Appendix A

TVWS Database Computational Practices

Draft Version 0.4.5 – Sept. 2nd, 2009

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1. Terminology and Conventions

1.1 Conventions

The key words “MUST”, “MUST NOT”, “REQUIRED”, “SHALL”, “SHALL NOT”, “SHOULD”, “SHOULD NOT”, “RECOMMENDED”, “MAY”, and “OPTIONAL” in this document are to be interpreted as described in [RFC2119].

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1.2 Abbreviations

AGL	Above Ground Level
AMSL	Above Mean Sea Level
ATV	Analog Television
BAS	Broadcast Auxiliary Service
CDBS	Consolidated Database System
CFR	Code of Federal Regulations
CMRS	Commercial Mobile Radio Service
DTS	Distributed Transmission System
DTV	Digital Television
EIRP	Effective Isotropic Radiated Power or Equivalent Isotropically Radiated Power
ERP	Effective Radiated Power (referenced to a dipole, equal to EIRP (in dB) – 2.15 dB)
FCC	Federal Communications Commission
FTP	File Transfer Protocol
GUI	Graphic User Interface
HAAT	Height Above Average Terrain
HTTP	Hypertext Transfer Protocol
LPTV	Low Power Television
MKS	Meter Kilogram Second
NAD	North American Datum (e.g., NAD83, NAD27)
NCA	No Channels Available
NLC	Noise Limited Contour
PLMRS	Private Land Mobile Radio Service
R&O	Report and Order
RCAGL	Radiating Center Above Ground Level
RCAMSL	Radiating Center Above Mean Sea Level
RFC	Request for Comments
RS	Repository Service
TV	Television
TVBD	TV Bands Device
TVWS	TV White Space
ULS	Universal Licensing System
WGS	World Geodetic System (e.g., WGS 84)
WM	Wireless Microphone
WSD	White Space Device (equivalent to a TV Band Device, or TVBD)
WSDB	White Space Database (also known as a TVWS Database)
WSSP	White Space Service Provider (also known as a Service Provider)

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1.3 Preface

The work in this document represents some of the discussions that have taken place in the White Space Database Group. The Group's founding members include Google, Neustar, Microsoft, Dell, HP, Motorola and Comsearch. The group was formed in February, 2009. The Group has been described by its hosts as "a forum for the open discussion of ideas" regarding TVWS Databases. As of November, 2009, there is no governance or voting structure in the Group. The Group was originally intended to develop open and non-proprietary interfaces, and one of the Group's key founding principles was that "Database Administration should be open and non-exclusive."[1] As such, it is expected that a healthy and competitive eco-system of multiple TVWS Databases will be supported by the Group. Several parties are expected to apply to the FCC to be authorized Database Administrators, as outlined in the FCC's 08-260 R&O.

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[1] The definition of non-exclusive (from Merriam-Webster) is: *not limiting possession, control, or use by a single individual or group.* In this case, the definition would apply to TVWS Database Administration, so as not to limit possession or control to one individual or group.

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2. TVWS Database Architectural Model

A TVWS Database is responsible for providing channel availability information to TVBDs, in addition to other functions (e.g., registering protected entities and TVBDs). There are several potential TVWS database architectures that could implement these functions. Specifically, there are several feasible variations in database architecture, including but not limited to:

1) Databases with a unified architecture, that provide all computational and registration functions, and interface directly to TVBDs (as shown in Fig. 1).
2) Databases with a split architecture (e.g., those with a Repository Service and Service Provider role, where the Repository Service entity may provide the computational protection results, and the Service Provider may provide the TVBD interfacing functions (as shown in Fig. 2)). Note that the Repository Service may also be a "Service Provider of last resort", and offer basic TVBD query services in this model. The architecture may also support interfaces to allow other 3rd party Service Providers.

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Comment [dpg2]: This is similar to the architecture promoted in the Group.

There are also several valid database computational implementation options, including but not limited to:

1) Those architectures that compute protection results in real-time. Note that an architecture that computes protection results in real-time is also generally capable of pre-computing channel availability results.
2) Those architectures that pre-compute protection results, and store the results for later distribution.

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Note that each particular architecture and computational implementation option may have certain advantages and disadvantages. For example, architectures that pre-compute protection results may provide fast TVBD query response times. It is expected that the FCC allowing multiple TVWS Databases will result in a range of architectures and implementations, as well as encourage improved (required and enhanced) TVWS Database services. A unified TVWS Database architecture is illustrated in Fig. 1 below. A split TVWS Database architecture is illustrated in Fig. 2 below. The WSDB Group has thus far concentrated on the development of a particular split TVWS Database architecture, shown in Fig. 2 below.[2] As stated above, alternative database architectures to the ones outlined here also exist. Overall system architectures are further discussed in Section 3 below.

[2] The development of this document by Motorola does not necessarily represent an endorsement of a particular TVWS database architecture. Motorola believes that there are multiple valid TVWS Database architectures, and that having multiple TVWS Databases available will encourage innovation, as well as support the lowest cost database services for consumers.

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2.1 Database Architectural Diagrams

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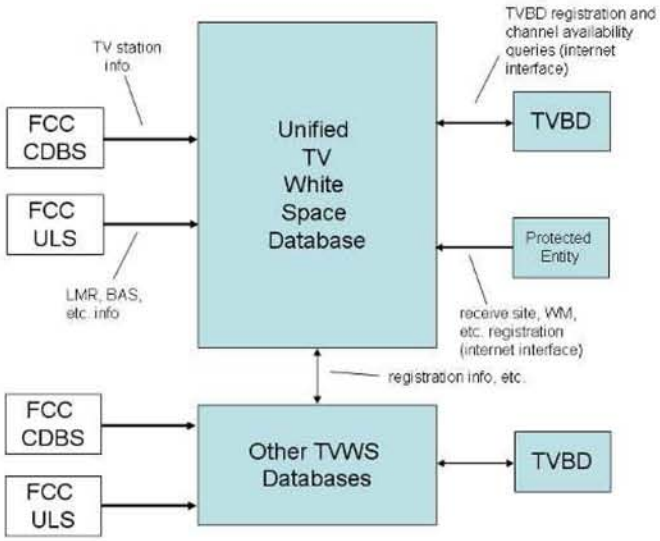

Fig.1 Basic Unified TVWS Database Architecture

Figure 1: A Unified TVWS Database Architecture.

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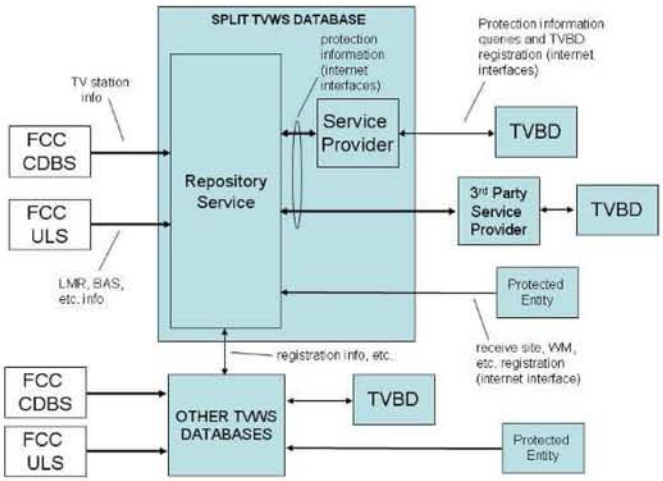

Fig. 2 Split TVWS Database Architecture

Figure 2: A Split TVWS Database Architecture.

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2.2 Channel Availability Data Calculations

A TVWS Database is responsible for providing channel availability data to TVBDs. Channel availability calculations must consider a wide variety of protected entities that are contained in the FCC CDBS, FCC ULS, and TVWS Databases [see Section 15.713 of the FCC 08-260 R&O]. Some examples of the services that are to be protected include TV broadcast services (full-power DTV, analog and digital LPTV, including TV translator and fixed broadcast auxiliary receive sites), PLMRS/CMRS (both inside and outside of the 13 metropolitan areas defined in Section 90.303(a)), Cable TV headend receive sites, offshore radio-telephone services, radio astronomy, and low-power auxiliary stations.

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The channel availability data must also take into account the type of WSD and antenna height above ground level for fixed WSDs. For example, fixed WSDs must not operate at full power inside of the protection zone on the first adjacent channels of a television station while personal/portable WSDs may operate at reduced power. Not withstanding any channel availability calculations, all WSDs are subject to Section 15.5 and must not cause harmful interference to any authorized use of the spectrum by any protected entity.

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All geographic coordinates should be expressed in NAD83 format. For all practical purposes coordinates in WGS 84 format can be treated as if they are in NAD83 format, since the differences between the two coordinate systems is small. All measurement units described herein are expressed in the metric (MKS) system.

2.2.1 Protection of TV Transmitters

The FCC 08-260 R&O requires protection of all licensed television broadcast services. Protection is generally based on the protected service contours (Grade B contour or NLC) of TV transmitters. Specifically, the FCC 08-260 R&O requires the use of R-6602 (F-curves) to compute protected service contours based on various TV transmitter parameters as described below (see also Appendix A):

Section 15.712 Interference protection requirements.

(a) Digital television stations, and digital and analog Class A TV, low power TV, TV translator and TV booster stations:

(1) Protected contour. TVBDs must protect digital and analog TV services within the contours shown in the following table. The contours are based on the R-6602 curves contained in Section 73.699 of this chapter.

Comment [dpg6]: This wording reflects the Federal Register version of the rules, which omitted the terrain roughness corrections contained in the initial TVWS operating rules erratum. Clarification should be sought with the FCC. All terrain roughness references have currently been removed.

Type of station	*Protected contour*		
	Channel	*Contour (dBu)*	*Propagation curve*
Analog: Class A TV, LPTV, translator and booster	*Low VHF (2-6)*	*47*	*F(50,50)*
	High VHF (7-13)	*56*	*F(50,50)*
	UHF (14-69)	*64*	*F(50,50)*
Digital: Full service TV, Class A TV, LPTV, translator and booster	*Low VHF (2-6)*	*28*	*F(50,90)*
	High VHF (7-13)	*36*	*F(50,90)*
	UHF (14-51)	*41*	*F(50,90)*

Several different FCC service designations must be protected, including those listed below:

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DT	Full power digital TV (DTV)
DC	Class A DTV
LD	Low power DTV
DX	Auxiliary DTV
DS	Temporary DTV (STA)
CA	Class A Analog TV (ATV)
TX	Analog translator
TS	Auxiliary analog TV
TA	Analog allotment
TB	Analog booster
DD	DTV DTS

Comment [dpg7]: Question as to whether these classes (DX, DS) always need protection (e.g., back-up facilities)… Can assume that they do for now.

Comment [dpg8]: This class (TA) likely does not need protection… Can assume that no protection is needed for now.

Note that the 'TV' service code applies to full power analog TV transmitters, and is no longer applicable after the DTV transition (i.e., stations with those service codes can be ignored)[3]. All of the analog stations listed above are considered low power stations. Also note that DTV DTS services are not currently intended to extend the protected service contours of the stations that they are simulcasting[4] (so they should not affect the protection requirements of a particular DTV station).

Note that low power TV service is currently treated as though it were full power TV service (i.e., the protected service contour level is lowered by 15, 12, and 10 dB at low-VHF, high-VHF, and UHF channels, respectively) for the purposes of computing protected service contours. This can result in a substantial increase (e.g., ~2x increase) in the protected service areas for LPTV stations, and may cause some overlap among protected service contours.

In particular, the database is required to utilize the following TV transmitter parameters to compute TV station's protected service contours:

15.713 (h) The TV bands database shall contain the listed information for each of the following:

(1) Digital television stations, digital and analog Class A, low power, translator and booster stations:

(A) transmitter coordinates (latitude and longitude in NAD 83)
(B) Effective radiated power (ERP)
(C) height above average terrain of the transmitting antenna (HAAT)
(D) horizontal transmit antenna pattern (if the antenna is directional)
(E) channel number
(F) station call sign

Though not specifically mentioned, FCC service codes (which determine the transmitter type, above), and FCC license status (which can be currently used to determine protection status) are important parameters in determining protection. Note that most stations have multiple listings in the FCC CDBS, often reflecting differing stages in the licensing process. In the absence of an unambiguous indication from the FCC as to which TV stations to protect, the stations requiring protection need

[3] The DTV transition was to be completed by June 12, 2009, though some TV stations (e.g., high VHF stations) may alter their transmitting frequencies after this date.

[4] See Section 73.626 (2) on DTV Distributed Transmission Systems coverage area limitations.

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to be inferred from their current license status. Obviously, all stations with a "LIC" ("licensed") license status should be protected, as well as those with "STA" ("special temporary authority") status. For stations with a "CP" ("construction permit") or "CP-MOD" ("modification of construction permit") status, it is recommended that they be promoted to a quasi-licensed (i.e., protected) status if no other licensed transmitter of the same call sign and type exists at the location[5]. (Often times, a station will have "CP", "CP-MOD", and "LIC" entries for the same facility.) Generally speaking, the entry with the recent-most status (e.g., "LIC" or "CP-MOD" if no "LIC" entry exists) will contain the most accurate representation of the station's current operating parameters.

Protected service contour calculations may generally be performed with 1-degree radial resolution (e.g., for radial HAAT values). Note that effective radiated power levels are typically expressed in kW (as in the FCC CDBS), and TV transmitter antenna patterns are generally expressed using relative field strength at 10-degree radials. Linear interpolation is acceptable for all inter-radial computations. Based on discussions in the WSDB Group, radial HAAT values (with 1-degree resolution) should be utilized in computing protected service contours, as opposed to utilizing an average HAAT value. For the purposes of contour computations using F-curves, any HAAT value below 30 m should be treated as if it were saturated at the 30 m value (since the F-curves are not defined below those values).

