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Via Electronic Filing

December 16, 2013

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 Twelfth St., S.W.
Washington, DC 20554

Re: Written *ex parte* presentation — Incentive Auctions, *GN Docket No. 12-268*

Dear Ms. Dortch:

The FCC has sought public comment on creating a 600 MHz wireless band plan from the spectrum made available for flexible use through the broadcast television incentive auction.[1] The Consumer Electronics Association ("CEA") is pleased to submit the attached technical paper entitled *Protection Bands and Potential Interference at 600 MHz* to assist the FCC in its ongoing analysis.

Please do not hesitate to contact the undersigned with any questions.

Respectfully submitted,

/s/ Julie M. Kearney
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[1] Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions, GN Docket No. 12-268, *Notice of Proposed Rulemaking*, FCC 12-118 (rel. Oct. 2, 2012) ("*NPRM*"); *Wireless Telecommunications Bureau Seeks to Supplement the Record on the 600 MHz Band Plan*, GN Docket No. 12-268, Public Notice, DA No. 13-1157 (May 17, 2013) ("*Public Notice*").

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Protection Bands and Potential Interference at 600MHz

CEA Technical Paper

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Executive Summary

The Federal Communications Commission ("FCC" or "Commission") has sought public comment on creating a 600 MHz wireless band plan from the spectrum made available for flexible use through the broadcast television incentive auction.[1] But realizing these changes in the 600 MHz band spectrum will pose a number of significant technical challenges. To varying degrees depending on location and the extent of clearing and repacking that occurs in any given area a number of different types of services are expected to operate in various portions of the band simultaneously:

(1) Commercial Mobile Radio Services ("CMRS") for licensed[2] wireless broadband, most likely using a Long Term Evolution ("LTE") air interface developed by the Third Generation Partnership Project ("3GPP");

(2) TV white space ("TVWS"), unlicensed wireless broadband devices possibly using one or more standards from the Institute of Electrical and Electronics Engineers ("IEEE"), such as IEEE 802.11af, or any proprietary standard complying with the adopted rules;

(3) Digital Television ("DTV"), digital over-the-air broadcast television based on Advanced Television Systems Committee ("ATSC") standards;[3]

(4) Wireless Microphones utilized by a variety of theaters and venues in addition to live news broadcasts and sound stage recordings; and

(5) Wireless Medical Telemetry Services ("WMTS"), a wireless data service utilized within hospitals and other medical facilities.

A further consideration is the protection of Radio Astronomy ("RA"), which is a passive system operating in specific geographical locations around the U.S.

A closely spaced allocation of spectrum for different purposes can increase spectrum utilization, enhance efficiency and increase value. At the same time, however, such a configuration can introduce harmful interference and overload.

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[1] Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions, GN Docket No. 12-268, *Notice of Proposed Rulemaking*, FCC 12-118 (rel. Oct. 2, 2012) ("*NPRM*"); *Wireless Telecommunications Bureau Seeks to Supplement the Record on the 600 MHz Band Plan*, GN Docket No. 12-268, Public Notice, DA No. 13-1157 (May 17, 2013) ("*Public Notice*").

[2] The terms "licensed" and "unlicensed" are used here because they are well understood in this context. These are regulatory terms, however, and have nothing to do with the radio technology itself. For example, LTE technology could be also used for TV White Spaces, if it complies with FCC rules.

[3] Other interference considerations as well as alternative air interfaces are also possible. To the extent that broadcast incumbents forgo relocation expenses in exchange for additional operational flexibility in the post-auction 600 MHz band, the new technologies DVB-H standard published by the European Telecommunications Standards Institute (ETSI) might need to be considered. Such other air interfaces are not considered here.

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Market Variability is another important consideration in the context of 600 MHz band spectrum reallocation. A fixed national band plan in 600 MHz would be highly desirable to optimize performance of equipment. On the other hand, different markets will "clear" different numbers of DTV channels based on factors such as the size of the market and the response of local broadcasters to the reverse auction. A fixed national plan allows consumer electronics designers to plan for fixed band edges and use efficient, high rejection "band select" filtering. A plan that varies by market (Market Variability) may eliminate this approach. It is not clear what the hardware designer options are in this situation.

The present study reviews thirteen coexistence scenarios that may occur within some or all of the 600 MHz band plans being actively considered by the FCC. The study considers interference scenarios under the "Down from 51" frequency division duplex ("FDD") band plans advanced by many commenters in the proceeding. TDD is not considered directly, but these results are applicable to TDD with the understanding that TDD will also introduce additional interference scenarios, since under a TDD plan the uplink will cover additional spectrum and introduce additional adjacent channel scenarios.

The purpose of this study is to perform a first level of quantitative analysis on the potential for interference and to assess the feasibility of coexistence among the different services in the 600 MHz band under various types of frequency assignment configurations.

In this study, a device which is operating in a guard band or duplex band is referred to as a Protective Band Device. Such device types may include TVWS, wireless microphones or other intentionally-radiating services as authorized by the FCC. While potential unlicensed devices operating in the protective bands of the post-auction 600 MHz band are not technically TVWS devices, we refer to them as TVWS devices for simplicity unless context requires us to distinguish between the device categories.

The study is limited to the effects of receiver overload and out-of-band emissions ("OOBE") interference throughout the band against likely in-field deployment of equipment certified as compliant with widely recognized industry standards. Intermodulation, which can be significant for some of the systems considered here, is fairly receiver-dependent and not amenable to this kind of analysis.

This leads to two limitations of this study. First, because intermodulation is not considered, the study only highlights potential coexistence issues from overload or OOBE. The study does not identify "safe" or acceptable coexistence situations because intermodulation could exceed acceptable levels even when overload and OOBE do not.

Second, this study is based on certain numeric assumptions, which are listed in tables with each case. The criteria are intentionally conservative. Other assumptions could be considered in individual cases, and the reader is free to experiment with the parameters.

Overall, the study was intended to provide technical analysis to identify the most significant issues regarding the implementation of new services in the duplex gap and guard bands. The study arrives at the following primary conclusions:

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- Overload and OOBE do not pose a significant problem with current equipment configurations in most of the scenarios considered so long as the FCC follows its standard practice of employing protection bands, physical separation distances, and careful frequency assignment to minimize the risk of harmful interference.

- However, under the assumptions used in this study, unlicensed devices generally cannot operate in the guard bands above unacceptably low transmission power thresholds without the potential for harmful overload or OOBE interference to adjacent-channel end-user broadband equipment, unless the "victim" equipment is designed to exceed accepted performance levels by a wide margin. An option to mitigate this result is to add frequency separation within the protective band. For an unlicensed device operating in a protective band, such as the UL/DL duplex band, three to four MHz separating the unlicensed operation from the licensed service may be enough to: (1) allow for some attenuation (roll-off); and (2) get sufficiently past the worst of the filter bandpass instabilities. For a six MHz technology such as 802.11af, this implies a 12 to 14 MHz duplex band.

- Market Variability will significantly limit hardware designers' options with current technology to protect services from each other. Without a priori knowledge of band edges, transmitter and receiver designers will be required to implement frequency-agile technologies, which are either more costly or less able to limit harmful interaction between services. Broadcast transmitters are least impacted by this; mass market duplex receivers and mass market simplex (broadcast) receivers are most impacted.

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1. Introduction

Background

The need for spectrum to support a growing number of mobile, fixed, broadcast, two-way, licensed and unlicensed services continues to increase. The Commission is considering the reallocation of spectrum that historically supported a single type of service to support multiple new uses that are far different from those provided by the incumbent users of the band. This transition presents technical challenges. Guard bands and duplex gaps in the 600 MHz band represent two spectrum allocations where the Commission is considering expanding the range of permitted services to include unlicensed operation.

Guard bands serve as a buffer between radio transmitters with widely different transmission power levels or OOBE characteristics in adjacent spectrum. Specifically, guard bands serve two primary functions:

1) They provide frequency separation so that excessive radiofrequency emissions do not fall into adjacent bands causing a material degradation in victim receiver performance.

2) They alleviate the performance requirements placed on receiver filters used for overload protection and OOBE rejection, which reduces the cost of those filters and makes network and user equipment more economical to deploy.

Duplex gaps provide frequency separation between uplink and downlink frequency segments in band plans for two-way services. The duplex gap accommodates the implementation of a duplexer, which allows radios to transmit and receive simultaneously on different frequencies. The width of a duplex gap is dictated by the frequencies in operation and the filtering technology used in receivers. Generally, the larger the duplex gap, the easier and more cost-effective it is to fabricate a duplexer, although beyond a sufficient duplex gap the incremental benefit is reduced.

Until recently, the FCC did not allow any services to use the guard band to avoid the potential of interference between neighboring bands. Duplex gaps, however, have long supported additional services. For example, the original 800 MHz Cellular band allocated 824-849 MHz as uplink and 869-894 MHz as downlink, yielding a duplex gap from 849 to 869 MHz. Most of this cellular duplex gap spectrum (851-869 MHz) was assigned as a Specialized Mobile Radio ("SMR") downlink, providing almost full use of the duplex gap for another service with no apparent problems.

While the experience with cellular and SMR adjacent coexistence demonstrates that different services can use duplex gaps, in general, the operating parameters of both services must maintain compatible transmission power and OOBE parameters to coexist. The failure to consider and analyze all pertinent technical coexistence issues prior to deployment can create harmful interference or overload conditions that are exceptionally difficult and expensive to remedy. For instance, when Motorola and Nextel upgraded Nextel's Integrated Digital Enhanced Network ("iDEN") service, the OOBE performance of the new digital iDEN transmitters was different from the earlier analog system implementation. This fact, compounded by the collocated deployment of iDEN base station equipment in sites with cellular transceivers, caused an unacceptable interference impact to the cellular base station receivers. This problem had to be remedied in the field by the costly and resource-intensive exercise of deploying filters on the iDEN

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transmitters to reduce the OOBE level in those collocated sites. The lesson learned here is that engineering challenges are not always obvious, and apparently minor changes can have serious repercussions

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2. Scope

This section identifies the types of devices under consideration, the types of interaction to be analyzed, and the types of interference considered in this analysis.

Device Types

The following device types will be paired as transmitter of one type and receiver of another, and considered for interference analysis. Not all possible combinations are included. Some signal combinations have already been demonstrated in practice, such as DTV transmitters and WMTS receivers. Also, because this report is specific to the protective band behavior, combinations such as LTE Base Station (BS) Downlink (DL) to DTV receiver, where neither device is operating in the guard band, are not considered.

- DTV: Broadcast "Digital (Terrestrial) Television" based on ATSC (American Television System Committee) specifications.

- LTE: "Long Term Evolution" is used to refer to various releases of 3GPP standards for wireless mobile communications. Currently, 3GPP does not carry band assignments applicable to the 600 MHz auction. In this report, "LTE" will refer to base station (BS) and user equipment (UE) which has substantially similar characteristics as LTE Release 9 FDD equipment used in the 700 MHz bands, but translated in frequency to channels in the 600 MHz band. LTE BS and LTE UE (User Equipment) are considered here.

- WMTS: "Wireless Medical Telemetry Service" devices operating in Channel 37 (608-614 MHz) (see 47 C.F.R. 95.1101 – 95.1129).

- TVWS: TV White Space; in this report, a TVWS device has characteristics based on vendor information and 47 C.F.R. §§ 15.701-717 (Subpart H—Television Band Devices).

- WiFi: Also "WiFi-type;" in this report a WiFi or WiFi-type device is a hypothetical device with substantially similar key characteristics as 802.11a/b/g equipment used in the ISM bands, but translated in frequency to channels in the 600 MHz band.[4] In this context, the key characteristics are transmitter power, antenna gain, and OOBE limits; receiver antenna gain and overload point. .

- Wireless Mic: Wireless Microphone; a device operating in the 600 MHz band and otherwise complying with restrictions in 47 C.F.R. §§ 74.801-882 (Subpart H—Low Power Auxiliary Stations).

- RA: "Radio Astronomy"; the frequency span of Channel 37 is generally reserved globally for Very Long Baseline Interferometry.

- Unlicensed Receiver: In this report any of White Space receiver, WiFi receiver, or Wireless Mic receiver.

[4] In this report we do not specifically consider versions of Wi-Fi currently under development, such as 802.11af, which has different channel bandwidths and out-of-band emissions characteristics.

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Device Interactions

Figure 1 below presents the band plan considered in this study.

