Register everyone: on the whitespace use of wireless microphone channels, channel 37, and the soon-to-be guard bands

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Register everyone: on the whitespace use of wireless microphone channels, channel 37, and the soon-to-be guard bands

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***Abstract*—This report is intended as a response to some of the questions posed by the FCC regarding the upcoming TV-band incentive auction, given in their NPRM [1], as they relate to the television whitespaces.**

In particular, we argue (1) that channel 37 should be made available for whitespace use; (2) that the channels reserved for wireless microphones should be reserved on an as-used basis only; and (3) that the guard bands which will be created via the incentive auction must be considered as database-registration-requiring whitespace if unlicensed devices are authorized to use them.

These three proposals have two common themes: (1) they each work toward the goal of making otherwise-wasted spectrum available as whitespace; and (2) in each case, the key concept is that the involved parties can (and in some cases *must*) register their devices and use geolocation of some sort.

We will sketch each of our proposals and show how together they can make whitespace available for up to 10 million *more* Americans with minimal overhead while ensuring that licensed users receive the quality of service that they expect. As a result, essentially no one would be left without whitespace access.

I. Introduction

On October 2, 2012, the FCC released its Notice of Proposed Rulemaking (NPRM) for incentive auctions in the television bands [1]. The intent is to monetarily incentivize broadcasting licensees to modify their spectrum usage rights (either by giving them up completely or moving to another band) in order to reorganize ("repack") the spectrum currently occupied by over-the-air television broadcast.

At the same time, unlicensed TV-bands devices (TVBDs, a.k.a. whitespace devices) may operate in the same frequencies under the FCC's rules [2]–[4]. These TVBDs represent an enormous economic and innovative opportunity. To that end, the FCC recognizes the need for more whitespaces:

> Currently, some urban markets do not have channels available for white space use. To address this issue, the National Broadband Plan recommended that, as the FCC seeks to provide additional spectrum for broadband services, it make available for exclusive or predominant use by unlicensed devices sufficient spectrum to enable innovators to try new ideas for increasing broadband access and efficiency, and to enable new unlicensed broadband access providers to serve rural and unserved communities. [1, ¶231]

Furthermore, the FCC expects and intends to maintain the whitespaces as a place for innovation and development:

> Given that there is considerable white space available now in many areas—more than 100 megahertz in some markets—we expect that there will still be a substantial amount of spectrum available for use by these devices in the remaining broadcast television channels after the incentive auction. We also expect that there will continue to be more spectrum available in areas outside of the central urban areas of the largest markets than within those areas. We seek comment on these views. It is our intent to continue to allow both the use of white space devices and the development of devices for various applications that operate in the broadcast television bands after the incentive auction. [1, ¶233]

Furthermore, the FCC is contemplating allowing TVBDs to operate on channel 37[1] as well as the two channels currently reserved (from TVBDs) for wireless microphone use[2].

However, it is difficult to exactly predict what the results of the incentive auction—more specifically, the repacking—will be or what they will mean for the white spaces. A number of things may change as a result:

- The sets of channels which are available (UHF, VHF) may change; this is significant given the variation in propagation characteristics between these bands.
- The number of cochannel TV transmitters will likely decrease which improves the noise floor for TVBDs.

[1] "In addition, there may be an opportunity for unlicensed devices to operate in channel 37 (an additional 6 megahertz of spectrum), whether or not we relocate the WMTS and the Radio Astronomy Service now using channel 37. As discussed in section VII, the rules require that locations of WMTS operations be registered with the American Society for Healthcare Engineering (ASHE), and there are relatively few radio astronomy operations, all at specified locations. Therefore, we may be able to protect these services by establishing appropriate protection areas in the white space database. We propose to make channel 37 available for unlicensed use, while protecting WMTS and the Radio Astronomy Service." [1, ¶237]

[2] "The current rules for white space devices in the television bands designate two channels (when available) in all locations for use by wireless microphones. White space devices are not permitted to operate on these channels, preventing them from using 12 megahertz of spectrum that could otherwise be available for their use. We invite comment as to whether the Commission should maintain the designation of two channels for wireless microphones following the broadcast television spectrum incentive auction or whether this spectrum should be made available for unlicensed use." [1, ¶238]

- The effect of adjacent-channel restrictions may increase or decrease depending on the repacking.
- The total amount of whitespace available (in MHz) will almost certainly decrease as a result of the forward auction[3].
- Channel 37 may be available as whitespace.
- The two channels reserved for wireless microphone may be once again available for whitespace use.
- The existence of guard bands which will potentially provide "clean" whitespace for TVBDs.

The possibilities are endless; thus for clarity we only focus on the last three items in this report. We do not attempt to predict the results of the repacking and instead use the current allocations [5] and rules [4] (which will be valid for the next few years when many TVBDs are being developed). We fully expect that the details of these results will change after the incentive auction; however, we expect that our general message will not change.

