considered by the Authority, in due course, including geographical zones determined by population density. The Authority adopts an applicable spectrum usage fee consistent with the frequency spectrum fee schedule and Kenya Information and Communications (Radio Communications and Frequency Spectrum) Regulations, 2010.

Under the prevailing frequency spectrum fee schedule, TVWS applications are classified under Non-Protected Wireless Access Systems and each **Master** white space device shall attract an annual fee. The applicable spectrum fee shall be subject to periodic review by the Authority under the Regulations. Further, the Authority shall determine the database access fee payable by a network operator to a database service provider in the course of implementation of the framework.

6.2. Charging Framework

A long-established framework for analysing issues around charging and cost recovery in regulation is in the form of the six principles of cost recovery:

a. **Cost causation**: costs should be recovered from those whose actions cause the costs to be incurred;
b. **Cost minimisation**: the mechanism for cost recovery should ensure that there are strong incentives to minimise costs;
c. **Effective competition**: the mechanism for cost recovery should not undermine or weaken the pressures for effective competition;
d. **Reciprocity**: where services are provided reciprocally, charges should also be reciprocal.
e. **Distribution of benefits**: costs should be recovered from the beneficiaries especially where there are externalities; and
f. **Practicability**: the mechanism for cost recovery needs to be practicable and relatively easy to implement.

6.3. Costs Incurred by the Authority

Cost recovery considerations are as follows:

a. **Cost causation**: The costs are incurred for the benefit of a specific group of WSD operators. It would, therefore, be more efficient for the operators to bear the costs;
b. **Cost minimisation**: The Authority shall ensure any of its costs are efficiently incurred including in the qualification and monitoring of geolocation databases accuracy;
c. **Effective competition**: If database providers and/or WSDs face the cost of making the spectrum available this should help to prevent inefficient market entry (too many database providers/WSDs). However, the costs should not be prohibitively high to discourage efficient entry so as not to undermine efficient competition;
d. **Practicability**: The Authority shall specify fee tariffs in the database authorisation mechanism. In any case, efficient charging shall ensure that there is no over-recovery and that the charges match the underlying cost structure;
e. The Authority considers that since the spectrum has been allocated for use by the DTT on a primary basis, then DTT is the higher value use of the spectrum;

f. **Hindrance of development of the market**: a high cost for WSD users to access geolocation databases could harm the development of the market. The Authority shall monitor deployment progress for a period at the start of TVWS operation and review the charges as the band becomes established.

The authority shall determine spectrum fees to ensure an efficient degree of use and implement the framework to ensure costs are efficiently incurred.

6.4. Costs Incurred by the Geolocation Database Provider

Cost recovery considerations are as follows:

a. **Cost causation**: The WSD operational parameters are computed for the benefit of WSD operators who shall pay to access the data from their preferred database.
b. **Cost minimisation**: Competition between database providers would ensure their costs are competed down to the efficient level, both in the short term and over time, and also provides an additional spur to increase the quality of service.
c. **Effective competition**: The costs passed on to WSDs should not be so high as to prohibit efficient deployment. They should also not be set to unduly discriminate between different WSDs such that competition is distorted.
d. **Practicability**: The Authority may not explicitly state how a database provider chose to charge for its services (per request, annual subscription fee, etc.) as this would be part of the business model it chose to deploy.

The Authority shall allow database providers to charge WSD users for access to their databases. Competition between database providers would ensure costs are efficiently incurred and ensure minimal distortion of competition in the market for WSD users.

7. White Space Devices Coexistence Considerations

7.1. Approach to Coexistence

The band 470-694 MHz is allocated to the broadcasting service, which is protected from harmful interference from secondary services or adjacent mobile services. To manage coexistence, restricting the maximum allowed power at which a WSD can transmit in each frequency shall reduce the probability of harmful interference to DTT by the WSDs.

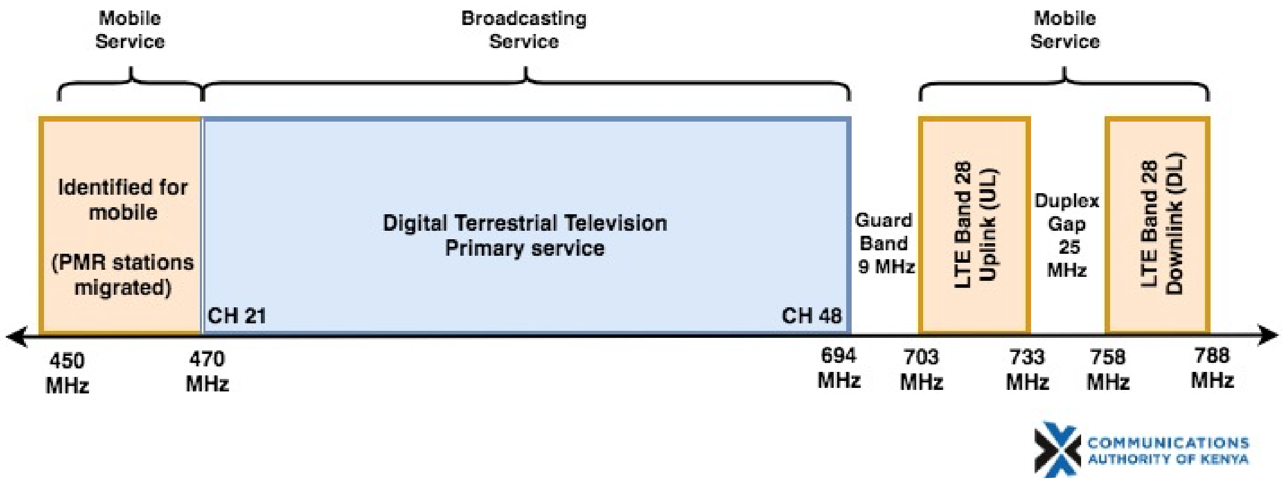

Figure 7.1: Illustration of UHF band Coexistence of Services

Figure 7.1 indicates DTT primary band coexistence with services in adjacent bands. To ensure that existing users are protected, the geolocation databases will be required to apply the coexistence approach summarised in Table 7.1 and provided in detail in the coexistence rules as an annex.

Table 7.1: Summary of approach to coexistence

Existing use type	Approach
Broadcasting Service	Maximum power limits required to protect broadcasting service, WSD powers will be limited on channels for WSDs close to DTT transmissions.
Broadcasting Service (Neighbouring Countries)	Maximum power limits required to protect services in other countries are generated around the borders of Kenya
Mobile Service 450 - 470MHz	Maximum power limits generated for WSD to limit out of band emissions.
Mobile Service 700 MHz	The existing 9 MHz guard band ensures no interference from WSDs

A DTT transmitter is primarily able to cover a particular area, although there are areas of overlapping coverage served by more than one DTT transmitter. The Authority shall improve existing information on actual transmitter usage in the spectrum management database to ensure an accurate base for the DTT co-existence calculations. The predictions of multiple transmitter availability shall inform the process of gathering information on actual transmitter usage. For the TVWS framework, the Authority has incorporated data on actual & simulated transmitter usage on the spectrum management database to calculate TVWS availability and generate maps and figures.

Some uncertainty around the locations of WSDs is expected because GPS measurements on devices have a margin of error, which devices will report to the geolocation database. Client devices may not have GPS or other means to report locations (and their masters must report their locations). For these cases, power limits are calculated to ensure that even where a WSD is in very close proximity to a DTT aerial, there would still be a low probability of harmful interference to DTT reception.

Adequate measures have been taken to ensure a low probability of harmful interference to users above and below the band, and neighbouring countries within the band. For a given WSD, the framework will need to ensure a low probability of interference both for DTT receivers that may be near to it and for those which may be far away, using different approaches to each as follows:

a. **Mobile Service above 694 MHz**: The 700 MHz band (703 to 788 MHz) is allocated to the mobile service. This band is separated by a 9 MHz guard band to ensure a low probability of harmful interference from other services;
b. **(Future) Mobile Services below 470 MHz**: Frequency range 450 MHz - 470 MHz is identified for mobile broadband, although it was previously used for Private Mobile Radio applications (PMR) which have mostly been migrated. Adequate protections have been incorporated to restrict out of band emissions following the ETSI standard.
c. **Cross-border implications**: The band 470-694 MHz is in use primarily for TV broadcasting service, in neighbouring countries. The rules shall ensure the use of WSDs in Kenya will not cause harmful interference to the neighbours.

Kenya is a party to the GE06 Plan (which is part of the Geneva 2006 (GE06) Agreement). The objective of the plan is to protect DTT services in signatory countries by ensuring cross border emissions do not exceed certain levels. These emission levels can be relatively high if they are subject to coordination agreements: typically, a neighbouring country is likely to allow higher emissions into some channels if emissions are restricted to specific locations where these channels are not being used for DTT.