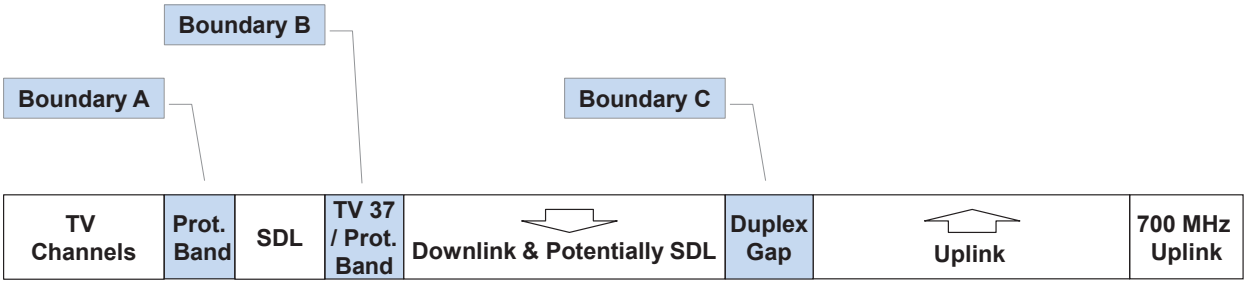

Figure 1: Definition and Locations of Boundary Areas

The sizes of Boundary A and Boundary C in Figure 1 above are independent of their exact frequency locations. Their location will vary depending on the amount of DTV spectrum reallocated for CMRS use in each geographical area. Only Channel 37 is assumed to be a hard boundary condition in this analysis; that is, we assume here that the Radio Astronomy and Wireless Medical Telemetry Service (WMTS) are not moved from this channel. The analysis we will perform is valid regardless of the number of channels ultimately made available in each market.

The cases in Table 1 below capture the relevant relationships among licensed and unlicensed services for the proposed 600 MHz band and are the specific situations used in this study.

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Table 1: Cases Considered

Case	Case Description	Boundary
1	DTV transmitter to Unlicensed Receiver	A
2	LTE SDL[5]/downlink transmitter to Unlicensed Receiver	A,B,C
3	Unlicensed transmitter to DTV receiver	A
4	Unlicensed transmitter to mobile user equipment (UE) receiver	A,C
5	LTE BTS (Base Transceiver Station) transmitter to Channel 37 WMTS	B
6	LTE BTS transmitter to Channel 37 Radio Astronomy	B
7	Unlicensed transmitter to Channel 37 Radio Astronomy	B
8	Unlicensed transmitter to Channel 37 WMTS	B
9	Mobile UE LTE transmitter to Unlicensed Receiver	C
10	Unlicensed transmitter to LTE BTS receiver	C
11	DTV transmitter to mobile UE LTE receiver	A,B,C
12	Mobile UE LTE transmitter to DTV receiver	A,B,C
13	DTV transmitter to LTE BTS receiver	A,B,C

Interference Types

Two types of interference that may be encountered in each of these cases are considered. The first type of interference is OOBE, which is radiofrequency energy leaking outside of the intended transmission channel into neighboring channels. This energy is received within the desired receive channel, and cannot be filtered out at the neighboring victim receiver. Mechanisms to manage OOBE considered in this study include: lowering transmitter power; transmitter filtering; using a guard band to provide additional frequency spacing for filter roll off; and distance separation between the transmitter and receiver.

The second type of interference is overload, also called receiver blocking or receiver desensitization ("desense"). When a strong transmitter is in close proximity to a neighboring receiver, the high neighboring energy level at the receiver may obscure its ability to receive weak signals within its desired channel. Mechanisms to manage receiver blocking may include: receiver filtering; improved receiver linearity; using a guard band to provide additional frequency spacing for filter roll off; and distance separation between the transmitter and the receiver.

[5] SDL, Supplemental Downlink, is a mechanism for increasing downlink capacity in LTE Release 9 and beyond by using unpaired spectrum as additional carriers along with the original paired downlink and uplink. From an interference perspective, LTE SDL channels will perform the same as any other forward link channels in an LTE system. See, e.g., 3GPP TS 36.101 Table 5.5-1 E-UTRA operating bands, Band 29.

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A third type of interference, intermodulation interference, is also possible, but our analysis focuses only on receiver overload and OOBE interference. This type of intermodulation interference occurs at harmonic frequencies (integer multiples) of the component emissions, at the sum and difference frequencies of the original emissions and at multiples of those sum and difference frequencies of the original emissions. Such interference is difficult to accurately predict.

As this study is limited to two kinds of interference, it is not comprehensive in scope. Instead, the results here may be used as a leading indicator of problems for overload and OOBE issues between services. Additional receiver-specific analysis and physical testing would be required for a complete understanding of the potential for interference.

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3. Result Summary

In the Table below, we summarize the results for the cases that were analyzed in this study:

Case Number	Case Description	Boundary	Findings	Direction of Potential Interference	Expected Probability of Interference	Coordination Helps?	Exclusion Zone
1	DTV transmitter to Unlicensed Receiver	A	No material concern; a challenge for unlicensed devices	Licensed to Unlicensed	Limited	Yes but not practical	
2	LTE SDL/downlink transmitter to Unlicensed Receiver	A,B,C	No material concern	Licensed to Unlicensed	Low		
3	Unlicensed transmitter to DTV receiver	A	Could pose a problem causing overload or excessive OBEE but properly designed devices can co-exist with a DTV receiver	Unlicensed to Licensed	High		
4	Unlicensed transmitter to mobile UE receiver	A,C	Most significant problem identified; could cause shut down of LTE UE in proximity to TVWS UE	Unlicensed to Licensed	High	Yes but not practical	BTS Coverage
5	LTE Base Station transmitter to Channel 37 WMTS	B	No material concern	Licensed to Licensed	Low		
6	LTE Base Station transmitter to Channel 37 Radio Astronomy	B	No material concern	Licensed to Licensed	Low		
7	Unlicensed transmitter to Channel 37 Radio Astronomy	B	No material concern	Unlicensed to Licensed	Limited	Yes	RA Exclusion
8	Unlicensed transmitter to Channel 37 WMTS	B	Problematic when operated in close proximity of WMTS devices	Unlicensed to Licensed	Limited	Yes	WMTS Coverage
9	Mobile UE LTE transmitter to Unlicensed Receiver	C	Could cause shut down of TVWS UE in proximity to Mobile UE transmitter	Licensed to Unlicensed	High		BTS Coverage
10	Unlicensed transmitter to LTE Base Station receiver	C	No material concern	Unlicensed to Licensed	Low		
11	DTV transmitter to mobile UE LTE receiver	A,B,C	No material concern	Licensed to Licensed	Low		
12	Mobile UE LTE transmitter to DTV receiver	A,B,C	No material concern	Licensed to Licensed	Low		
13	DTV transmitter to LTE Base Station Receiver	A,B,C	No material concern	Licensed to Licensed	Low		

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4. Analysis

Each of the various "Down from 51" reallocation band plans includes a duplex gap between the FDD allocations for broadband use, and provides for two guard bands, which are located between the DTV broadcast allocation and the SDL and on either side of Channel 37, to protect existing users from the transmissions above and below Channel 37 (see Figure 1 above).

Depending on the implementation, services located in the guard bands or duplex gap could coexist with the surrounding licensed services without causing interference. However, coexistence may not always prove practical. The potential for harmful interference to adjacent channel services may mean that some services in some locations will not be practical without the availability of additional spectrum devoted to the guard band bandwidth.

Radio Frequency System Parameters

Operating parameters of transmitters and receivers play a decisive role in the interference environment anticipated for the 600 MHz band, but deriving these values is not an entirely straightforward exercise. Transmitters routinely perform considerably better than the specifications identified by industry standard bodies or the FCC. Receiver specifications can also exceed industry specifications, but the margin over the standard tends to be considerably less and can vary substantially from manufacturer to manufacturer and even model to model.

For purposes of this study, transmitter parameters are drawn from FCC rules associated with the primary service being considered, such as CMRS, DTV, or TVWS.[6] Receiver parameters are based upon published specifications for equipment currently available in the market. In certain cases, however, assumptions about receiver performance based on known parameters associated with similar equipment and our knowledge of the field were necessary due to the absence of public domain data. We identify our assumptions in Tables 2 and 3, which present the transmitter and receiver characteristics used as limits in the analysis that follows. In some of the Cases that follow, use-case specific parameters are included in additional tables; such parameters may include, for example, a lower antenna gain where indicated by the use case.

Some parameters are included for reference only and were not used in the analysis, such as modulation options, channel bandwidth, duplexer isolation, duplexer loss, and filter attenuations. Needless to say, performance at substantial variance with the assumptions in these tables could lead to materially different outcomes.

In the case of LTE and some licensed services, the OOBE is specified as X+10logP at the transmitter output, where P is transmitting power, X is some fixed number of dB, and the equation results in a minimum attenuation factor below the transmitting power. This yields a fixed OOBE independent of transmitter power, therefore antenna gain will increase this fixed component by the antenna gain. Other services (DTV and WiFi, for example) have OOBE power referenced to carrier power, so it shifts with the operating power. In these cases, the OOBE was referenced to the

[6] While unlicensed devices operating in the protective bands of the post-auction 600 MHz band are not technically TVWS devices, we refer to them as TVWS devices for simplicity unless context requires us to distinguish between the device categories.

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operating ERP (Effective Radiated Power), which included antenna gain. In a number of cases antenna gain was assumed to be zero, so there was no net effect.

Battery powered unlicensed devices tend to have transmit output Power Amplifiers (PA) that adapt the bias current according to output power level, much as does an LTE UE. TVWS base stations typically use local A.C. mains supply power. OOBE falls off with a reduction in PA output power, but it typically does so more quickly with a constant bias PA than with a variable bias PA. It is reasonable to expect that OOBE decreases faster than the reduction in transmitted power output. This is less valid for a battery powered user device.

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Table 2: Transmitter Parameters

Characteristic	Unit	DTV [7]		LTE Base Station [8]		LTE UE [9]		WMTS [10]		Whitespace [11]		WiFi [12]		Wireless Mic [13]	
Max/Min		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Transmit Power	Watts	1,000,000	50,000	2,000	200	0.2	0.04	0.1	0.04	4	0.04	4	0.04	0.25	0.01
Transmit Power[14]	dBm	90	77	63	53	23	16	20	16	36	16	36	16	24	10
Bandwidth	MHz	6	6	4.5	4.5	4.5	0.18	1.5	0.5	5.5	5.5	varies	varies	0.2	0.15
Antenna Gain	dBi	10	10	14	14	-5	-5	-3	-3	6	6	6	6	0	0
OOBE (ACLR) FCC Reg.	dBm	See tables for each case below		-13	-13	-13	-13	-10.00	-10.00	-36.78	-56.78	-3.98	-23.98	-1	-15
OOBE Equipment Performance w/ Antenna Gain		See tables for each case below		1	1	-18	-18	-10	-10	-37	-57	-4	-24	-1	-15
Nominal Antenna Height	m	300	300	40	20	1.5	1.5	1.5	1.5	30	1.5	30	1.5	1.5	1.5

[7] Advanced Television Systems Committee, Inc., ATSC Recommended Practice: Receiver Performance Guidelines (Apr. 7, 2010), *available at* http://www.atsc.org/cms/standards/a_74-2010.pdf (last accessed Oct. 23, 2013) (subsequent DTV data from the same source).

[8] Information provided by vendors (subsequent LTE base station data from the same sources).

[9] 3GPP TS 36.101, Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception, *available at* http://www.3gpp.org/ftp/Specs/html-info/36101.htm (subsequent LTE UE data from the same source) ("3GPP TS 36.101").

[10] 47 C.F.R. § 95.1115 (General technical requirements).

[11] Information provided by vendor; 47 C.F.R. §§ 15.701-717 (Subpart H—Television Band Devices) (subsequent whitespace data from the same sources).

[12] 47 C.F.R. § 15.247 (Operation within the bands 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz).

[13] 47 C.F.R. §§ 74.801-882 (Subpart H—Low Power Auxiliary Stations).

[14] Throughout this study, we express power in both watts (W) and decibels of the measured power referenced to one milliwatt (dBm). There is no difference between these two values; the different values are strictly the result of a mathematical conversion. Nonetheless, both values are offered here for reference because DTV operations are typically measured in watts whereas CMRS operations are typically measured in decibels referenced to the milliwatt.

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Table 3: Receiver Parameters[15]

Characteristic	Unit	DTV	LTE Base Station	LTE UE	WMTS	White space	WiFi	Wireless Mic	Radio Astronomy[16]	Comments
Channel Bandwidth	MHz	6	4.5	4.5	1.5	5.5	22	0.2	--	Occupied Channel
RX Antenna Gain[17]	dBi	12	14	-5	3	-5 or +6	-5 or +6	0	--	Ref. to Isotropic Antenna
RX Noise Figure	dB	8	2.5	9	8	8	8	8	--	Typical
RX Thermal Noise - KT	dBm/Hz	-174	-174	-174	-174	-174	-174	-174	-174	Thermal Noise Floor
Duplex Isolation	dB	N/A	50	50	N/A	N/A	N/A	N/A	--	TX band: TX and RX isolation est.
Duplexer Loss (Rx/Tx)	dB	N/A	3	3.5	N/A	N/A	N/A	N/A	--	Estimated
RX Adjacent Channel Selectivity	dB	-33	50	33	33	33	33	33	--	Specification of Standards Doc
Overload Point	dBm	-5	-12	-44	-30	-10	-44	-44	--	Estimated or Specifications

The analysis that follows is organized into a number of cases. Each case is related to a specific boundary condition and a specific service-to-service effect, such as DTV to TVWS. Each case will be composed of two analyses, one addressing the impact of neighboring device transmit power (*i.e.*, receiver overload) and one addressing the effect of OOBE (*i.e.*, an increase in the noise floor).