We expect that, through the use of modern technology, we can easily protect wireless microphones and channel 37 services while using the remainder of these channels for TVBDs. This has the opportunity to provide huge gains in whitespace, including opening it up for use by up to 10 million people who currently do not have access to whitespace spectrum.

II. Registration

As the title implies, one of our central themes is that everyone seeking protection from TVBDs—television licensees, wireless microphone operators (both licensed and unlicensed), channel 37 occupants, **and the winners of the forward auction**—should register their sites in a real-time database in order to minimize interference to protected services while maximizing whitespace availability. The FCC rules for whitespace use in the TV bands already mandate such a database [2]–[4] for TV licensees and licensed wireless microphones; it is reasonable and technically easy to add to the list of protected services.

A. Registration benefits for protected services

When a protected entity (e.g. TV licensee) registers in the database, the database administrator calculates the corresponding protected region in which no TVBDs may transmit cochannel. The protected region is designed from the parameters of the entity (e.g. transmit power, location) to minimize the amount of interference to the protected entity's receivers (e.g. consumers' television sets).

There is always a protected region cochannel to the protected entity and sometimes (as in the case of TV licensees) there are adjacent-channel protected regions as well. TVBDs must[4] request permission from the database before they can transmit; this ensures that they do not erroneously transmit so as to cause harm inside a protected region.

The burden on the protected entity depends on its type. Many such entities are at fixed locations and have relatively static needs, e.g. TV licensees, the winners of the forward auction[5], and the channel 37 occupants (described in more detail in Section III). In these cases, registration is a one-time process and could even be done automatically by the FCC when the entities receive or modify their operating permits.

Some entities, e.g. wireless microphones, may be used intermittently and at a wide variety of locations. Due to this unpredictability, the level of involvement required is higher but still not unreasonable, as argued in Section IV.

B. Registration benefits for TVBDs

The FCC's current rules for the TV whitespaces [4] allow TVBDs to either (1) contact a database to request permission to transmit; or (2) sense with high sensitivity to determine if the channel is currently occupied by a protected entity. While advances in sensing, especially collaborative sensing, are promising, it has been shown that there is a significant loss of whitespace when sensing instead of contacting a database [6]. This is as a result of the safety margin that *must* be included to ensure adequate protection for the protected services.

Furthermore, the FCC allows for limited "chaining" of devices: a device *without* location services may receive a list of allowed channels from a device which is able to communicate directly with the database. This allows for the deployment of many smaller, cheaper devices in the presence of one more sophisticated device, further reducing the cost of database access.

We believe that the promise of increased spectrum availability will outweigh the increased cost of location-estimation equipment[6] and thus that most manufacturers of TVBDs will opt to use the database method for whitespace discovery.

III. Argument for Channel 37

Both radioastronomy and WMTS (wireless medical telemetry service) are very important and should continue to operate normally. However, we believe that there is also room for whitespace devices in these channels.

A. Radioastronomy sites

The few radioastronomy sites in the United States are already registered with the FCC whitespace database. They are currently afforded 2.4 km of separation from whitespace devices on all channels. Although we recognize that this equipment is very sensitive, we argue that there exists a distance

[3]The repacking is intended, in part, to increase the efficiency with which the spectrum is used. However, increasing the efficiency means that there are fewer "cracks" (a.k.a. whitespaces) for TVBDs to use.

[4]The caveat to this is explained in the following subsection.

[5]We expect that the winners of the forward auction will implement LTE *or* will deploy an LTE-like system given the characteristics of the spectrum.

[6]One low-cost alternative—which is not currently in the FCC's rules—is to allow devices to submit a "fuzzy location." This is a region (of any size) in which the device is guaranteed to be located. The database would authorize the use of only those channels which are available at *all* points inside the region. In this way, manufacturers can individually choose a point on the tradeoff curve between equipment cost and spectrum availability.

at which it is safe to operate wireless devices on the same channel. Indeed, this already happens with WMTS devices (which are prohibited from operating near the radioastronomy sites but are otherwise allowed to operate on channel 37). We do not pretend to know[7] what this distance is or should be, but for illustrative purposes we assume that this distance is 50 km. We then see the following excluded areas (in black) in Figure 1. Here we see that even though 50 km is a large separation distance, a large portion of the nation (shown in blue) is still available for whitespace use on channel 37. This number should be carefully chosen so that interference is unlikely. However, it is important to realize that we can *easily* and *quickly* make modifications via the databases should the need arise.

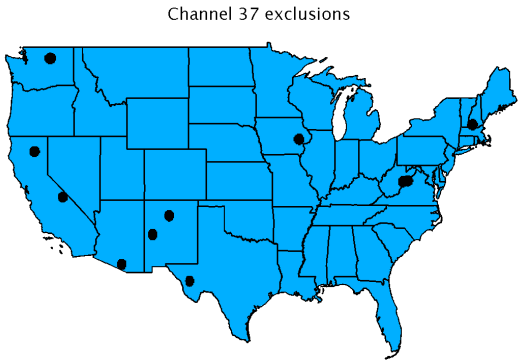

Fig. 1. Exclusions on channel 37 due to radioastronomy sites: black indicates locations where secondaries are not permitted to transmit.

