IEEE Recommended Practice for Information Technology— Telecommunications and information exchange between systems

Wireless Regional Area Networks (WRAN)— Specific requirements

Part 22.2: Installation and Deployment of IEEE 802.22™ Systems

IEEE Computer Society

Sponsored by the
LAN/MAN Standards Committee

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Abstract: Engineering practices for the installation and deployment of IEEE 802.22™ systems are discussed in this recommended practice.
Keywords: broadband, cognitive radio, IEEE 802.22, IEEE 802.22.2, TV bands, white spaces

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Introduction

This introduction is not part of IEEE Std 802.22.2-2012, IEEE Recommended Practice for Information Technology—Telecommunications and information exchange between systems—Wireless Regional Area Networks (WRAN)—Specific requirements—Part 22.2: Recommended Practice for the Installation and Deployment of IEEE 802.22™ Systems.

IEEE Std 802.22.2-2012 is a recommended practice for the installation and deployment of IEEE 802.22 Wireless Regional Area Networks (WRANs). Adhering to the installation and deployment recommendations provided in this recommended practice will best enable an IEEE 802.22 cognitive network to provide service at the highest broadband rates, to serve the largest area, and to make the most efficient use of the spectrum that is available. Ignoring the recommendations provided in IEEE Std 802.22.2 will lead to the IEEE 802.22 WRAN transmissions causing more service disruption into other services and to the network experiencing its own service disruption from the transmissions of other services.

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Wireless Regional Area Networks (WRAN)— Specific requirements

Part 22.2: Installation and Deployment of IEEE 802.22™ Systems

1. Overview

1.1 Scope

This document recommends best engineering practices for the installation and deployment of IEEE 802.22 systems to help assure that such systems are correctly installed and deployed.

1.2 Purpose

This document provides detailed technical guidance to installers, deployers, and operators of IEEE 802.22 compliant systems to help assure that such systems are correctly installed and deployed.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std 802.22™-2011, IEEE Standard for Information Technology—Telecommunications and information exchange between systems—Wireless Regional Area Networks (WRAN)—Specific requirements—Part 22: Cognitive Wireless RAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Policies and Procedures for Operation in the TV Bands.[1, 2]

Radio Regulations, International Telecommunications Union, Geneva, Switzerland.[3]

3. Definitions

For the purposes of this document, the terms and definitions listed in Clause 3 of IEEE Std 802.22-2011 apply.[4] The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.[5]

4. Acronyms and abbreviations

8-VSB	8-vestigial side-band modulation
AGL	above ground level
ATSC	Advanced Television Systems Committee
BS	base station
CBP	Coexistence Beacon Protocol
CDBS	Consolidated Data Base System
CPE	customer premise or portable equipment
DS	downstream
D/U	desired-to-undesired protection ratio
DTV	digital television

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[5] *IEEE Standards Dictionary Online* subscription is available at http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.

EIRP	effective isotropic radiated power
EMC	electromagnetic compatibility
ERP	effective radiated power
FCC	U.S. Federal Communications Commission
HAAT	height above average terrain
iNARTE	International Association for Radio, Telecommunications and Electromagnetics
ITU-R	International Telecommunications Union—Radiocommunication Sector
LOS	line of sight
MIB	Management Information Base
QPSK	Quadrature Phase-Shift Keying
RF	radio frequency
SBE	Society of Broadcast Engineers
SCH	Superframe Control Header
TIREM	Terrain Integrated Rough Earth Model
TPC	transmit power control
TV	television
US	upstream
USGS	United States Geological Survey
WRAN	Wireless Regional Area Network

5. Deployment

This clause contains guidelines and recommendations for an individual who is planning to deploy a WRAN system (the system planner) to select the service area of such WRAN system. This individual should be a competent professional installer,[6] such as an iNARTE Certified EMC Engineer, a Society of Broadcast Engineers (SBE) Certified Professional Broadcast Engineer, or a Registered Professional Engineer.

Subclause 5.1 provides technical and statistical features that should be considered by the system planner for calculating the coverage of a WRAN system. Guidelines for calculating potential interference from the WRAN system are also described. Subclause 5.2 identifies the items that should be considered by the system planner for selecting the deployment location of a WRAN system in order to protect incumbent broadcast services. Subclause 5.3 addresses the customer premise or portable equipment (CPE) radio frequency (RF) front-end aspects while 5.4 deals with the residual delay in the CPEs.

[6] See the definition of *professional installer* in Table A.3 of the IEEE Std 802.22-2011.

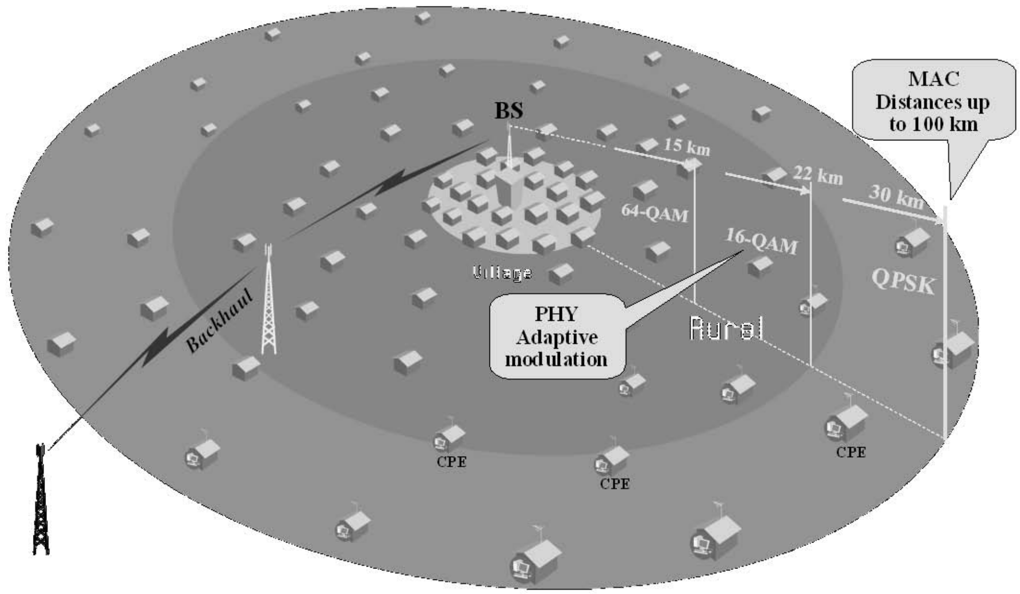


Figure 1—An IEEE 802.22 WRAN cell with a base station and user terminals

5.1 Coverage and interference prediction model

System planners should use more precise coverage and interference models than the U.S. Federal Communications Commission (FCC) Part 73 coverage curves or the ITU-R Recommendation P.1546 for deployment planning of WRAN systems (e.g., Longley, Rice [B11], TIREM [B13][7]). Such more precise models should have the following features.

5.1.1 Characteristics

System planners should use a coverage and interference prediction model for the planning of a WRAN service that incorporates at least the following:

- Point-to-point propagation model
- Desired-to-undesired protection ratios (D/U's) for the various channel relationships considered
- Transmitting and receiving antenna pattern characteristics for the broadcast incumbents, base stations (BSs), and CPEs
- Height of the transmitting antenna above ground level (AGL)
- Terrain data
- Ground cover and surface of the Earth electrical characteristics
- Ground clutter (trees, urban buildings, etc.)
- K-factor and other atmospheric effects on signal fading

[7] The numbers in brackets correspond to those of the bibliography in Annex C.

— Long-term fading effects, such as those described in Environmental Science Services Administration (ESSA) Technical Report ERL 79–ITS 67 (Longley, Rice [B11])

— Population from current census data

5.1.1.1 Point-to-point propagation model

A point-to-point propagation model determines the signal power loss between a point where a transmitter might be located and a point where a receiver might be located considering all obstructions and atmospheric effects on the propagation path. The power loss determination between two points represents the performance of a link.

A point-to-point propagation model can be extended to an area by subdividing the area to be analyzed with a rectangular grid where each intersection point becomes a point to be considered for propagation prediction. Typically, in a unidirectional transmission system, a transmitter is positioned at a unique point while it is assumed that a receiver is located at each intersection in the grid. Over the entire area to be analyzed, each intersection point is independent and its propagation link is quantified by its power loss from the point where the transmitter is located. In a bidirectional transmission system, the propagation path is usually reciprocal but it may not be because of factors such as the use of different frequencies in the two directions, local level of man-made noise, effect of antenna diversity, etc. In such case, the power loss when the transmitter is located at the intersection point and the receiver at the single point (i.e., the *upstream*) would also need to be calculated.

The point-to-point propagation model is more precise than empirical point-to-multipoint propagation models based on field test measurements. The estimations and approximations inherent to empirical point-to-multipoint propagation models decrease processing time but increase the likelihood of inaccurate propagation predictions. Popular empirical point-to-multipoint propagation models are outdated and processing power is more readily available to perform more complex point-to-point propagation modeling. A system planner should invest in any additional processing resources to gain as much precision as possible so that the planned service operates efficiently and without harmful interference.

5.1.1.2 Desired-to-undesired protection ratios

D/U's for the various channel relationships considered should be selected from a scientific technically reputable reference (e.g., ATSC [B1]) that provides results from analysis examining the specific modulations used by both the desired and undesired signals as well as agreed upon typical transmitter and receiver characteristics for the equipment involved.