[15] The FCC does not provide equipment performance requirements for receivers; as a result, in this analysis we made assumptions for some of the equipment performance specifications based on published specifications for equipment currently available in the market.

[16] Direct comparison in this format is difficult because of a variety of factors. For example, RA antenna gain must be taken at the side lobes because the main beam is aimed at space. Generally speaking, however, ITU recommendation Rec. ITU-R RA.769-2 specifies the performance requirements of Radio Astronomy as extremely low noise emissions from co- and adjacent-channel services as the signal received from an observation of interest may be as low as 10^{-18} watts, or 0.001 femtowatts, or lower.

[17] Two values are shown in some columns. The value used depends on the use case. For example, a directional antenna mounted on a tower may have +6dBi gain; a handheld device antenna may have -5dBi.

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Model Assumptions

Propagation models can be used for determining the impact distances associated with overload or OOBE of a transmitter. This paper uses three basic models, depending on the range of the interference conditions analyzed. The three basic models and their uses are as follows:

- ***The COST-Hata Model*** (or more completely, the COST 231[18] extensions to the urban Hata model) is a radio propagation model that extends the urban Hata model for long distance effects over ranges of more than one kilometer. This model is especially useful for assessing the effects elevated transmitters might encounter as the model can be varied according to the height differential of the relevant transmitters.[19]

- ***The Free Space Loss Model or 20LOG Model*** ignores the effects of absorptive surfaces, reflecting surfaces, earth curvature and other obstacles in calculating the effects of emissions. This model can be particularly useful for short distances of less than five meters, where these mitigating factors play less of a role. Free space loss might reasonably apply to portable devices operating in close proximity to one another.

- ***A 40LOG Model*** is based on the rapid decay of signal power after a short distance from the antenna over flat smooth earth, and is used to assess coexistence at intermediate distances of more than five meters but less than one kilometer.[20]

- ***Free Space then 40LOG Model beyond transition distance*** incorporates the impact of the ground reflection on device-to-device or base-station-to-device propagation and also incorporates the impact of device and base station heights.

In each of these models, path loss increases as distance increases; however, the models offer varying degrees of accuracy, depending on the distances involved and, in the case of the COST-Hata model, the transmit and receive antenna heights incorporated into the model. The 20LOG and 40LOG models may be considered as probable bounds in the absence of macro shadowing, while HATA is a median sort of loss more applicable to greater distances.

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[18] COST 231 refers to COST Action 231, "*Evolution of Land Mobile Radio (including personal) Communications*", a research project funded by the European Co-operation in the field of Scientific and Technical research. See http://www.lx.it.pt/cost231/final_report.htm.

[19] *See generally, e.g.*, Yuvraj Singh, Comparison of Okumura, Hata and COST-231 Models on the Basis of Path Loss and Signal Strength, *International Journal of Computer Applications* (Dec. 2012), *available at* http://research.ijcaonline.org/volume59/number11/pxc3884216.pdf (last accessed Oct. 11, 2013).

[20] A comparison of the 40LOG and Free Space propagation models is available in OET Bulletin 91-1. *See* William Daniel and Harry Wong, "Propagation in Suburban Areas at Distances less than Ten Miles," Federal Communications Commission Office of Engineering and Technology, FCC/OET TM 91-1 (Jan. 25, 1991), *available at* http://transition.fcc.gov/oet/info/documents/technical/tm91-1.pdf (last accessed Oct. 23, 2013).

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Figure 2 below shows the characteristic slope for each of the models used in this study, including three variations of the COST-Hata model, each with different relative antenna heights. The resulting figure allows for a determination of impact distances based upon the use of alternate models, or by adjusting operating parameters which would, in turn, yield different path losses.

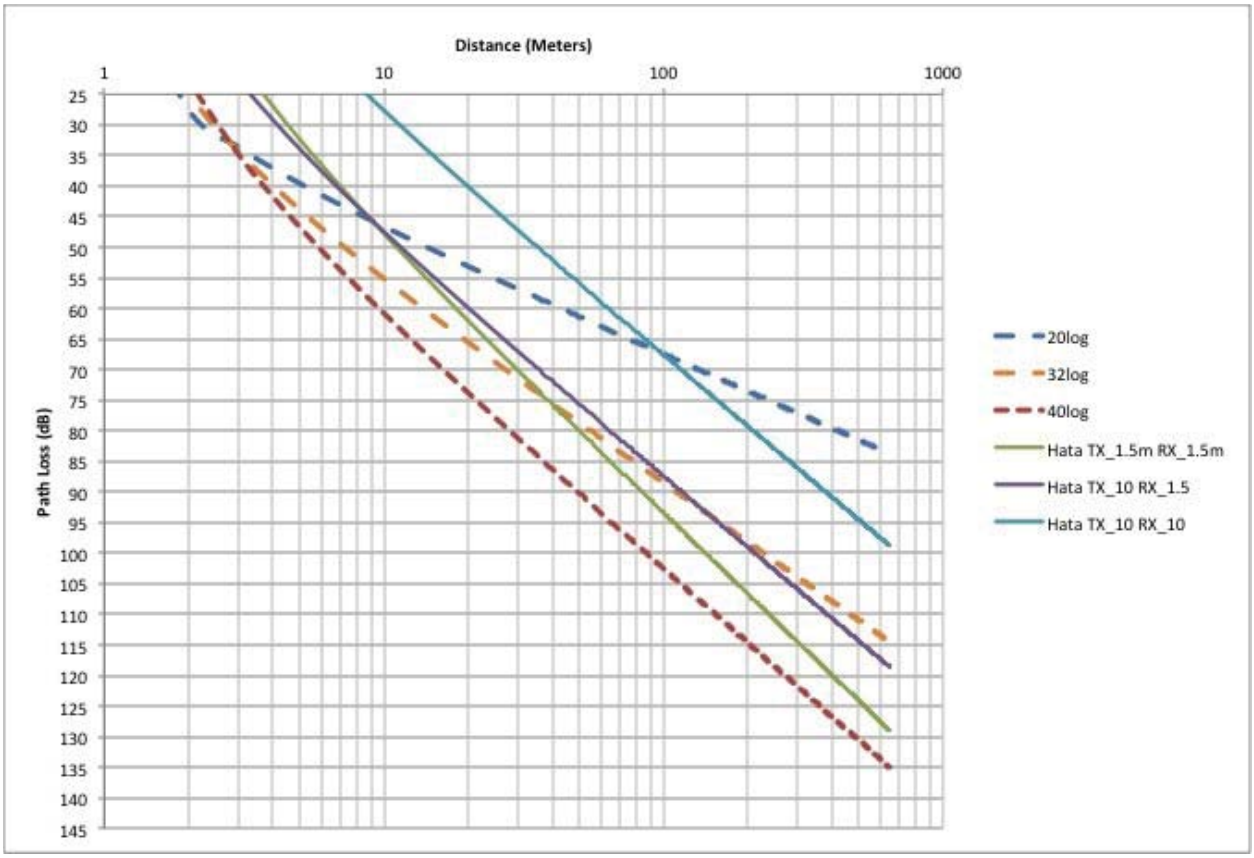

Figure 2: Propagation Model Comparisons

Analysis Limitations

The analysis that forms the basis for this study has some limitations. Generally, the analysis is done on a "worst-case" basis. All calculations of distance are independent of environmental losses (*e.g.*, terrain, foliage, man-made land usage) aside from the path loss predicted by the model. Only building losses are used, when required by the use case. While the COST-Hata model calculations take into account relative elevations of transmitter and receiver antennas, the 20LOG and 40LOG models do not use relative antenna heights in their respective formulae. The calculations used in the analysis do not include the effects of specific antenna patterns such as vertical pattern and downtilt and do not assume transmit power control (or rather, the devices are transmitting at the maximum allowed value). The "increase in noise floor" criterion for interference does not necessarily mean that service will be cut off at that point; the device may be able to operate with that level of interference. For distances over 60 to 80km, curvature of the earth limits real signal propagation. Finally, no body loss is assumed in any calculation.

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5. Specific Cases

Case 1: DTV Transmitter to Unlicensed Receiver (Boundary A)

As illustrated below, this case addresses the impact of a DTV transmitter (DTV TX) into an Unlicensed Receiver located in the guard band that separates a television channel from LTE SDL operations.

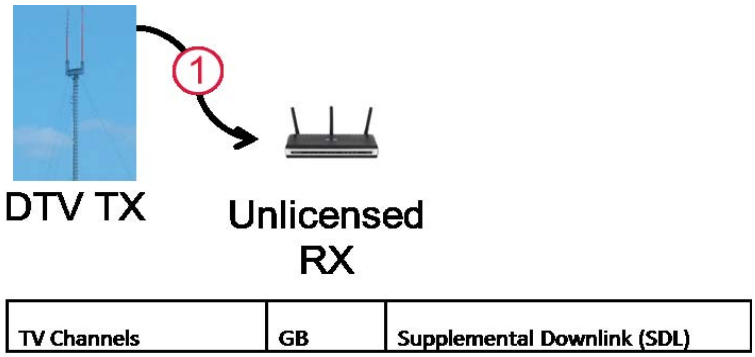

Figure 3: DTV Transmitter into Unlicensed Receiver

ASSUMPTIONS:

Table 4: Transmitter Performance Assumptions

Characteristic	Unit	DTV	
Max/Min		Max	Min
Transmit Power	Watts	1,000,000	50,000
Transmit Power	dBm	90	77
Bandwidth	MHz	6	6
Antenna Gain	dBi	10	10
OOBE (ACLR) FCC Reg.	dBm	From Figure 4	
OOBE Equip. Perf. w/ Ant. Gain		From Figure 4	
Nominal Antenna Height	m	300	300

Tables 4 and 5 list specific assumptions made for this Case. As noted in section III under “Device Types”, “WiFi” or “WiFi-type” in this report refers to a hypothetical device with substantially similar characteristics as 802.11a/b/g equipment used in the ISM bands, but translated in frequency to channels in the 600 MHz band. Two receiver antenna gains are listed, a higher value for a hypothetical directional antenna and a lower (negative) value for a less favorable antenna in a mobile or in-home device.

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Table 5: Receiver Performance Assumptions

Characteristic	Unit	Whitespace	WiFi[21]	Wireless Mic
Channel Bandwidth	MHz	5.5	22	0.2
RX Antenna Gain	dBi	-5 or +6	-5 or +6	0
RX Noise Figure	dB	8	8	8
RX Thermal Noise	dBm/Hz	-174	-174	-174
Duplexer Loss (Rx/Tx)	dB	N/A	N/A	N/A
RX Adjacent Channel Selectivity	dB	33	33	33
Overload Point	dBm	-10	-44	-44

Table 6: Other Assumptions

DTV Antenna Height	300	Meters
Mobile Protective Band Device antenna height	1.5	Meters
Base Station Protective Band Device Antenna Height	10	Meters
In Home Protective Band Device Antenna Height	1.5	Meters
Building Attenuation for in Home case	12	dB

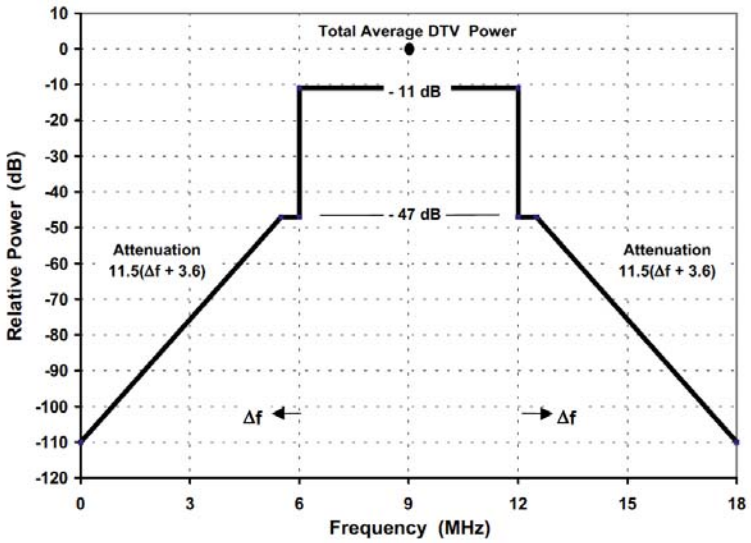

Figure 4: ATSC Out of Band Emissions

[21] As noted in section III under "Device Types", "WiFi" or "WiFi-type" in this report refers to a hypothetical device with substantially similar characteristics as 802.11a/b/g equipment used in the ISM bands, but translated in frequency to channels in the 600 MHz band.