Administrations can request additional DTT requirements to those registered in the GE06 Plan, but they must operate below a specific coordination trigger field strength level if they wish to proceed without a coordination agreement. If this level is exceeded international coordination agreement(s) are required to protect existing broadcast services. If emission levels are considered low and unlikely to cause interference, such coordination is not required. The GE06 Plan specifies the trigger field strength levels, listed in table 7.2, for the protection of broadcasting services:

Table 7.2: GE06 co-ordination trigger levels

Broadcasting System	Trigger Field Strength (dB(µV/m))	
	Band IV - CH's 21-34 (470-582MHz)	Band V - CH's 35-51 (582-718MHz)
DVB-T	21 dBµV/m	23 dBµV/m

If these levels are exceeded, international coordination is triggered. Affected administrations analyse each case to determine any incompatibilities with registered services and in most cases the negotiation results in agreeing to levels of field strengths acceptable to both parties. WSDs have no official internationally recognised frequency plan or treaty to govern registration, deployment, interference potential and the requirement for coordination, but Kenya is internationally bound by the GE06 treaty to ensure that its neighbouring countries' DTT services do not suffer harmful interference from its secondary services.

While the trigger field strength levels were determined for managing DTT to DTT interference, the values are a base for determining power levels for WSDs at any location and channel such that the GE06 international coordination trigger thresholds are not exceeded in our neighbouring countries.

7.2. White Space Availability

There are different ways in which TVWS can arise at any given location. Nonetheless, the amount of spectrum available in the form of TVWS can vary significantly across different locations and will depend on various factors including geographical features, the level of interference potential to the incumbent TV broadcasting service. TVWS availability can be categorised as follows:

a. **Frequency**: idle channels of a TV band plan in some geographical areas due to interference avoidance techniques, using frequency separation (guard channels).
b. **Height**: defines the availability of TVWS at a given area in terms of the height of the TVWS transmission site and its antenna height, with surrounding TV broadcasting coverage reception. Basically, the higher the TVWS transmission site/antenna, the higher the likelihood of interference to TV receivers.
c. **Space**: geographical areas that are outside the current TV coverage and therefore no broadcasting signal is currently present. Also, those geographical separation areas (planned) between locations using the same TV channels.
d. **Time**: TVWS could become available when a broadcasting emission is off-air; hence the licensed broadcasting transmitter is not using the assigned frequency channel during a specific period.

Some illustrative information on the likely TVWS availability under the framework is provided in this section. In particular, the simulations have been generated using the tools available to the Authority and shall be improved with qualified geolocation databases.

The framework allows considerable flexibility in the type of deployment that could be undertaken as it accommodates different devices with varying classes of emission and antenna heights. The potential use cases for WSDs are wireless access points for client devices including broadband applications and base stations for a rural broadband network. TVWS availability varies significantly depending on the location of the WSDs because the strength of the signal of the DTT networks is different at various locations.

The potential TVWS availability in the selected geographical areas takes account of the required rules to implement the coexistence, location restrictions and cross border restrictions. Figure 7.2 below gives an example of available TV channels in Kitui Town. The gaps in the table indicate channels, which could potentially accommodate WSDs.

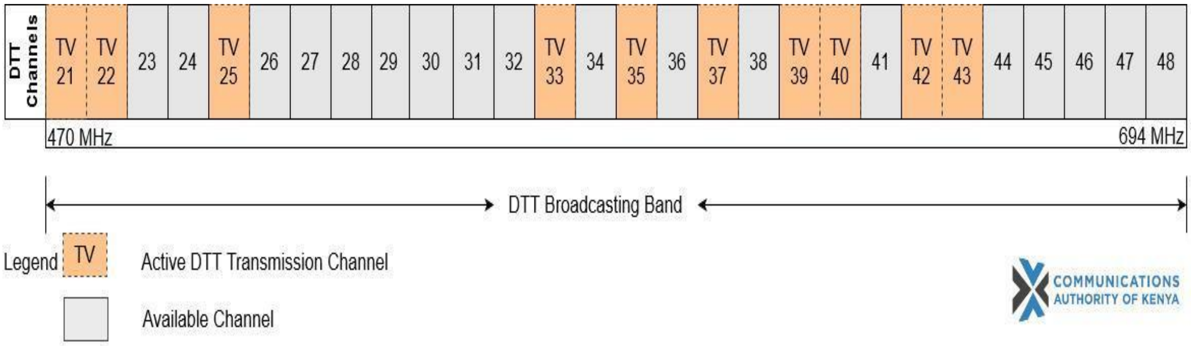

Figure 7.2: **Example of available TV White Spaces in Kitui**

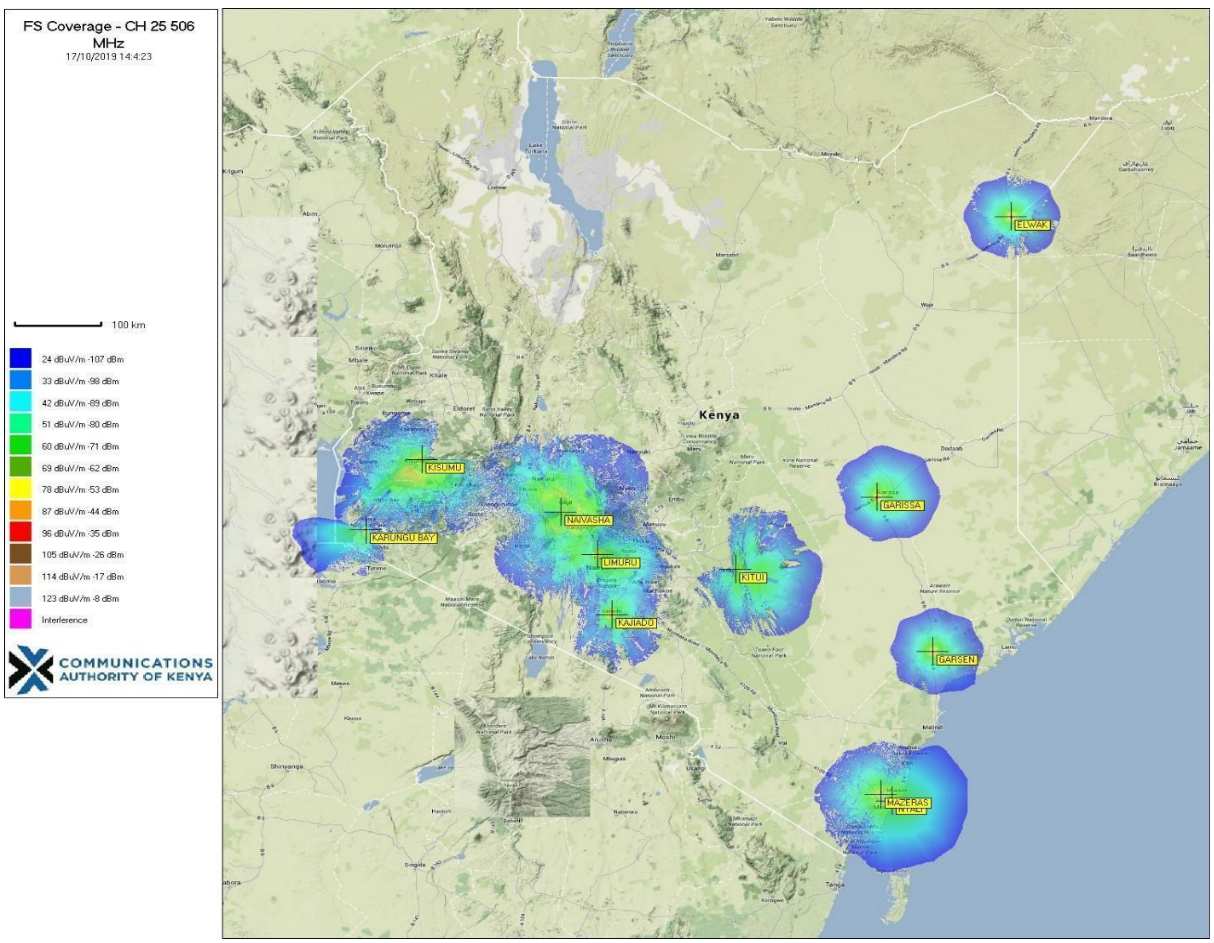

Figure 7.3: Active DTT Transmissions on CH 25 spectrum and available TVWS

Figure 7.3 above is a field strength coverage map that displays the potential 'white space' for a given DTT channel (channel 25, 502-510 MHz). High power DTT transmissions on a co-channel basis naturally need their coverage areas to be separated to reduce harmful interference. The blue edged polygons indicate the approximate coverage areas of DTT transmissions in channel 25 while the unshaded areas indicate the ‘white spaces’ for channel 25 in Kenya.