D/U's express the desired field strength above any undesired field strength in dB that is required in order to avoid harmful interference and to allow acceptable reception of an RF service. The desired field strength is that which is produced by the transmitter providing the desired RF service while the undesired field strength is that which is produced by a potentially interfering signal. The D/U is measured at the antenna terminals of a receiver.

D/U's should be selected depending on the channel relationship between the desired and undesired signals. For example, D/U's are usually defined for co-channel and adjacent channel relationships. D/U's are also often defined for channel relationships that can extend out to ±15 channels of separation between the desired and undesired signals (e.g., ATSC [B1]). D/U's are specified to account for any interference mechanism, including co-channel interference, leakage from out-of-band interfering signals at the receiver, out-of-band emission at the interfering transmitters, and higher-order inter-modulation interference caused by the presence of high power interfering signals at the receiver.

D/U's may vary depending on the modulation used for the desired signal and the modulation used for the undesired signal. The D/U's should be determined through compatibility testing in a laboratory using the specific modulations. Typically, the robustness of the modulation of the desired signal to RF noise tends to be indicative of its robustness to co-channel interference from a wideband interfering signal (i.e., greater than 100 kHz; see Salechian et al. [B12]). Also, an interfering signal modulation may be more aggressive than another modulation, especially when it is produced by a narrowband interfering signal, and the D/U should reflect this difference. Annex A presents, as example, the D/U's to be used for the protection of the Advanced Television Systems Committee (ATSC) digital television (DTV) systems.

5.1.1.3 Antenna pattern characteristics

More data that is available to characterize the antennas being used in the coverage and interference prediction model will result in more precision in the predictions. A system planner should use antenna data for the BS and the CPEs of the WRAN to be planned and of the neighboring WRANs, as well as the antenna data for the incumbent transmitters and receivers. Separate antenna data should be used for CPE transmitting and receiving antennas if different antennas are used by the CPE. Antenna data for the azimuth pattern and the elevation pattern should be used for both horizontal and vertical polarizations. Azimuth pattern data are often available for numerical gain values in degree increments from 0 to 359 degrees. Elevation pattern data are often available in quarter degree increments from +90 to –90 degrees. The system planner should also take into account any antenna rotation, electrical tilt, or mechanical tilt that is being used. Not considering the detailed data of the antennas will result in less accurate predictions and possible harmful interference.

When determining the antenna gain that contributes to the received power from both desired and undesired transmissions, the system planner should assume that any directional CPE antenna will be aligned so that the main lobe of the pattern is pointing in the direction of the transmitter emitting the desired signal. It should be assumed that, in practice, the CPE installer will do fine adjustment of the azimuth and elevation of the directional antenna to try to maximize the D/U signal ratio at the receiver while maintaining the base station (BS) in the main beam of the antenna.

The development of IEEE Std 802.22-2011 assumed a level of cross-polarization discrimination as per the third column of Table 3 between the WRAN CPE transmit antenna and the DTV receive antenna when their main beams are aimed at each other. If this cannot be achieved, i.e., resulting in the minimum separation distances indicated in the second column of Table 1, the installer should take corresponding compensating measures to reduce such minimum required separation distances when needed.

5.1.1.4 Antenna height (AGL)

The height above ground level (AGL) of the transmitting and receiving antennas used by the BS, CPEs, neighboring WRANs, and incumbents is important to include in the coverage and interference prediction calculations to increase accuracy. The heights should be within 1 m of accuracy.

5.1.1.5 Terrain data

Terrain data for at least the entire geographic area that is being analyzed is essential to include in the coverage and prediction analysis. Terrain is one of the most influential factors in a propagation analysis, especially in mountainous or hilly regions. The system planner should use terrain data with a resolution of at least 30 m.

5.1.1.6 Ground cover and surface of the Earth electrical characteristics

Radio transmissions can propagate differently depending upon the surface of the Earth electrical characteristics over which they are traveling. The propagation model should account for and make use of the conductivity and permittivity of the surface by determining the type of ground cover that is present. The conductivity and permittivity—and therefore radio propagation—will be different depending upon whether the ground cover is: sea water, fresh water, wet ground, medium dry ground, very dry ground, or ice. Conductivity and permittivity values for the types of ground cover listed are provided by sources such as ITU-R Report P.1145 [B10] and ITU-R Recommendation P.527 [B9].

5.1.1.7 Ground clutter

Depending on the type of ground clutter present upon an area over which radio transmissions are propagating, the field strength of radio transmissions might be attenuated by a varying amount. The common practice is to set a height AGL trigger for each type of ground clutter along with an attenuation value in dB for a range of operating frequencies.

In the areas where the path profile between transmitter and receiver drops below the height trigger for the ground clutter type that is present, the field strength is attenuated by the number of dBs listed for the ground clutter type at the operating frequency. Ground clutter information can be obtained from the U.S. Geological Survey (USGS) [B19].

5.1.1.8 K-factor and other atmospheric effects

A system planner should use a propagation model that takes into consideration the K-factor that represents the impact of surface refractivity and tropospheric scatter on a point-to-point propagation link. These effects are mostly important for those links where the transmitter and receiver are beyond line of sight (LOS). Other atmospheric effects should also be considered such as seasonal variations.

5.1.1.9 Long-term fading effects

Long-term fading effects cause median fade variability on a radio transmission link at frequencies in the TV band. The total loss in the link should be properly adjusted by the median long-term fade variability.

A system planner should determine the median fade variability using the calculation procedure given in ESSA Technical Report ERL 79–ITS 67 (Longley, Rice [B11]) and providing to the calculation procedure the path length, the height of the center of radiation for both transmitter and receiver, the operating frequency, the climate type, and the desired percent availability.

5.1.1.10 Population data

In order to translate propagation results into population served or affected by interference, the system planner should include population data. Population data can be obtained from many populous areas of the world through census data. Since population density can change significantly over several years, the most current census should be used in a population count.

5.1.2 Statistics

System planners should use the following statistical information when performing a coverage and interference prediction analysis:

- IEEE 802.22 coverage simulations should use 99.9% and 1% for time availability for desired and undesired signals, respectively, in order to provide for sufficient time reliability for the bi-directional communications to the subscribers of the WRAN service, and 50% for location availability.
- Digital television (DTV) interference analysis should use 90% and 10% for time availability for desired and undesired signals, respectively, and 50% for location availability.
- Analog television interference analysis should use 50% and 10% for time availability for desired and undesired signals, respectively, and 50% for location availability.

5.1.2.1 IEEE 802.22 location and time availability

When modeling the coverage of an IEEE 802.22 network, a system planner should design the service for maximum availability. The system planner should consider a unit area (usually of size 500 m × 500 m) produced from subdividing the larger study area to be reliably served if the desired transmissions exceed the minimum field strength for at least 50% of the locations in the cell and at least 99.9% of the time. The 50% location probability will allow the service provider to extend its coverage area to hard-to-reach areas even though service may not be provided to all potential subscriber sites. The 99.9% time probability provides that, once a location is reached, the data service availability will minimally vary in time.

During the stage of the design where potential harmful interference from IEEE 802.22 devices to broadcast TV incumbent systems is considered, the system planner should use 50% for the location statistic but use 1% for the time statistic for DTV and 10% for analog TV. These statistics would determine where an IEEE 802.22 device would produce an unacceptably low D/U (see 5.1.1.2) in the unit areas where the DTV and/or analog TV services need to be legally protected from harmful interference (see 5.1.2.2 and 5.1.2.3). Planning a WRAN service where the IEEE 802.22 device will cause harmful interference with a very small probability in protected unit areas will help avoid the unlicensed operator having to shut down the system at the request of the regulators.

5.1.2.2 DTV Location and time availability

Since the incumbent DTV service has been operating for many years, coverage and interference statistics have long since been established. The system planner should conform to these established specifications (FCC [B17]) when determining the locations where the DTV service is receivable, and is therefore legally protected from harmful interference. The system planner should consider that a DTV service is receivable if the DTV transmissions exceed the minimum field strength for at least 50% of the locations in the unit area and at least 90% of the time.

The WRAN system planner should also consider the potential harmful interference from DTV into the WRAN service by using 50% of the locations and 10% of the time to control the extent of desensitization and saturation of the WRAN receivers caused by DTV interference (see 5.2.2.2).

5.1.2.3 Analog TV location and time availability

Similar to the DTV case, the incumbent analog TV service statistics have been well established through many years of modeling its coverage and interference. The analog TV service is considered receivable with a lower coverage statistic due to its graceful degradation capabilities. Unlike the DTV service's "cliff effect," where the service is either perfectly clear or totally dark, the analog TV service has many grades in between. As either the field strength that is present from an analog TV transmission decreases or the noise or interference increases, the analog TV service visibly degrades, but it is still considered receivable—or useable (see Longley, Rice [B11]) Therefore, a system planner should determine the locations where the analog TV service is receivable using a location availability statistic of 50% and a time availability statistic of 50%.

While modeling potentially harmful interference from the analog TV service into WRAN services, the system planner should again use 50% for the location availability statistic and 10% for the time availability statistic to control the extent of desensitization and saturation of the WRAN receivers caused by analog TV interference (see 5.2.2.2).

5.2 Selection of deployment location

5.2.1 Keep-out distance recommendations

5.2.1.1 TV station protected contours

WRAN devices should be deployed outside the keep-out distance that is beyond co- and adjacent channels protected contours of TV stations as specified by the local regulations (e.g., 47CFR73.625(b) [B2]).