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As seen above, the ATSC carrier's OOBE levels are significant and are only 47 dB lower than the full carrier power in the first 500 kHz of the adjacent channel. While the emissions power declines after the first 500 kHz, there is still significant energy over the first three megahertz of the adjacent channel, which in the case of the 600 MHz band would be one of the protection bands, either the duplex gap or a guard band separation.

To allow for further calculations of the coexistence environment in this situation, we provide a reference measurement showing transmission power levels removed from the channel edge. Table 7 below shows absolute transmission power levels that do not take into account any propagation losses or gains that might result from reflections, absorptive effects, earth curvature or other factors. The transmission power from a one megawatt transmitter that rolls off into the guard band on a per megahertz basis is as follows:

Table 7: DTV Transmitter Roll Off

MHz removed from channel edge	Average Transmission Power per MHz from Band edge (dBm) for a 1 MW TX [22]	Average Transmission Power per MHz from Band edge (watts)
1	42.11	16.2466
2	34.39	2.7458
3	22.89	0.1944
4	11.39	0.0138
5	-0.11	0.0010
6	-11.61	0.0001

ANALYSIS AND CALCULATIONS:

Building on the assumed DTV roll off, we analyze two circumstances: (1) the effect of transmission power causing overload; and (2) the effect of OOBE raising the noise floor within the mobile receiver channel.

For both receiver overload and OOBE, we take into consideration a variety of Protective Band Devices with different antenna gains and heights. Specifically, we review typically observed operating parameters for WiFi-type end user equipment, WiFi-type consumer base stations, and WiFi-type outdoor or commercial base stations, and then apply these across variable levels of DTV transmit power.

The results of this analysis show that interference will be driven largely by the proximity of devices to the DTV signal. Since propagation losses will reduce both received signal power and OOBE, there is a distance from the unlicensed device where the effects of transmit power and OOBE will greatly limit the operation of unlicensed devices, creating what we term an Exclusion Zone for these products. The precise size of the Exclusion Zone will depend on the type of Protective Band Device employed as well as the power of the DTV transmitter.

[22] Linear power average; attenuation values read off the curve in Figure 4 are taken from 90dBm to find the power at each point, then these were converted to linear power and averaged, then converted back to dBm.

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In Table 8 we show the radius of the Exclusion Zone as against the power of DTV transmitters operating at different transmitter power levels.

Table 8: Overload Exclusion Zone Distance vs. DTV Transmit Power

DTV TX Power	1000	750	450	200	125	15	kW
Exclusion Zone for below case:							
WiFi Mobile Protective Band Device, -5 dB ant gain 1.5 m Height	6.6	6.0	5.0	3.8	3.2	1.5	km
WiFi Base Station Protective Band Device, +6 dB ant Gain 10 M Antenna Height	78.6	71.1	59.5	44.8	38.0	18.2	km
WiFi In Home Protective Band Device, -5 dB ant gain 1.5 M Antenna Height	2.5	2.3	1.9	1.4	1.2	0.6	km
Whitespace Mobile Protective Band Device, -5 dB Ant gain 1.5 M Antenna Height	0.43	0.39	0.33	0.25	0.21	0.10	km
Whitespace Base Station Protective Band Device, +6 dB ant gain 10 M Antenna Height	5.1	4.6	3.9	2.9	2.5	1.2	km
Whitespace In Home Protective Band Device, -5 dB ant gain 1.5 M Antenna Height	0.16	0.15	0.12	0.09	0.08	0.04	km

For OOBE, a different approach is required. A nearby DTV transmitter on an adjacent channel will have a significant impact on the desired channel. The OOBE power over the first three megahertz from the band edge is likely to cause significant problems for any broadband device. This makes averaging the DTV OOBE power over a 6 MHz span unfairly favorable.

Rather than consider receiver specifics, Table 9 analyzes the significant OOBE from DTV on a per MHz basis. Given the extreme OOBE power levels in the adjacent channel, we present this in one megahertz increments. The analysis basically shows the distance required for the signal in that one megahertz to attenuate to a level equal to the equivalent thermal noise level.[23] This is shown for various levels of DTV transmitter power.

As shown below, the predicted exclusion zones range from as much as 191.7 kilometers from a full-power DTV station for an unlicensed (outdoor) base station operating 0-1 megahertz from the band edge to as little as 0.2 kilometers from a 2 kW DTV station for an unlicensed in-home (indoor) device two to three megahertz from the band edge.

[23] The criteria of "*attenuate to a level equal to the equivalent thermal noise level*" may seem conservative, depending on one's point of view. For comparison, one might assume that the receivers can tolerate an additional 6dB of increased noise over the equivalent thermal noise level before experiencing loss of service. However, the path loss curves have a slope of roughly 10dB per factor of two in distance. The 191.7 km distance will be reduced by less than a factor of two, still well above 100 km, if an additional 6 dB is assumed in the criterion.

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Table 9: OOBE Noise Floor Rise Zone Distance in Each MHz of Adjacent Channel vs DTV Transmit Power

DTV TX Power in Watts	1000	750	450	200	125	15	2	KW
Exclusion Zone for:								
Mobile Protective Band Device:								
Max. Impact distance, 0 MHz to 1 MHz from Band edge	39.1	35.3	29.6	22.3	18.9	9.0	1.4	km
Max. Impact distance,1 MHz to 2 MHz from Band edge	21.0	19.0	15.9	12.0	10.2	4.9	0.8	km
Max. Impact distance, 2 MHz to 3 MHz from Band edge	8.3	7.5	6.3	4.8	4.0	1.9	0.4	km
Base Station Protective Band Device:								
Max. Impact distance, 0 MHz to 1 MHz from Band edge	191.7	173.4	145.1	109.3	92.8	44.3	5.0	km
Max. Impact distance, 1 MHz to 2 MHz from Band edge	103.1	93.3	78.0	58.8	49.9	23.8	3.0	km
Max. Impact distance, 2 MHz to 3 MHz from Band edge	40.9	37.0	31.0	23.4	19.8	9.5	1.4	km
In Home Protective Band Device:								
Max. Impact distance, 0 MHz to 1 MHz from Band edge	14.9	13.5	11.3	8.5	7.2	3.4	0.6	km
Max. Impact distance, 1 MHz to 2 MHz from Band edge	8.0	7.3	6.1	4.6	3.9	1.9	0.4	km
Max. Impact distance, 2 MHz to 3 MHz from Band edge	3.2	2.9	2.4	1.8	1.5	0.7	0.2	km

RESULTS:

When in close proximity to a DTV transmitter an unlicensed device can suffer significant interference and overload. This may be mitigated somewhat by the vertical pattern of the antenna. Since under the FCC rules an unlicensed device must tolerate interference from all licensed devices this case does not imply that unlicensed use of the guard band is infeasible. In fact this situation is identical to what occurs under today's FCC white space rules and must be and is dealt with by manufacturers. Unlicensed device manufacturers focused on producing TVWS devices have incorporated very robust overload performance to avoid this type of interference, and devices intended for indoor use operating in this band have a lessened impact area due to the effects of building attenuation on the potentially interfering signal. So long as unlicensed 600 MHz devices are designed to cope with the high power associated with DTV transmissions, high power DTV stations need not significantly affect the operation of unlicensed devices in the protection bands when reasonable physical separation is maintained. Of course, there will be no impact at all in markets where adjacent-channel DTV transmitters are not deployed.

While the OOBE profile of the ATSC signal causes significant effects into the first two to three megahertz of the adjacent protection band, the precise degree of impact on the Protective Band Devices will vary depending on the power level of the interfering signal. For example, an interfering signal operating at lower transmit power would

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require less than three megahertz of separation while one operating at higher power may require somewhat more separation to avoid effects in the protection band.[24]

The area impacted by overload from the DTV transmitter should also lessen due to the move away from the guard band edge. The amount of improvement cannot be calculated without a far greater understanding of the inner workings of receivers in the band, their filtering capability, and the dynamic range available to the front end of these systems.

CONCLUSIONS:

This Case considers a protection band between DTV and SDL allocations, and the impact of an adjacent DTV transmitter on unlicensed devices operating in that band. The adjacent signal will make the first few megahertz of the protection band unavailable within an exclusion zone around the DTV transmitter; the size of this exclusion zone will vary based on device parameters. Unlicensed devices can operate outside the local exclusion zone or in a portion of the protection band beyond the first three megahertz adjacent to the DTV transmission frequency.

[24] The distance from the interfering transmitter also plays an important role. This may be a good reason to have any transmitters operating in the adjacent band to register their location in a database. The database could use that information to protect those band-edge operators from unlicensed operations, and it would allow for more unlicensed opportunities in locations where no band-edge operators are active.

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Case 2: LTE SDL/Downlink (DL) Transmitter to Unlicensed Receiver (Boundary A, B & C)

As illustrated below, this case addresses the impact of an LTE DL or SDL transmitter to an Unlicensed Receiver located in the adjacent guard band or duplex gap.

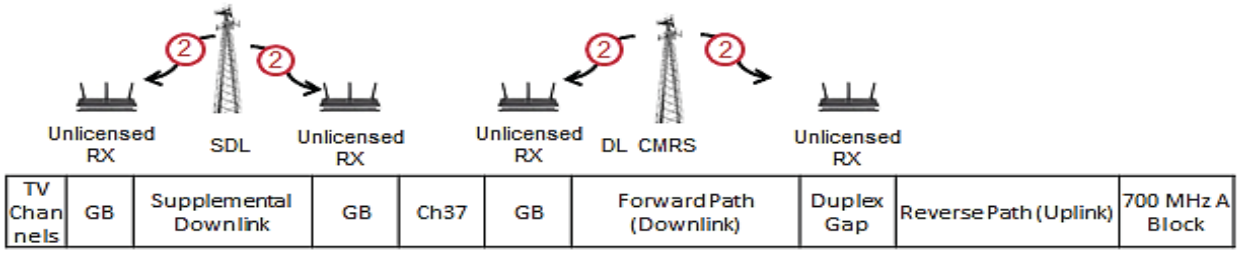

Figure 5: SDL/DL Transmitter to Unlicensed Receiver

ASSUMPTIONS:

Table 10: Transmitter Performance Assumptions

Characteristic	Unit	LTE Base Station	
Max/Min		Max	Min
Transmit Power	Watts	2,000	200
Transmit Power	dBm	63	53
Bandwidth	MHz	4.5	4.5
Antenna Gain	dBi	14	14
OOBE (ACLR) FCC Reg.	dBm	-13	-13
OOBE Equip. Performance Actual	dBm	<-25	<-25
Nominal Antenna Height	m	40	20

Table 11: Receiver Performance Assumptions

Characteristic	Unit	Whitespace	WiFi	Wireless Mic
Channel Bandwidth	MHz	5.5	22	0.2
RX Antenna Gain	dBi	-5 or +6	-5 or +6	0
RX Noise Figure	dB	8	8	8
RX Thermal Noise	dBm/Hz	-174	-174	-174
Duplex Isolation	dB	N/A	N/A	N/A
Duplexer Loss (Rx/Tx)	dB	N/A	N/A	N/A
RX Adjacent Channel overload point	dB	-10	-44	-44

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ANALYSIS AND CALCULATIONS:

The study analyzes two circumstances: the effect of transmit power causing overload, and the effect of OOBE raising the noise floor within the mobile receive channel.

The results of this analysis are driven by the proximity of devices. Since propagation losses will reduce both received signal power and OOBE, there is a distance from the unlicensed device where the effects of power and OOBE will be below the critical impact threshold, the Exclusion Zone. LTE DL and SDL transmitters can work at a variety of power levels that relate to the actual service needs in an area; therefore, Table 12 below shows the radius of the Exclusion Zone as against the power of the LTE DL/SDL transmitter.

Table 12: DL/SDL to Unlicensed Receiver Device Overload Distances

DL or SDL TX Power	2000	1000	200	Watts
Exclusion Zone for below case				
WiFi Mobile Protective Band Device, -5 dB ant gain 1.5 m	0.32	0.27	0.17	km
WiFi Base Station Protective Band Device, +6 dB ant Gain 10 M	2.42	1.99	1.26	km
WiFi In Home Protective Band Device, -5 dB ant gain 1.5 M	0.148	0.121	0.077	km
Whitespace Mobile Protective Band Device, -5 dB Ant gain 1.5 M	0.035	0.029	0.018	km
Whitespace Base Station Protective Band Device, +6 dB ant gain 10 M	0.262	0.216	0.136	km
Whitespace In Home Protective Band Device, -5 dB ant gain 1.5 M	0.016	0.013	0.008	km

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Table 13: DL/SDL to Unlicensed Receiver Device OOBE Noise Floor Rise Distances

DL or SDL OOBE Transmitted Power (OOBE level plus Antenna gain)	+1 (per FCC Rule limit)[25]	-11 (based upon nominal equip performance)	dBm
Noise Floor rise Zone for below case:			
Reference 0 dB gain antenna at 1.5 meters outdoor	393	204	Meters
Mobile Protective Band Device WiFi like -5 dB ant gain 1.5 m	283	147	Meters
Base Station Protective Band Device WiFi Like +6 dB ant Gain 10 M	2124	1105	Meters
In Home Protective Band Device WiFi like -5 dB ant gain 1.5 M	129	67	Meters
Mobile Protective Band Device Whitespace like -5 dB Ant gain 1.5 M	283	147	Meters
Base Station Protective Band Device Whitespace Like +6 dB ant gain 10 M	2124	1105	Meters
In Home Protective Band Device Whitespace like -5 dB ant gain 1.5 M	129	67	Meters

[25] This Case uses two levels of OOBE. The value listed as "OOBE (ACLR) FCC Reg." is the FCC requirement for OOBE (or adjacent channel leakage ratio, in 3GPP terms). However, equipment is generally designed to exceed this requirement. To see the impact of this improved performance, a second OOBE value labeled "OOBE Equip. Performance Actual" is listed in Table 10.