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For radial HAAT computations, the use of a terrain database may be necessary. Computation of radial HAAT values typically utilize 50 evenly spaced terrain elevation points between 3 and 16 km away from the transmitter. The selection of a particular terrain database for these computations should not be especially critical, since different terrain databases should produce similar results for the contour calculations as long as a statistically significant number of points are taken into account. In WSDB Group discussions, terrain databases using 3-second, 1-second, or better resolution were suggested. It was noted that the FCC typically utilizes a 3-second terrain database for its TV band planning simulations, though it also appears that the FCC may utilize a 30-second (~1 km) terrain database for radial HAAT computations.[6] It may be more consistent (with FCC contour calculation methods) to utilize the FCC's 30-second terrain database to compute radial HAAT values, and hence protected contours. If multiple Repository Services exist, a mutually agreed upon terrain database should be utilized, along with mutually agreed upon interpolation methods. Note that other antenna effects, such as mechanical beam tilt could also be absorbed into adjusted antenna pattern values with little impact on the database computational methods. Such approaches could be utilized to significantly reduce the number of variables required in the database calculations.

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Comment [dpg10]: FCC clarification of the desired terrain database for radial HAAT calculations would be helpful.

The end goal of the contour calculations is to produce a scalar value (based on several input variables described above) that represents the distance in a particular direction to the protected service contour. Since the contour calculations are critical to TV service protection, it has been suggested in the WSDB Group (by Fox) that the database contain a mechanism for tracking adjustments/corrections to the numerous input variables involved in computing protected service contours. Such an approach would allow timely adjustments to be made to the TV transmitter parameters that the database utilizes. (These adjustments would need to have some type of fast-track approval process by the FCC, since the current paper-based approval method can apparently take a long time to process at the FCC.) A temporary or mirrored TV transmitter parameter database (or "Ingest Buffer") could be utilized to contain these modifications, to allow relatively quick adjustments to protection data.[7] It is also envisioned that the Broadcasters would have an interface into the TVWS Databases, in order to be able to check/verify the protection data that is contained within it.

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Several contour calculation issues are discussed in Appendix B, including various interpolation methods and keep-out zone computations. Once the protected service contours are computed, a keep-out region or required separation distance can be applied around them to generate partial channel availability information (see the re-printed Section 15.712 Table below). Note that the separation distance should be applied in a direction perpendicular to the tangent of (i.e., normal to) the protected contour arc. The required separation distance is also based on the antenna height of the WSD, which must be sent during the database query. Currently, the rules require the use of WSD antenna height AGL (or RCAGL), which should be similar), for

[5] Currently in the TV bands, several stations with CP-MOD status are on the air, while a much lesser number of stations with CP status are on the air. It is expected that the FCC will adjust the CDBS to reflect the actual status of transmitters after the DTV transition. It is also expected that Broadcast stations will verify their information in the database.

[6] See http://www.fcc.gov/mb/audio/bickel/haat_calculator.html for details of the FCC's HAAT computation source code.

[7] See WSDB Group document: *White Space Database Functional Layout*, R. Evans Wetmore, Fox Technology Group, April 6, 2009. It is understood that Broadcasters are under legal obligations to provide timely and accurate information about their broadcast services.

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determining the required co- and adjacent channel separation distances from protected contours.[8] Personal/portable WSDs are always assigned to the *less than 3 m* WSD antenna height category given below.

The current rules allow for full-power WSD operation (i.e., 4 W EIRP for fixed devices, and 100 mW EIRP for personal/portable devices) once the keep-out distances are satisfied. Personal/portable WSDs are currently allowed to transmit up to 40 mW EIRP while operating inside of adjacent channel contours (while fixed WSDs are currently not allowed to transmit inside of adjacent channel contours). Note that the required separation distance is always computed to the *nearest* contour edge (for all protected contours in the region). Note that computing the keep-out zone distance to the nearest contour edge may alter the shape of the protected service contour (see Appendix B). It is assumed that personal/portable WSDs may operate at closer separation distances than the 100 m adjacent channel keep-out zone, as long as they reduce their transmit power level to 40 mW (otherwise there would be a 100 m prohibited zone in between the contour edge and the full-power operating region).[9] Finally, note that WSD power levels are always expressed as EIRP levels, which are about 2.15 dB higher than corresponding ERP levels.

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Section 15.712 Interference protection requirements.

(a) Digital television stations, and digital and analog Class A TV, low power TV, TV translator and TV booster stations:

(2) Required separation distance. Fixed TVBDs and personal/portable TVBDs operating in Mode II must be located outside the contours indicated in paragraph (1) of this section of co-channel and adjacent channel stations by at least the minimum distances specified in the following table. Personal/portable TVBDs operating in Mode II must comply with the separation distances specified for an unlicensed device with an antenna height of less than 3 meters. Alternatively, Mode II personal/portable TVBDs may operate at closer separation distances, including inside the contour of adjacent channel stations, provided the power level is reduced as specified in Section 15.709(a)(2).

Antenna Height of Unlicensed Device	*Required Separation (km) From Digital or Analog TV (Full Service or Low Power) Protected Contour*	
	Co-channel	*Adjacent Channel*
Less than 3 meters	*6.0 km*	*0.1 km*
3 – Less than 10 meters	*8.0 km*	*0.1 km*
10 – 30 meters	*14.4 km*	*0.74 km*

A general flowchart of the protection process is shown in Figure 3 below. The flowchart is shown for illustrative purposes. Note that there are many different methods to implement the calculations, which arrive at the same protection results. For the purposes of the diagram, TV transmitter parameters may include radial HAAT data, and "buffer/keep-out zones" refer to the required separation distance in the Table above.

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[8] Note that several parties have filed Petitions for Reconsideration requesting the use of HAAT values for specifying WSD antenna heights. In this case, if adopted, WSDs could report antenna height AGL (or AMSL) and an operating location to the database, and rely on the database to compute a HAAT value based on local terrain data. A method would need to be defined for reasonably computing an average HAAT value for WSDs (given their typically limited transmission ranges).

[9] See Section 15.709 (a) (2) *"For personal/portable TVBDs, the maximum conducted output power over the TV channel of operation shall not exceed 100 milliwatts; except that for personal/portable TVBDs that do not meet the adjacent channel separation requirements in Section 15.712(a), the maximum conducted output power shall not exceed 40 milliwatts."*

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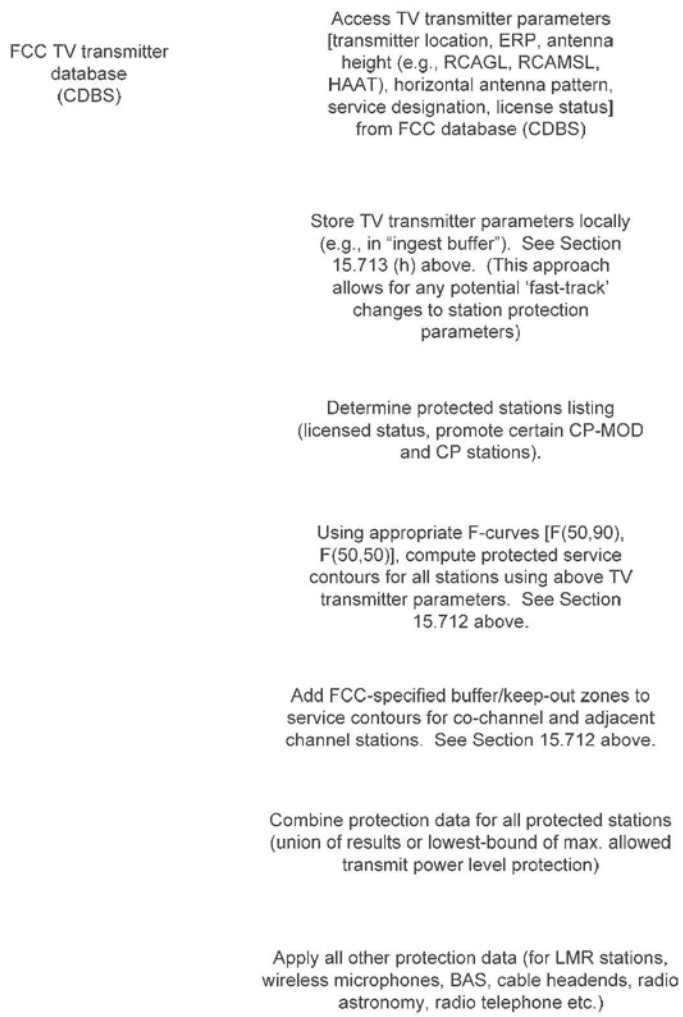

Figure 3. Flowchart for TV service protection (computed per location)

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Though the database is currently only required to compute protected service contours, and provide protection to TV services utilizing keep-out regions (beyond the contour), the FCC 08-260 R&O has left the record open on both higher power rural

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use, and variable power adjacent channel use. These potential changes may significantly impact the database calculations, and further changes to the database could become necessary in the future[10].

2.2.2 Protection of CMRS/PLMRS

The FCC 08-260 R&O also requires protection of CMRS and PLMRS systems. Note that PLMRS are used for mission critical mobile two-way radio public safety communications. Due to the sensitive nature of these communications, large co-channel and adjacent channel keep out zones are applied around these systems. These systems operate primarily in 13 major markets listed below and in Section 90.303(a). Note that currently, only 11 of the 13 markets contain CMRS/PLMRS services. A WSD co-channel keep-out zone (or required separation distance) of 134 km is required from the center coordinates of the listed metropolitan areas, and a WSD 131 km keep-out zone is required for adjacent channel operations. CMRS/PLMRS operations outside of the 13 major markets listed below (contained in the FCC ULS) must also be protected with a 54 km co-channel, and a 51 km adjacent channel WSD keep-out region from a CMRS/PLMRS base station.

Comment [dpg11]: These coordinates appear to be in the desired format (NAD83).

Urbanized area	Geographic center		Banks (MHz)	TV channels
	North latitude	West longitude		
Boston, MA	42° 21′24.4″	71° 03′ 23.2″	470–476, 482–488	14, 16
Chicago, IL[1]	41° 52′ 28.1″	87° 38′ 22.2″	470–476, 476–482	14, 15
Cleveland, OH[2]	41° 29′ 51.2″	81° 49′ 49.5″	470–476, 476–482	14, 15
Dallas/Fort Worth, TX	32° 47′ 09.5″	96° 47′ 38.0″	482–488	16
Detroit, MI[3]	42° 19′ 48.1″	83° 02′ 56.7″	476–482, 482–488	15, 16
Houston, TX	29° 45′ 26.8″	95° 21′ 37.8″	488–494	17
Los Angeles, CA[4]	34° 03′ 15.0″	118° 14′ 31.3″	470–476, 482–488, 506–512	14, 16, 20
Miami, FL	25° 46′ 38.4″	80° 11′ 31.2″	470–476	14
New York/NE NJ	40° 45′ 06.4″	73° 59′ 37.5″	470–476, 476–482, 482–488	14, 15, 16
Philadelphia, PA	39° 56′ 58.4″	75° 09′ 19.6″	500–506, 506–512	19, 20
Pittsburgh, PA	40° 26′ 19.2″	79° 59′ 59.2″	470–476, 494–500	14, 18
San Francisco/Oakland, CA	37° 46′ 38.7″	122° 24′ 43.9″	482–488, 488–494	16, 17
Washington, DC/MD/VA	38° 53′ 51.4″	77° 00′ 31.9″	488–494, 494–500	17, 18

[1] In the Chicago, IL, urbanized area, channel 15 frequencies may be used for paging operations in addition to low power base/mobile usages, where applicable protection requirements for ultrahigh frequency television stations are met.
[2] Channels 14 and 15 are not available in Cleveland, OH, until further order from the Commission.
[3] Channels 15 and 16 are not available in Detroit, MI, until further order from the Commission.
[4] Channel 16 is available in Los Angeles for use by eligibles in the Public Safety Radio Pool.

2.2.3 Protection of Cable Headends and Other Protected Receive Sites

Registered cable TV headend and TV translator receive sites, as well as BAS links must be protected by TVWS Databases. These types of receive sites are protected by a key-hole protection zone, which includes a 8 km circular co-channel and a 2 km circular adjacent channel keep-out zone around the receive site, in addition to a 60 degree protection arc/cone extending towards the transmitter site.

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[10] For example, the FCC originally proposed the use of F(90,90) curves to predict TV signal strength within the protected contour, to base a variable maximum allowed WSD transmit power level on (using specified D/U ratios) while operating inside of a TV station's protected contour on an adjacent channel - see FCC 04-113, ET Docket No. 04-186, *In the Matter of Unlicensed Operation in the TV Broadcast Bands*, Released May 25, 2004, paragraphs 29-32. Based on FCC comments, it is likely that adjacent channel usage (for fixed devices) will require more detailed TV signal propagation models, incorporating detailed terrain data. Future enhancements such as this should be expected as the database evolves.