If a TV bands database exists in the regulatory domain of the intended deployment location (see 6.2.5), it may provide access for a WRAN system planner to determine the available TV channels for the deployment area of the WRAN system. A system planner should access the TV bands database to determine the available TV channels at all those locations where the WRAN devices might be deployed. The TV bands database will return an available TV channel list, and in some cases, the maximum allowed *effective isotropic radiated power* (EIRP) on these available channels for a WRAN device deployed at a location. In such case, the WRAN device will be allowed to operate on a specific channel only if it is deployed at or below the specified EIRP so that the recommendation in 5.2.1.1 is satisfied.

If a TV bands database does not exist or is not accessible, a system planner should gather the necessary information for each of the protected TV stations in the area to calculate the coordinates of the contours for each of those stations. The station information is often available from a station database maintained by the local regulator. The equations to calculate contour coordinates are also often specified in local regulations. A system planner should use these protected contours so that the recommendation in 5.2.1.1 is satisfied.

5.2.1.2 Other protected communications services or RF devices specified by local regulations

WRAN devices should be deployed outside the regulatory required keep-out distances from any other communications services or RF devices as specified by the local regulations.

As an example, communications services that are protected by required keep-out distances as specified by U.S. regulations include: translator receive sites; cable head-ends; fixed broadcast auxiliary service links; private land mobile radio services/commercial mobile radio services; offshore radiotelephone services; Part 74 devices including wireless microphones; border areas communication services; and radio astronomy services. A database service (see 6.2.5) that provides public access to query for available TV channels, and that accounts for the required keep-out distances for such additional registered services needing protection, might exist in a regulatory domain of intended operation.

If a TV bands database exists and it is accessible, a deployment of a WRAN system operating on any of the available TV channels returned by the TV bands database for each of the potential WRAN device deployment locations should satisfy the recommendation in 5.2.1.2.

If a TV bands database does not exist or is not accessible, a system planner should determine the location of all the nearby operating sites for the communication services that need protection as identified by the local regulator. This information may be available from databases that are maintained by the local regulators. The system planner should use this information to make sure that the WRAN system is deployed so that the deployment satisfies the recommendation in 5.2.1.2.

In particular, system planners should avoid a channel that is occupied by low power auxiliary device operation for program making and special events (e.g., wireless microphones); otherwise, the WRAN device should be located beyond a radius of 4 km from these low power auxiliary devices or reduce its maximum EIRP according to Equation (1):

$$\text{Maximum EIRP} = 6 - \text{path loss exponent} \times 10 \times \log((\text{actual distance in km})/4)\ (\text{dBW}) \tag{1}$$

Where path loss exponent = 3.0 (or less if indicated by terrain or actual measurement).

5.2.1.3 Data collection

System planners should collect specific data that would influence RF propagation, including the difference in height above mean sea level (AMSL) between transmit and receive antennas, terrain topography, ground cover, ground clutter, and long-term atmospheric characteristics for the deployment area of interest.

5.2.1.4 Prediction modeling

System planners should use the data collected in 5.2.1.3 as input into an RF propagation prediction tool with the characteristics listed in 5.1.1 to determine the necessary keep-out distances to avoid causing harmful interference.

5.2.1.5 Maximum keep-out distance

System planners should respect the greater keep-out distances among those required from 5.2.1.1, those required from 5.2.1.2, and those resulting from 5.2.1.4.

5.2.2 Interference considerations

5.2.2.1 Interference into incumbent DTV and TV services when WRAN devices are inside the protected contours

WRAN devices should not cause harmful interference into the protected licensed services.

Before allowing a device to transmit, a system planner should know the details of the regulatory requirements pertinent to the deployment location and the operational frequency band. For example, if the intention is to deploy the WRAN in the U.S. TV White Space, the specific regulatory rules can be obtained from 47CFR15 Subpart H [B4]. The system planner should also follow the recommendations provided in this document..

5.2.2.1.1 CPE Separation from TV receive antenna

The CPE should not be located closer than the minimum required separation distance from a TV receive antenna for each channel relationship. The values provided in Table 1 are applicable to ATSC and correspond to the required interference rejection specified in the ATSC A/74 Receiver Performance Guidelines [B1]. Two sets of values are specified for the fixed device case where there is no antenna polarization discrimination between the CPE antenna and the TV receive antenna (i.e., when both antennas use the same polarization orientation), and when, for example, a 14 dB polarization discrimination can be assumed between the two antennas (i.e., the two antennas use orthogonal polarization) for channel relationships N±2 and beyond. For N and N±1, both antennas at the CPE and at the TV receiver are assumed to be looking in opposite directions and each provide, for example, 14 dB discrimination because the CPE has to be located outside the protected contour of the TV station to be allowed to operate (see 5.2.1.1; see also Chouinard [B6] for the detailed calculations).

A third set of separation distances is included for portable devices operating at a maximum of 100 mW (i.e., 16 dB below the 4 W fixed devices) where no CPE antenna directivity or polarization discrimination is assumed. In such case, only the DTV receive antenna directivity can be assumed (e.g., 14 dB) for N and N±1 since the CPE has to be located outside the protected contour of the TV station to be allowed to operate (see 5.2.1.1; see also Chouinard [B6] for the detailed calculations). It should be noted that in the U.S., since a 40 mW device would be allowed to operate on N±1 inside the protected contour of the TV station, the DTV receive antenna discrimination would no longer be available, and the additional reduction of 4 dB in EIRP would not be able to compensate for the loss of 14 dB antenna discrimination, and the minimum separation distance would increase to 169 m.

Overload occurs when a strong power is received by an undesired transmission that disrupts or distorts the RF front-end amplifiers in the receiver. In the case of the TV service, a TV receiver will most likely experience overload when an undesired transmission exceeds –8 dBm at the input of the receiver (see IEEE Std 802.22.1™-2010 [B7]). Overload interference can occur regardless of the channel relationship between the operating channel of the WRAN system and the TV service. An installer should maintain a separation distance of at least 16 m between a CPE transmit antenna and any TV receive antenna in order to avoid overload interference into the TV receiver if no antenna off-axis discrimination or cross-polarization discrimination can be relied upon. However, if 14 dB of antenna off-axis or cross-polarization discrimination can be achieved, this distance can be reduced to 3 m, as shown in Table 1.

5.2.2.1.2 CPE prohibition inside of TV protected contours

In the case of ATSC, a CPE should not be operated within a TV protected contour on any of the channel relationships where the recommended separation distance exceeds 20 m as shown in Table 1. A system planner can determine the DTV stations operating in an area in the U.S. by performing an online query using either the FCC database (FCC [B18]) or an FCC approved database that provides public query access. A DTV protected contour as defined by the FCC can be determined using the regulatory method described in 47CFR73.684 [B3].

Table 1—Separation distance between a CPE transmit antenna and a DTV receive antenna

Channel relationship	Separation distance (m)		
	Fixed device (4 W)		Portable device (100 mW)
	0 dB cross-polar or off-axis discrimination	14 dB cross-polar or off-axis discrimination	0 dB cross-polar or off-axis discrimination
N	3443 [a]	3443 [a]	3102 [b]
N±1	87 [a]	87 [a]	69 [b] / 169 [c]
N±2	236	75	60
N±3	129	29	23
N±4	57	11	9
N±5	28	6	4
N±6	32	6	5
N±7	32	6	5
N±8	32	6	5
N±9	32	6	5
N±10	32	6	5
N±11	32	6	5
N±12	32	6	5
N±13	32	6	5
N±14 [d]	142	33	27
N+15 [d]	142	33	27
All other channels	16	3	2

[a] In the co-channel and adjacent channel cases for the 4 W fixed device, the CPE transmit and DTV receive antennas are assumed to be looking in opposite directions since the CPE has to be outside the DTV protected area, resulting in 14 dB off-axis discrimination at the CPE antenna and 14 dB at the DTV antenna, resulting in a total of 28 dB antenna discrimination.

[b] In the co-channel and adjacent channel cases for the 100 mW portable device, the DTV receive antenna is assumed to be looking away from the CPE since the CPE has to be outside the DTV protected area, resulting in a 14 dB off-axis discrimination at the DTV antenna.

[c] In the adjacent channel case for a 40 mW portable device where the device is allowed to operate inside the protected contour, the 14 dB off-axis discrimination is no longer available and cannot be compensated by the additional 4 dB decrease in EIRP, resulting in an increased minimum separation.

[d] DTV receivers showed less immunity to interference coming from channel separations ±14 and +15 in the ATSC laboratory tests because of the image frequency, see ATSC [B1].

5.2.2.2 Interference from incumbent services

System planners should plan the deployment area so that WRAN receivers are capable of operating while tolerating an undesired co-channel interference signal level from licensed services that is 6 dB lower than the desired received signal level at edge of coverage (i.e., an operating margin that corresponds to 6 dB D/U).

Assuming that this interference from high power incumbent systems operating on the same channel, or adjacent channels (N±1 and beyond, coming from their level of out-of-band emission), is noise-like, this 6 dB D/U will translate into a 1 dB desensitization of the WRAN receivers when located at the edge of coverage for the most robust modulation scheme (i.e., QPSK, rate:1/2). Such desensitization will result in a reduced coverage distance and/or higher average operating power for the WRAN systems located close to an incumbent operation. Sufficient separation distance should be provided to minimize the effect of this interference on the WRAN systems (see 5.2.2.2.1).

Furthermore, although the effect of incumbent operation on channels N±2 and beyond may have minimal effect on WRAN receiver desensitization because of the receiver filtering performance, the presence of such high power interference at the input of the WRAN receiver may bring it into saturation, resulting in objectionable interference (see 5.2.2.2.2).