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RESULTS:

While the analysis shows that there will be impact from overload in proximity to the LTE DL/SDL base station, the area of impact is fairly limited. The analysis shows impact distances to an outdoor Protective Band Device with good overload performance to be up to 300 meters; however, the vertical beam width of the antenna will result in the actual energy in the first few hundred meters being ten dB lower than calculated. As a result, the values in Table 13 may be lower than expected under real-world conditions and should more closely resemble the values predicted for in-building performance.

The OOBE analysis shows smaller impact areas to bring the OOBE to levels approximating thermal noise, which can be modeled by statistical noise with a normal probability density function. Accounting for actual vertical antenna patterns, except for the case of an elevated outdoor Protective Band Device acting as a base station, these small impact distances once again fall to an area very near the DL/SDL antenna.

CONCLUSIONS:

The analysis shows that this case does not appear to be problematic. DL/SDL transmitters should not cause significant impact to protective band UE devices operating in a home or office environment, but will cause degradation over a greater distance to devices operating outdoors at higher elevations. In any event these effects should not generally preclude the use of unlicensed devices.

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Case 3: Unlicensed Transmitter to DTV Receiver (Boundary A)

As illustrated below, this case addresses the impact of an unlicensed guard band transmitter (unlicensed TX) to a DTV receiver located in the channel adjacent to the duplex gap.

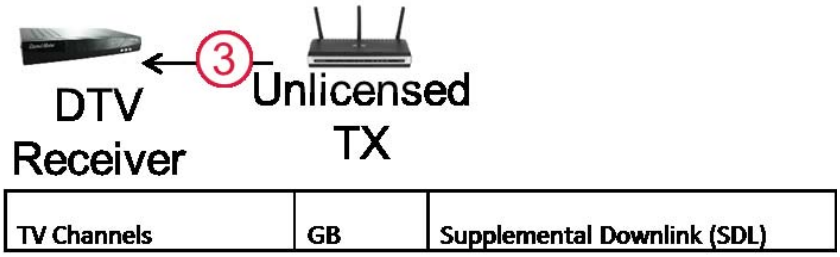

Figure 6: Unlicensed Transmitter to DTV Receiver

ASSUMPTIONS:

Table 14: Transmitter Parameters

Characteristic	Unit	Whitespace		WiFi		Wireless Mic	
Max/Min		Max	Min	Max	Min	Max	Min
Power	Watts	4	0.04	4	0.04	0.25	0.01
Power	dBm	36	16	36	16	24	10
Bandwidth	MHz	5.5	5.5	22	22	0.2	0.15
Antenna Gain	dBi	6	6	6	6	0	0
OOBE (ACLR) FCC Reg.	dBm	-36.78	-56.78	-3.98	-23.98	-1	-15
OOBE Equip. Perf. w/ Ant. Gain		-37	-57	-4	-24	-1	-15
Nominal Antenna Height	m	30	1.5	30	1.5	1.5	1.5

Table 15: Receiver Parameters

Characteristic	Unit	DTV	Comments
Channel Bandwidth	MHz	6	Occupied Channel
RX Antenna Gain	dBi	12	Ref. to Isotropic Antenna
RX Noise Figure	dB	8	Typical
RX Thermal Noise	dBm/Hz	-174	Thermal Noise Floor
Duplex Isolation	dB	N/A	TX band: TX to RX isolation est.
Duplexer Loss (Rx/Tx)	dB	N/A	Estimated
RX Adjacent Channel Selectivity	dB	-33	Specification of Standards Doc
Overload Point	dBm	-5	Single Carrier overload Specification

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ANALYSIS AND CALCULATIONS:

For this interference scenario, we analyze the OOBE and power overload effect that unlicensed transmitters will have on DTV receivers. For both overload and OOBE, we review typically observed parameters for unlicensed transmitters, including power, bandwidth, antenna gain, antenna height, noise floors (for OOBE) and overload points (for receiver overload).

The results of this analysis are driven by proximity of devices. Since propagation losses will reduce both received signal power and OOBE, there is a distance from the unlicensed device where the effects of power and OOBE will be below the impact threshold.

Table 16: Overload Calculations:

Characteristic	Unit	Whitespace		WiFi		Wireless Mic	
Max/Min		Max	Min	Max	Min	Max	Min
Power	Watts	4	0.04	4	0.04	0.25	0.01
Power	dBm	36	16	36	16	24	10
Bandwidth	MHz	5.5	5.5	22	22	0.2	0.15
TV overload point	dBm	-5	-5	-5	-5	-5	-5
Protective Band Device Antenna Gain	dBi	6	0	6	0	0	0
Nominal Antenna Height	m	10	1.5	10	1.5	1.5	1.5
indoor DTV RX antenna gain	dBi	0	0	0	0	0	0
Outdoor DTV RX antenna gain	dBi	12	12	12	12	12	12
Protective Band device to outdoor DTV antenna impact distance based upon 20LOG loss	Meters	19	2	19	2	5	1
Protective Band device to DTV with Indoor (Rabbit Ear) antenna impact distance	Meters	5	<1	5	<1	1	<1

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Table 17: OOBE Calculations:

Characteristic	Unit	Whitespace		WiFi		Wireless Mic	
Max/Min		Max	Min	Max	Min	Max	Min
Bandwidth	MHz	5.5	5.5	22	22	0.2	0.15
Antenna Gain	dBi	6	6	6	6	0	0
OOBE (ACLR) FCC Reg.	dBm	-37	-57	-4	-24	-1	-15
Nominal Antenna Height	m	10	1.5	10	1.5	1.5	1.5
Thermal noise floor/ 6 MHz + RX NF	dBm	-98	-98	-98	-98	-98	-98
Indoor TV RX antenna gain “Rabbit Ears”	dBi	0	0	0	0	0	0
Indoor Protective Band Device noise floor rise distance to DTV receiver using 20LOG or 40LOG loss as appropriate	Meters	34	4	51	17	61	33
Outdoor DTV Antenna Gain	dBi	12	12	12	12	12	12
Outdoor Protective Band Device noise floor rise distance to DTV receiver with outdoor antenna using 40LOG loss	Meters	16	14	102	32	122	55

RESULTS:

The analysis of receiver overload shows that overloads will impact devices only within a fairly small radius. Even short distances may be problematic if Protective Band Device transmitters are located in the same room as the DTV receiver, as seems plausible. Within limited separation distances, the impact of power overload could be significant.

Meanwhile, the analysis of OOBE effects on DTV receivers suggests the need for careful consideration of OOBE performance metrics for unlicensed 600 MHz devices. Applying Part 15.247’s metric of 20 dB below carrier levels yields a significant noise floor rise well outside the operating channel. Though newer TVWS devices may have very tightly controlled OOBE, even these values may prove problematic to standard DTV end-user equipment.

CONCLUSIONS:

A Protective Band Device may cause harmful interference to over-the-air DTV under certain common use conditions. The weaker the DTV signal, the more opportunity for the Protective Band Device to cause interference to the DTV receiver through either overload, noise floor rise, or a combination of both. It appears that a Protective Band Device may cause harmful interference to over-the-air DTV under certain common use conditions.

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Case 4: Unlicensed Transmitter to Mobile User Equipment (UE) Receiver (Boundary A, C)

As illustrated below, this case addresses the impact of an unlicensed guard band transmitter (unlicensed TX) to an LTE mobile receiver (UE receiver) located in the channel adjacent to the guard band or the duplex gap.

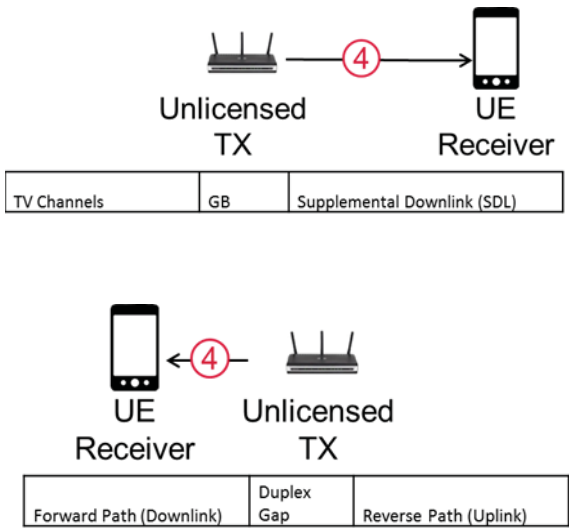

Figure 7: Unlicensed Transmitter to Mobile UE Receiver

ASSUMPTIONS:

Table 18: Transmitter Parameters

Characteristic	Unit	Whitespace		WiFi		Wireless Mic	
Max/Min		Max	Min	Max	Min	Max	Min
Power	Watts	4	0.04	4	0.04	0.25	0.01
Power	dBm	36	16	36	16	24	10
Bandwidth	MHz	5.5	5.5	22	22	0.2	0.15
Antenna Gain	dBi	6	6	6	6	0	0
OOBE (ACLR) FCC Reg.	dBm	-36.78	-56.78	-3.98	-23.98	-1	-15
OOBE Equip. Perf. w/ Ant. Gain		-37	-57	-4	-24	-1	-15
Nominal Antenna Height	m	30	1.5	30	1.5	1.5	1.5

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Table 19: Receiver Parameters

Characteristic	Unit	LTE UE	Comments
Channel Bandwidth	MHz	4.5	Occupied Channel
RX Antenna Gain	dBi	-5	Ref. to Isotropic Antenna
RX Noise Figure	dB	8	Typical
RX Thermal Noise - KT	dBm/Hz	-174	Thermal Noise Floor
Duplex Isolation	dB	53	TX band: TX to RX isolation est.
Duplexer Loss (Rx/Tx)	dB	3.5	Estimated
RX Adjacent Channel Selectivity	dB	-33	Specification of Standards Doc
Overload Point	dBm	-44	Estimated or Specifications

ANALYSIS AND CALCULATIONS:

For this interference scenario, we analyze the effect OOBE and receiver overload from unlicensed transmitters will have on LTE UE receivers. For both overload and OOBE, we review typically observed parameters for Unlicensed Receivers, including power, bandwidth, antenna gain, antenna height, noise floors (for OOBE) and overload points (for receiver overload).

The results of this analysis will be driven by the proximity of devices. Since propagation losses will reduce both received signal power and OOBE, there is a distance from the LTE mobile device where the effects of power and OOBE will be below the impact threshold.

Table 20: Overload Impact on an LTE UE Receiver

Characteristic	Unit	Whitespace		WiFi		Wireless Mic	
Max/Min		Max	Min	Max	Min	Max	Min
Power	Watts	4	0.04	4	0.04	0.25	0.01
Power	dBm	36	16	36	16	24	10
Bandwidth	MHz	5.5	5.5	22	22	0.2	0.15
Licensed UE overload point	dBm	-44	-44	-44	-44	-44	-44
Protective Band Device Antenna Gain	dBi	6	0	6	0	0	0
Nominal Antenna Height	m	10	1.5	10	1.5	1.5	1.5
Licensed UE DL RX antenna gain	dBi	0	0	0	0	0	0
Overload impact distance from Protective Band Device to Licensed UE based upon 40LOG loss	Meters	21	7	21	7	10	5

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Table 21: OOBE Impact on an LTE UE Receiver

Characteristic	Unit	Whitespace		WiFi		Wireless Mic	
Max/Min		Max	Min	Max	Min	Max	Min
Bandwidth	MHz	5.5	5.5	22	22	0.2	0.15
Antenna Gain	dBi	6	0	6	0	0	0
OOBE (ACLR) FCC Reg.	dBm	-37	-57	-4	-24	-1	-15
Nominal Antenna Height	m	10	1.5	10	1.5	1.5	1.5
Thermal noise floor/ 4.5 MHz + RX NF	dBm	-99	-99	-99	-99	-99	-99
UE RX antenna gain	dBi	-5	-5	-5	-5	-5	-5
Protective Band Device noise floor rise distance to UE using 40 LOG loss	Meters	14	4.5	90	29	77	34

RESULTS:

With results rather similar to those in the previous case, this analysis shows that receiver overloads will impact devices within a relatively small radius. And as was considered in that case, short distances may be problematic here as well. If the LTE UE device is are located in the same vicinity as the Protective Band Device transmitter, as seems likely considering the applications of the devices, significant impact is possible. The OOBE results also follow the path of the previous case.