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2.2.3.1 Cable Headend and TV Translator Receive Sites

From the FCC 08-260 Part 15.712 (b) rule: *"For translator receive sites and cable headends registered in the TV bands database, TVBDs may not operate within an arc of +/-30 degrees from a line between the registered translator or cable headend receive site and the TV station being received within a distance of 80 km from the protected contour for co-channel operation and 20 km from the protected contour for adjacent channel operation. Outside of this +/-30 degree arc, TVBDs may not operate within 8 km from the receive site for co-channel operation and 2 km from the receive site for adjacent channel operation."*

Also, from Part (c) Restrictions on registration,

> *(1) Television translator low power TV and Class A station receive sites within the protected contour of the station being received are not eligible for registration in the database.*
>
> *(2)* ***Cable television headends within the protected contour of a television channel are not eligible to register that channel in the database.***

and from Paragraph 186 of the 08-260 R&O:

"We will protect TV translator receive sites and cable headends using the criteria recommended by the NTA.251 ***Specifically, to prevent interference within the main reception beam of the TV translator station or cable headend receive antenna, operation of TV band devices will be prohibited co-channel and adjacent channel to the channel(s) being received by these facilities over an arc of +/-30 degrees from a line between the receive site and the TV station(s) being received. The protected zone will extend to the edge of the TV station protected contour, and will be limited in distance to 80 kilometers from the protected contour for co-channel operation and to 20 kilometers*** *from the protected contour for adjacent channel operation. We believe that there are very few cases where a translator receive site or cable headend could be farther outside a TV station protected contour than 80 kilometers and still receive a usable signal."*

Cable TV headend receive sites within a TV station's protected contour are not currently entitled to any special additional protection[11]. The text implies that the protection arc (or cone) normally *extends to the edge* of the TV station's protected service contour, and does not exceed 80 km in length for co-channel protection, and 20 km in length for adjacent channel protection. Note that co-channel protection is already provided inside of the TV station's protected service contour, and that only low power (40 mW) personal/portable WSDs are currently allowed to operate on adjacent channels inside of a TV station's protected service contour. Based on these conclusions, the TV receive site protection rule can be paraphrased as:

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"For translator and cable headend receive sites registered in the TV bands database TVBDs may not operate co-channel within an arc whose center is the receive site, whose radius is 80 km or the distance from the receive site to the TV station transmitter, whichever is less, and which extends +/-30 degrees from a line between the receive site and the TV station transmitter. TVBDs may not operate on adjacent channels within this same arc within 20 km of the receive site, unless the TVBD is a Mode II personal/portable device operating within the station's protected contour, in which case Sections 15.712(a)(2) and 15.709(a)(2) shall apply. In addition to the above provisions, TVBDs may not operate within 8 km from the receive site for co-channel operation or within 2 km from the receive site for adjacent channel operation in any direction."

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Comment [dpg12]: NCTA proposed this text, and Fig. 4.

A diagram of the required protected key-hole region is provided in Figure 4 below. Note that the diagram is not drawn to scale, and is for general illustrative purposes only.

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[11] See also Part 15.713 (c) Restrictions on registration. (1) Television translator low power TV and Class A station receive sites within the protected contour of the station being received are not eligible for registration in the database. (2) Cable television headends within the protected contour of a television channel are not eligible to register that channel in the database.."

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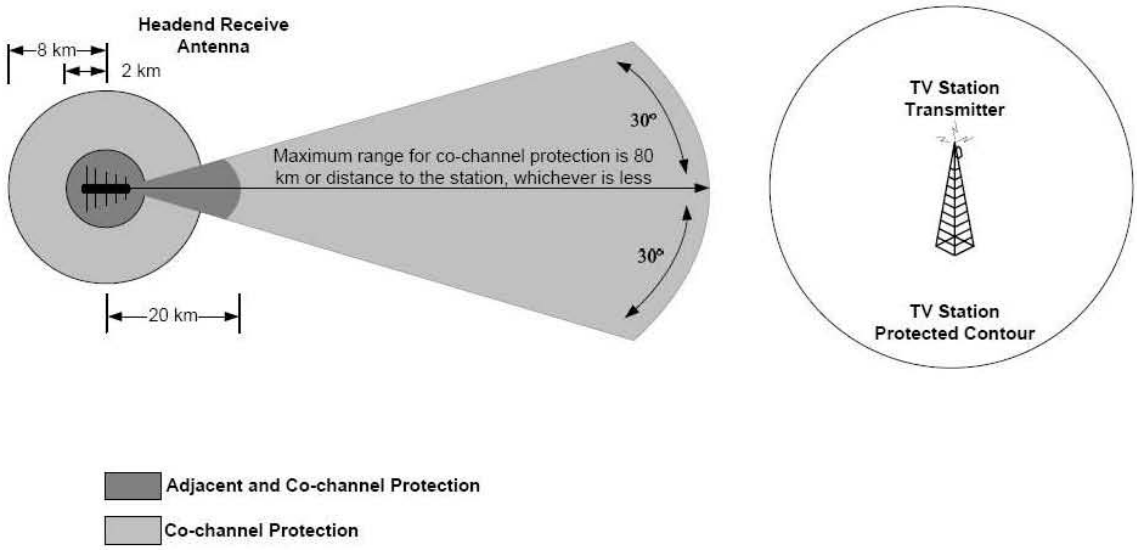

Figure 4. Key-hole protection zone for registered cable headend and translator receive sites

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2.2.3.2 Fixed Broadcast Auxiliary Service Receive Sites

Both fixed and temporary BAS receive sites (i.e., permanent BAS receive sites appearing in the FCC ULS or temporary BAS receive sites registered with the Repository) must also be protected using the above protected key-hole region, based on the path to the associated BAS transmitter. From the FCC 08-260 Part 15.712 (c) rule: *"Fixed Broadcast Auxiliary Service (BAS) Links: For permanent BAS receive sites appearing in the Commission's Universal Licensing System or temporary BAS receive sites registered in the TV bands database, TVBDs may not operate within an arc of +/-30 degrees from a line between the BAS receive site and its associated permanent transmitter within a distance of 80 km from the receive site for co-channel operation and 20 km for adjacent channel operation. Outside this +/-30 degree arc, TVBDs may not ope*rate within 8 km from the receive site for co-channel operation and 2 km from the receive site for adjacent channel operation."

From Paragraph 189 of the 08-260 R&O: *"We find that the most appropriate way to protect fixed BAS links is to specify an exclusion zone near the receive sites similar to the zone we are allowing for translator receive sites and for cable headends located outside the protected service contour of a TV station.* ***Specifically, we will not allow TV band devices to operate co-channel or adjacent channel to a fixed BAS link receiver within +/- 30 degrees of the line extending from the BAS transmitter to the receiver. The protection zone for BAS links will similarly extend to a maximum distance of 80 kilometers from the receiver toward the transmitter for co-channel operations and to 20 kilometers from the receiver toward the transmitter for adjacent channel operation."***

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Note that the 80 km (co-channel) and 20 km (adjacent channel) distance limits apply to the distance between the BAS receive site and the associated BAS transmitter site (and not its protected contour). As above, these rules strongly imply that the protection arc/cone normally extends from the BAS receive site to the BAS transmitter, and is limited to a 80 km maximum length (see Paragraph 189 above). Figure 5 below illustrates the protection scheme (also not shown to scale).

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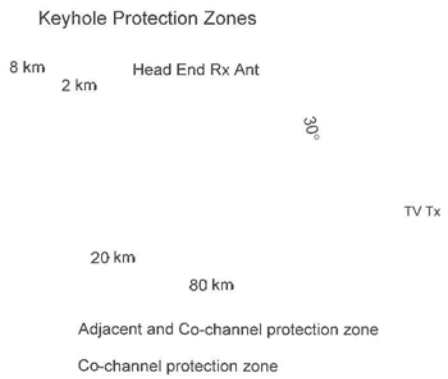

Figure 5. [Figure under revision] Key-hole protection zone for BAS receive sites.

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2.2.4 Protection of Other Services

Several other services that operate in the TV bands also need to be protected, including registered wireless microphone usage, medical telemetry, radio astronomy sites, and radio telephone services.

2.2.4.1 Protection of Registered Wireless Microphones

Part 74 wireless microphone sites with significant usage, on a regular basis, at well defined times and locations are entitled to protection in the database[12]. The protected region for wireless microphone operations is a 1 km circular co-channel keep-out zone, centered on the wireless microphone installation, during the specific times of WM use. Note that very large sites may have multiple keep-out zones associated with the site. The FCC is expected to qualify which WM users are entitled to protection (since many WM users are not authorized under the current Part 74 rules). It is also expected that there will be mechanisms in place to combat frivolous registrations in the database. Currently, the TVWS Database update time is 24 hours (except among Repository Services), and the required maximum allowed WSD database query period is 48 hours, which has implications for timed protection of wireless microphone users. This would normally require any protected wireless microphone usage to be registered at least 48 hours in advance. Also note that two open channels near channel 37 will be reserved in major markets for wireless microphone operations (details TBD). These rules are also subject to revision under the 08-260 R&O Petitions for Reconsideration process.

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2.2.4.2 Protection of Medical Telemetry

In order to protect medical telemetry equipment operating on channel 37, TV channels 36 through 38 have special WSD emissions limitations, listed below. These limitations form absolute emissions requirements for devices operating on channels 36 or 38, and would normally be tested as part of the device certification process. Note that other emission limiting approaches are possible (e.g., by reducing the maximum WSD transmission power levels allowed on channels 36 and 38, the absolute emissions limits can be met on those channels). For example, a 95 dBuV/meter/120KHz emissions limit corresponds to roughly a 5 mW maximum allowed WSD EIRP level on those channels, assuming a spectrally white or flat modulation occupying a 6 MHz bandwidth (on channel 36 or 38). In WSDB Group discussions, it was suggested that either the WSD itself or the database could recognize and enact the emission limitations on these channels (TBD). Note that the Part 15.209 (WSD alternate channel) emissions limits, and the normal (4 W EIRP) WSD adjacent channel emission limits

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Comment [dpg13]: Note that the broadcasters believe that this should be determined by the device itself, and should be met during the type acceptance process.

[12] See Part 15.713(h)(8) and Part 15.715 (d) for details of wireless microphone registrations. Specifically, the rules require a process for "registering facilities where Part 74 low power auxiliary devices are used on a regular basis" such as "*Sites with significant wireless microphone use at well defined times and locations*", which implies under the current rules that nomadic wireless microphone usage is not registered in the database.

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(of -55 dBr/100 KHz) for devices operating on channels 34-35 or 39-40 are already below the emission limits below for channels 36 and 38 (though not necessarily for channel 37). WSD operation on channel 37 is strictly prohibited (as is WSD operation on Ch. 3 & 4).

Section 15.709 General technical requirements.

(4) Emissions in the band 602 – 620 MHz must also comply with the following field strength limits at a distance of one meter.

Comment [dpg14]: MSTV suggested removing this section.

Frequency (MHz)	*TV Channel Number*	*Field Strength dBμV/meter/120 kHz*
602 – 607	*36*	*120 – 5[F(MHz) – 602]*
607 – 608	*36*	*95*
608 – 614	*37*	*30*
614 – 615	*38*	*95*
615 – 620	*38*	*120 – 5[620 – F(MHz)]*

2.2.4.3 Protection of Radio Astronomy Sites

Specific radio astronomy sites must also be protected, as listed below.

Section 15.712 Interference protection requirements.

(h) Radio astronomy services: Operation of fixed and personal/portable TVBDs is prohibited on all channels within 2.4 kilometers at the following locations.

(1) The Naval Radio Research Observatory in Sugar Grove, West Virginia at 38°31'12" N and 79º16'24" W

(2) The Table Mountain Radio Receiving Zone (TMRZ) at 40°07'50" N and 105°15'40" W.

(3) The following facilities.

Comment [dpg15]: Need to check location coordinates (NAD83)…

Comment [dpg16]: Need to verify that coordinates are in the desired format (NAD83), and that all facilities are protected

Observatory	***Longitude (Deg/Min/Sec)***	***Latitude (Deg/Min/Sec)***
Allen Telescope Array	*121 28 24 W*	*40 49 04 N*
Arecibo Observatory	*066 45 11 W*	*18 20 46 N*
Green Bank Telescope (GBT)	*079 50 24 W*	*38 25 59 N*
Very Large Array (VLA)	*107 37 04 W*	*34 04 44 N*
Very Long Baseline Array (VLBA) Stations		
Pie Town, AZ	*108 07 07 W*	*34 18 04 N*
Kitt Peak, AZ	*111 36 42 W*	*31 57 22 N*

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Los Alamos, NM	*106 14 42 W*	*35 46 30 N*
Ft. Davis, TX	*103 56 39 W*	*30 38 06 N*
N. Liberty, IA	*091 34 26 W*	*41 46 17 N*
Brewster, WA	*119 40 55 W*	*48 07 53 N*
Owens Valley, CA	*118 16 34 W*	*37 13 54 N*
St. Croix, VI	*064 35 03 W*	*17 45 31 N*
Hancock, NH	*071 59 12 W*	*42 56 01 N*
Mauna Kea, HI	*155 27 29 W*	*19 48 16 N*

2.2.4.4 Protection of Offshore Radio Telephone Services

In addition, offshore radio telephone services (see Section 74.709(e)) must be protected from WSD operations. Please refer to Section 74.709 (e) and 47 CFR 22.1007 for a full description of the protected zones and frequencies. Radiotelephone services operate on Channels 15-18 in the following areas near the Gulf of Mexico, as described below:

Section 74.709 (e) *To protect stations in the Offshore Radio Service, a low power TV or TV translator station construction permit application will not be accepted if it specifies operation on channels 15, 16, 17 or 18 in the following areas. West Longitude and North Latitude are abbreviated as W.L. and N.L. respectively.*

(1) On Channel 15: west of 92°00′ W.L.; east of 98°30′ W.L.; and south of a line extending due west from 30°30′ N.L., 92°00′ W.L. to 30°30′ N.L., 96°00′ W.L.; and then due southwest to 28°00′ N.L., 98°30′ W.L.