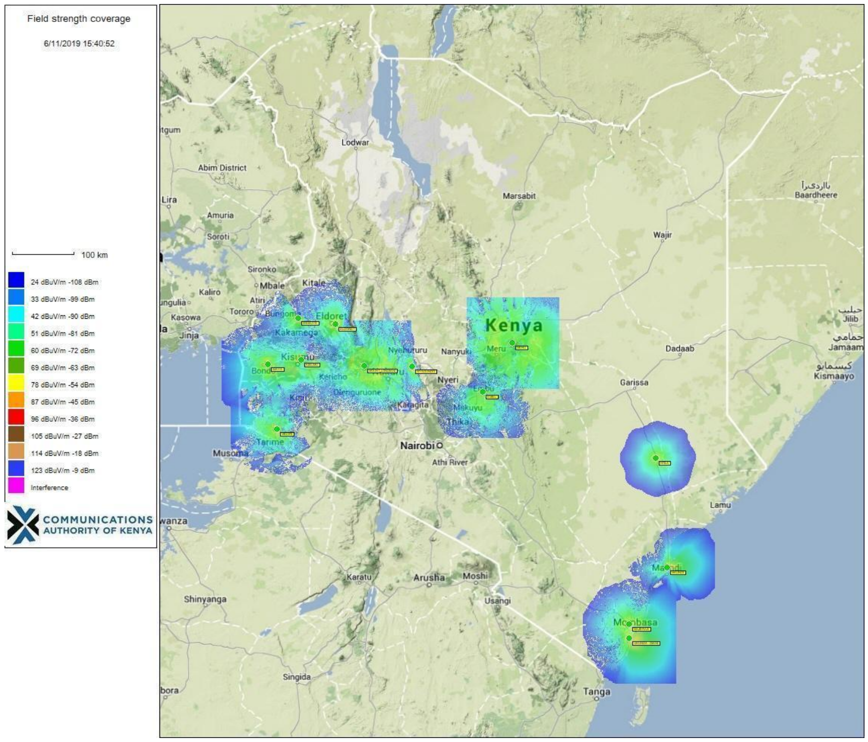

Figure 7.2: Active DTT Transmissions on CH 34 spectrum and available TVWS

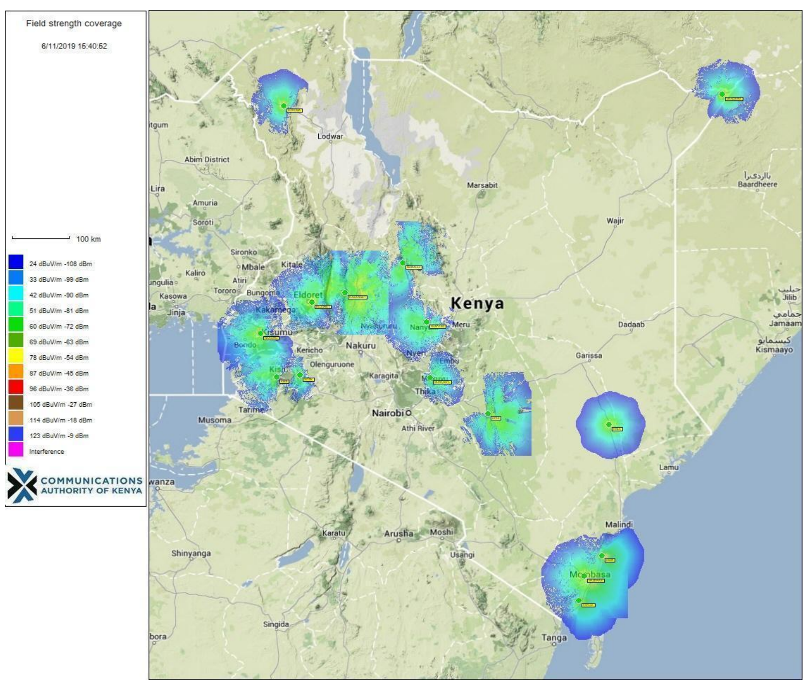

Figure 7.3: Active DTT Transmissions on CH 40 spectrum and available TVWS

8. Implementation of the DSA Framework for use of TV White Spaces

8.1. General

The Authority has taken several steps towards the implementation of the TVWS framework, including a joint feasibility study, planning for qualification of databases and the determination of applicable spectrum utilisation fee by master devices.

a. **Devices**: The technical and operational conditions for authorisation of WSDs on a lightly licensed basis are attached as an annex and are consistent with the Authority's spectrum management regime.
b. **Databases**: To implement the TVWS framework the Authority will undertake the process of qualification of geolocation databases. The process will involve:
   - Consultation on technical requirements including data exchange.
   - The payment/subscription model for interested operators to databases.
   - Qualification of databases involving demonstrations and end-to-end testing.
c. **Spectrum fee**: The Authority shall periodically review the currently applicable spectrum usage fee for master WSDs, this cost shall be consistent with the frequency spectrum fee schedule and Kenya Information and Communications Regulations, 2010.

8.2. Future Developments

Dynamic spectrum access presents an alternative method to manage underutilised spectrum to provide connectivity in rural areas. Spectrum sharing techniques have undergone research and development and are poised to be a prominent feature in 5G ecosystems. A more comprehensive framework shall be formulated to meet the Authority's objective of ensuring efficient use of radio frequency spectrum resource.

This document has explained the Authority's approach to spectrum sharing in the UHF band though practical applications will change in due course and the Authority shall continually engage stakeholders over the evolution of the framework following the Authority's strategic plan objectives. The implementation of the framework will split the function of calculating available channels operational parameters between the Authority and qualified geolocation databases.

8.3. Testing

Testing shall be conducted on the mechanisms and processes the Authority shall use to communicate with geolocation databases to verify suitability for TVWS implementation and to understand whether any amendments or improvements to processes may be necessary or desirable for the operational solution. The testing shall cover the following areas:

a. Transfer of data from the Authority to geolocation databases.
b. WSD Device authorisation procedures by geolocation databases.
c. Listing of qualified geolocation databases on the Authority's website.
d. Interference management procedures, including verification of the protocols through which geolocation databases do the following:
    - Communicate with WSDs.
    - Accurately report operational WSDs location and parameters.
    - Interface with the Authority.
    - Effectively activate and deactivate WSDs.

Before the network deployment by an operator, the Authority shall conduct tests of WSDs communications under the control of a geolocation database and assess compliance to the framework. The framework for TVWS shall be continually improved to incorporate the impact of multiple activated WSDs in the event their numbers become significant and cause a change to the emissions assessment model.

8.4. Feasibility Study

This work was subjected to a feasibility study conducted from January 2020 to May 2020 to confirm the viability of the framework through comprehensive stakeholder consultation and survey on select sites adding onto the previous TVWS trials. The feasibility study comprised a validation exercise with stakeholder engagements on TVWS authorisation in Kenya. Surveys on the spectral opportunity of TVWS were conducted in three rural counties in Kenya. These counties included Kisumu, Kitui and Laikipia. The objectives of the feasibility study were:

a. To provide a platform for stakeholder engagement on spectrum sharing solutions and validation of the framework.
b. To conduct a field survey on technical aspects of spectrum sharing in the UHF band.
c. To evaluate practical opportunities, project the impact, estimate the value and provide recommendations regarding the suitability of spectrum sharing in the UHF TV band.

The study was conducted in two parts as indicated below:

1. **Part I:** Assessment and validation of the Dynamic Spectrum Access (DSA) framework for TVWS. This involved the following:
    a. Stakeholder engagement on the draft framework.
    b. Analysis of existing spectrum gaps for rural Kenya.
    c. Assessment of spectrum sharing opportunity for rural Kenya.
2. **Part II:** Site Surveys at sampled Sites in rural Kenya. This involved the following:
    a. Site survey in 3 rural counties on the viability of spectrum sharing in the UHF band.
    b. Determination of actual utilisation of UHF band for DTT broadcasting in 3 counties.
    c. Assessment of opportunity and impact of spectrum sharing.

9. Bibliography

The following standards and reference documents were in the drafting of the framework.

1. ECC Report 186: Technical and operational requirements for the operation of white space devices under geo-location approach
2. IETF PAWS RFC 7545: IETF Protocol to Access White Space Databases
3. ETSI EN 301 598 v2.1.1: White Space Devices (WSD); Wireless Access Systems operating in the 470 MHz to 790 MHz frequency band;
4. ECC Report 159: Technical and operational requirements for the possible operation of cognitive radio systems in the 'white spaces' of the frequency band 470-790 MHz
5. ECC Report 185: Complimentary Report to ECC Report 159.Further definition of technical and operational requirements for the operation of white space devices in the band 470-790 MHz
6. ETSI TR 102 907: Use Cases for Operation in White Space Frequency Bands
7. ETSI TS 102 946: System requirements for Operation in UHF TV Band White Spaces
8. ETSI TS 103 145: System Architecture and High-Level Procedures for Coordinated & Uncoordinated Use of TV White Spaces
9. ETSI TS 103 143: System architecture for information Exchange between different Geo-Location databases enabling the operation of White Space Devices (WSDs)
10. ETSI EN 303 144: Parameters and procedures for information exchange between different GDBs
11. RFC 7545: The Internet Engineering Task Force, Protocol to Access White Space Databases
12. ETSI EN 303 387: Signalling Protocols and information Exchange for Coordinated use of TV White Spaces;
13. ECC Report 132: Light Licensing, License-Exempt and Commons
14. IEEE 802.19.1-2014: Standard for Information technology- Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - TV White Space Coexistence Methods
15. IEEE 802.11af: Standard for Information Technology - Telecommunications & Information Exchange Between Systems - Local & Metropolitan Area Networks - Specific Requirements - Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications- TV White Spaces Operation