5.2.2.2.1 WRAN receiver desensitization

System planners should adhere to the minimum separation distances as provided in Table 2 from a high power TV transmitter to limit the WRAN receiver desensitization to no more than 1 dB.[8]

Table 2—Distance from a DTV transmit station for 1 dB WRAN receiver desensitization

DTV into WRAN	Desens.	CPE at 10 m AGL	BS at 10 m AGL	BS at 60 m HAAT	BS at 106 m HAAT	BS at 500 m HAAT
Co-channel, N	1 dB	364 km	367 km	542 km	602 km	758 km
Adjacent channels, N±1	1 dB	78.2 km	78.9 km	145 km	176 km	278 km
N±2 and beyond	1 dB	4.6 km	4.7 km	15.9 km	21.2 km	39.5 km
NOTE—Calculation based on ITU-R Rec. P 1546, 1 MW effective radiated power (ERP) and 300 m height above average terrain (HAAT) DTV station, FCC DTV emission mask.						

While it is not recommended to allow a WRAN receiver to be desensitized by more than 1 dB, Table 3 is provided to show the values of the separation distance that should be exceeded in order to limit the WRAN receiver desensitization to no more than 10 dB. Table 3 gives an indication of the latitude that the WRAN operator has in locating the WRAN cell closer to a TV transmitter at the cost of an increase in the apparent noise level in the vicinity.

Table 3—Distance from a DTV transmit station for 10 dB WRAN receiver desensitization

DTV into WRAN	Desens.	CPE at 10 m AGL	BS at 10 m AGL	BS at 60 m HAAT	BS at 106 m HAAT	BS at 500 m HAAT
Co-channel, N	10 dB	231 km	233 km	272 km	425 km	583 km
Adjacent channels, N±1	10 dB	46.1 km	46.5 km	80 km	97 km	166 km
N±2 and beyond	10 dB	1.12 km	1.14 km	4.9 km	7.5 km	19.5 km
NOTE—Calculations based on ITU-R Rec. P 1546, 1 MW ERP and 300 m HAAT DTV station, FCC DTV emission mask.						

5.2.2.2.2 WRAN receiver saturation

System planners should maintain the necessary separation from high power TV transmitters operating on any TV channel in order to avoid saturation of the WRAN receiver leading to generation of intermodulation products falling into the desired channel.

5.2.2.3 Self-coexistence means provided in IEEE Std 802.22-2011

IEEE 802.22 systems are equipped with the means necessary to provide self-coexistence (i.e., coexistence with other WRAN systems in the area). The operator can therefore install the system even if there are other WRANs in operation in the area since it will automatically adjust to either select a different channel than

[8] Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

the ones used by other WRAN systems in the area (i.e., *spectrum etiquette*) or share a same channel by having the frames being automatically fairly distributed amongst WRAN systems using the same channel (i.e., *on-demand frame contention*, see 7.20.3.2 of IEEE Std 802.22-2011).

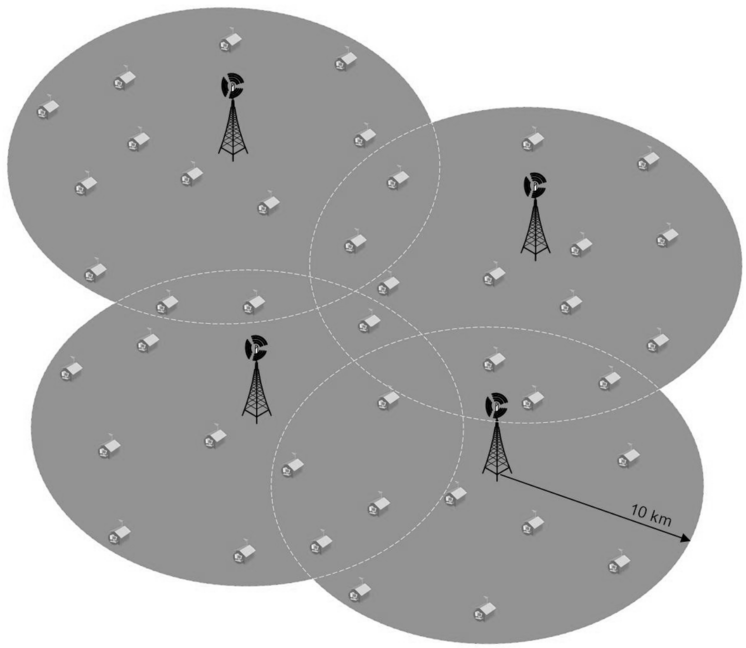


Figure 2—Example of IEEE 802.22 deployment configuration

5.2.2.3.1 Scan for other WRAN operation in the area

A scan of the TV channels available in the area should be conducted using either a spectrum analyzer or the inherent scanning capabilities of the WRAN systems used at initialization so that the system planner can determine if this WRAN operation will need to operate in a coexistence environment, either permanently or temporarily (i.e., the operating channel or the backup channels would need to be shared with other WRAN systems).

5.2.2.3.2 Avoiding line of sight between BSs

System planners should prevent BS interference into neighboring BSs by avoiding line of sight (LOS) and/or maximizing the separation distances between BSs.

The system planner should try to locate the BS so that there is no line of sight with the other BSs that may be using the same channel or adjacent channels to avoid BS-to-BS interference, which would result in having to synchronize the downstream/upstream (DS/US) split in each frame (Chouinard [B5]) This could be done relying on local physical structures such as buildings, hills, etc., blocking the signal path. If such BS-to-BS interference can be avoided, each BS can have independent control of its DS/US split, which will only be driven by the DS/US requirement for the data traffic that it carries.

Interference between LOS BSs or nearby BSs operating on the same TV channel would create DS/US collisions. These collisions would be prevented by either an agreement between the operators of the BSs involved to set a constant and common DS/US split or by applying the automatic technique that has been included in 7.20.3 of IEEE Std 802.22-2011. This automatic technique consists in a synchronization of the upstream/downstream (US/DS) split via exchange of relevant information through Superframe Control Header (SCH) or Coexistence Beacon Protocol (CBP) transmissions as well as using the algorithm defined in Table 184, 7.20.3, and 7.21.2.1 of IEEE Std 802.22-2011.

5.2.2.3.3 Condition for successful exchange of CBP bursts

The operator may want to deploy a sufficient number of CPEs about the outer edge of the coverage area to increase the probability of successful transmission and reception of CBP bursts during the self-coexistence windows (SCW) scheduled by the WRAN systems.

Unreliable CBP burst transmissions across overlapping WRAN cells operating on the same TV channel would not allow proper coexistence and would result in either interference or having to switch to different channels for operation. Optimal placement for these CPEs should be selected from locations derived from the recommendations in 5.2.1.

5.2.2.4 RF sensing to protect broadcast incumbents

IEEE Std 802.22-2011 includes means to sense the presence of broadcast incumbents in an area. If the regulatory domain requires RF sensing, the operator will need to make sure that the necessary sensing capabilities are enabled. If RF sensing is used, the WRAN system will automatically select a channel that will avoid interference to the broadcast incumbents through dynamic spectrum access (DSA).

5.2.3 Expanding the network

The general procedure for determining new, additional, and potential CPE deployment locations in a given area of interest has been defined in 5.2.1 and 5.2.2. System planners should progressively refine the candidate CPE deployment locations as they execute each of the recommendations in 5.2.1.1 to 5.2.1.5 and 5.2.2.1 to 5.2.2.3. The recommendations in 5.2.3.1 to 5.2.3.3 define the use of supplemental information to help refine candidate CPE deployment locations within the context of sub-recommendations in 5.2.1.1 to 5.2.1.4. The final candidate CPE deployment locations are not complete until after the candidates have been refined according to 5.2.1.5.

5.2.3.1 Potential CPE installation locations

The recommendations in 5.2.1.1 and 5.2.1.2 can be satisfied by supplementing the list of available channels and their corresponding EIRP limits obtained from the TV bands database with similar lists of available channels and EIRP for all the WRAN devices of all the other WRAN cells in the area of interest. This would be based on the regulated keep-out distance and contour information for all WRAN devices that have already been deployed in the WRAN to which the system planner would like to add a new CPE. This information is present at each BS in the MIB object *wranIfDbsChannelIndicationTable* (see Clause 13 of IEEE Std 802.22-2011) to be viewable for each BS in the area of interest. If these MIB objects can be acquired from the other BSs in the area over their backhaul connection and can be viewable at the BS for which a new CPE needs to be added (note that a collaborative agreement to exchange this information among BSs will be needed), then the operator can overlay information regarding current installations of CPEs (e.g., where they are located and what channels are available at those locations) on top of the protected contours for TV stations along with the protected locations for other services to build maps defining potential (valid) installation sites for CPEs in a given area of interest.

After obtaining channel usage and location information from these MIB objects for existing CPE deployments and overlaying contours from protected incumbent services, what remains is a space for candidate locations. For each resulting candidate location, channel availability should be double-checked for viability by re-querying the database service. Any candidate location, for which the database service returns no channel availability, should be removed from consideration (before moving on to the recommendation in 5.2.1.3).

5.2.3.2 RF Propagation data collection

RF propagation data should be collected along with the data collected from the recommendation in 5.2.1.3 that is available from the previous installation of CPEs associated with the WRAN or from the continued operation of these CPEs.