(2) On Channel 16: west of 86°40′ W.L.; east of 96°30′ W.L.; and south of a line extending due west from 31°00′ N.L., 86°40′ W.L. to 31°00′ N.L., 95°00′ W.L. and then due southwest to 29°30′ N.L., 96°30′ W.L.

(3) On Channel 17: west of 86°30′ W.L.; east of 96°00′ W.L.; and south of a line extending due west from 31°00′ N.L., 86°30′ W.L. to 31°30′ N.L., 94°00′ W.L. and then due southwest to 29°30′ N.L., 96°00′ W.L.

(4) On Channel 18: west of 87°00′ W.L.; east of 95°00′ W.L.; and south of 31°00′ N.L.

2.2.4.5 Protection of U.S. Border Areas

No WSD operations are allowed within 32 kilometers of the Canadian Border (on both UHF and VHF channels), and within 40 kilometers of the Mexican border on UHF channels, or within 60 kilometers of the Mexican border on VHF channels. These border restrictions will prevent WSD operations in some major U.S. cities (e.g., San Diego, Detroit).

2.3 Database Computational Implementation Considerations

There are several other database computational implementation considerations that must be taken into account in a split TVWS database architecture, including the location of channel availability calculations, the spatial resolution of channel availability results, and TVBD motion effects.

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2.3.1 Location of Channel Availability Calculations

Based on discussions within the WSDB Group, the main location of the channel availability computations shall be in the Repository Service for this particular split TVWS Database architecture. In practice, channel availability data can be pre-computed (and stored) by the Repository Service, and distributed to the various WSSPs, who would in turn directly interface with WSDs in the field. Note that in other architectures (e.g., a unified TVWS Database architecture), the computations may

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be performed elsewhere, and may also be done in real-time (upon TVBD query). It is envisioned that WSSPs would typically locally cache channel availability results generated by the Repository Service on a daily basis (e.g., a WSSP could download channel availability data for the entire U.S. early in the morning each day)[13]. WSSPs are envisioned to be trusted sites, enabled by the authority of the Repository Service under one model discussed in the WSDB Group. The advantage of locally caching channel availability results in the WSSPs is that the required communications bandwidth to the Repository Service is reduced, since WSD queries can be responded to by the WSSP, as opposed to having to go back to the Repository Service for queries.[14]

Comment [dpg17]: There has been significant discussion in the Group about where calculations may be performed. Several database companies (e.g., Key Bridge, Spectrum Bridge) want to perform these calculations in real-time in a each unified TVWS Database architecture.

The locally cached approach remains viable as long as the data set to be transferred from the Repository Service to the WSSPs is manageable in size. The size of a complete database for the U.S. (assuming a 50 m spatial resolution) under the current FCC rules has been estimated:[15]

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- US land area: 9,826,630 km^2 => 3.93 G locations/entries (50 m grid)
- Utilize 1-byte of info allocated to each channel's result (regardless of availability)

  (each entry corresponds to 47 bytes per lat.-long. pair + 4 byte lat. & 4 byte long.)
  => Assume 64 bytes per lat.-long. pair (includes 9 reserved bytes/loc.)

  - Currently, only 3 required codes (<2-bits) per channel & location (i.e., not available, available at full power [4 W/100 mW fixed/portable], partially usable adj. ch. [0 mW/40 mW fixed/portable]) – service provider could readily make WSD class determinations (based on WSD input)…
  - Byte sizing individual channel results allows for future expandability (e.g., to address variable adj. ch. power usage, high powered rural use, etc.)
- => U.S. Database results require: 3.93 G locations x 64B = 252 GB of data

- Currently, FCC rules require 3 sets of data results (corresponding to 3 ranges of WSD antenna RCAGL)

  => Corresponds to ~ 750 GB of data for completely specified database (for all WSD operating classes & configurations, assuming that WSSPs are allowed to classify WSD operational classes)…
- *Above analysis does not account for very significant data redundancies…*
  - Would result in >10:1 data compression => ~ 75 GB total data
- *Above analysis does not account for sending only delta-data (e.g., updates compared to previous day)…*
  - Would result in >10:1 data compression => <10 GB total data

Though this amount of data is only a rough estimate, it illustrates that the data transfer between the Repository Service and the WSSPs would be manageable, even for transferring the entire U.S. channel availability data results. Note that since the channel availability data is highly spatially redundant, very significant data compression ratios are possible (even if the

[13] Note that the minimum required update rate is dictated by FCC regulations [FCC 08-260 R&O]. The current minimum database update rate is 24 hours, although multiple Repository Services (if present) may be required to synchronize more frequently. WSSPs would need to synchronize with the Repository at least as often as the minimum update rate. It is envisioned that the Repository Service could send an 'Updated Data Available' (or equivalent) message to the WSSPs whenever updated channel availability data is ready for transfer.

[14] Note that this approach assumes some basic level of trust in the WSD and WSSP function (e.g., to correctly classify WSD operations and serve the proper data). It has been proposed that WSSPs are certified on a time-limited (e.g., 24-hour or shorter) basis through the Repository. All WSSPs should be approved by the Database Administrator. All WSDs are required to be type-approved by the FCC (or related testing agencies) to ensure proper operation.

[15] Note that several parties (e.g., IEEE 802, WISPA, etc.) have filed reconsideration petitions with the FCC to expand the number of WSD height ranges (e.g., from 3 categories to 6 categories), which would scale up the total size of the database channel availability data results.

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channel availability data is represented by a maximum allowed EIRP level on each channel vs. location[16]). There are a wide range of compression techniques available for use, which must be supported by both ends of the link (e.g., RS-WSSP, WSSP-WSD, or RS-WSD). The use of open source compression techniques is preferred wherever possible. Note that any signing of data entries in the database would significantly increase the size of the data transfers (and limit the compressibility of the data). Also note that TVWS Database architectures that compute channel availability results in real-time would not have the same bulk data transfer requirements.

2.3.2 Spatial Resolution of Channel Availability Data

The FCC 08-260 R&O generally requires WSDs with geo-location means to be capable of determining device location (using NAD83 referenced latitude and longitude coordinates) to within 50 meters.[17] This implies about a 50 m spatial resolution for pre-computed geo-location database channel availability data results in order to keep the overall error levels low, though FCC clarification is sought on this matter. Note again that TVWS Database architectures that compute protection results in real-time (upon TVBD query) would generally be expected to support much higher spatial resolutions. The use of coarser spatial resolutions (e.g., 100 m) increase the location quantization error when looking up precalculated channel availability results (since WSD location input must be 'snapped' to the nearest pre-computed grid point). Note that the smallest keep-out distance specified under the current rules is 100 m (for adjacent channel TV stations). Also note that when computing protected service contours, the resolution of such calculations can be assumed to be high. For uniformly distributed WSD locating errors over the range of +50 m to -50 m in any direction (clearly, a worst case assumption, since locating errors are typically Gaussian in nature), and a pre-calculated spatial grid resolution of 50 m, the overall mean locating error in the combined TVBD-TVWS Database would be about 26 m (a reasonable amount of error, relative to the minimum specified keep out zone size of 100 m).

Comment [dpg18]: Key Bridge has made this point previously in FCC filings.

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There may be a desire to reduce the resolution (i.e., increase the spatial grid size) of the channel availability results. It is possible to reduce the resolution (or increase the block size) of the channel availability results to some lower resolution (e.g., 1 km blocks), however, such an operation will generally negatively impact channel availability results. If the channel availability data is expressed at a lower resolution for a given region, the results should take into account the worst case higher (50 m) resolution operating point within that region (i.e., the results should provide protection equivalent to or better than the 50 m required resolution). In other words, if a 1 km x 1 km geographic region contains any higher resolution channel availability results that indicate a lower transmit power level is permitted, the maximum allowed transmit power level result for that region (and channel) should be lowered to the lower value over the entire region. Similarly, gross channel availability could be expressed over a pre-defined region (e.g., over a circle of a given radius as in Fig. 6 below, or over a polygon of defined dimensions), if supported by a particular TVWS Database. This approach results in the most conservative (incumbent-protective) interpretation of channel availability results when they are expressed at reduced resolution. This type of operation may be desirable when requesting channel availability data for controlling client mode WSDs, that do not possess knowledge of their exact locations (only their operating region may be known, e.g., as bounded by the serving master WSD cell size). Thus, a WSD base station, controlling client devices, could broadcast the lower resolution channel availability data over its coverage area, which client devices could then safely utilize for communications. An illustration of this process is provided for a fixed WSD coverage area, and a mode I personal portable (client) WSDs in Figure 6 below.

Comment [dpg19]: This could be utilized for a variety of scenarios, including WSD motion, and for variable location certainty. Currently, TVBDs must be able to locate their position within 50 m.

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[16] Note that the FCC [in the 08-260 R&O] has left the record open on both higher power rural WSD use, and higher/variable power adjacent channel use. In addition, the R&O is scheduled to be revisited for any potential changes two years after its release. TVWS Databases should be able to accommodate these potential modifications.

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[17] See Section 15.713 (g) *A personal/portable device operating in Mode II shall provide the database its FCC Identifier (as required by Section 2.926 of this chapter), serial number as assigned by the manufacturer, and the device's geographic coordinates (latitude and longitude (NAD 83) accurate to +/- 50 m).*

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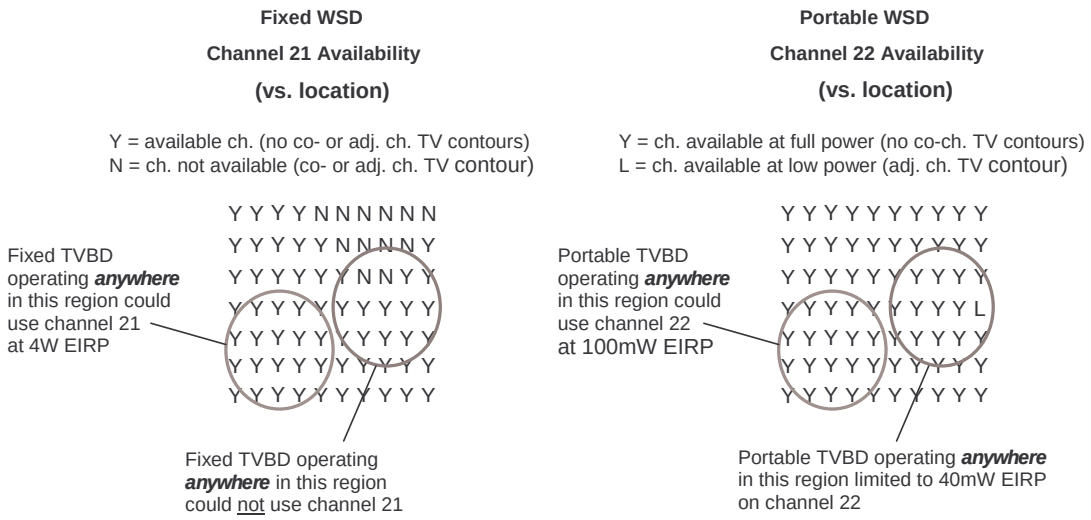

Figure 6. Channel availability over larger regions

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2.3.3 WSD Unit Motion

The FCC 08-260 R&O supports TVBD motion while operating (i.e. transmitting).

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> ***§ 15.703 Definitions.***
>
> *"(l) Personal/portable device. A TVBD that transmits and/or receives radiocommunication signals while in motion or at unspecified locations that may change."*

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The FCC 08-260 R&O specifies that portable TVBDs should access the database upon a "location change".[18] No other constraints on operation while in motion are spelled out in the rules. The amount of device location change required between database queries is not clearly defined in the R&O. FCC clarification may also be needed on this matter. Based on the above approaches of keeping the overall spatial quantization error levels low relative to the minimum keep-out zone sizes a reasonable definition for a location change can be estimated. Assuming that the relative locating error of the WSD is at an acceptable level (such that it can accurately resolve positional changes of 50 m), a device location change of 50 m would nominally place the WSD into the next location 'bin', as illustrated in Figure 7 below:

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Comment [dpg20]: MSTV disagrees, and believes that any motion requires the TVBD to stop transmitting, and listen for incumbents for 30 seconds...

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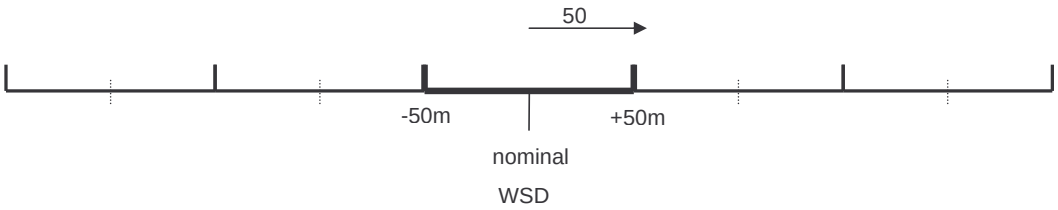

Figure 7. WSD location change example

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[18] See Section 15.711 (b) (ii) *A Mode II personal/portable device must access the database for a list of available channels each time it is activated from a power-off condition and re-check its location and the database for available channels if it changes location during operation.*

Using these techniques, any WSD movement of 50 m would trigger a database query (due to device location change). Assuming a 50 m spatial grid for pre-calculated database results, this would nominally push the device's location into the next pre-computed spatial grid point (possibly changing the incumbent protection requirements that must be observed). The WSDs would effectively have a +/- 50 m locating "dead-zone", where they could ignore any location changes within those limits. Note that many WSD locating techniques (e.g., GPS) produce some degree of reported location dither even when the locating device is fixed in position (even after a reasonable degree of averaging). As described in Appendix B, the total location errors in the system should be considered when determining required location reporting distances.