16. CEPT Report 24: "Technical considerations regarding harmonisation options for the Digital Dividend". A preliminary assessment of the feasibility of fitting new applications/services into the non-harmonised spectrum of the digital dividend
17. ETSI TR 103 231: White Space Devices (WSD); Wireless Access Systems operating in the 470 MHz to 790 MHz TV broadcast band; Information on web-listings of TV White Space Databases.
18. Dynamic Spectrum Alliance, Model Rules and Regulations for the Use of Television White Spaces v2.0, December 2017;
19. Federal Communications Authority, Amendment of Part 15 of the Commission's Rules for Unlicensed White Space Devices, FCC-19-24, March 2019
20. Final Acts of the Regional Radiocommunication Conference for the planning of the digital terrestrial broadcasting service in parts of Regions 1 and 3, in the frequency bands 174-230 MHz and 470-862MHz (RRC-06) Geneva, 15 May - 16 June 2006;
21. Independent Communications Authority of South Africa, Regulations on the use of Television White Spaces, v1, March 2018;
22. Office of Communications, United Kingdom, Implementing TV White Spaces, February 2015;
23. National Spectrum Agency, Colombia, Resolution on TV Whites Spaces, August 2017;

Annex I: Rules for use of TV White Spaces

1. Overview

The Communications Authority of Kenya has considered procedures adopted by other regulatory administrations and drafted rules for TVWS utilisation in Kenya. The rules for the use of TV white spaces contemplate that available frequencies and maximum transmit powers for a white space device (WSD) at a given location shall be determined based on a geolocation and database method. In particular, database(s) qualified by the Authority will provide this information based on the location of the requesting white space devices, and spectrum use by licensed broadcast signal distributors and self-provision broadcasters near the geographic area of operation of the WSD.

A database shall supply a list of available frequencies and permitted maximum to transmit powers to white space devices according to the rules which further specify the method by which a geolocation database provider uses input data to compute available frequencies and maximum power limits for WSDs. To reliably protect DTT transmission and reception, this method requires a model for computing the propagation loss of VHF and UHF radio signals over irregular terrain to compute the field strength of a television signal at a particular geographic location. The Authority has adopted the ITU-R Recommendation P-1812, a path-specific propagation prediction method for point-to-area terrestrial services in the VHF and UHF bands for computation of propagation loss.

2. Key Terms

a) **Available frequency**: Radiofrequency channel that is not being used by an authorised service at or near the same geographic location as the WSD and is acceptable for use by a WSD device at a maximum transmit power indicated by a database.

b) **Client device**: A personal/portable WSD that does not use an automatic geolocation capability and access to a geolocation database to obtain a list of available frequencies. A client device must obtain a list of available frequencies on which it may operate from a master device. A client device may not initiate a network of fixed and/or personal/portable WSDs nor may it provide a list of available frequencies to another client device for operation by such a device.

c) **Contact verification signal**: An encoded signal broadcast by a master device for reception by client devices to which the master device has provided a list of available frequencies for operation. Such signal is to established in that, the client device is still within the reception range of the master device for purposes of validating the list of available frequencies used by the client device and shall be encoded to ensure that the signal originates from the device that provided the list of available frequencies. A client device may respond only to a contact verification signal from the master device that provided the list of available frequencies on which it operates. A master device shall provide the information needed by a client device to decode the contact verification signal at the same time it provides the list of available frequencies.

d) **Fixed device**: A master WSD that transmits and/or receives RF signals at a specified fixed location. A fixed WSD may select frequencies for the operation itself from a list of available frequencies provided by a geolocation database and initiate and operate a network by sending enabling signals to one or more fixed WSD and/or personal/portable WSDs.

e) **Geolocation capability**: The capability of a WSD to determine its geographic coordinates in WGS84 format. This capability is used with a geolocation database approved by the Authority to determine the availability of frequencies at a WSD's location.

f) **Geolocation database**: It is capable of determining available frequency channels at a specific geographic location and provides lists of available frequency channels to WSDs. Geolocation databases that provide lists of available frequencies to WSDs must be authorised by the Authority.

g) **Master device**: A fixed or personal/portable WSD that uses a geolocation capability and access to a geolocation database, either through a direct connection to the Internet or through an indirect connection to the Internet by connecting to another master device to obtain a list of available frequencies. A master device may select a frequency range from the list of available frequencies and initiate and operate as part of a network of WSDs, transmitting to and receiving from one or more WSD. A master device may also enable client devices to access available frequencies by:

i. Querying a database to obtain relevant information and then serving as a database proxy for the client devices with which it communicates; or;

ii. Relaying information between a client device and a database to provide a list of available frequencies to the client device.

h) **Network initiation**: The process by which a master device sends control signals to one or more WSDs and allows them to begin communications.

i) **Operating frequency**: An available frequency used by a WSD for transmission and/or reception.

j) **Personal/portable device**: A WSD that transmits and/or receives RF signals either at unspecified locations or at specified locations that may change.

3. Permissible Frequencies of Operation

a) White space devices ("WSDs") are permitted to operate on a non-protected basis subject to the interference protection requirements outlined in these rules.

b) WSDs shall operate in the UHF band 470-694 MHz on a non-protected and non-interference basis

c) WSDs shall only operate on available frequencies determined according to the co-existence and interference avoidance mechanisms.

d) Client WSDs shall only operate on available frequencies determined by the database and provided via a master WSD according to article 2(f).

4. Geo-location and Database Access

a) A WSD shall rely on the geo-location and database access mechanism described in this section to identify available frequencies.

b) Fixed WSD geolocation determination.

1. The horizontal geographic coordinates of a fixed WSD must be provided, as latitude and longitude (WGS84), and shall be determined to an accuracy of ± 50 meters by automated geolocation at a confidence of ≥95%.

2. The vertical geolocation (height) of the antenna of a fixed WSD must be reported and shall be determined by automated geolocation. Height shall be measured above ground level (WGS84 datum). The device shall report the vertical accuracy of its geolocation capability (e.g., ± 5 meters) at a confidence of ≥95% to the database.

3. A fixed WSD may report whether its antenna is situated outdoors or indoors; if it does not report its situation it will be assumed to be outdoors.

4. The geographical coordinates of a fixed WSD shall be determined at the time of installation and first activation from a power-off condition, and this information shall be stored by the device. If the fixed WSD is moved from the last location, it must be reported to the database. The operator shall then re-establish the device's geographical location using automated geolocation.

c) Personal/Portable Master WSD geolocation determination.

1. The horizontal geographic coordinates of a personal/portable master WSD must be provided, as latitude and longitude (WGS84) and shall be determined by automated geolocation. The device shall report its geographic coordinates as well as the accuracy of its geolocation capability (e.g., ± 50 meters) at a confidence of ≥95% to the database.

2. The vertical geolocation (height) of the antenna of a personal/portable master WSD may be reported and shall be determined by automated geolocation and the height shall be measured above ground level. The device shall report the vertical accuracy of its geolocation capability (e.g., ± 5 meters) at a confidence of ≥95% to the database.

3. A personal/portable master WSD may report whether its antenna is situated outdoors or indoors; if it does not report its situation it will be assumed to be outdoors.

4. Where the vertical geolocation (height) of the antenna of a personal/portable master WSD is not reported, it will be assumed to have a height of 1.5 meters above the ground.

5. Where the vertical geolocation (height) of the antenna of a personal/portable master WSD is reported and exceeds 2m, and its situation is not reported, it will be assumed to be indoors.

6. A personal/portable master device must re-establish its position each time it is activated from a power-off condition and use its geolocation capability to check its location at least once every 60 seconds while in operation, except while the device is inactive but not powered down.

d) Determination of available frequencies and maximum transmit powers.

1. Master WSDs shall access a qualified geolocation database over the Internet to determine the frequencies and maximum transmit powers available at the device's geographical coordinates. A database will determine available frequencies and maximum transmit powers based on the algorithm described in article 3. However, in no case shall the maximum transmit power exceeds the values provided in Article 6.

2. Master devices must provide the database with the device's geographic coordinates in WGS84 format, a unique alphanumeric code supplied by the manufacturer that identifies the make

and model of the device, and a unique device identifier such as a serial number. Fixed master devices must, and personal/portable master devices may also provide the database with the antenna height of the transmitting antenna specified in meters above ground level.