While executing the recommendation in 5.2.1.3, a system planner should collect relevant data that has been previously gathered by the BS for existing CPE installations or periodically updated through the continued operation of the CPEs. This information might be more accurate than the information that would otherwise be obtained from sources such as publicly available databases. However, it should not be assumed that the information collected by the BS for CPEs previously installed on the WRAN would be correct for the candidate deployment locations being considered for the new CPE. The system planner should further refine this data to reflect the characteristics of the new candidate deployment sites in executing the recommendations in 5.2.1.1 and 5.2.1.2. New candidate CPEs may have additional constraints on where they can be installed. Examples of constraints can include: land-use rights, lack of structures to which a CPE can be affixed, lack of a customer (i.e., no one lives at that location).

5.2.3.3 Keep-out distance determination

The data collected from both 5.2.1.3 and 5.2.3.2 should be utilized to determine the necessary keep-out distances according to the prediction modeling as specified in 5.2.1.4.

This determination should also take into account RF propagation data collected from existing CPE installations as well as any data that has been collected for these candidate locations (see 5.2.3.2).

5.3 RF front end

CPE RF front end should be built to allow simultaneous WRAN receive operation and sensing on different channels. For example, if RF sensing is done through its own sensing signal path, sensing could be done on one channel while WRAN operation would take place on a different channel, allowing more freedom for out-of-band sensing. RF sensing may need to be interrupted during the transmission periods on the WRAN signal path due to the limited RF isolation possible between the WRAN transmit path and the sensing receive path. Reduction in sensing time will come from the parallel sensing and WRAN reception.

However, when sensing is to be done on channels where WRAN transmissions are involved or on their respective adjacent channels, the WRAN signal path will be needed to acquire the SCH or the CBP burst to identify the timing of the quiet periods so that the presence of incumbents can be sensed underneath the WRAN operation in those channels.

5.4 Residual delay measurement

CPEs whose residual delay has been measured by the manufacturer with an accuracy of at least ±30 nsec should be used.

The “fine” ranging process described in 10.5.2 of IEEE Std 802.22-2011 will need to work with accuracy in the range of nanoseconds and the various amounts of residual delay present in different CPEs will need to be taken into account. Such residual delay may vary from one CPE model to another as well as from one antenna setup to another because of the different cable lengths in the case where the antenna is not integrated to the CPE. Such residual delay will need to be measured by the manufacturer with an accuracy of at least ±30 ns, as specified in 7.7.7.3.4.10 of IEEE Std 802.22-2011, by locating the CPE at a known distance from the BS and setting the *timing advance* (see 7.7.4.1 of IEEE Std 802.22-2011) to the corresponding signal delay. This can also be done by using a coaxial cable of known length between the BS and CPE antenna connectors if the additional delay that will result from the use of the antennas is known. This CPE residual delay will be declared during the CPE registration process through the registration request (REG-REQ) MAC message (see 7.7.4.1 of IEEE Std 802.22-2011).

6. Installation

This clause contains recommendations for the installer of WRAN systems.

IEEE 802.22 transmit equipment should be installed by a trained, competent professional installer,[9] such as an iNARTE Certified EMC Engineer, an SBE Certified Professional Broadcast Engineer, or a Registered Professional Engineer. Local regulatory authority should be consulted for the requirements to be a professional installer.

After the WRAN system planner completes the suggested deployment process described above in Clause 5, the professional installer should follow the suggestions provided in this clause for a proper installation. This clause also describes the characteristics of the WRAN system devices that should be installed. IEEE Std 802.22-2011 was designed while assuming the WRAN system characteristics provided in this clause.

General recommendations for WRAN systems are described in 6.1. Detailed recommendations for installing IEEE 802.22 BS and CPEs are provided in 6.2 and 6.3, respectively.

6.1 System

6.1.1 Certified IEEE 802.22 equipment

The installer should use only IEEE 802.22 equipment that has been certified to meet local regulations and the requirements of IEEE Std 802.22-2011.

6.1.2 BS and CPEs

WRAN systems are comprised of a BS and CPEs (customer premise or portable equipment).

6.1.3 Damaged equipment or loose connectors

The installer should not install equipment with physical damage or loose connectors.

[9] See the definition of *professional installer* in Table A.3 of IEEE Std 802.22-2011.

6.1.4 Weather stripping tape for outdoor use

Appropriate weather stripping tape should be applied to any connector that might be exposed to the outdoor environment.

6.1.5 Cable TV protection

6.1.5.1 Separation from cable TV equipment

Transmitting equipment should be installed at least 8 m away from cable-ready consumer electronic equipment. This 8 m of separation can be calculated assuming 8 dB CPE antenna discrimination toward the cable equipment as well as 10 dB wall absorption and 5 dB additional indoor attenuation, as indicated in FCC R&O 08-260 [B15].

For example, the maximum level of direct pickup interference that cable-ready consumer electronic equipment can support in the U.S. corresponds to an ambient field strength of 100 mV/m. In free space, this corresponds to a power-flux density of –45.8 dB(W/m^2). The power-flux density that is produced by a 4 W EIRP transmission, considering the losses mentioned in the previous paragraph, can be calculated as shown in Equation (2):

$$Pfd = 10 \times \log(4) - 10 \times \log(4\pi \times R^2) - 8 - 10 - 5 \quad (2)$$

where Pfd is the power-flux density in dB(W/m^2) and R is the separation distance in meters.

Solving this equation for R for a Pfd of –45.8 dB(W/m^2) results in a required minimum separation distance between the CPE transmit antenna and cable equipment of 8 m.

6.1.5.2 TV receiving installation inspection

The installer should check nearby TV receiving installations to confirm that the installed WRAN transmission equipment will not cause interference to the TV service.

6.1.5.3 Metallic objects or reflectors

The installer should remove metallic objects or reflectors that are close to or in the path of the WRAN transmitting antenna or change the location of the antenna to improve the signal path.

6.2 Base station

Base stations should be professionally installed (see Table A.3, IEEE Std 802.22-2011).

6.2.1 Fixed outdoor antenna

The BS antennas should be installed in a fixed position, outdoors, and in the clear.

6.2.2 Antenna height

The BS antennas should be installed at a height that satisfies the local regulations. The antenna height can be defined by its height AGL at the antenna site, or by its *height above average terrain* (HAAT) defined as the antenna height relative to a level averaged over a number of radials and distances around the BS (e.g., minimum of 8 equi-spaced radials, with a minimum of 50 samples per radial between 3.6 km and 16 km from the BS).

6.2.3 Database service network address

The BS should be configured with the network address of the database service.

6.2.4 Root Certificate Authority network address

The BS should be configured with the network address of the root Certificate Authority that issues the certificate to the database service.

6.2.5 Database service connection

The BS should not be allowed to transmit unless the following conditions are satisfied:

a) The BS has been certified to operate with a regulatory certified database service.

b) The BS has established a connection through its backhaul to the Internet with the database service;

c) The BS has received channel availability information relevant to its geographic location from the database service.

Before starting operation, the BS operator should make sure that the BS has access to the broadcast incumbent database service provided for the area according to the rules applicable to the local regulatory domain. Proper registration, access, and secure communication through the BS backhaul should be provided using the means and the primitives specified in 10.7.1 of IEEE Std 802.22-2011. Policies described in 10.2.5 of IEEE Std 802.22-2011 should be applied unless the local authority has required different policies that have precedence over the former (e.g., FCC [B16]).

A connection to the database service is identified by the Universal Resource Location (URL) that is used to access the database service across the Internet. The database service URL should be a fully qualified URL that starts with http:// or https://. Connectivity to the database service, via the URL, should be verified by using the database connectivity primitives, see 10.7.1.1 and 10.7.1.2 of IEEE Std 802.22-2011. Connectivity to the database service should be verified as often as required by the local regulatory authority.

Connection to the database service will have to be secure. Securing access to the database service can be accomplished by providing some form of security credential when connecting to the database service, via its URL. A security credential may take on the form of a X.509 Public Key Infrastructure (PKI)-type of certificate, or possibly be a User ID || Password tuple. If a User ID || Password tuple is used, then the User ID and Password must conform to User ID and Password requirements as governed by the database service provider (e.g., minimum number of total characters, proscribing use of certain numbers of letters/numbers/special characters).

Where configuring a BS for database service access, the operator should provide both the URL and security credential associated with the database service. If possible, the operator should configure the URL and credential for more than one database service on the BS. This is to prevent shutdown of services in case the first database service provider cannot be reached.

In areas where such database service is not required by the local regulatory authority, the BS operator may access a locally provided broadcast incumbent database or develop his or her own database to facilitate the operation of his WRAN service. No channels not allowed in the area by the local regulator should be added to these local databases. Only policies 2 to 8 contained in Table 234 of IEEE Std 802.22-2011 should then be applicable. Such a local database should be used by the operator to only subtract channels from local operation, beyond the channels forbidden by local regulatory authority.

6.2.6 Transmit/receive antenna

6.2.6.1 Vertical pattern antenna gain

The installer should use a transmit/receive antenna at the BS with at least 6 dBi of gain contributed by the vertical pattern. In case separate transmit and receive antennas are used, both should have a gain of at least 6 dBi contributed by their vertical pattern.

6.2.6.2 Orthogonal polarization

The installer should orient the BS transmit/receive antenna so that its polarization is the same as the polarization orientation of its associated CPEs (see 6.3.5.10) and, to the extent possible, orthogonal to that of the TV receive antennas in the area. This orthogonal orientation will maximize the RF link effectiveness with the CPEs and increase isolation towards nearby TV receivers.

6.2.7 Sensing antenna

The sensing antenna should be mounted above the transmit antenna if they are not integrated.