Assuming that WSDs need to report location changes every *D* m (e.g., *D*=50 m as above), the required database query per second rate (*R*) can be expressed as a function of WSD velocity (*V*): $R = V(m/s) / D\ (m)$, or $R = (V(mph)*0.447) / D\ (m)$. This results in about one database query every two seconds for a WSD moving at a velocity of about 56 mph (for D=50 m). It is assumed that the latency in TVWS Database responses is bounded such that a reasonably small location error is introduced during the time that the database takes to respond to a query to a moving WSD. For example, if the TVWS Database required 0.5 seconds to respond to a WSD query for a WSD moving at 56 mph (25 m/s). an additional 12.5 m of location error would be introduced into the overall system due to WSD motion during the query response time. Again, overall system locating errors should be considered relative to the minimum keep-out zone sizes, and kept at reasonable levels.

Optionally, it is also envisioned that a WSD may desire to pre-download (or cache) relatively small portions of the channel availability data over its operating region (e.g., for mobile WSDs, or base stations controlling other mobile WSDs), in order reduce the required communications bandwidth to the TVWS Database, as well as TVWS Database latency concerns. Note that the techniques shown in Fig. 6 can also be used to reduce the required communications bandwidth to the TVWS Database and latency concerns, at the potential expense of individual channel availability (since channel availability may be negatively impacted compared to techniques using locally-cached finer-resolution results). For example, a base station WSD may be responsible providing database access to 200 highly mobile WSDs (e.g., each moving at about 60 mph), requiring about 100 database queries per second if the location of each mobile is tracked at the highest resolution. If the base station is allowed to locally cache database results for its coverage area (at least on a daily basis), it would typically not need to access the TVWS Database continually throughout the day, which reduces the loading on several components in the system. The required update rates in the overall system would not change when using the technique (i.e., if more frequent database updates are required, locally cached results would also need to be updated more frequently). The TVWS Database should be able to support several flexible modes of access.

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Comment [dpg21]: MSTV has put forth that movements as small as 1 m should require re-querying the database.

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3. System Data Integrity Issues

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It is a common goal to assure a high level of consistency in protection results among TVWS Databases (or multiple Service Providers). This can be achieved through a variety of means. For example, automated consistency checking mechanisms can be utilized to continuously check the output results of numerous TVWS Databases. The protection results from different TVWS Databases (for the same operating locations and WSD configurations) can be compared to each other or a golden reference to assure proper system operation. Any significant differences between protection results could then be readily flagged in an automated fashion for immediate inspection by the affected TVWS Database operators and the FCC. Protection data that is identified in error can be sourced from another properly functioning TVWS Database, or the affected Database can be shut down. This approach would automatically identify databases that are either intentionally or unintentionally improperly functioning. Note that the consistency checking mechanism could be distributed among multiple Databases (e.g., with each performing consistency checks on each other), or the function could be centralized.

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Another potential method to help ensure consistent protection results would be to tightly specify the protection computations. For example, FCC-approved reference protection algorithms can be used to act as a golden reference for TVWS Database computations. Note that many of the protection algorithms (e.g., F-curves) already exist on the Commission's website. TVWS Database implementations should still have the freedom to optimize the calculations (e.g., for improved speed) as long as the protection results are reasonably consistent. This approach would help ensure that all players would have a full understanding of the incumbent protection requirements. Many of these issues could also be resolved through FCC clarifications.

Comment [dpg22]: WSDB LLC has made comments about calculation optimization in FCC comments, though WSDB LLC does not participate in the WSDB Group.

Another possible method to help ensure consistent protection involves the use of a unified incumbent data source (see Appendix C). The unified incumbent data source could contain information on all protected entities (e.g., TV, LMR, BAS links, receive sites, wireless microphone operations, etc.), that would be used by all TVWS Databases in the system. Much of the information contained in the unified incumbent data source would come from existing public FCC databases, such as CDBS and ULS. Thus, the unified data source would look similar to existing FCC databases, and would contain unambiguous data on protected entities. A significant advantage of a unified incumbent data source is that registered protected entities (e.g., cable headends and wireless microphone operations) would only need to register in one place to be assured protection. The alternative to this approach is to require synchronization of registered protected entities across multiple TVWS Databases, and clear guidance (from the FCC) as to which entities should receive protection.

See Appendix C for further details of all of these mechanisms. All of the described mechanisms are intended to help ensure a high level of incumbent protection, while promoting a competitive eco-system of TVWS Databases. A competitive TVWS Database environment will promote innovation (e.g., in basic and enhanced TVWS Database services), as well as the lowest cost services for consumers.[19]

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[19] Motorola believes that Database architectures based on a single Repository Service do not offer the same level of innovation or cost-competitiveness, though such architectures may be supported by some Broadcasters.

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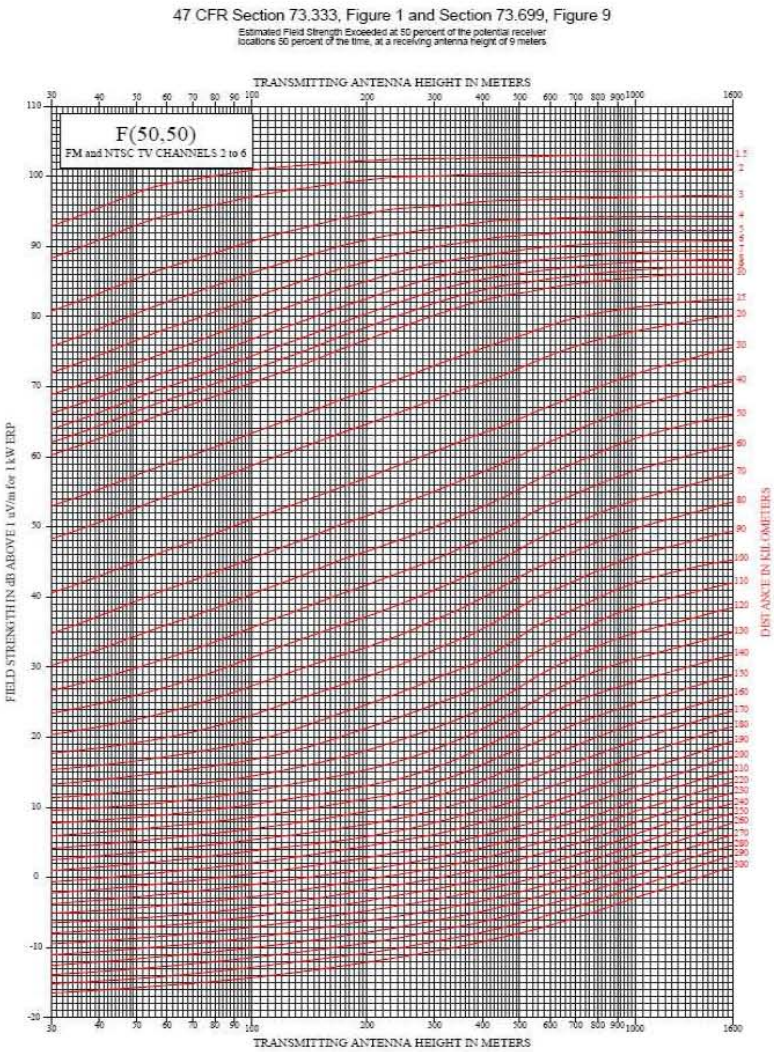
Appendix A: FCC R-6602 curves

The database must compute the protected service contours of TV stations through the use of FCC R-6602 curves (also termed F-curves). From Section 73.699, the following R-6602 propagation curves are utilized for computing TV signal propagation. These propagation models are based on empirical measurements taken by the FCC in the different TV bands. They assume a 9 m receive antenna height. The F-curves are specified in terms of location (*l*) and time (*t*) availability parameters (F(*l*,*t*)). F(50,50) curves for the appropriate band are utilized to compute analog TV coverage areas, and F(50,90) curves are utilized to compute digital TV coverage areas. The curves should be interpolated by utilizing the Association of Computing Machinery's (ACM's) Algorithm 474 for performing Bivariate Interpolation.



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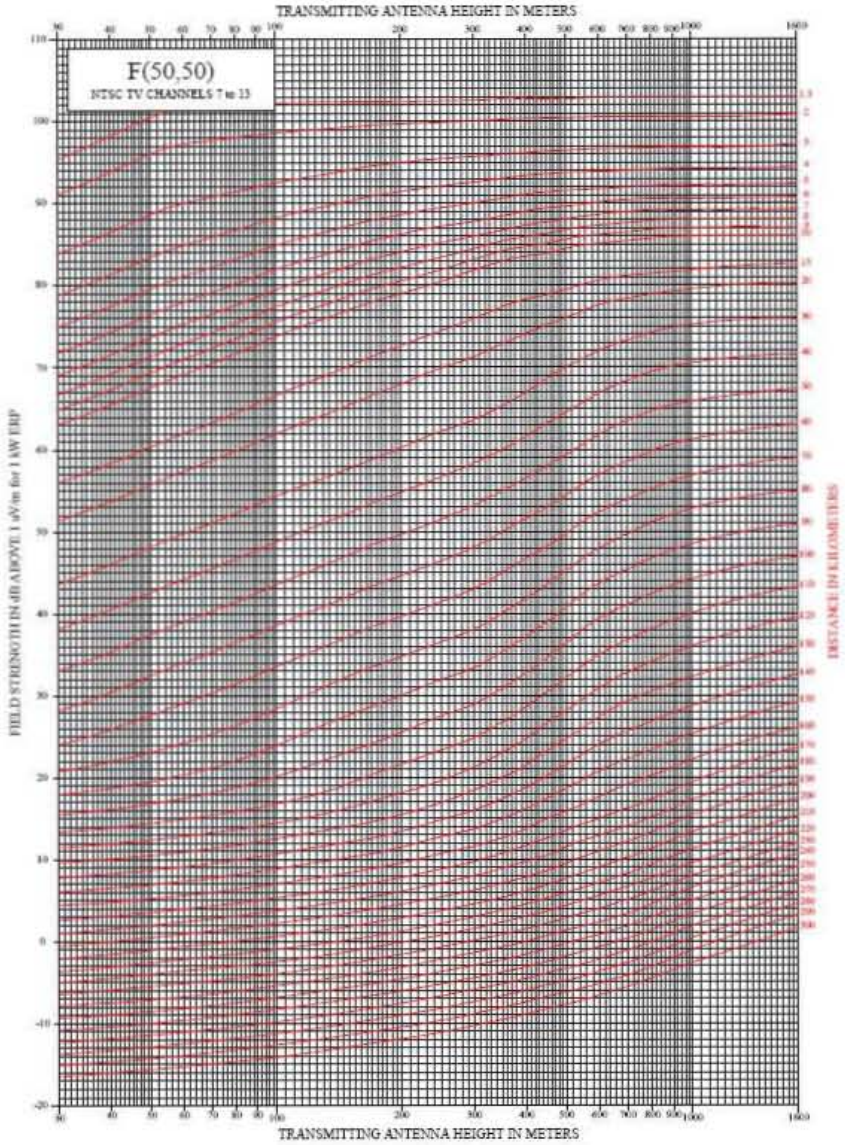
47 CFR Section 73.699, Figure 10

Estimated Field Strength Exceeded at 50 percent of the potential receiver locations 50 percent of the time, at a receiving antenna height of 9 meters



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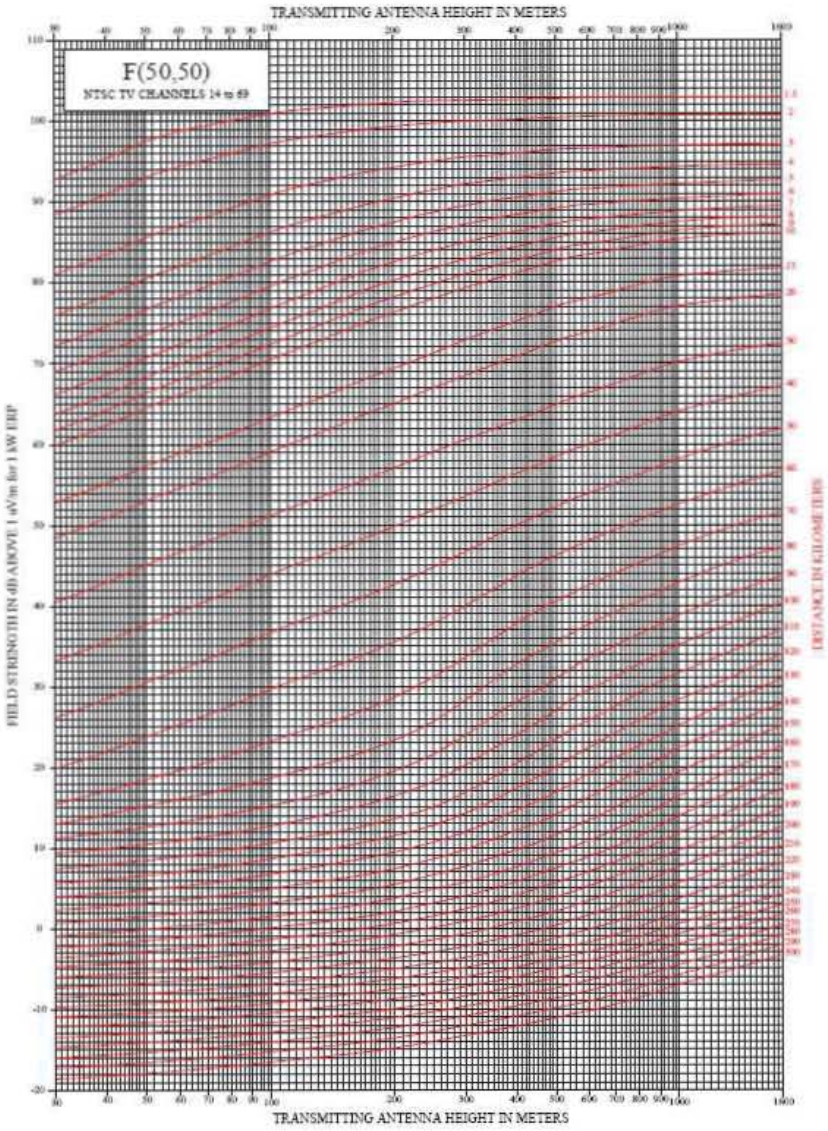
47 CFR Section 73.699, Figure 10b