3. When determining frequencies of operation and maximum transmit power, the geolocation database may consider additional information provided by a master WSD about its operating parameters and indicate to the WSD that different frequencies and/or different maximum transmit powers are available based on this additional information. This information may include out-of-band emission (Article 6), or antenna transmission pattern, alignment, and polarity.
4. WSDs may transmit in a range or ranges of frequencies which are indicated as available by a database provided that the device does not exceed the indicated maximum transmit powers at any frequencies and the device complies with the out-of-band emission limits in articles 6-7. The device's transmit bandwidth is not required to be an integer multiple of the underlying DTT broadcast 8 MHz bandwidth, or to align with TV broadcast channels. WSDs must comply with any limits on the maximum total transmit bandwidth and maximum contiguous transmit bandwidth indicated by a database.
5. WSD operation in a frequency range must cease immediately, or transmit power must immediately be reduced to a permissible level, if the database indicates that the frequencies are no longer available at the respective frequency or operating power.
6. A master device must access a geolocation database to re-check its available frequencies and maximum transmission powers when the device changes location by more than 100 meters from the last point location reported to the database.
7. A personal/portable master WSD may request available frequencies for a geographic polygon area or series of areas and may operate on a mobile basis at all locations within each polygon using the frequencies and power limits available within that polygon. A personal/portable master WSD using such available frequencies for geographic polygon areas must contact the database again if/when it moves beyond the stated area(s) where the frequency availability data is valid.

e) Time validity and database re-check requirements.

1. A geolocation database shall provide master devices with a period of validity for the frequencies of operation and maximum transmit powers described in article 2(d).

2. A geolocation database shall provide master devices with the required polling time interval for contacting the database to confirm that its frequencies and maximum transmit powers are still valid. A WSD must immediately cease transmitting and must not commence or re-commence transmitting if the time since the database last indicated validity exceeds this interval.

3. A master device that is unable to contact a database due to external causes (e.g. database downtime, Internet unavailability) may continue to operate with its current available frequencies and maximum transmit powers until 24 hours after the current period of validity expires, or one polling interval after contact with the database is re-established, whichever is sooner.

4. Before commencing transmission, a master device must report to the geolocation database the frequencies and power level(s) at which a master device intends to transmit. If the master device intends to change frequencies or increase its power above the reported level(s), it must report the new frequencies and power level(s) to the geo-location database before changing its transmissions.

5. A master device must report to the geolocation database the frequencies and power level(s) at which it has instructed each of its client devices to transmit.

f) Master device registration.

1. Before operating for the first time, a master WSD must register with a database by providing the information listed in article 2(f)(3).

2. The party responsible for a master WSD must ensure that a database has the most current, up-to-date information for that device.

3. The database shall contain the following information for master WSDs:

    i. A unique alphanumeric code supplied by the manufacturer identifies the make and model of the device.

ii. Manufacturer’s serial number of the device;

iii. Device’s geographic coordinates as latitude and longitude (WSG84)

iv. Device’s antenna height above ground level (meters, optional for personal/portable master devices);

v. Business name of the network operator that owns the device;

vi. Name of a contact person responsible for the device's operation;

vii. Address for the contact person;

viii. Email address for the contact person;

ix. The phone number for the contact person.

g) Client device operation.

1. A client WSD may only transmit upon receiving a list of available frequencies and maximum transmit powers from a master WSD that has contacted a geolocation database. To initiate contact with a master device, a client device may transmit on available frequencies and power limits provided by the master WSD as available for use by a client device.

2. A master WSD may provide a client WSD with the same list of available frequencies and maximum transmit powers that are available to that master WSD. A master WSD may omit one or more available frequencies or provide maximum transmit powers that are lower than those available to the master WSD. These frequencies may be used by the client WSD for ongoing transmissions following its initial contact with the master WSD.

3. A client WSD must provide a master device with a unique alphanumeric code supplied by the manufacturer that identifies the make and model of the client WSD, and the manufacturer's serial number of the client WSD.

4. At least once every 60 seconds, except when in sleep mode, i.e., a mode in which the device is inactive but is not powered-down, a client device must communicate with a master device, which may include contacting the master device to re-verify/re-establish frequency availability or receiving a contact verification signal from the master device that provided its current list of

available frequencies.

5. A client device must cease operation immediately if it has not communicated with the master device as described above after more than 60 seconds. In addition, a client device must re-check/re-establish contact with a master device to obtain a list of available frequencies if the client device resumes operation from a powered-down state. If a master device loses power and obtains a new frequency list, it must signal all client devices it is serving to acquire a new frequency list.

h) Master devices without a direct connection to the Internet.

1. If a master (fixed or personal/portable) WSD does not have a direct connection to the Internet and has not yet been initialised and communicated with a geolocation database consistent with this section, but can receive the transmissions of another master WSD, it may initiate contact with that master device in the same manner as described for a client device in article 2(g)(1).

2. Following the initial contact, the WSD needing initialisation may use the list of available frequencies and power limits to access the geolocation database, using the master WSD, to receive a list of frequencies and power levels that are available for that WSD to use.

3. After communicating with the database, the master (fixed or personal/portable) WSD must then only use the frequencies and power levels that the database indicates are available for it to use.

4. For purpose (fixed or personal/portable) WSD may then in turn act as a master to other fixed or personal/portable devices in the same manner described in article 2(d).

i) Security.

1. To obtain a list of available frequencies and related matters, master WSDs shall only contact geolocation databases qualified by the Authority.

2. Communications between WSDs and geolocation databases are to be transmitted using secure methods to protect data from unauthorised modification; this requirement also applies to

communications of frequency availability and spectrum access information between master devices.

3. Communications between devices for purposes of obtaining a list of available frequencies shall employ secure methods to protect data from unauthorised modification. Contact verification signals transmitted for devices are to be encoded with encryption to secure the identity of the transmitting device. Devices using contact verification signals shall accept, as valid for authorisation, only the signals of the device from which they obtained their list of available frequencies.
4. Geolocation database(s) shall be protected from unauthorised data input or alteration of stored data. To provide this protection, a database administrator shall establish communications authentication procedures that allow master devices to be assured that the data they receive is from an authorised source.

5. Geolocation Database Provider(s)

a) The Authority will qualify multiple private entities to provide geolocation database(s) services and each provider shall:

1. Maintain a database that requests data on the protected Digital Terrestrial Television broadcasting service from the Authority's portal in the specified format.
2. Implement propagation algorithms and interference parameters issued by the Authority according to article 5 to calculate operating parameters for WSDs at a given location and support models that consider the variability in terrain in calculating propagation and spectrum availability including ITU-R P-1812. Other models may be appropriate, provided that they use point-to-point calculations and consider terrain variability interference parameters that can be shown to return results that provide at least the same protection to licensed DTT service. Database operators will update the algorithms or parameter values provided by the Authority.
3. Establish a process for acquiring and storing in the database necessary and appropriate information from the Authority's databases and synchronising the database with the Authority's database at least once a day to include changes to licensed frequencies and associated parameters.
4. Establish a process for operators to register master WSDs.
5. Establish a process for the database provider to include in the geolocation database any facilities that the Authority determines are entitled to protection but not contained in a database maintained by the Authority.
6. Provide accurate information regarding permissible frequencies of operation and maximum transmit powers available at a master WSD's geographic coordinates based on the information provided by the device according to article 2(d). Database providers shall allow prospective operators of WSDs to query the database and determine the available frequencies at a particular location.
7. Establish protocols and procedures to ensure that all communications and interactions between the database and WSDs are accurate and secure and that unauthorised parties

cannot access or alter the database or the list of available frequencies sent to a WSD.

8. Respond promptly to verify, correct and/or remove, as appropriate, data if the Authority brings a claim of inaccuracies in the geolocation database to its attention.
9. Provide functionality such that upon request from the Authority it can indicate that no frequencies are available when queried by a specific WSD or model of WSDs.
10. Provide data on registered WSDs and operational parameters to the Authority and other qualified databases. In the event of a large number of deployments in a geographic area, the authority shall require the qualified databases to exchange data and synchronise operations of Master WSDs.
11. Cooperate, with other qualified geolocation database providers to provide coexistence data to all other WSD databases to ensure consistency in the records of protected facilities.

b) Non-discrimination and administration fees.

1. Geolocation databases must not discriminate between devices in providing the minimum information levels. However, they may provide additional information to certain classes of devices.
2. A database provider may charge a fee for the provision of lists of available frequencies to fixed and personal/portable WSDs, and for registering master WSDs.
3. The Authority shall review the fees and can require changes in those fees if they are found to be excessive once a harmonised charging methodology is adopted by the Authority.

6. Technical Requirements for WSDs

a) Geolocation and Database method

1. WSDs shall rely on the geolocation database method of determining available frequencies and only transmit using the maximum transmit powers provided by the database according to article 5.
2. Devices must comply with the emission limits specified in ETSI EN 301 598.
3. A device shall report its out-of-band emissions as one of ETSI's Emission Classes 1-5.
4. Maximum transmit powers provided by the database shall specify the maximum equivalent isotropically radiated power (EIRP) in 8 MHz bands, which shall not exceed 42 dBm/8 MHz in any 8 MHz band.
5. The maximum EIRP in each 100 kHz band within an 8 MHz band shall be 19 dB below the maximum EIRP in that 8 MHz band.
6. The conducted power delivered to the antenna system of a device in an 8 MHz band must not exceed the maximum EIRP less the directional gain of the antenna(s) in dBi.
7. Maximum transmit powers shall be applied similarly by Fixed, Personal/Portable, Master, and Client devices.