6.2.7.1 Antenna gain

The installer should use a BS sensing antenna with a constant gain in all azimuthal directions and all polarization orientations as much as possible and a well-documented minimum gain to be used to define the sensing receiver sensitivity to meet the required sensing threshold specified by local regulations.

6.2.7.2 Sensing threshold adjustment to compensate for antenna loss

If the minimum sensing antenna gain minus all losses between the antenna and the input to the sensing receiver is less than 0 dBi in any azimuthal direction or polarization orientation, the sensing threshold should be decreased by an equal number of dBs to be more sensitive and to account for the dB loss in antenna gain and access cable.

6.2.8 GPS unit installation at the BS

The installer should make sure that the GPS unit is located outdoors. The unit may or may not be integrated to the transmit/receive WRAN antenna. If it is integrated, the same cable may be used to feed direct current (dc) to the unit and carry the output of the GPS receiver to the BS (see 9.12.2 of IEEE Std 802.22-2011). If it is not integrated, special cable and standard GPS interface to the BS will need to be provided and the maximum cable length will need not to be exceeded.

6.3 Customer premise or portable equipment

Where required by local regulations, CPEs should be professionally installed (see Table A.3, IEEE Std 802.22-2011). Personal/portable terminals do not need to be professionally installed and are assumed to be located at 1.5 m aboveground when operated outdoors.

6.3.1 Fixed outdoor antenna

Transmit/receive and sensing antennas should be permanently installed outdoors, in the clear, on a fixed structure, and properly aligned.

6.3.2 Fixed location verification

Verification should be made that the CPE sensing antenna remains in the location where it was installed.

6.3.3 Installation verification

CPE transmissions should be prevented absent reliable verification of the recommendations in 6.1.5.1 to 6.1.5.3, and 6.3.1 to 6.3.2.

6.3.4 Provisions to prevent discouraged use

Provisions should be employed to prevent the use of antenna equipment that could impair or defeat the recommendations in 6.3.1 to 6.3.3.

6.3.5 Transmit/receive antenna

6.3.5.1 Minimum separation distance from TV receiving antennas

A minimum separation distance should be enforced, as specified in the last row of Table 1, between the CPE transmit/receive antenna and TV receiving antennas as a function of the type of CPE used.

6.3.5.2 Pointing away from TV receive antenna

The CPE transmit/receive antenna should be oriented so that it and the TV receiving antenna are pointed away from each other, whenever possible.

6.3.5.3 Keeping the path to the BS away from TV receiving antenna

The CPE transmit/receive antenna should be installed so that the TV receiving antenna is not in the path between the CPE transmit/receive antenna and the BS, whenever possible.

6.3.5.4 Cable and connectors leakage

Cable and connectors leakage should be avoided between the CPE transmit/receive antenna and the CPE receiver.

6.3.5.5 Antenna interface to the transmit/receive unit

In the case where the CPE is constituted of separate transmit/receive and antenna units, they will be connected by a coaxial interface that will convey the radio signals as well as ancillary signals that will carry the information on the antenna maximum gain for each channel that it can use. This will allow the BS to safely control the transmit EIRP and not only the conducted power going to this coaxial interface. A 50 Ω coaxial cable will be used to connect these units and the transmit/receive (TX/RX) unit will query the antenna unit for its maximum gains at initialization. If the antenna unit cannot provide this information, the CPE will not initialize properly and stop operating. The user or the installer needs to make sure that a compatible antenna unit with adequate ancillary capability is used (see 9.12.2 of IEEE Std 802.22-2011).

6.3.5.6 Installation height

The CPE transmit/receive antenna should be installed outdoors at a nominal height of 10 m AGL and co-located with the CPE sensing antenna.

6.3.5.7 Orientation toward the selected BS

The CPE transmit/receive antenna should be oriented toward the BS of the selected service provider.

6.3.5.8 Re-orientation toward a newly selected BS

The CPE transmit/receive antenna should be reoriented toward the BS of the new service provider if a new service provider is selected.

6.3.5.9 Minimizing the gain toward an interfering source

The CPE transmit/receive antenna should be further adjusted to minimize the gain in the direction of an interfering source while keeping the gain toward the BS of the service provider within 2 dB of its maximum.

6.3.5.10 Orthogonal polarization to TV receiving antennas

The orientation of fixed CPE transmit/receive antennas should be adjusted so that they are polarized orthogonally to the nearby TV receiving antennas within a tolerance of 10 degrees to the extent possible when their main beams are aimed at each other and when there is a need to reduce the minimum required separation distance as shown in the second and third columns of Table 1.

6.3.5.11 Same height as nearby TV receiving antenna

The CPE transmit/receive antenna should be mounted at the same height as the nearby TV receiving antenna, whenever possible, to maximize cross-polar discrimination.

6.3.6 Sensing antenna

6.3.6.1 Installation height

The CPE sensing antenna should be installed outdoors at a nominal height of 10 m AGL, co-located and above the CPE transmit/receive antenna if they are not integrated. The outdoor sensing antenna should be omni-directional, be able to receive in all polarization orientations and be installed so that it does not affect the pattern of the WRAN transmit/receive antenna.

6.3.6.2 Local obstructions

The installer should give special attention to the installation of the sensing antenna to make sure that the sensing capabilities of the CPE are not impacted by local obstructions.

6.3.6.3 Antenna gain

The installer should use a CPE sensing antenna with constant gain in all azimuthal directions and polarization orientations as much as possible and a well-documented minimum gain to be used to define the sensing receiver sensitivity to meet the required sensing threshold specified by local regulations.

6.3.7 GPS unit installation at the CPE

The installer should make sure that the GPS unit is located outdoors. The unit may or may not be integrated to the transmit/receive WRAN antenna. If it is integrated, the same cable may be used to feed direct current (dc) to the unit and carry the output of the GPS receiver to the CPE (see 9.12.2 of IEEE Std 802.22-2011 for a description of the antenna interface that can carry the GPS data in a similar fashion as for the maximum antenna gains). If it is not integrated, special cable and standard GPS interface to the CPE will need to be provided and the maximum cable length will need not to be exceeded.

Annex A

(informative)

Desired-to-undesired protection ratios for protecting ATSC DTV systems

The level of susceptibility of DTV receivers to co-channel and adjacent channels for various channel separations was established by the Advanced Television Systems Committee (ASTC) in its reference document A/74:2010 [B1], which DTV receiver manufacturers consider in their receiver design. This ATSC DTV receiver interference susceptibility is summarized in Table A.1.

Table A.1—ATSC DTV receiver susceptibility to interference (D/U requirements)

ATSC A/74 DTV RX performance guidelines	Measured D/U at 3 desired signal levels			D/U at the noise-limited contour (at –84 dBm)
	Strong	Moderate	Weak	
	–28 dBm	–53 dBm	–68 dBm	
N (continuous)	15.5 dB	15.5 dB	15.5 dB	23 dB
N (impulsive)	5 dB	5 dB	5 dB	5 dB
N±1	–33 dB	–33 dB	–33 dB	–33 dB
N±2	–20 dB	–40 dB	–44 dB	–48.2 dB
N±3	–20 dB	–40 dB	–48 dB	–56.4 dB
N±4	–20 dB	–40 dB	–52 dB	–64.7 dB
N±5	–20 dB	–42 dB	–56 dB	–70.8 dB
N±6 to N±13	–20 dB	–45 dB	–57 dB	–69.7 dB
N±14 and 15	–20 dB	–45 dB	–50 dB	–55.3 dB
RF front-end overload				–8 dBm

These performance guidelines were developed based on laboratory measurements carried out during the development of the ATSC standard. The measurements of the required D/U's were carried out for three levels of desired signal presented to the receivers: strong, moderate, and weak levels. In order to determine the D/U's at the edge of the noise-limited coverage area that represent the worst-case situation, a linear extrapolation (in dB values) needed to be done from the "moderate" and "weak" cases to establish the D/U's corresponding to a desired signal level of –84 dBm. The resulting D/U's are presented in the last column on the right of Table A.1.

It should be noted that in the case of co-channel interference, even though the D/U was measured at 15.5 dB, it was decided by the FCC that this D/U is only valid at locations where the signal-to-noise ratio is strong (i.e., S/N ≥ 28 dB). At the edge of the noise-limited coverage area, where the signal-to-noise ratio is 15.5 dB, the co-channel D/U was increased to 23 dB in the FCC OET Bulletin 69 (FCC [B17]) to limit the contribution of co-channel interference at the edge of coverage to correspond to a DTV receiver desensitization of 0.7 dB.

Annex B

(informative)

Planning of service procedure example

a) Acquire the necessary tools and information

1) WRAN BS operating parameters

— Antenna characteristics (omni-directional dipole is assumed)

— Intended height of the center of radiation (AGL) (75 m is assumed)

— Operating channel

2) Incumbent receiver characteristics (Table B.1)

Table B.1—Incumbent receiver characteristics

	Low VHF	High VHF	UHF
Lead in loss (dB)	1	2	4
Front to back ratio (dB)	10	12	14
Antenna gain (dBi)	6.15	8.15	12.15

— Receivers are outdoors at 9 m AGL height.

— Receiver antenna patterns use a cosine exponent equal to 4. If the azimuth offset between the WRAN transmission and the main lobe of the receiver antenna azimuth pattern is less than 90 degrees, the pattern contribution returned is the maximum of either the cosine of the azimuth offset raised by the pattern exponent or the front-to-back ratio. If the azimuth offset is greater than 90 degrees, the pattern contribution is equal to the front-to-back ratio.