CONCLUSIONS:

If both unlicensed transmitters and licensed 600 MHz receivers are operating in the same room or in close proximity, an unlicensed device operating in the guard band or duplex gap could cause an LTE UE receiver to fail. This failure is unlikely to be resolved through typical self-help measurements, such as a consumer moving away from the unlicensed transmitter to achieve better coverage. Instead, the interference mechanism will prevent the LTE UE receiver from receiving incoming signals.

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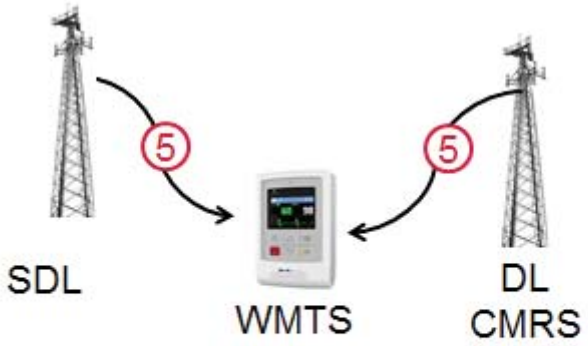
Case 5: LTE Base Station Transmitter to Channel 37 WMTS (Boundary B)

As illustrated below, this case addresses the impact of an LTE DL or SDL base station transmitter (SDL or DL CMRS) to a licensed WMTS device located in the adjacent Channel 37.



Supplemental Downlink (SDL)	GB	Ch37	GB	Forward Path (Downlink) and Potentially SDL

Figure 8: Base Station Transmitter to Channel 37 Incumbent WMTS

ASSUMPTIONS:

Table 22: Transmitter Parameters

Characteristic	Unit	LTE Base Station	
Max/Min		Max	Min
Power	Watts	2,000	200
Power	dBm	63	53
Bandwidth	MHz	4.5	4.5
Antenna Gain	dBi	14	14
OOBE (ACLR) FCC Reg.	dBm	-13	-13
OOBE Equip. Perf. w/ Ant. Gain		1	1
Nominal Antenna Height	m	40	20

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Table 23: Receiver Parameters

Characteristic	Unit	WMTS	Comments
Channel Bandwidth	MHz	1.5	Occupied Channel
RX Antenna Gain	dBi	3	Ref. to Isotropic Antenna
RX Noise Figure	dB	8	Typical
RX Thermal Noise - KT	dBm/Hz	-174	Thermal Noise Floor
Duplex Isolation	dB	N/A	TX band: TX to RX isolation est.
Duplexer Loss (Rx/Tx)	dB	N/A	Estimated
RX Adjacent Channel Selectivity	dB	33	Estimated
Overload Point	dBm	-30	Estimated

ANALYSIS AND CALCULATIONS:

Two circumstances will be analyzed: the effect of power causing overload and the effect of OOBE raising the noise floor within the channel.

The results of this analysis are driven by the proximity, location, and antenna gain of the WMTS devices. Since propagation losses and in-building penetration will reduce both received signal power and OOBE, there is a distance from the base station transmitter where the effects of power and OOBE will be below the critical impact threshold, the Exclusion Zone. LTE DL and SDL transmitters can work at a variety of power levels that relate to the actual service needs in an area; therefore, Table 24 below shows the radius of the Exclusion Zone as against the power of the LTE DL/SDL transmitter.

Table 24: Overload Impact Distance

DL or SDL TX Power	2000	1000	200	Watts
Exclusion Zone for below case based upon Free space loss and 40LOG loss:				
Assumed WMTS indoor in-Hospital usecase, Hospital building Attenuation	30	30	30	dB
Impact distance to WMTS Receiver 0 dB antenna gain 20LOG/40 LOG	60/10	42/9	19/6	Meters
Impact distance to WMTS Receiver 6 dB antenna gain 20LOG/40 LOG	119/15	84/12	37/8	Meters

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Table 25: OOBE Noise Floor Rise Distance

DL or SDL TX OOBE (per equipment test results) with Antenna gain of 14 dBi	-11	-11	-11	dBm
Noise Floor in 1.5 MHz channel plus RX noise figure	-104	-104	-104	dBm
Assumed WMTS indoor in-Hospital usecase, Hospital building Attenuation	30	30	30	dB
Noise Floor rise Zone for below case based upon Free Space:				
Impact distance to WMTS Receiver 0 dB antenna gain 20LOG	60	60	60	Meters
Impact distance to WMTS Receiver 6 dB antenna gain 20LOG/40 LOG	119	119	119	Meters

RESULTS:

The analysis above shows that the Exclusion Zones are expected to be modest and there is relatively little risk of interference under the expected use cases. Given the use case for WMTS is indoors in health care facilities, a DL/SDL base station transmitter should not cause harmful interference unless it is located on the grounds of the health care facility and operating near full allowable power.

CONCLUSIONS:

There is little risk of interference in this scenario. Indeed, the risk is so limited that protective bands may not be necessary to protect this case. As noted, however, the assumption here is that the WMTS devices are used inside a medical facility, and thus the LTE BS transmitter power is attenuated. If this use case is extended to outside the facility walls, such as in a convalescent garden, or off facility grounds, the WMTS devices will be exposed to higher power levels.

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Case 6: LTE Base Station Transmitter to Channel 37 Radio Astronomy (Boundary B)

As illustrated below, this case addresses the impact of an LTE DL or SDL base station transmitter (SDL or DL CMRS) to a licensed Radio Astronomy device located in the adjacent Channel 37.

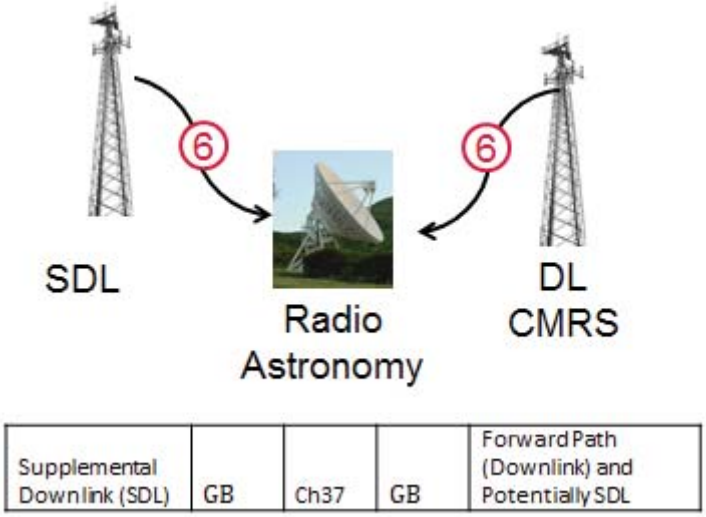

Figure 9: Base Station Transmitter to Channel 37 Incumbent Radio Astronomy

ASSUMPTIONS:

Table 26: Transmitter Parameters

Characteristic	Unit	LTE Base Station	
Max/Min		Max	Min
Power	Watts	2,000	200
Power	dBm	63	53
Bandwidth	MHz	4.5	4.5
Antenna Gain	dBi	14	14
OOBE (ACLR) FCC Reg.	dBm	-13	-13
OOBE Equip. Perf. w/ Ant. Gain		1	1
Nominal Antenna Height	m	40	20

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ANALYSIS AND CALCULATIONS:

In 1995, the FCC proposed limiting power from Channel 36 and 38 DTV broadcast operations to 64 dBu at the 13 locations specified as Radio Astronomy ("RA") sites.[26] A level of 64 dBu converts to a power level of -73 dBm and this level is used in the analysis below for determining the necessary separation range.

The results of this analysis will be driven by the proximity of the LTE BS to RA operations. As a result of propagation losses, there is a distance from the base station transmitter where its effects will be below the critical impact threshold, the Exclusion Zone. LTE DL and SDL transmitters can work at a variety of power levels that relate to the actual service needs in an area; therefore, Table 27 shows the radius of the Exclusion Zone as against the power of the LTE DL/SDL transmitter.

Table 27: DL/SDL Base State Transmitter to RA Operation Impact Distances

DL or SDL TX Power	2000	1000	200	Watts
Exclusion Zone for below case based upon Free space loss and 40LOG loss				
RA acceptable power in adjacent channel per FCC 95-4556	-73	-73	-73	dBm
Impact distance to RA Receiver 40LOG	655	574	384	Meters

RESULTS:

The above results demonstrate that RA operations should not be impacted by the operation of DL/SDL transmitters unless those transmitters are collocated with the RA facility. As each of the nation's 13 RA sites are located on large controlled areas, such collocation is highly unlikely to occur.

Moreover, the OOBE performance of DL/SDL equipment is considerably better than DTV (over 50 dB better 3 MHz into the adjacent channel, based on specifications). Thus, if the current contour limits are based upon OOBE raising the noise floor at the RA site, then the exclusion zones resulting from DL/SDL equipment will be further reduced, to 39 meters or less.

CONCLUSIONS:

Given the modest exclusion zones and the large controlled areas surrounding all of the RA operations, this interference scenario is unlikely to cause harmful interference.

[26] *See* Protection of Radio Astronomy Operation on TV Channel 37, 60 Fed. Reg. 10,341 (Feb. 24, 1995), *available at* http://www.gpo.gov/fdsys/pkg/FR-1995-02-24/pdf/95-4556.pdf (last accessed Oct. 9, 2013).

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Case 7: Unlicensed Transmitter to Channel 37 Radio Astronomy (Boundary B)

As illustrated below, this case addresses the impact of unlicensed wireless microphones (unlicensed TX) on licensed Radio Astronomy ("RA") operations located in the adjacent Channel 37.

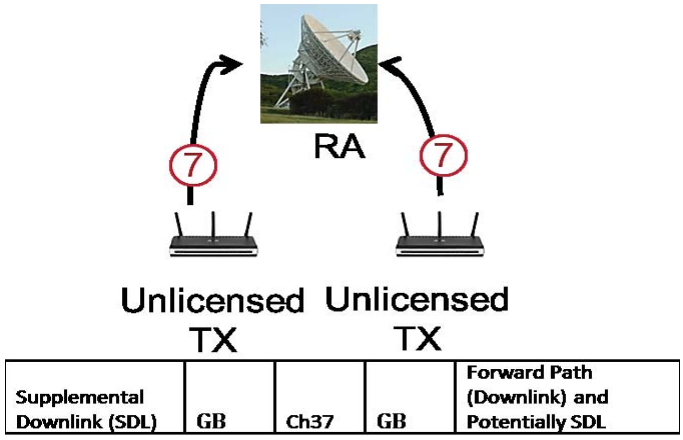

Figure 10: Unlicensed Transmitter to Radio Astronomy in Channel 37

ASSUMPTIONS:

Most of the band plans under consideration provide no guard band immediately below Channel 37 and include a guard band immediately above Channel 37 that is only four megahertz wide. As a result, this upper guard band is only able to fit equipment with carrier bandwidths smaller than 3.5 MHz. Wireless microphones employ such a small bandwidth and so are candidates for use of this band segment, and form the basis of the unlicensed device use case analyzed below.

Table 28: Transmitter Assumptions

Characteristic	Unit	Wireless Mic	
Max/Min		Max	Min
Power	Watts	0.25	0.01
Power	dBm	24	10

ANALYSIS AND CALCULATIONS:

In 1995, the FCC proposed limiting power from Channel 36 and 38 DTV broadcast operations to 64 dBu at the 13 locations specified as RA sites.[27] A level of 64 dBu converts to a power level of -73 dBm and this level is used in the analysis below for determining the necessary separation range.

[27] *See id.*

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The results of this analysis will be driven by the proximity of the RA operation. As a result of propagation losses, there is a distance from the unlicensed microphone where its effects will be below the critical impact threshold, the Exclusion Zone. Wireless microphones work at a variety of power levels; therefore, Table 29 shows the radius of the Exclusion Zone as against the power of the wireless microphone.

Table 29: Unlicensed Wireless Microphones to RA Device Impact Distances

Wireless Mic power	0.25	0.10	Watts
Exclusion Zone for below case based upon Free space loss and 40LOG loss			
RA acceptable power in adjacent channel per FCC 95-4556	-73	-73	dBm
Impact distance to RA Receiver 40LOG	73	32	Meters

RESULTS:

The above results demonstrate that RA operations should not be impacted by the operation of unlicensed wireless microphones unless those microphones are operated in close proximity to the RA operations. As each of the nation's 13 RA sites is located on large controlled areas, operating an unlicensed wireless microphone in such close proximity to an RA facility is highly unlikely to occur.

CONCLUSIONS:

Given the modest exclusion zones and the large controlled areas surrounding all of the RA operations, this use scenario is unlikely to cause any potential interference.