Estimated Field Strength Exceeded at 50 percent of the potential receiver locations 50 percent of the time, at a receiving antenna height of 9 meters



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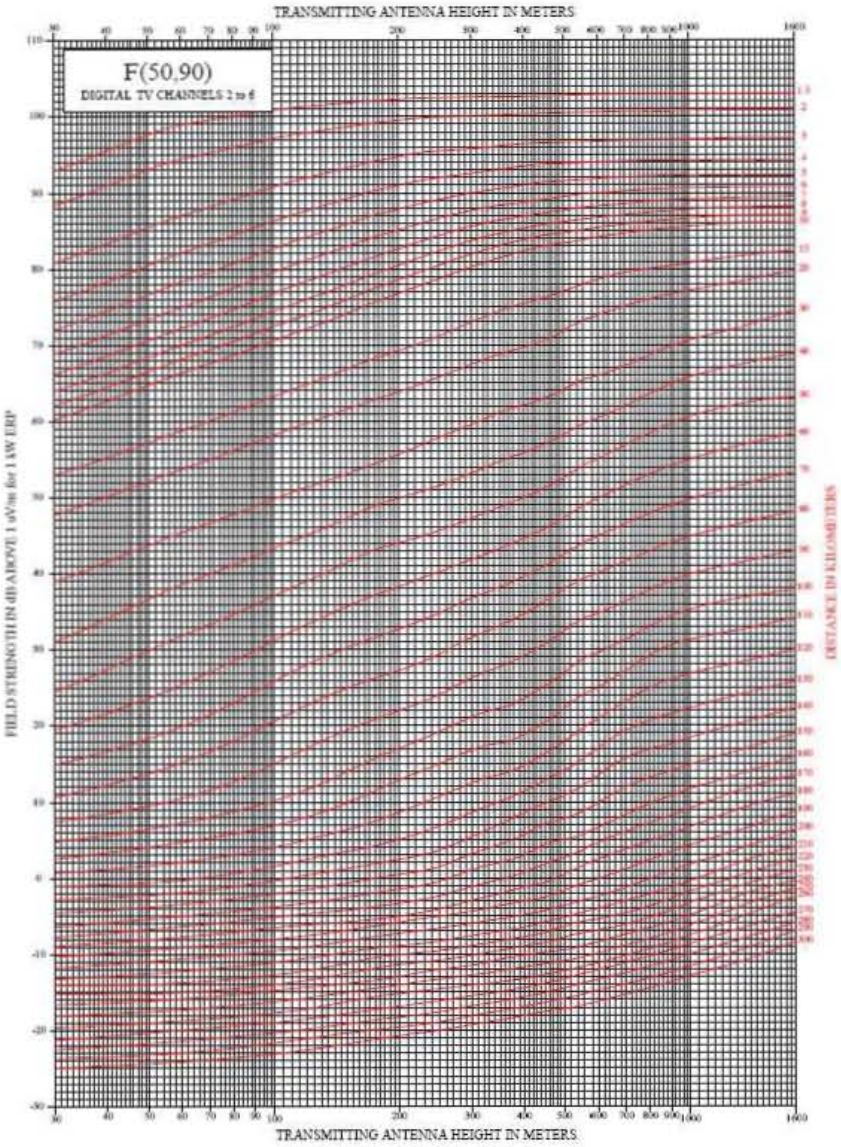
Estimated Field Strength Exceeded at 50 percent of the potential receiver locations 90 percent of the time, at a receiving antenna height of 9 meters



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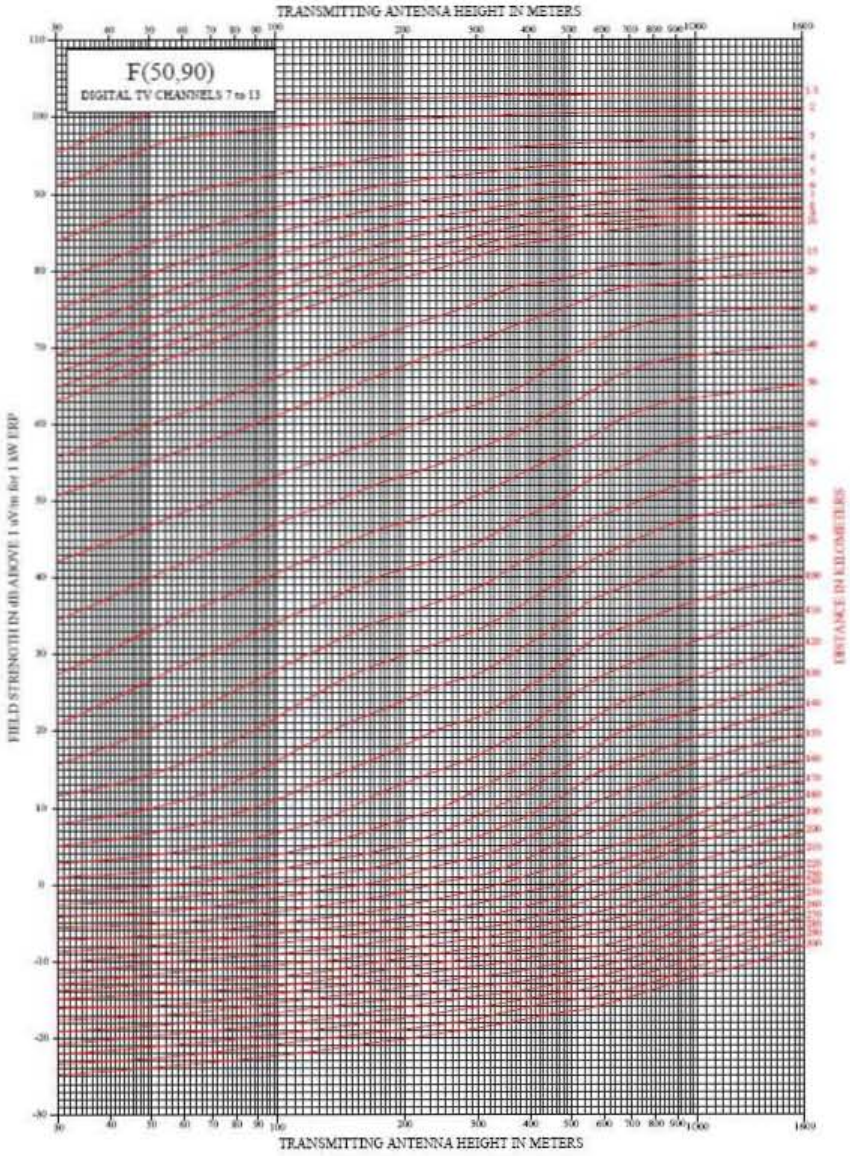
Estimated Field Strength Exceeded at 50 percent of the potential receiver locations 90 percent of the time, at a receiving antenna height of 9 meters



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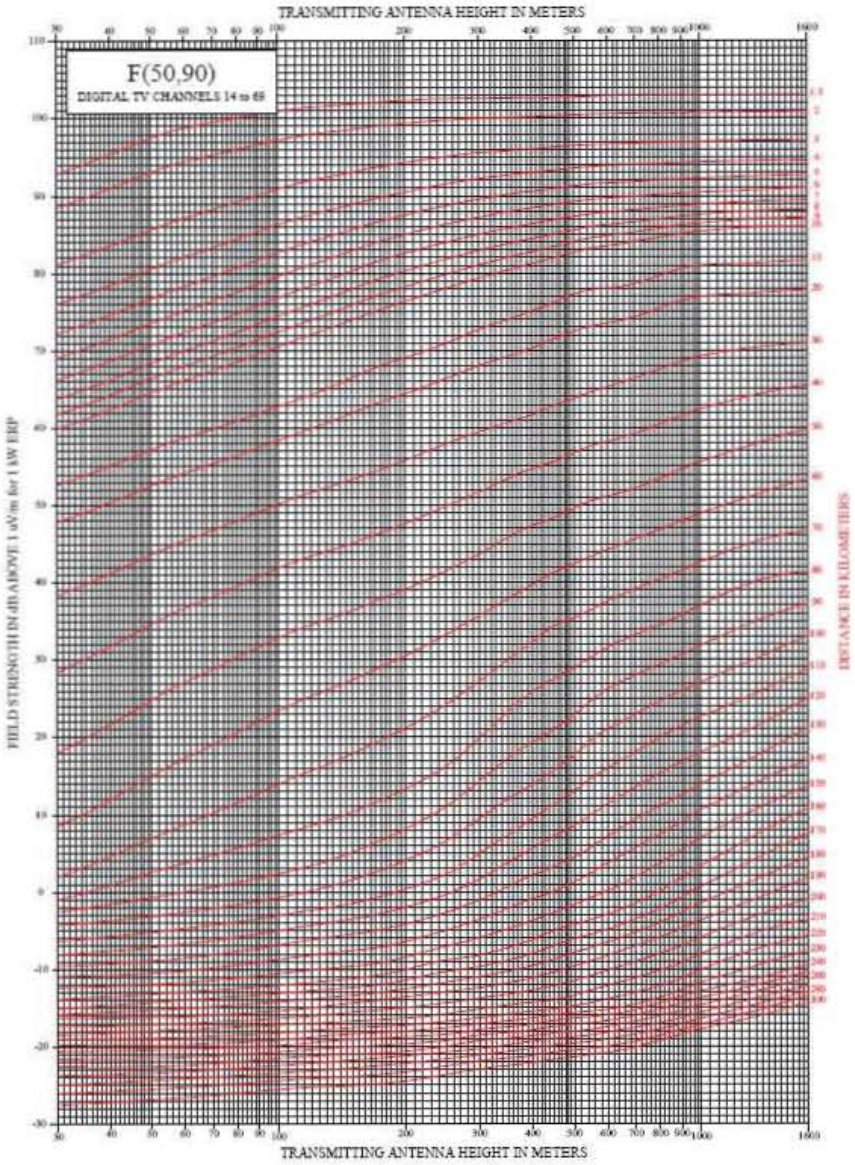

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Appendix B: TV Station Contour Computations and Keep-out Zone Computational Considerations

The following material is taken from a presentation on "**Geo-location Database Protected Contour / Keep-out Zone Computational Issues**" made to the group:

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Geo-location Database Protected Contour / Keep-out Zone Computational Issues

Dave Gurney

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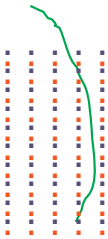
Contour Calculations

- Some basic comments on contour calculations
  - In general, contour computation is not an exact science…
    - Does not consider (even average) terrain effects beyond 16 km from transmitter
    - Statistical in nature (e.g., 50% of locations, 50% of the time…)
  - Obviously, need reasonably high degree of accuracy & consistency in calculations…
    - Especially if multiple repositories are present
    - Would prefer to not over-specify computations (much beyond what is already specified), since they can ***significantly affect computational complexity & computational time…***
      - Would assume that we can foresee best possible implementation methods…
      - Does not allow for innovative/optimized implementations (e.g., in terms of speed/memory/etc.)…
      - Would rather specify maximum allowed error levels…
    - ***At the end of the day, contour (+ keep-out zone) forms a demarcation line...***
    - There are likely to be very minor differences in computational results (i.e., within 50 m) due to slightly differing grid references, interpolation methods, high-precision (e.g., floating-pt.) comparisons, processor/compiler selection, etc.
      - All differences should be resolved within 1 spatial grid point
      - As in other approaches (e.g., motion), attempt to keep relative error levels small
      - ***Small errors should have virtually no impact on protection…***
        - » can always pad keep-out zones to deal with aggregate errors



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A Look at Linear Interpolation of Contours…

red circle = linearly interpolated contour point

black circle = exact computed contour point (w/Φ angular resolution)

Ideal protected service contour (omni ant./terrain)

r = distance to linearly interpolated contour point

R = contour radius

Φ/2

Φ = angular resolution of contour calc. (shown exaggerated)

TV TX

Linearly interpolated contour error (red line) =
R - R cos (Φ/2) = R (1-cos(Φ/2))