3) Incumbent database

— TV transmitter operating parameters are from the 12/20/06 FCC Consolidated Data Base System (CDBS) database.

— Only co-channel and adjacent channel interference was considered (“taboo” channel relationships were not considered).

— Only high power TV stations were considered (low power or “class A” TV stations were not considered).

4) Propagation analysis tool

— 8-Vestigial Side-Band (8-VSB) ATSC modulation for IEEE 802.22 systems.

— Desired-to-undesired protection ratios (D/U’s) from the FCC Office of Engineering and Technology Bulletin 69 (FCC [B17]).

— 30 m U.S. Geological Survey terrain data (USGS [B20]).

— Population from 2000 Topographically Integrated Geographic Encoding and Referencing system census data (U.S. Census Bureau [B14]).

— Terrain Integrated Rough Earth Model (TIREM) propagation prediction model (TIREM [B13]).

— Long-term fading, ESSA Technical Report ERL 79–ITS 67 (Longley and Rice [B11]).

— Surface of the Earth Electrical Characteristics from ITU-R Recommendation P.527 [B9].

— IEEE 802.22 coverage simulations use 99.9% time availability.

— DTV interference analysis; desired and undesired signals use 90% and 10%, respectively, for time availability.

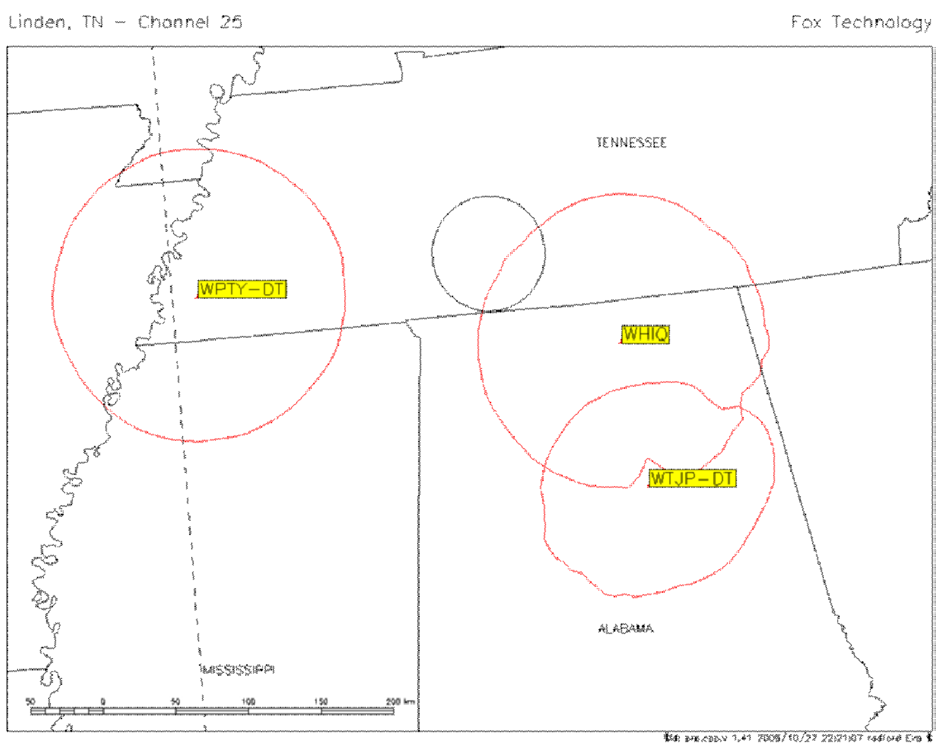
— Analog interference analysis; desired and undesired signals use 50% and 10%, respectively, for time availability.

— Other assumptions regarding transmitter and receiver parameters for link budgets are from IEEE 802.22 document number 22-04-0002-19-0000 (Chouinard [B6]).

b) Identify the area of interest to deploy the WRAN service.

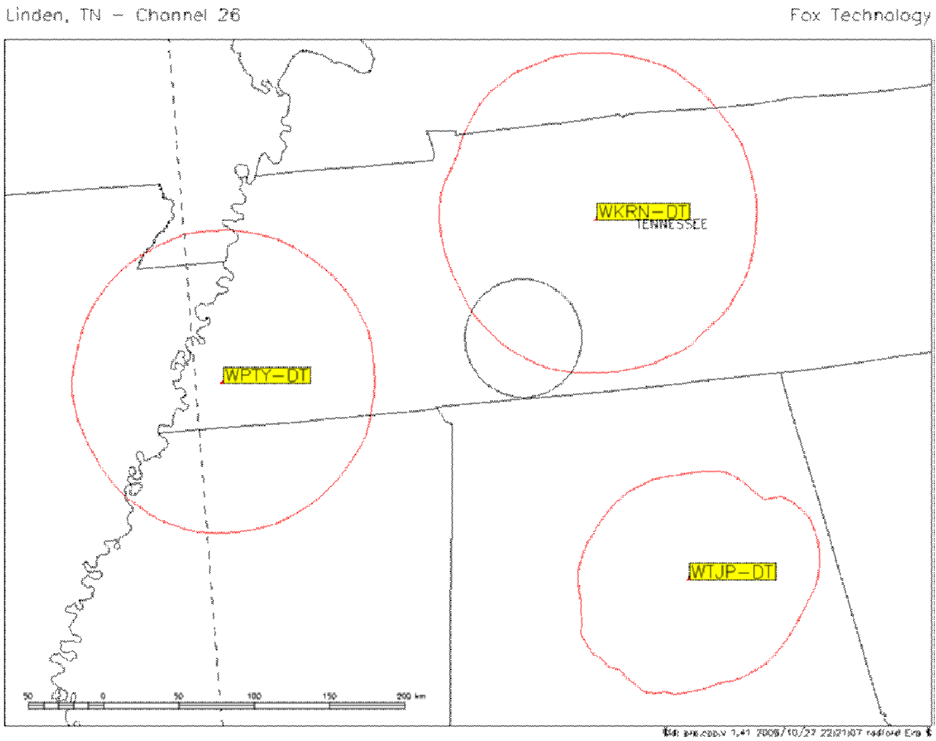
In this example, a location in Linden, TN was chosen (35.37°, –87.50°).

c) Determine a useable channel by plotting the co- and adjacent channel incumbent service noise-limited contours in the area of interest. See Figure B.1 to Figure B.4.



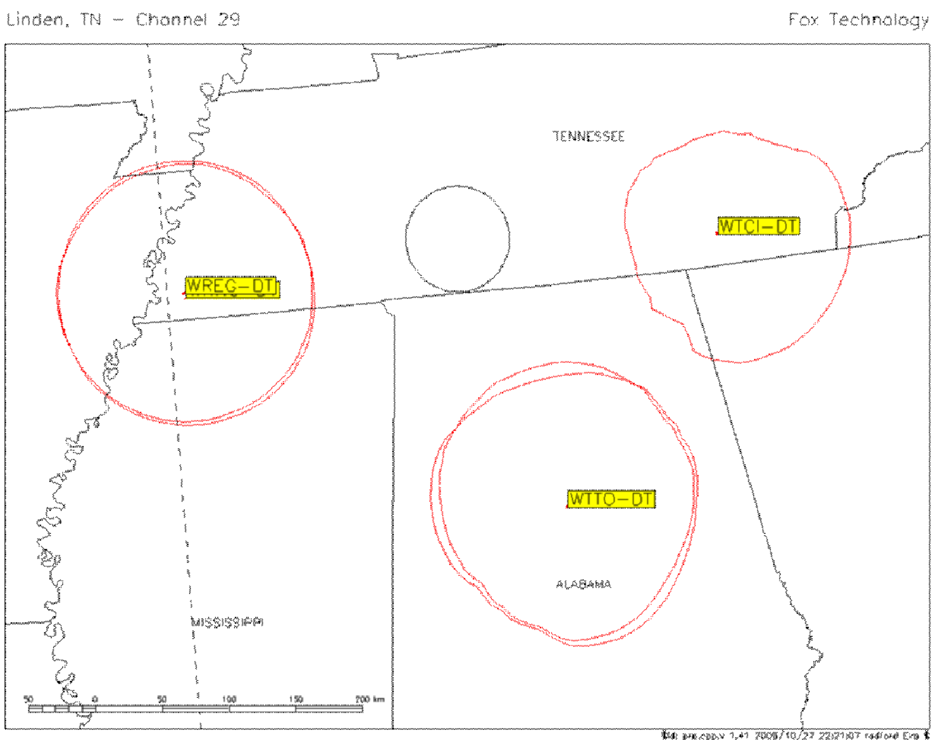
NOTE—The contours do not accurately represent final post-transition DTV service or associated service contours.