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Case 8: Unlicensed Transmitter to Channel 37 WMTS (Boundary B)

As illustrated below, this case addresses the impact of an unlicensed transmitter (unlicensed TX) on an unlicensed WMTS device located in the adjacent Channel 37. (WMTS devices are generally unlicensed devices regulated under Part 90 of the FCC's rules.)

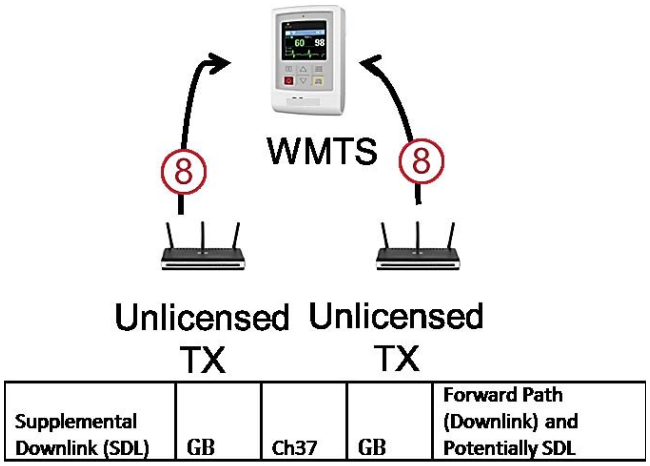

Figure 11: Unlicensed Transmitter to Channel 37 Incumbent WMTS

ASSUMPTIONS:

Table 30: Transmitter Parameters

Characteristic	Unit	Whitespace		WiFi		Wireless Mic	
Max/Min		Max	Min	Max	Min	Max	Min
Power	Watts	4	0.04	4	0.04	0.25	0.01
Power	dBm	36	16	36	16	24	10
Bandwidth	MHz	5.5	5.5	22	22	0.2	0.15
Antenna Gain	dBi	6	6	6	6	0	0
OOBE (ACLR) FCC Reg.	dBm	-36.78	-56.78	-3.98	-23.98	-1	-15
OOBE Equip. Perf. w/ Ant. Gain		-37	-57	-4	-24	-1	-15
Nominal Antenna Height	M	30	1.5	30	1.5	1.5	1.5

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Table 31: Receiver Parameters

Characteristic	Unit	WMTS	Comments
Channel Bandwidth	MHz	1.5	Occupied Channel
RX Antenna Gain	dBi	3	Ref. to Isotropic Antenna
RX Noise Figure	dB	8	Typical
RX Thermal Noise - KT	dBm/Hz	-174	Thermal Noise Floor
Duplex Isolation	dB	N/A	TX band: TX to RX isolation est.
Duplexer Loss (Rx/Tx)	dB	N/A	Estimated
RX Adjacent Channel Selectivity	dB	33	Estimated
Overload Point	dBm	-30	Estimated

ANALYSIS AND CALCULATIONS:

For this interference scenario, we analyze the effect that OOBE and power overload from unlicensed transmitters will have on licensed WMTS devices operating in the adjacent Channel 37. For both power overload and OOBE, we review typically observed parameters for unlicensed transmitters, including power, bandwidth, antenna gain, antenna height, noise floors (for OOBE) and overload points (for power overload).

The results of this analysis will be driven by proximity of devices. Since propagation losses will reduce both received signal power and OOBE, there is a distance from the unlicensed device where the effects of power and OOBE will be below the impact threshold.

Table 32: Overload Impact on WMTS

Characteristic	Unit	Whitespace		WiFi		Wireless Mic	
Max/Min		Max	Min	Max	Min	Max	Min
Power	Watts	4	0.04	4	0.04	0.25	0.01
Power	dBm	36	16	36	16	24	10
Bandwidth	MHz	5.5	5.5	22	22	0.2	0.15
WMTS overload point	dBm	-30	-30	-30	-30	-30	-30
Protective Band Device Antenna Gain	dBi	6	0	6	0	0	0
Nominal Antenna Height	m	10	1.5	10	1.5	1.5	1.5
WMTS RX antenna gain	dBi	0	0	0	0	0	0
Overload impact distance from Protective Band Device to WMTS based upon 40LOG loss	Meters	12	4	12	4	6	3

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Table 33: OOBE Impact on WMTS

Characteristic	Unit	Whitespace		WiFi		Wireless Mic	
Max/Min		Max	Min	Max	Min	Max	Min
Bandwidth	MHz	5.5	5.5	22	22	0.2	0.15
Antenna Gain	dBi	6	0	6	0	0	0
OOBE (ACLR) FCC Reg.	dBm	-37	-57	-4	-24	-1	-15
Nominal Antenna Height	m	10	1.5	10	1.5	1.5	1.5
Thermal noise floor/ 1.5 MHz + RX NF	dBm	-99	-99	-99	-99	-99	-99
UE RX antenna gain	dBi	-5	-5	-5	-5	-5	-5
Protective Band Device noise floor rise distance to UE using 40LOG loss	Meters	10	3	65	21	77	34

RESULTS:

The results of the analysis above demonstrate that unlicensed Protective Band Devices operating adjacent to Channel 37 could cause interference to WMTS devices within a modest radius. Given this potential interference, Protective Band Devices should not be allowed to operate in medical locations utilizing WMTS hardware.

CONCLUSIONS:

Unlike RA operations, WMTS devices do not operate in large controlled areas. Additional consideration is required regarding whether it is feasible to prevent unlicensed Protective Band Devices from operating within medical locations. Failure to attain high levels of compliance with medical location exclusions could result in interference to WMTS devices.

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Case 9: Mobile UE LTE Transmitter to Unlicensed Receiver (Boundary C)

As illustrated below, this case addresses the impact of a mobile UE transmitter (UE TX) on an Unlicensed Receiver.

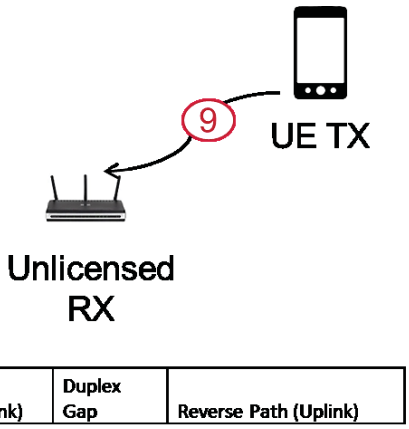

Figure 12: Mobile UE Transmitter to Unlicensed Receiver

ASSUMPTIONS:

Table 34: Transmitter Parameters

Characteristic	Unit	LTE UE	
Max/Min		Max	Min
Power	Watts	0.2	0.04
Power	dBm	23	16
Bandwidth	MHz	4.5	0.18
Antenna Gain	dBi	-5	-5
OOBE (ACLR) FCC Reg.	dBm	-13	-13
OOBE Equip. Perf. w/ Ant. Gain		-18	-18
Nominal Antenna Height	m	1.5	1.5

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Table 35: Receiver Parameters

Characteristic	Unit	Whitespace	WiFi	Wireless Mic
Channel Bandwidth	MHz	5.5	22	0.2
RX Antenna Gain	dBi	-5 or +6	-5 or +6	0
RX Noise Figure	dB	8	8	8
RX Thermal Noise - KT	dBm/Hz	-174	-174	-174
Duplex Isolation	dB	N/A	N/A	N/A
Duplexer Loss (Rx/Tx)	dB	N/A	N/A	N/A
RX Adjacent Channel overload point	dB	-10	-44	-44

ANALYSIS AND CALCULATIONS:

For this interference scenario, we analyze the effect that power overload from LTE UE devices will have on Unlicensed Receivers operating in the adjacent channel. We review typically observed parameters for a variety of unlicensed devices, including antenna gain, antenna height, and overload point.

The results of this analysis are driven by the proximity of devices. Since propagation losses will reduce received signal power overloads, there is a distance from the unlicensed device where the effects of power overload will be below the impact threshold.

Table 36: Overload Impact from LTE UE to Protective Band Device

Characteristic	Unit	Whitespace		WiFi		Wireless Mic	
Protective Band Device overload point	dBm	-10	-10	-44	-44	-44	-44
Protective Band Device Antenna Gain	dBi	6	0	6	0	0	0
Nominal Antenna Height	m	10	1.5	10	1.5	1.5	1.5
Licensed UE DL TX antenna gain	dBi	-5	-5	-5	-5	-5	-5
Overload impact distance from Protective Band Device to Licensed UE based upon 40LOG loss	Meters	2	1	13	10	10	10

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Table 37: OOBE Impact from LTE UE to Protective Band Device

Characteristic	Unit	Whitespace		WiFi		Wireless Mic	
OOBE Equip. Perf. w/ Ant. Gain	dBm	-18	-18	-18	-18	-18	-18
Protective Band Device noise floor	dBm	-99	-99	-99	-99	-113	-113
Protective Band Device Antenna Gain	dBi	6	0	6	0	0	0
Nominal Antenna Height	m	10	1.5	10	1.5	1.5	1.5
Licensed UE UL TX antenna gain	dBi	-5	-5	-5	-5	-5	-5
OOBE noise Floor Rise distance from Licensed UE to Protective Band Device based upon 40LOG loss	Meters	28	28	28	28	65	65

RESULTS:

The results show that power overloads will impact devices only within a radius of approximately 28 meters (or approximately 92 feet). These distances will be problematic in the expected use case, where a Protective Band Device is located in the same room or on the same street corner as licensed UE. The impact on the unlicensed device is significant because it is likely that the UE transmitter and the protected band device could be as close as 1 to 2 meters. For example, someone using a WSD or wireless mic may have a smartphone in their pocket.

CONCLUSIONS:

This potential for interference at the close proximities contemplated by the expected use case is the rationale for implementing guard bands between services. Similar issues have been identified worldwide with the implementation of TDD services in the FDD Duplex Gap in the 2.5 GHz band, where it was noted that handsets operating at 200 mW would impact each other at a 10 meter range, and could cause equipment to cease operating at separation distances of 2 meters or less.

If the overload performance of the Protective Band Device is improved to the level currently available on whitespace devices, the impact distance would be reduced but not eliminated. As unlicensed devices must accept interference from all sources, this could preclude their successful operation in the duplexer gap.

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Case 10: Unlicensed Transmitter to LTE Base Station Receiver (Boundary C)

As illustrated below, this case addresses the impact of an unlicensed transmitter (unlicensed TX) on a licensed LTE BTS receiver (BTS RX).

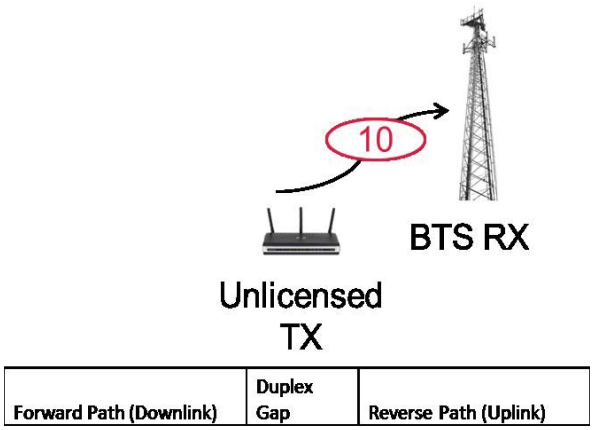

Figure 13: Unlicensed Transmitter to LTE Base Station Receiver

ASSUMPTIONS:

Table 38: Transmitter Parameters

Characteristic	Unit	Whitespace		WiFi		Wireless Mic	
Max/Min		Max	Min	Max	Min	Max	Min
Power	Watts	4	0.04	4	0.04	0.25	0.01
Power	dBm	36	16	36	16	24	10
Bandwidth	MHz	5.5	5.5	22	22	0.2	0.15
Antenna Gain	dBi	6	6	6	6	0	0
OOBE (ACLR) FCC Reg.	dBm	-36.78	-56.78	-3.98	-23.98	-1	-15
OOBE Equip. Perf. w/ Ant. Gain		-37	-57	-4	-24	-1	-15
Nominal Antenna Height	m	30	1.5	30	1.5	1.5	1.5

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Table 39: Receiver Parameters

Characteristic	Unit	LTE UE	Comments
Channel Bandwidth	MHz	4.5	Occupied Channel
RX Antenna Gain	dBi	14	Ref. to Isotropic Antenna
RX Noise Figure	dB	2	Typical
RX Thermal Noise - KT	dBm/Hz	-174	Thermal Noise Floor
Duplex Isolation	dB	53	TX band: TX to RX isolation est.
Duplexer Loss (Rx/Tx)	dB	3.5	Estimated
RX Adjacent Channel Selectivity	dB	33	Specification of Standards Doc
Overload Point	dBm	-44	Estimated or Specifications

ANALYSIS AND CALCULATIONS:

For this interference scenario, we analyze the effect that OOBE and power overload from unlicensed transmitters will have on base station receivers. For both overload and OOBE, we review typically observed parameters for unlicensed transmitters, including power, bandwidth, antenna gain, antenna height, noise floors (for OOBE) and overload points (for power overload).