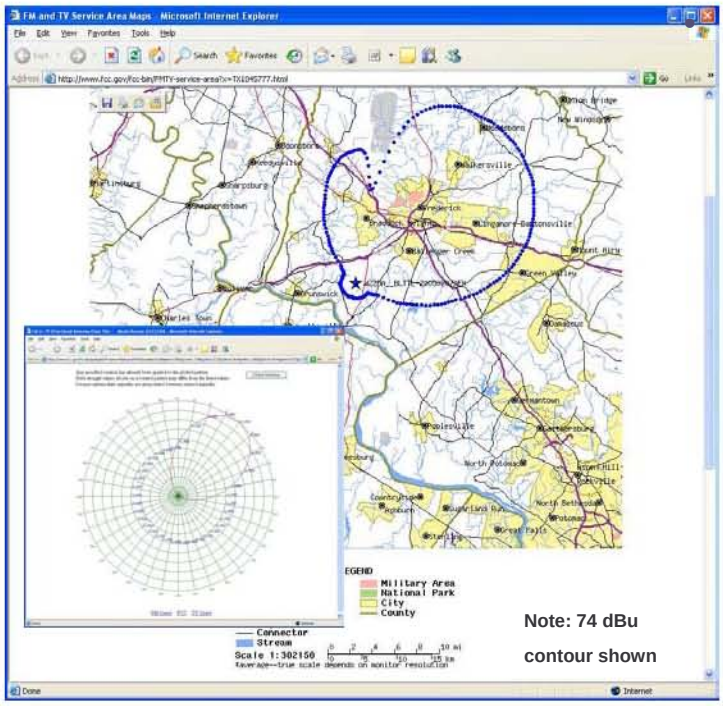
For Φ=1 degree, error = 3.8 x 10^{-5} (38 ppm or 0.0038%)
For Φ=0.5 degree, error = 9.5 x 10^{-6} (9.5 ppm or 0.00095%)

(e.g., for 500kW ERP, 400m HAAT UHF DTV station,
1-degree lin. interp. contour error = 3.79 m
0.5 degree lin. interp. contour error = 0.95 m

=> 1-degree linear interpolation introduces negligible (max.) contour calculation error (even for high power TV stations, with R=99.6 km & omni TX ant. patterns)

- Examine one scenario that could have large errors using lin. interp.
  - A high power DTV transmitter with a very large service area…
    - Since errors are proportional to contour distances (R), should have large error
    - 500 kW ERP, 400 m HAAT omni-directional UHF DTV station has contour radius of 99.6 km
    - Assume some angular resolution of 'exact' contour pt. computations (e.g., 1-degree), and interpolate contour points in between
  - Even for this case, max. interpolation error is very small…
    - For 1-degree 'exact' contour computation, max. **lin. interp. error is < 4 m**
    - Error shown as red line in drawing…

What about stations with more varied contour patterns?…



Both terrain and antenna patterns can cause more rapid changes in protected contours

- Effects typically more pronounced for lower power/lower ant. ht. TV stations…
  - Smaller contour distances generally mean smaller absolute errors
  - Assume terrain (HAAT) defined in 1-degree steps
  - Antenna patterns generally defined in 10-degree steps in CDBS
  - F-curves are generally ***non-linear*** functions…
  - Real-world RF environments will further muddy the waters
  - May be an argument for supporting 'ingest buffer' modifications…
- Points of interest…
  - Might expect largest errors to occur along contour edges with the highest rates of curvature (though also have large number of 'exact' pts.)
  - Also, potential errors near nulls of patterns (though keep-outs may make less important…)

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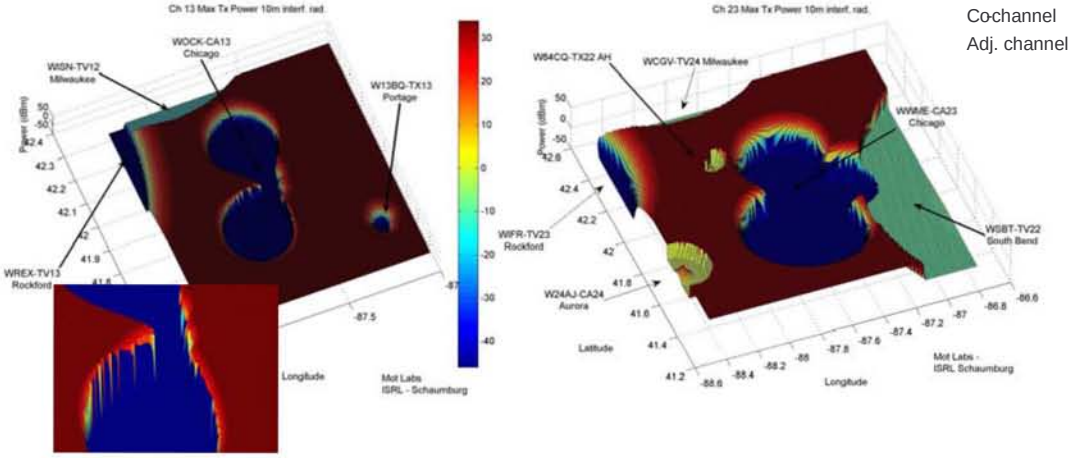
Nearest Contour Edge Modeling Examples

Max Allowed WSD EIRP vs. Lat-Long Coordinates



Co-channel
Adj. channel

The charts show the Max allowed EIRP versus location coordinate for operation on TV channels 13 (left) and 23 (right) in the Chicago area (under originally proposed FCC rules)

- The color code indicates the allowed EIRP in dBm to satisfy various co- and adjacent channel interference criteria, taking into account the different protection requirements for different classes of licensed stations – also includes nearest contour edge modeling (shown in magnified region)
- Reddish-brown indicates +36 dBm, dark blue < -45 dBm (essentially unusable)

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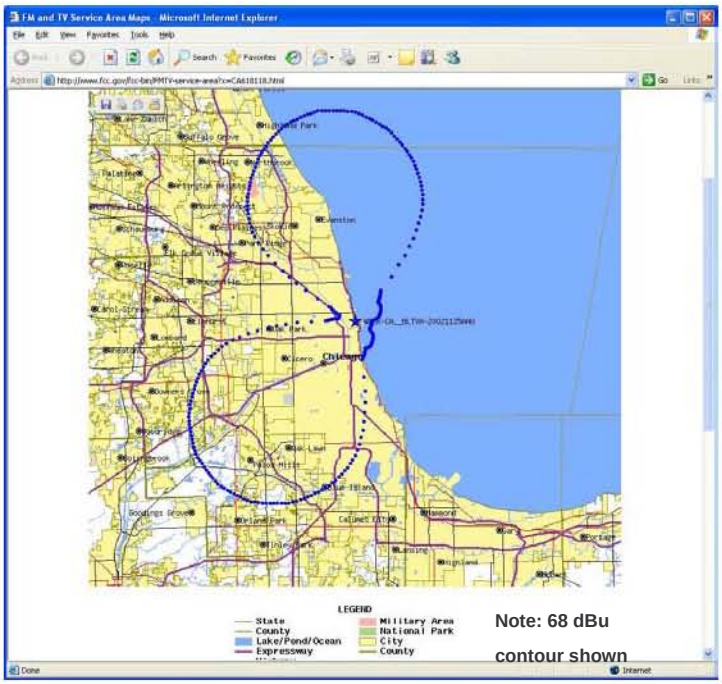
Nearest Contour Edge Modeling Effects…



- Keep-out (min. separation) distances should be applied in a direction perpendicular to tangent of contour
  - Equivalent to finding nearest contour edge…
  - Can significantly alter nulls in contour patterns…
    - 1-D analysis does not reveal these features, since keep-out radial not always in the same direction as LOS to TX (see red arrow to left)
  - There are multiple ways to implement these effects… (with either exact or interpolated contour pt. modeling)
    - e.g., keep-out circle around WSD…
  - If errors in service contour modeling are small – errors in keep-out zone modeling should also be small
    - as long as properly implemented, as described above

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Appendix C: Other Data Integrity Issues

The following material is taken from a presentation on "**TVWS Database Computational and Data Integrity Issues**" made to the group by Motorola:

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TVWS Database Computational and Data Integrity Issues (Part 2)

Motorola

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Summary – Data Integrity/Computational Issues

Previously, we discussed *3 optional methods to help* ensure consistency among multiple TVWS Databases

- Automated consistency checking mechanisms to check TVWS Database outputs for consistent protection results
- More fully specifying incumbent protection calculations (e.g., in reference ANSI C code implementation)
- Utilizing unified incumbent data to assure consistent input data

These methods were designed to enhance incumbent protection

- Methods do not significantly impact internal TVWS Database architectures (e.g., either unified or split)
- Some incumbents appeared to like the ideas (e.g., NCTA, some WM interests), while others appeared to not like the ideas (?)…

The described approaches also support a competitive eco-system for TVWS database implementations

- Having multiple TVWS databases will drive equipment and service prices down for consumers, and spur innovation in TVWS database services…
- Numerous companies (several potential database users and database providers) have supported multiple TVWS database approaches in past FCC filings…

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Automated Consistency Checking Mechanisms

Automated consistency checking mechanisms can be utilized to check TVWS Database outputs for consistent protection results

- **Can quickly flag any inconsistent protection results**
  - **As compared to other TVWS Databases (or known good reference)**
  - **May accept a very low level of spatial and temporal differences among databases**
    - to account for varying db update times, and slightly different protection algorithm implementations
- **Would be useful for any TVWS Database system that has multiple outputs (e.g., multiple TVWS Databases, multiple Service Providers, etc.)**

Again, this method was intended to enhance incumbent protection

- **Would be able to identify offending (i.e., inconsistent) database results, which could further be tracked down by database administrators to find root cause**
- **Offending results could be sourced by another known good TVWS database**
- **Method could be applied independently of other methods…**

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Fully Specifying Protection Computations

Incumbent Protection algorithms can be fully specified

- **Helps to eliminate any discrepancies in protection computations…**
- **Ensures that all players have a full understanding of protection requirements**
  - FCC has already specified basic algorithms (e.g., F-curves)
  - Could go one step further (e.g., FCC-approved reference ANSI C-code implementation, or at least more detailed protection algorithm descriptions)
  - Forms a functional reference to verify protection computations being properly performed…
- **Would be useful for any TVWS Database architecture that has multiple outputs (e.g., multiple TVWS Databases, multiple Service Providers, etc.)**

Again, this method was intended to enhance incumbent protection

- **Yet, *this method still allows for innovation on part of TVWS Databases…***
  - For example, ***database vendor could optimize calculations*** (e.g., parallelize) to improve speed, which would provide direct benefits to TVWS database customers (and incumbents such as nomadic WMs)
  - Allows for differentiation of database service levels (e.g., in terms of db response times, breadth of results, etc.)… valuable to TVWS Database eco-system…
  - Vendor would still need to produce the same basic protection results (compared to FCC-approved reference protection algorithm implementation)
  - Vendors still could offer numerous enhanced database services (as previously discussed)…
- **Method could be applied independently of other methods…**

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Unified Incumbent Data

A unified incumbent data source may also be utilized…

- **Contains all protected entity information (including TV, LMR, BAS, WMs, receive sites, etc.) – most information comes from public FCC databases**
- **Provides registered protected entities (RPEs, such as cable headends and WMs) a unified registration interface**
  - Avoids TVWS database synchronization issues, since all TVWS databases operating off of same input data
- **Ideally, would be a FCC-administered data source (similar to CDBS, ULS)**
  - Contains licensed/protected system info, similar to other FCC databases
- **Approach readily supports open competition among multiple TVWS Databases…**
  - Will drive down costs for consumers, and result in innovative database services (including both basic and enhanced database services)…

Again, this method was intended to enhance incumbent protection

- **Yet, this method also readily supports multiple, independently developed TVWS Databases (of various architectures)…**
  - Multiple TVWS Databases are best for TVWS eco-system development…
    - Since each TVWS Database architecture has inherent strengths and weaknesses…
    - And will offer varying service levels (e.g., speed of response, enhanced services, etc.)
  - Provides the most scalable/future-proof approach to TVWS Database development…
- **Method could be applied independently of other methods…**

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Previously Shown Slides (for reference)

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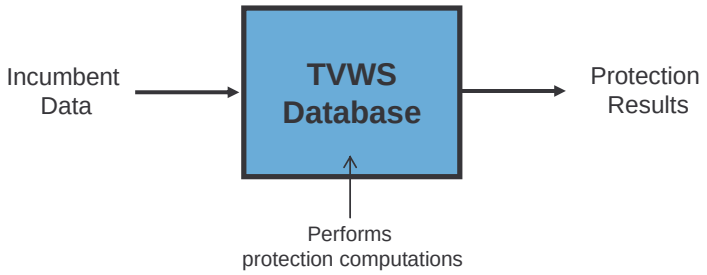
Abstract TVWS Database

Any TVWS database can be thought of as a simple black-box model

- **It has inputs (i.e., incumbent operational data/parameters)**
  - **For example, TV/LMR/BAS transmitter locations, ERP, antenna patterns, etc.**
  - **Accepts various registration data**
    - Receive site data (cable headends, wireless mics (WMs), BAS sites, etc.), TVBD data, etc.
- **It performs incumbent protection computations…**
  - **Computes protected service contours and applies min. required separation distances**
- **It outputs protection results (i.e., channel availability data)**
  - **Based on incumbent data inputs, TVBD class, and protection algorithms/computations**



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TVWS Database Architectural Variations

Internal detailed TVWS database architecture should not be particularly important to users – as long as it functions properly…