7. Database Coexistence Calculations

Brief Description

a) The input to a geolocation database will be information from a master WSD (Article 2), used by licensed DTT service in the geographic area of operation of the WSD, and geographic data describing e.g. terrain elevation and the borders between regions. The database will supply a list of available frequencies and maximum transmit powers to WSDs according to the algorithm provided in article 6.

b) Information about spectrum utilisation by licensed DTT service will be provided from the Authority's database.

c) Any facilities that the Authority determines are entitled to protection but are not recorded in the Authority's databases shall be permitted to register with a geolocation database according to article 4.

d) Propagation Algorithm

A database shall supply a list of available frequencies and permitted maximum to transmit powers to WSDs according to the coexistence calculations. The calculations describe the method by which a database operator uses the relevant inputs to indicate available frequencies and maximum power limits for WSDs. To reliably protect incumbent TV users, this method requires a model for predicting the propagation loss of UHF radio signals over irregular terrain, to compute the field strength of a television signal at a particular geographical location.

The ITU-R Recommendation P-1812 is a path-specific propagation prediction method for point-to-area terrestrial services in the VHF and UHF bands that has been adopted for this framework. A specified percentage of time that transmission loss is not exceeded (p%) 50%, assuming 50 % of locations (pL%).

The Extended Hata model shall be used for modelling transmissions from WSDs to DTT Receivers, to determine available white spaces, flat earth/terrain between WSD TX and DTT Rx assumed.

.

Annex II: Coexistence Calculations

1. Overview

a) The coexistence framework computes spectrum allocation parameters for a white space device (WSD) taking into account geolocation and category details of the WSD, and information on protected DTT service from the Authority.

b) It is the responsibility of the geolocation database to perform these calculations.

c) The Authority will specify which channels are available for TVWS use in Kenya with 8 MHz channels.

d) A spectrum allocation consists of maximum transmit powers in the frequencies of each channel and metadata describing the location and time ranges in which they are valid.

e) A power limit in a given channel constrains the WSD's intentional emissions in that channel and is specified as a limit in dBm over the full width of the 8 MHz channel.

f) The tuning parameters (section 9) are a mechanism with default values for balancing the level of protection to incumbents with the availability of spectrum to WSDs.

g) The Authority adopts ITU-R propagation model 1812, a path-specific propagation prediction method for point-to-area terrestrial services in the VHF and UHF bands.

2. General Considerations

2.1. Channel Plans

a) I is defined as the set of channels that are available for TVWS at a bandwidth b of 8 MHz, the set does not need to be contiguous in channel number and/or in frequency ranges.

b) Where there are several contiguous blocks of channels, the band-edge channels are defined as the highest and lowest channel in each contiguous block.

c) For any two TVWS channels $i \, and \, j$, Δf is defined to be one greater than the number of bandwidths, or parts thereof, separating the nearest edges of i and j; if $i = j$ then $\Delta f = 0$

d) Δf may span frequency ranges that are not assigned to TVWS, which does not present a problem within the context of the coexistence calculations.

e) In the case where a single contiguous block of channels is assigned for TVWS then , $\Delta f = i - j$.

f) The Authority defines the separation $\Delta fedge$ between a TVWS channel i and the nearest non-TVWS frequency band to be one greater than the number of bandwidths, or parts thereof, separating the nearest edges of i and the contiguous block containing i. Where i is a band-edge channel $\Delta fedge = 1$. (Authorised within 470 – 694 MHz, usage of 450 – 470 MHz by mobile to be protected, while guard band provided above 694 MHz)

2.2. Geolocation Database Optimisation

a) The coexistence framework for TVWS presents a complex series of calculations that the database must perform within a reasonable computation time. To address these practical constraints, a geolocation database will be permitted to make any approximations that have no significant effect on the power limits it computes.

b) When considering the many nested iterations across many sets of objects, a geolocation database may ignore or discard any iterations or set members at its discretion for performance optimisation, provided the resulting power limits do not differ significantly from an exhaustive calculation.

c) The geometry and resolution of any spatial sampling, e.g. for calculating coverage over an area, or for terrain profiles, are left to the discretion of the geolocation database.

d) Where a path loss in channel i has been computed, it may similarly be used with a frequency-based correction to approximate the path loss in channel j at the geolocation database's discretion.

e) Some or all parts of the calculation may be precomputed or calculated on the fly at the discretion of the database. Precomputed data may be rounded to an appropriate precision to facilitate efficient storage.

f) Any horizontal location may be rounded to an appropriate grid by the database to facilitate precomputation.

g) The height above ground level of a WSD may be rounded by the database to the nearest member of a preconfigured set (i.e. {1.5, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50m}) to facilitate precomputation.

2.3. WSD Horizontal Location Uncertainty

a) Where a WSD reports a region of uncertainty around its horizontal point location or has reported its location as a polygon (e.g. for mobility purposes), the geolocation database shall perform any path loss calculations by selecting at its discretion a subset of locations within the polygon, calculating path loss from each of those locations, and selecting the path loss which will ultimately cause the most stringent power limit.

b) The subset of locations should be chosen to handle cases where the path loss varies significantly within the polygon e.g. due to intervening terrain.

2.4. WSD Height

a) Where a WSD reports its height Above Ground Level "AGL", the height is used without modification, except reported heights below 1.5m are to be rounded up to 1.5m.

b) Where a WSD reports a range of uncertainty in its AGL height, the geolocation database shall perform any path loss calculations by selecting at its discretion a subset of heights within the range of uncertainty, calculating path loss from each of those heights, and selecting the path loss which will ultimately cause the most stringent power limit.

c) Where a personal/portable WSD does not report its height, it is assumed to be 1.5m AGL with no uncertainty.

d) Where a personal/portable WSD reports its height as being above 2m AGL, it is assumed to be indoors.

e) An additional margin of $M_{indoor} = 7dB$ is added to the power limits $PPTx: WSD$ of an indoor device up to not exceeding. $Pcap$.

2.5. Time Validity

a) Typically, WSDs will request a spectrum allocation for immediate use, will periodically check that the allocation is still valid, and will request a new allocation when the period of validity expires. Typically, the set of incumbent users requiring protection will not change during this validity period, and, where unexpected changes occur, the geolocation database will inform the WSD that its allocation is no longer valid.

b) When calculating spectrum allocation, a database may know in advance that an incumbent user will start and/or stop operating (i.e. requiring protection) within the period of validity of the allocation. It may then divide the period of validity according to changes in the incumbent set to calculate multiple allocations which are disjoint in time. It may instead, at its discretion, compute one allocation on the simplifying assumption that any incumbent which requires protection for part of the period of validity receives protection for the whole period.

c) Where the set of incumbents changes or any other underlying factors change, a database must evaluate which existing spectrum allocations may be affected by the change (e.g. due to geographic proximity) so that the relevant WSDs will be informed that their allocation is no longer valid. This invalidation should take place even where the availability of spectrum has increased, or where the WSD is currently not using any channels which are affected by any changes.

d) A database may accept requests for spectrum allocations that begin at a specified time in future. Such allocations will be subject to the WSD's normal validity-checking requirements.

2.6. Mathematical Notation

a) TVWS coexistence frameworks are sufficiently complex such that without a very precise notation system it is easy to confuse two similar but distinct concepts. The notation used here has been carefully chosen to be explicit and unambiguous, at the cost of brevity.

b) Power is denoted by P, gain by G, loss by L and margin by M, many variables have several indices.

c) Superscripts denote channels and subscripts describe the detailed meaning of the variable. Indices are concatenated with

: denoting "of"

| denoting "to protect"

→ denoting "towards"

←× denoting "from", or

@ denoting "at location".

d) For example, $P^{i}_{Tx:WSD|TV@X}$ denotes the transmit TX power limit P of a White Space Device WSD in channel i to protect television TV at a location $@X$

3. **WSD Power Limits**

3.1. Formal Framework

a) The coexistence framework is a function of f to compute WSD power limits in each channel such that;

$$P_{Tx:WSD} = f(WSD, incumbents, terrain) \quad (3.1)$$

$$\text{where} \quad P_{Tx:WSD} \equiv \{P^{I}_{Tx:WSD} : \forall i\} \quad (3.2)$$

denotes limits on the intentional emissions' of a WSD in each channel $i \in I$, where I is the set of channels of bandwidth b made available for use of TVWS.

b) In the following sections f is divided into its constituent parts, each of which produces 'candidate' power limits:

$$P_{Tx:WSD} = g(WSD, incumbents, terrain)$$

$$= \{\left(g_{TV}(\bullet)^{i}, g_{band}(\bullet)^{i}, g_{border}(\bullet)^{i}, P_{cap}\right) : \forall i\} \quad (3.3)$$

where (•) is shorthand for each functions respective arguments and P_{cap} is constant (e.g. 42 dBm) upper bound on WSD emissions in a channel.

c) Prerequisite data: The following properties of the WSD are required:

- Latitude & longitude of the WSD's antenna, either at a single point or a polygon;
- Height of the WSD's antenna above ground level "AGL" (WGS84 datum);
- Ranges of uncertainty in the geolocation measurements;
- ETSI Emission Class for an 8 MHz bandwidth channel.

d) The following additional properties improve the accuracy of the calculations:

- Directivity pattern & alignment of the WSD's antenna;

- o Polarization of the WSD’s antenna;
- o Situation (indoors, outdoors) of the WSD’s antenna.

e) Where not specified the WSD’s antenna is assumed to be omnidirectional with vertical polarisation and situated outdoors.

f) A Digital Elevation Model is required to describe the terrain elevation above the WGS84 datum at a good (e.g. 1 arc-second) resolution throughout Kenya.