Figure B.1—Examples of co- and adjacent channel DTV noise-limited contours



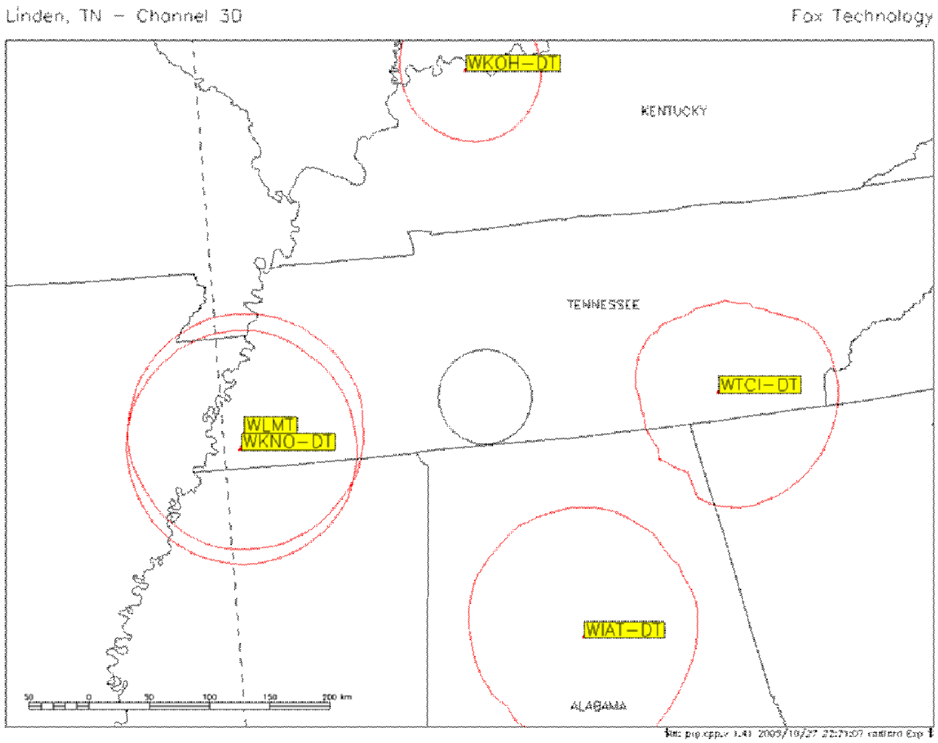
NOTE—The contours do not accurately represent final post-transition DTV service or associated service contours.

Figure B.2—Examples of co- and adjacent channel DTV noise-limited contours



NOTE—The contours do not accurately represent final post-transition DTV service or associated service contours.

Figure B.3—Examples of co- and adjacent channel DTV noise-limited contours



NOTE—The contours do not accurately represent final post-transition DTV service or associated service contours.

Figure B.4—Examples of co- and adjacent channel DTV noise-limited contours

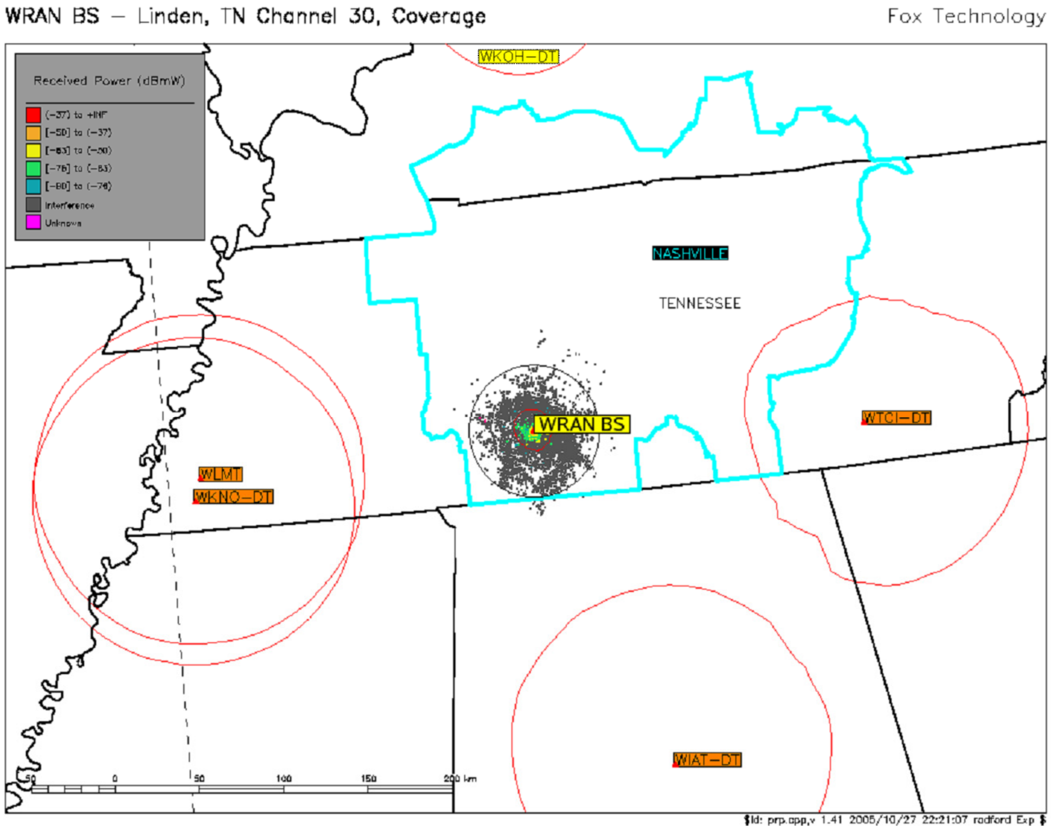
Current co- and adjacent channel DTV noise-limited contours were plotted in the Linden, TN, area for channels 25 through 30. In Figure B.1 to Figure B.4, the black circle is a 40 km radius circle with center at a site in Linden, TN, of high terrain elevation. The red contours are the co- and adjacent channel DTV noise-limited contours. It can be seen in Figure B.1 and Figure B.2 that channels 25 and 26 through 28 are unusable for the Linden, TN, site. It appears that channels 25, 29, and 30 are possible in Figure B.3 and Figure B.4 because the selected site would not be contained within either a co- or adjacent channel DTV noise-limited contour.

For this example channel 30 is selected.

d) Analyze the coverage achieved by the WRAN system.

The 4 W transmission from the WRAN BS does a good job serving the 40 km circle with a –102 dBm signal or greater. However the interference caused to this transmission from the nearby co- and adjacent channel higher power DTV transmissions is significant. The interference is represented by the gray color in Figure B.5.

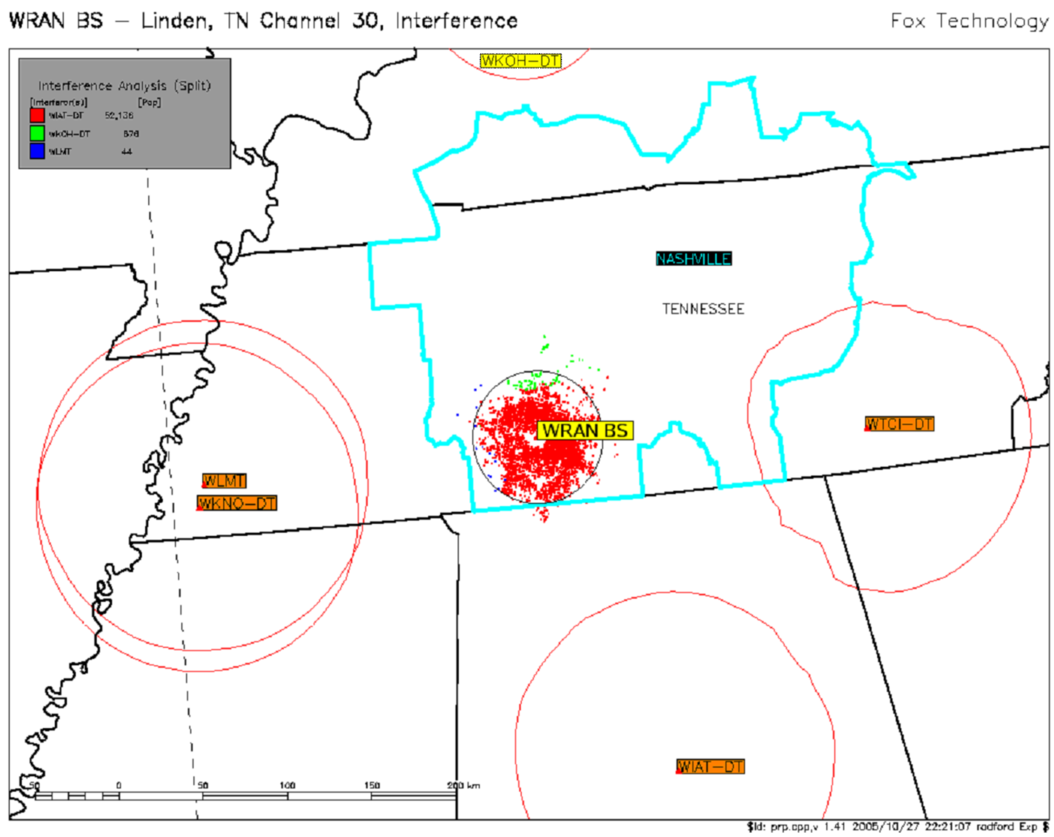
e) Analyze the interference potential into the planned WRAN system from the nearby DTV service.



NOTE—Coverage shown may not be accurate.

Figure B.5—An example of an IEEE 802.22 WRAN contour with DTV interference

The co- and adjacent channel interference into the WRAN BS from the nearby DTV transmissions is once again depicted in Figure B.6. In this figure the interference is color coded to indicate the particular station that is causing the particular interference.



NOTE—The interference shown may not be accurate.

Figure B.6—An example of an IEEE 802.22 WRAN contour with color-coded DTV interference

Annex C

(informative)

Bibliography

Bibliographical references are resources that provide additional or helpful material but do not need to be understood or used to implement this standard. Reference to these resources is made for informational use only.

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[B3] Code of Federal Regulations Title 47 Part 73 Section 73.684 [47CFR73.684], Radio Broadcast Services, Prediction of Coverage.[12]

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