- ***Protection results should be consistent and essentially guaranteed correct across different architectures and TVWS databases***
- **Many different TVWS database architectures are feasible/possible…**
  - **Unified database architecture (i.e., one-stop shop) – what the FCC originally envisioned…**
  - **Split database architecture (e.g., Repository Service and Service Provider)**
- **Competition is crucially important to consumers (i.e., database users)**
  - **Competition encourages innovation, and drives down prices for consumers (and manufacturers)…**
  - **Public interest dictates that multiple databases be allowed – especially for large potential markets (e.g., see Perspective Associates TVWS study)**
    - A single Repository Service (or unified TVWS database) is a monopoly, and will drive database access costs much higher for everyone…
    - Several other methods can be utilized to guarantee consistent protection results among TVWS databases…
  - **Several corporations have recently filed with the FCC in support of multiple TVWS databases, and unrestricted TVWS database architectures…**
    - Including **Microsoft, Dell, Motorola, Spectrum Bridge, Telcordia, Comsearch, WSDB**…

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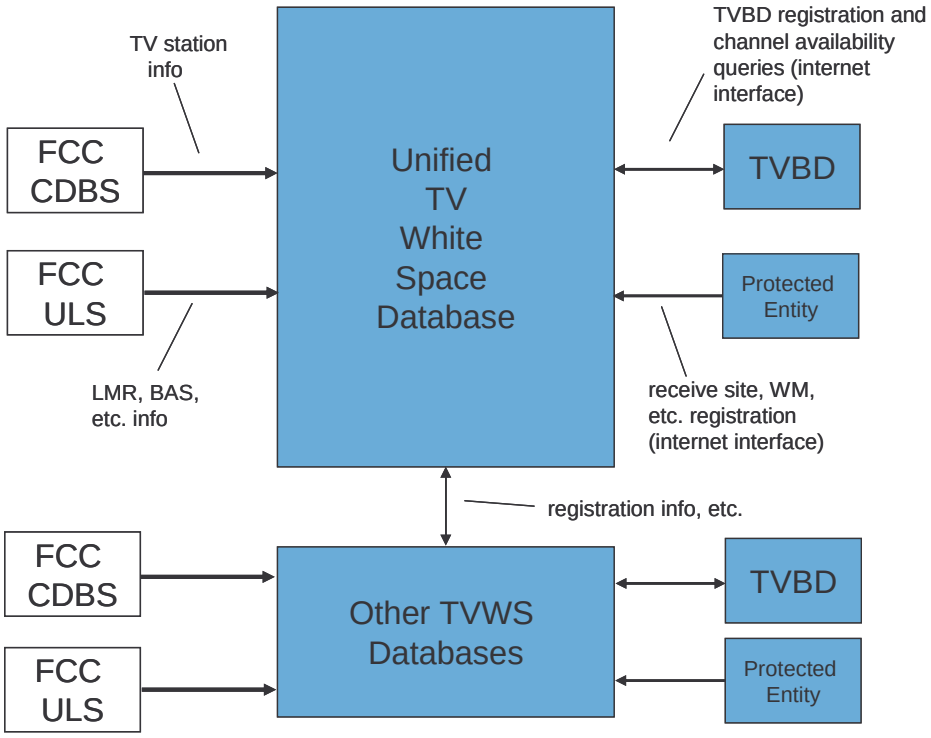
Unified TVWS Database Architecture



Basic Unified TVWS Database Architecture

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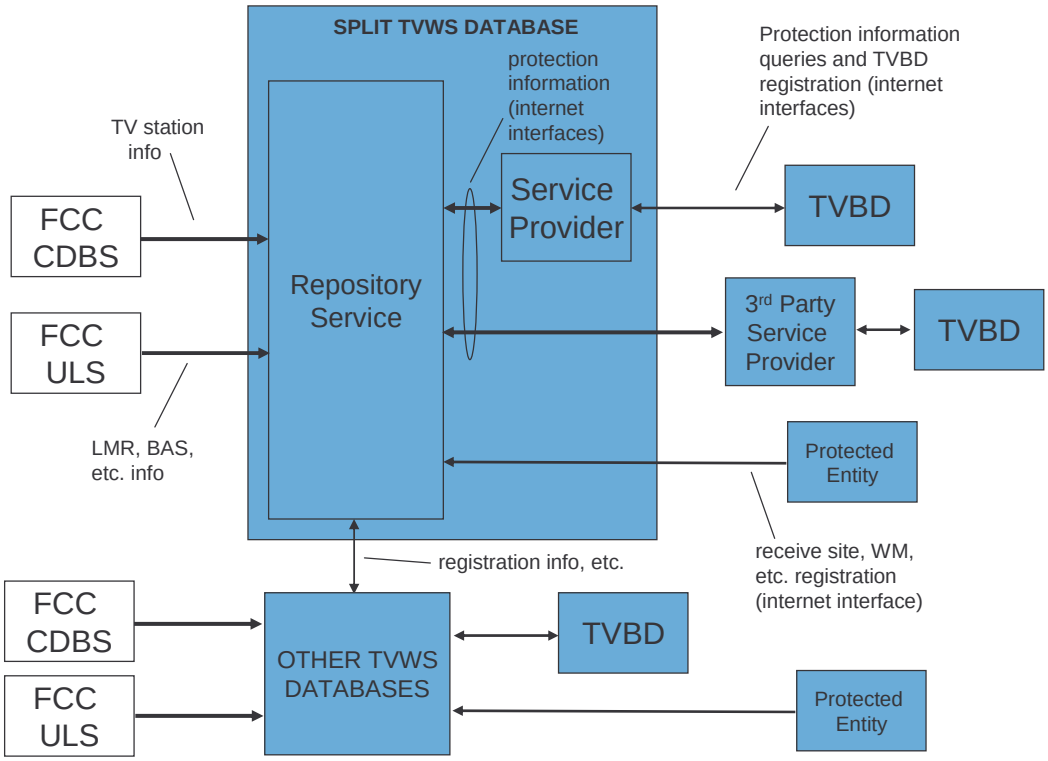
One Possible Split TVWS Database Architecture



Split TVWS Database Architecture

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Data Integrity Issues (1)…

Key Question: ***How do we ensure consistent incumbent protection results in TVWS database computations?...***

- Especially since the protection computations may be performed in multiple places, by different entities (e.g., different TVWS databases)…
- Since protected entity information needs to be consistent across multiple TVWS databases…
- Clearly, this question is important for reliable incumbent protection…

One desirable solution: ***Utilize automated consistency checking mechanisms to compare different TVWS database output results…***

- Automatically, and continuously monitors different TVWS database (or Service Provider) output results to identify any incumbent protection inconsistencies
- Can query same test locations simultaneously among multiple TVWS databases (or Service Providers), and compare protection results…
- Can flag any channel availability results that are inconsistent (among TVWS databases, or with a golden reference)
  - Very low level of specified spatial and temporal differences may be allowed between databases (e.g., up to 100m, and up to four hours)
  - Affected databases could be shut down, or sourced from other known good databases

Approach ensures consistency among TVWS database output results

- Method would quickly identify any incumbent protection discrepancies (e.g., due to database hacking, etc.)
- Can be applied independently of (or in addition to) two other described approaches…

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Data Integrity Issues (2)…

Another desirable approach to ensure protection consistency: *Fully specify incumbent protection algorithms…*

- ***Incumbent protection results should be "black and white" (i.e., not subject to any interpretation)…***
  - **Eliminate any doubt over protection requirements (e.g., interpolation algorithms, quantization errors, terrain database usage, etc.)…**
- **Protection computations should be rigorously specified and approved…**
  - **Define FCC-approved (and incumbent reviewed) protection algorithms (e.g., golden reference ANSI C-code)**
  - **Motorola has significant experience in this area (e.g., 2nd round FCC testing of WSD prototype devices)**
  - **Algorithm results should be understood by all participants, and distributed by FCC (to multiple TVWS databases…)**
- **Approach further ensures protection consistency, while still allowing competition among different TVWS databases…**
  - **TVWS databases should not be allowed to compete on channel availability results (FCC approval requirement)**
  - **TVWS databases should be allowed to compete on enhanced database services**
    - E.g., interference environment estimation (vs. location)
    - E.g., maximum available link budget estimation (vs. location)
    - E.g., unlicensed device co-existence or coordination services

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Data Integrity Issues (3)…

Yet another highly desirable approach to ensure protection consistency:
Utilize unified incumbent data to help protect incumbents

- **Contains a single (unified) source of all protected entity information**
  - ***All TVWS databases rely on this input information to compute protection results…***
  - **Assures highest possible level of consistency for all protected entity information (e.g., including TV, LMR, WM, cable headend data, etc.) –** ***one place to go to correct protection errors***
  - **Eliminates interpretational errors of FCC incumbent data (e.g., CP vs. CP-MOD status)**
  - **Can contain HAAT data - eliminates any discrepancies between use of different terrain databases…**
  - ***Eliminates registered protected entity (RPE) synchronization issues across multiple TVWS databases…***
  - ***Provides a consistent interface for RPEs (e.g., cable headends, WMs, etc.) to register their information***
- **Very similar to other FCC databases (e.g., CDBS, ULS),** ***but dis-ambiguated…***
  - **Similar to Fox's ingest buffer idea**
- **Approach addresses many incumbent protection consistency issues…**
- ***Yet, still encourages competition among TVWS database vendors…***

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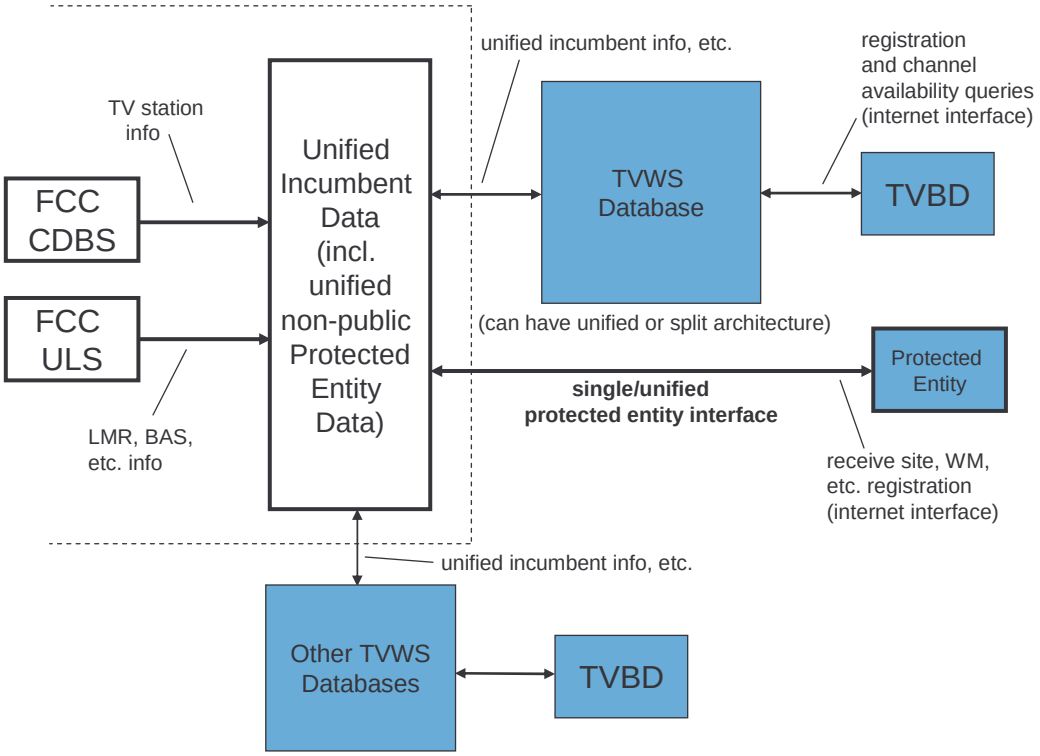
Unified Incumbent Data Architecture



Unified Incumbent Data Source Architecture

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Summary - Assuring Consistency in Protection w/Multiple TVWS Databases

Automated database results consistency-checking mechanisms can be implemented to continuously "police" multiple databases for proper operation

- Can quickly identify any protection discrepancies (e.g., due to hacking, etc.)
- Same protection data consistency issues exist with multiple Service Providers

Alternatively (or additionally), two other items can virtually guarantee consistency between different database implementations:

1) Using common protected entity information among all TVWS databases (for all incumbents: TV, Wireless Mics, Receive sites, etc.)
2) Using the same basic channel availability computational protection algorithms for all TVWS databases (e.g., F-curves, terrain databases, interpolation methods, etc.)

One way to achieve these two goals (while preserving competition) is to:

1) Enable open and non-exclusive access to unified protected entity data
   - This also eases protected entity (PE) registration concerns – *protected entities only need to go to single source to register all device operation (consistent interface)…*
2) Implement open and non-exclusive computational protection code
   - Motorola has offered to significantly aid this effort, based on past implementation experience

These approaches support a healthy, competitive eco-system for TVWS database implementations

- Having multiple TVWS databases will drive equipment and service prices down for all consumers, and spur innovation…

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Comment [dpg23]: These slides represent Motorola's views on these topics.

Summary

TV White Space Databases

- **The Commission should not artificially limit the number of entities that can provide Repository or TVWS database services**
  - **Limiting providers stunts competition & innovation – drives up costs for consumers, and harms greater public interest**
  - **Multiple TVWS Databases can provide safe, consistent protection**
- **There are multiple viable database architectures and configurations possible**
  - **Numerous database companies have expressed an interest in providing services, each with differing TVWS database architectures**
  - **There are many opportunities for value-added database services (that do not alter incumbent protection)**

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