4. Candidate WSD Power Limits for Protecting TV Users

4.1. Formal Framework

This section defines the function $g(.)$such that

$$P_{Tx:WSD|TV} = g_{TV}(WSD, TV\ transmitters, terrain). \quad (4.1)$$

4.2. Prerequisite Data

a) This section relies on data describing TV transmitters. For protection purposes, details are required of TV transmitters in or near the region where WSD operation is permitted. Additionally, for a more accurate calculation of noise levels, details are required of TV transmitters in adjacent regions, even if their transmissions are not to be protected.

b) The minimum properties required for a TV transmitter are:

- Latitude & Longitude (WGS84) of the transmitter;
- Height of the transmitting antenna above ground level “AGL” (WGS84 datum);
- Effective Radiated Power “ERP”, in dBm;
- Centre frequency of the channel used by the transmitted signal.

c) The following additional properties improve the accuracy of the calculations:

- Directivity pattern & alignment of the transmitting antenna;
- Polarization of the transmitting antenna.

d) Where unspecified, the antenna is assumed to be omnidirectional with vertical polarisation.

4.3. Method

a) Given WSD location W, derive a set of locations X to describe the area in which the WSD may cause interference. The minimum distance between W and X is $d_{min:WSD\rightarrow X}$ with a default value of 60m.

b) For each point $X \in \mathbf{X}$: Find all TV transmitters, T, within distance $d_{max:X\rightarrow T}$ (default 100km) from point X.

c) For each transmitter $T \in \mathbf{T}$, for each of its transmit channels *i* calculate the path loss $L^{i}_{T\rightarrow X}$ in dB between T and X using a terrain-based propagation model at the centre frequency of the channel, given the height of the transmitter and the household antenna of 10m.

d) Given that the transmit power $P^{i}_{Tx:T}$ in dBm, the received power of the wanted signal at the antenna X is defined as follows:

$$P^{i}_{Rx:T@X} = P^{i}_{TX:T} - L^{i}_{T\rightarrow X} \qquad (4.2)$$

e) The interference caused in channel *i* by another TV transmitter $T^{'} \in T \backslash T$ using channel j is defined as follows:

$$P^{i\leftarrow j}_{int:T^{'}@X} = P^{j}_{Rx:T^{'}@X} - ACLR_{TV}(\Delta f) + G_{ant@X\rightarrow T^{'}} + G_{Rx:inst} \qquad (4.3)$$

where Δf is defined in (§2.1e), ACLR in (dB) is the out-of-channel emission mask[1] of the transmitter,

$$ACLR_{TV} = \{0\ 61\ 87\ \infty\ \ \Delta f\ =\ 0\ \ \Delta f\ =\ \pm 1\ \Delta f\ =\ \pm 2\ |\Delta f| => 2, \qquad (4.4)$$

$$G_{ant@X\rightarrow T^{'}}(\phi) = \{0\ \frac{\phi - 20°}{40°}\ \ -\ 16 \times (-\ 16)\ \ |\phi|\ <\ 20°\ \ 20° \leq |\phi| \leq 60°\ |\phi| > 60° \qquad (4.5)$$

In equation (4.5) angle ϕ is defined as the 'cone' angle between a geodesic joining X and T and a geodesic joining X to $T^{'}$, taking account of both azimuth and elevation. Where the polarity of either T and $T^{'}$ is not known, they are assumed to be co-polar. Where T and $T^{'}$ are known to have orthogonal polarity, then (in dB). Equation (37b) from ITU F. 1336-5[2] used to calculate the cone angle.

$$G_{ant@X\rightarrow T^{'}}(\phi) = -\ 16 \qquad (4.6)$$

---

[1] ITU Spectrum limit masks for digital terrestrial television broadcasting. Recommendation BT.1206-3.

[2] ITU F.1336 : Reference radiation patterns of omnidirectional, sectoral and other antennas for the fixed and mobile service for use in sharing studies in the frequency range from 400 MHz to about 70 GHz

f) The cumulative noise and interference at the household antenna in channel i is defined as follows:

$$P_{noise:T@X} = 10\, log_{10}(10^{\frac{P_{thermal}}{10}}) \qquad (4.7\text{ a})$$

$$P^{i}_{intf:T@X} = 10\, log_{10}(\sum_{T'j} 10P^{i\leftarrow j}_{int:T'@X/10}) \qquad (4.7\text{ b})$$

where $P_{thermal}$ is the thermal noise, with a default value -105.2 dBm for 8 MHz channels[3].

g) At X the carrier to noise ratio in channel i at the tuner in dB is defined as follows:

$$CNR^{i}_{T@X} = P^{i}_{Rx:T@X} - P^{i}_{noise:T@X} + G_{Rx:inst} - M_{Rx:imp} + P^{i}_{intf:T@X} \qquad (4.8)$$

where default values are given for the receiver noise figure $L_{Rx:noisefig} = 7dB$,

Net receiver antenna installation gain $G_{Rx:inst} = 9.15dBi$,

Receiver implementation margin $M_{Rx:imp} = 1.5dB$.

h) Channel i considered to be 'in coverage' at X if:

$$CNR^{i}_{T@X} \geq CNR_{min} + M_{Rx:link} \qquad (4.9)$$

where CNR_{min} is determined for each T based on its TV standard, modulation scheme etc., but default value is 19.5dB for digital television and the receiver link margin defaults to $M_{Rx:link} = 7.6dB$;otherwise it is 'out of coverage'.

The above method outputs a set of locations $Y \subseteq X$ in which at least one channel is in coverage.

[3] ITU Directivity and polarization discrimination of antennas in the reception of television broadcasting. Recommendation BT.419-3. https://www.itu.int/dms_pubrec/itu-r/rec/bt/R-REC- BT.419-3-199006-I!!PDF-E.pdf.

i) For each $Y \in \mathbf{Y}$, and for each in-coverage channel i at Y.

j) Given $P^{i}_{Rx:T@Y}$ as calculated above and out of channel emission mask (§4.3 g) of the WSD, find the appropriate protection ratios $r\left(P^{i}_{Rx:T@Y} + G_{Rx:inst}, \Delta f\right)$, from tables A 9.5-9.9, given the wanted receiver power at the tuner $P^{i}_{Rx:T@Y} + G_{Rx:inst}$ and Δf as defined above.

k) The maximum tolerable 'nuisance 'power at the tuner in each channel $j \in I$ at Y so as to protect TV reception in channel i is then

$$P^{j|i}_{Rx:nuisanse@Y} = P^{i}_{Rx:T@Y} - r(P^{i}_{Rx:T@Y} + G_{Rx:inst}, \Delta f). \quad (4.10)$$

When the wanted power lies between two columns in the tables linear interpolation is used between two relevant values of r. When $i = j$, the protection ratio r is $CNR_{min} + M_{Rx:co-channel}$, where $M_{Rx:co-channel}$ defaults to 20dB.

For power (C) exceeding -12 dBm or below -70 dBm extrapolation required.

l) Calculate the path loss $L^{j}_{WSD\rightarrow Y}$ in dB between W and Y using a terrain based propagation model at the center frequency of each channel $j \in I$, given the height of the WSD and height of a household antenna is 10m. Where the antenna pattern of the WSD is known, the gain is the geodesic direction towards Y is included in the path loss.

m) The angle φ is defined as the 'cone' angle between a geodesic joining Y to the location of in-coverage TV transmitter, and a geodesic joining W to Y, taking account of both azimuth and elevation. The directional gain of antenna at Y with respect to a co-polar WSD signal from $W$is then (in dB).

$$G_{ant@Y\rightarrow WSD(\varphi)} = \{0 \; \frac{\phi - 20°}{40°} \; - 16 \times (-16) \;\; |\phi| < 20° \;\; 20° \leq |\phi| \leq 60° \;\; |\phi| > 60° \quad (4.11)$$

Where the polarity of either the WSD or T is not known, they are assumed to be co-polar.