The results of this analysis will be driven by proximity of devices. Since propagation losses will reduce both received signal power and OOBE, there is a distance from the LTE mobile device where the effects of transmit power and OOBE will be below the impact threshold.

Table 40: Overload Impact on an LTE BTS

Characteristic	Unit	Whitespace		WiFi		Wireless Mic	
Max/Min		Max	Min	Max	Min	Max	Min
Transmit Power	Watts	4	0.04	4	0.04	0.25	0.01
Transmit Power	dBm	36	16	36	16	24	10
Bandwidth	MHz	5.5	5.5	22	22	0.2	0.15
Licensed UE overload point	dBm	-12	-12	-12	-12	-12	-12
BTS Antenna Gain	dBi	14	14	14	14	14	14
Nominal protective band Antenna Height	m	10	1.5	10	1.5	1.5	1.5
Licensed UE DL RX antenna gain	dBi	0	0	0	0	0	0
Overload impact distance from Protective Band Device to LTE BTS based upon 20LOG/40LOG loss	Meters	53/10	5/3	53/10	5/3	14/5	3/2

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Table 41: OOBE Impact

Characteristic	Unit	Whitespace		WiFi		Wireless Mic	
Max/Min		Max	Min	Max	Min	Max	Min
Bandwidth	MHz	5.5	5.5	22	22	0.2	0.15
Antenna Gain	dBi	6	0	6	0	0	0
OOBE (ACLR) FCC Reg.	dBm	-37	-57	-4	-24	-1	-15
Nominal Antenna Height	m	10	1.5	10	1.5	1.5	1.5
Thermal noise floor/ 4.5 MHz + RX NF (2 dB)	dBm	-105	-105	-105	-105	-105	-105
LTE BTS RX antenna gain	dBi	14	14	14	14	14	14
Protective Band Device noise floor rise distance to LTE BTS using 40LOG loss	Meters	31	10	204	65	243	122

RESULTS:

The analysis above demonstrates that the radius of potential interference resulting from overload is small and unlicensed Protective Band Devices should not cause interference to LTE BTS receivers unless the Protective Band Devices are located on the same tower or an adjacent tower at similar antenna elevations.

Unlicensed Protective Band Devices have a larger impact radius for OOBE. Newer TVWS devices have very tightly controlled OOBE, and the OOBE for unlicensed Protective Band Devices would need to be at least as stringent as these current TVWS-type radios to avoid interference.

CONCLUSIONS:

Provided that the rules pertaining to Protective Band Device transmitters have adequate OOBE performance requirements, this scenario should not result in harmful interference.

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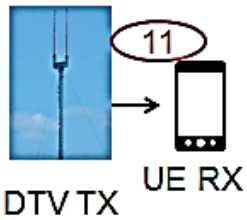
Case 11: DTV Transmitter to Mobile UE LTE Receiver (Boundary A, B & C)

As illustrated below, this case addresses the impact of a DTV transmitter (DTV TX) on an LTE UE Receiver (UE RX) located in the allocated spectrum.



TV Channels	GB	Supplemental Downlink (SDL)	GB & Ch37	Forward Path (Downlink) and Potentially SDL	Duplex Gap	Reverse Path (Uplink)	700 MHz A Block Uplink

Figure 14: DTV Transmitter to Mobile UE Receiver

ASSUMPTIONS:

The LTE UE is operating above 618 MHz, while the DTV TX is operating below 608 MHz. This yields a minimum of 10 MHz separation between the services as provided by the guard band. Similar cases currently exist between channel 51 operation and the Lower 700 MHz B and C blocks. Services facing these conditions are operational today and industry experience has determined that 10 MHz of guard band seems to be sufficient to protect the UE from DTV impact.

CALCULATIONS:

At a distance of 10 MHz, the DTV OOBE has reduced to noise floor, so it will have no impact. The filtering associated with the band filters and duplexer in the UE will likewise reduce the impact of the DTV transmit power by upwards of 50 dB.

RESULTS:

This case leads to no impact due to the large frequency separation between the services.

CONCLUSIONS:

This case results in no interference impact under the assumptions here.

However, different markets will have different spectrum assignments, based on the results of the reverse auction; that is, some markets will have more paired and SDL spectrum, and some will have less. This post-repack condition is referred to as Market Variability (or sometimes Market Variation). The consequence of Market Variability on this case is that the UE receiver filter requirements may be difficult – or extremely difficult – to implement as assumed here, as fixed ceramic SAW filters are no longer an option.

So, in this case, we have a guard band that is known to be sufficient at 700 MHz, but in that case there are fixed band-select filters.

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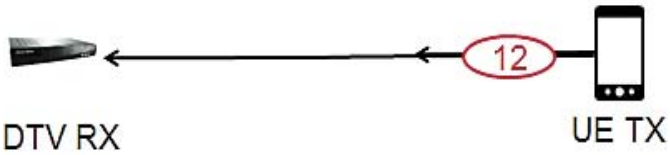
Case 12: Mobile UE LTE Transmitter to DTV Receiver (Boundary A, B, & C)

As illustrated below, this case addresses the impact of a mobile LTE transmitter (UE TX) on a DTV receiver (DTV RX).



TV Channels	G B	Supplemental Downlink (SDL)	GB & Ch37	Forward Path (Downlink) and Potentially SDL	Duplex Gap	Reverse Path (Uplink)	700 MHz A Block Uplink

Figure 15: Mobile UE Transmitter to DTV Receiver

ASSUMPTIONS:

The UE transmitter is operating between 663 and 698 MHz (35 MHz paired spectrum), while the DTV receiver is operating below 608 MHz (below channel 37). This yields a 55 MHz minimum separation between the services.

CALCULATIONS:

The LTE UE OOBE has reduced to noise floor over 55 MHz, so it will have no impact. The single carrier overload point of a DTV receiver is specified as -5 dBm, and the DTV receiver utilizes a horizontally polarized antenna. The 200 mW (23 dBm) maximum operating transmit power of an LTE UE will be attenuated by approximately 29 dB over the first meter, assuming Free Space Loss. The polarity mismatch between the UE (vertical) and the DTV receiver (horizontal) will yield additional coupling attenuation, on average approximately 3dB. Therefore the UE signal power at the DTV antenna input jack will be a maximum of -7 dBm if the UE is 1 meter away.

RESULTS:

This case leads to no impact due to the large frequency separation between the services. Other band configurations that are consistent with Down From 51 assumptions yield equivalent results.

CONCLUSIONS:

This case results in no interference impact.

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Case 13: DTV Transmitter to LTE Base Station Receiver (Boundary A, B, & C)

As illustrated below, this case addresses the impact of a DTV transmitter (DTV TX) on a base station receiver (BTS RX).

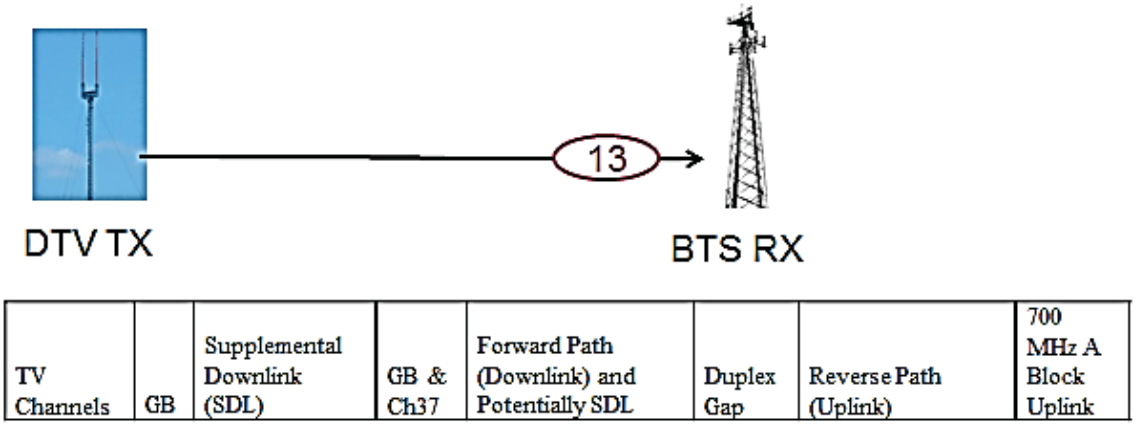

Figure 16: DTV Transmitter to Base Station Receiver

ASSUMPTIONS:

The BTS RX is located between 663 and 698 MHz, while the DTV TX is operating below 608 MHz. This yields a 55 MHz separation between the services.

CALCULATIONS:

The DTV transmitter OOBE has reduced to noise floor over 55 MHz, so it will have no impact. The overload point of a BTS receiver is approximately -12 dBm for signals within its receive bandpass. Given bandpass filtering will reduce the transmit signal power from a DTV transmitter at the receiver input by 70+ dB, the BTS is adequately protected due to the large frequency separation between the services.

RESULTS:

This case leads to no impact due to the large frequency separation between the services.

CONCLUSIONS:

This case results in no interference impact.

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6. Conclusion

Of the potential interference cases examined in this study, ten out of thirteen scenarios result in no or minimal impact. However, there are three scenarios that could give rise to critical inference because of the opportunity for licensed and Protective Band Devices to be used within close proximity of each other.

Case Number	Case Description	Boundary	Findings	Direction of Potential Interference	Expected Probability of Interference	Coordination Helps?	Exclusion Zone
1	DTV transmitter to Unlicensed Receiver	A	No material concern; a challenge for unlicensed devices	Licensed to Unlicensed	Limited	Yes but not practical	
2	LTE SDL/downlink transmitter to Unlicensed Receiver	A,B,C	No material concern	Licensed to Unlicensed	Low		
3	Unlicensed transmitter to DTV receiver	A	Could pose a problem causing overload or excessive OBEE but properly designed devices can co-exist with a DTV receiver	Unlicensed to Licensed	High		
4	Unlicensed transmitter to mobile UE receiver	A,C	Most significant problem identified; could cause shut down of LTE UE in proximity to TVWS UE	Unlicensed to Licensed	High	Yes but not practical	BTS Coverage
5	LTE Base Station transmitter to Channel 37 WMTS	B	No material concern	Licensed to Licensed	Low		
6	LTE Base Station transmitter to Channel 37 Radio Astronomy	B	No material concern	Licensed to Licensed	Low		
7	Unlicensed transmitter to Channel 37 Radio Astronomy	B	No material concern	Unlicensed to Licensed	Limited	Yes	RA Exclusion
8	Unlicensed transmitter to Channel 37 WMTS	B	Problematic when operated in close proximity of WMTS devices	Unlicensed to Licensed	Limited	Yes	WMTS Coverage
9	Mobile UE LTE transmitter to Unlicensed Receiver	C	Could cause shut down of TVWS UE in proximity to Mobile UE transmitter	Licensed to Unlicensed	High		BTS Coverage
10	Unlicensed transmitter to LTE Base Station receiver	C	No material concern	Unlicensed to Licensed	Low		
11	DTV transmitter to mobile UE LTE receiver	A,B,C	No material concern	Licensed to Licensed	Low		
12	Mobile UE LTE transmitter to DTV receiver	A,B,C	No material concern	Licensed to Licensed	Low		
13	DTV transmitter to LTE Base Station Receiver	A,B,C	No material concern	Licensed to Licensed	Low		

First, when an unlicensed transmitter operates in proximity to a DTV receiver (case 3), the likelihood of harmful interference increases as the DTV signal strength weakens. Second, when an unlicensed transmitter operates in proximity to a mobile UE receiver (case 4), interference will result and could prove especially harmful because the

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LTE receiver would not provide any outward indication of the interference condition. In both of these problematic cases, the potential for close physical coupling of unlicensed Protective Band Devices versus the relatively long coupling distance of a licensed receiver to its serving transmitter could create an environment where the noise and overload caused by the transmit power and OOBE of the nearby unlicensed device results in the licensed device being unable to hear the desired transmitter.

Third, when a mobile UE transmitter operates in proximity to an Unlicensed Receiver (case 9), interference may result that could prove challenging to avoid as a practical matter given the anticipated proximity of operations.

The types of interference considered here can be mitigated by good filtering in selected points of the link. Transmitter OOBE can be reduced by filtering, and receiver overload issues can be mitigated by ceramic SAW filters. Should Market Variability be implemented, caution should be exercised in assuming these strategies are available to designers. In particular, receivers of any of the technologies considered here are unlikely to have the same filtering advantages as would be expected in a fixed band environment.

With Market Variability, services will be jointly in-band to each other. Assumptions that were valid when those services had the luxury of assuming sole possession of a band will no longer be useful. The overload and OOBE conflicts identified here may be resolved with a few MHz of gap between services in a non-Market Variability scenario, but with Market Variability the challenge to industry becomes exponentially greater.

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