Where the WSD is known to have orthogonal polarity from T, then (in dB) [4]

[4] Ofcom. Implementing TV White Spaces. https://www.ofcom.org.uk/__data/assets/pdf_file/0034/68668/tvws-statement.pdf. 2015.

$$G_{ant@Y \rightarrow WSD(\varphi)} = -\ 16 \qquad (4.12)$$

n) The coupling gain in channel j between a WSD at W & the tuner in a household at Y is;

$$G^{j}_{WSD \rightarrow Y} = -\ L_{WSD \rightarrow Y} + G_{ant@Y \rightarrow WSD(\phi)} + G_{Rx:inst} \qquad (4.13)$$

Where $G_{Rx:inst}$ is the net antenna installation gain $Y$and defaults to 9.15 dB.

o) A candidate power limit $P^{j|i}_{Tx:WSD|TV@Y}$ to protect channel $i$at $Y$is then found in channel $j \in I$ as

$$P^{j|i}_{Tx:WSD|TV@Y} = P^{j|i}_{Rx:nuisance@Y} - G^{j}_{WSD \rightarrow Y} \qquad (4.14)$$

p) A candidate power limit $P^{j|i}_{Tx:WSD|TV@Y}$ to protect all in-coverage channel at Y is found in each channel $j \in I$ as

$$P^{j}_{Tx:WSD|TV@Y} = min(P^{j|i}_{Tx:WSD|TV@Y} : \forall i\ ) \qquad (4.15)$$

q) The power limit in each channel j to protect all TV receivers in Y is then

$$P^{j}_{Tx:WSD|TV} = min_{(m)}(P^{j}_{Tx:WSD|TV@Y} : \forall Y \epsilon Y) \qquad (4.16)$$

r) Where $Min_{(m)}$ is a function finding the minimum of a set having discarded the m lowest members, and m defaults to 0.1% of the size of Y. The final set of power limit is

$$P_{Tx:WSD|TV} \equiv \{P^{j}_{Tx:WSD|TV} : \forall j \in I\} \qquad (4.17)$$

4.4. Additional Considerations

a) If reliable data are available describing the set of all household locations **H** in the country, then the intersection $Y \cap H$ should be used in place of Y**.**

b) Where a particular TV transmitter is to be protected only in certain geographic regions G**,** then it is not considered to be “in coverage” at step (§4.3 h) where $X \notin G$**.** For example, where a TV transmitter is located in a neighbouring country, contributes tolerable but non-negligible interference, but is not eligible for protection.

c) In both the above cases, all TV transmitters are included in the calculation of the cumulative noise and interference.

5. Candidate WSD Power Limits for Protecting Band Edges

5.1. Formal Framework

This section defines the function g_{band} such that;

$$P_{Tx:WSD|band} = g_{band}(WSD, I, terrain) \quad (5.1)$$

Where I is the set of channel available for TVWS

5.2. Prerequisite Data

a) The maximum tolerable WSD emissions in each channel not available for TVWS use is required to determine protection limits.

5.3. Method

a) The Constant maximum power $P_{Em:WSD|band}$ which a WSD may intentionally or unintentionally emit outside the TVWS channels I is to be set by a regulator; a default value is $P_{Em:WSD|band} = -25dBm$ per channel. Note this may take different values in different frequency ranges.

b) For each channel $i \in I$, a candidate power limit is:

$$P^{i}_{Tx:WSD|band} \equiv P_{Em:WSD|band} - ACLR_{(\Delta f_{edge})} \quad (5.2)$$

Where ACLR is that WSD's unintentional emission behavior (§7 b) and Δf_{edge} is the separation between i and the nearest non-TVWS frequency as defined above (§2.1 e)

c) The final set of the power limits is

$$P_{Tx:WSD|band} \equiv \{P^{i}_{Tx:WSD|band} : \forall i\} \quad (5.3)$$

6. WSD Power Limits for Protecting Country Borders

Kenya is a signatory to the GE06 treaty, and specific protection requirements are provided.

6.1. Formal Framework

This section defines the function $g_{Border}(.)$ such that

$$P_{Tx:WSD|border} = g_{border}(WSD, borders, terrain) \quad (6.1)$$

6.2. Prerequisite data

a) The following are required:

- Latitude and longitude (WGS84) points, lines or polygons describing the international and maritime borders of Kenya.
- Maximum tolerable nuisance power in each channel;
- Height above ground level at which to measure nuisance power;

6.3. Method

The constant maximum received power $P_{Tx:WSD|border}$ which is tolerable at a point on the border due to WSD emissions is adopted as a default value of $P_{Tx:WSD|border} = -75$ dBm / MHz (equivalent to the 'trigger field strength' in GE06[5] Table API.9.)

a) At each of a series of points B along the country's border B, $f$or a channel $i \in I$

b) Calculate the path loss $L^{i}_{WSD \rightarrow B}$ in dB between the WSD's location *W* and *B* using a terrain-based propagation model at the centre frequency of *i,* given the height of the WSD and the height of a household antenna at 10 m. Where the antenna pattern for the WSD is known, the gain in the (geodesic) direction towards *B* is included.

[5] ITU. Final Acts of the Regional Radiocommunication Conference for planning of the digital terrestrial broadcasting service in parts of Regions 1 and 3, in the frequency bands 174-230MHz and 470-862MHz. Tech. rep. RRC-06. http://www.itu.int/pub/R-ACT-RRC.14-2006. ITU, 2006.

c) A candidate power limit $P^{i}_{TX;WSD|B}$ is then

$$P^{i}_{TX;WSD|B} = P_{Rx:WSD|border} - L^{i}_{WSD\rightarrow B} \quad (6.2)$$

The power limit in each channel *i* to protect all points on the border **B** is then:

$$P^{i}_{TX;WSD|border} = min(P^{i}_{Tx:WSD|B} : \forall B \in B) \quad (6.3)$$

The final set of power limits is

$$P_{TX;WSD|border} \equiv \{P^{i}_{TX;WSD|border} : \forall i \in I\} \quad (6.4)$$

7. WSD Out-of-Channel Emissions

Where the channels have bandwidth b = 8MHz, the WSD's ACLR as a function of its ETSI Emission Class[6] and the separation Δf (§2.1 e) is:

$\triangle f$	±1	±2	±3	±4
Class 1	55	60	65	68
Class 2	55	55	55	64
Class 3	45	55	65	68
Class 4	35	45	55	64
Class 5	24	34	45	55

Table 1: ACLR ($\triangle f$) in dB, being the ratio between intentional WSD emissions in a channel (dBm/8MHz) and unintentional WSD emissions (dBm/8MHz) in a channel separated by $\triangle f$ x 8 MHz

a) If | $\triangle f$ | > 4, the function is:

$$ACLR(\triangle f) = ACLR(4) + (|\triangle f| - 4) \times 10dB \tag{7.1}$$

8. Spectrum Allocation Metadata

a) When responding to spectrum requests, geolocation database should include several other parameters in addition to the power limits:

- Date/time range (UTC) in which the spectrum allocation is valid;
- Maximum Polling Time (s), being the maximum period within which a WSD must contact the geolocation database to confirm its spectrum allocation is still valid;
- Maximum Contiguous Bandwidth and Maximum Total Bandwidth (Hz), being the amount of spectrum a WSD may use in one contiguous block and in total (e.g. by channel- bonding);

[6] ETSI EN 301 598 v1.1.1. http://www.etsi.org/deliver/etsi_en/301500_301599/301598/01.01.01_60/en_301598v010101p.pdf. 2014.

- Maximum Location Change (m), being the distance outside of its stated location (including uncertainty) beyond which the WSD's spectrum allocation becomes invalid.

9. Tuning Parameters

The coexistence calculations depend on default 'tuning parameters', which may be set according to their specific requirements. Values in dBm are per channel width *b.*

Parameter	Default value	Description
P_{Cap}	42 dBm	Maximum WSD transmit power
$d_{min:WSD\rightarrow X}$	60 m	Min distance between WSD and simulated household
$d_{max:X\rightarrow T}$	110 km	Max distance between simulated household and TV transmitter
h_{Rx}	10 m	Household antenna height above the ground level
$L_{Rx:noise\ fig}$	7 dB	Household antenna noise figure
$G_{Rx:inst}$	9.15 dBi	Household antenna net installation gain
$M_{Rx:imp}$	1.5 dB	Household Receiver implementation margin
CNR_{min}	19.5 dB	Min acceptable household DVB-T Carrier to noise ratio.
$M_{Rx:link}$	4.6 dB	Household reception link margin
$M_{Rx:cochannel}$	20 dB	Additional margin for co-channel WSD operation
m	0.1%	Portion of lowest candidate power limits to discard in each channel
$P_{Rx:Z}$	-105.2 dBm	Maximum co-channel nuisance power in default protected zone
$P_{Em:WSD\|band}$	-25 dBm	Maximum unintentional WSD emission into a non TVWS channel
$P_{Em:WSD\|border}$	-75 dBm	Maximum received power from a WSD measured at border
M_{indoor}	7 dB	Additional margin applied to indoor devices to account for building entry loss
G_{DTT}	5 dB	Gain applied to DTT Tx to account for power correction to counter transmission loss

$Duration$	24 hours	Difference between start and end of validity of spectrum allocation (Flag on web-list server to indicate last update)
$maxTotalBwHz$	24 MHz	Maximum total bandwidth which a WSD may use at one time
$maxContiguousBwHz$	24 MHz	Maximum contiguous bandwidth which a WSD may use at one time
$maxPollingSecs$	86400s	Maximum period within which a WSD must contact the database. Flag to be implemented on listing server to indicate if DTT data has been updated from last update.
$maxLocationChange$	100 m	Maximum distance from stated WSD location