B. Wireless medical telemetry service (WMTS) devices

WMTS devices are devices which are used in hospitals to help monitor a patient's condition:

> WMTS spectrum is used for remote monitoring of a patients health. Wireless medical telemetry systems include devices to measure patients' vital signs and other important health parameters (e.g., pulse and respiration rates) and devices that transport the data via a radio link to a remote location, such as a nurses' station, equipped with a specialized radio receiver. For example, wireless cardiac monitors are often used to monitor patients following surgery. [7]

WMTS devices are already required to register with the FCC[8]. Not only are they registered but their locations (or at least locations which tend to use such devices) are predictable and relatively static over time. It would be no harder to accommodate WMTS devices than it is to accommodate TV stations.

[7]This question is definitely answerable but we have not done the calculations ourselves.

[8]"WMTS devices must be registered with the FCC's designated frequency coordinator, the American Society for Healthcare Engineering of the American Hospital Association (ASHE/AHA)." [7]

Note that since we do not have the locations nor the protection criteria of these devices/hospitals, we have not included them in our calculations. However, we expect that the impact would be relatively small compared to the benefit derived from allowing TVBDs to transmit on channel 37.

IV. Argument for wireless microphone channels

There are two characteristics that significantly set wireless microphones apart from radioastronomy equipment and WMTS devices:

1) Not all wireless microphones are licensed.
2) Registration of wireless microphones is more difficult.

We will tackle each of these issues in order in the following sections. In general, we argue that wireless microphones (or locations which utilize them) should register in the whitespace database in order to receive protection from TVBDs, thus allowing TVBDs to otherwise operate on these two channels.

A. Not all wireless microphones are licensed

In the FCC's 2010 regulations, they expanded the PLMRS/CMRS exclusions[9] to include the "reservation of two channels in the range of 14-51 to all markets nationwide as suggested by several petitioners" [3, ¶29]. The intent was to create a "safe haven" for unlicensed wireless microphones since they stated that it would be inappropriate to allow unlicensed wireless microphones to register as primaries in the database due to their unlicensed status:

> With regard to registration of unlicensed devices in the TV bands database, we first observe that unlicensed wireless microphones operate under the same general conditions of operation in Section 15.5 of the rules as TV bands devices, meaning they may not cause interference to authorized services and must accept any interference received, including interference from other non-licensed devices. As a general matter, we therefore find that it would be inappropriate to protected unlicensed wireless microphones against harmful interference from other unlicensed devices, and in particular TV bands devices. [3, ¶31]

The most natural solution, given their unlicensed status, is to turn unlicensed wireless microphones into TVBDs. However, this is impractical due to the difference in requirements: wireless microphones do not typically have Internet access and they need to be low-latency given their real-time use [3, ¶30].

It is likewise impractical to move wireless microphones to alternative bands or leave them unprotected: too many venues, ranging from professional sports events to local theatrical productions, rely on wireless microphones and replacing this equipment could be very costly.

Therefore rather than reserving two *full* channels nationwide for these unlicensed devices, we should simply allow unlicensed microphones to be registered for protection *on*

[9]These reserve 1-3 channels in 13 major metropolitan areas.

these two channels using the whitespace databases. Reserving two full channels nationwide *already* "protect[s] unlicensed wireless microphones against harmful interference from other unlicensed devices"—the FCC's stated reason for denying them registration rights—so allowing them to register (only within these two channels) would be no worse. Some of these unlicensed wireless microphones are further protected since "unlicensed microphones at event sites qualifying for registration in TV bands databases will be afforded the same geographic spacing from TVBDs as licensed microphones" [3, ¶32]

B. Registration of wireless microphones only seems hard

There are two reasons that the registration of wireless microphones seem more difficult than that of WMTS or radioastronomy sites:

1) Wireless microphones are more numerous and dispersed
2) Wireless microphones are not necessarily operated by professionals, organizations, etc.

However, we believe that the prevalence of smart phones today can help solve this problem. We propose the development of an application for iPhones, Android devices, etc. that would make the registration procedure for wireless microphones quick and easy for any operator. In fact, the FCC has already suggested that operators of wireless microphones consult the whitespace database for a list of available channels:

> Entities desiring to operate wireless microphones on an unlicensed basis without potential for interference from TVBDs may use the two channels in each market area where TVBDs are not allowed to operate, as well as other TV channels that will be available in the vast majority of locations. *Such entities may consult with a TV bands database to identify the reserved channels at their location, as well as the TV channels that may not be available for TV bands devices.* [3, ¶32]

Furthermore, Spectrum Bridge has produced an application [8] which helps wireless microphone operators determine the best channels on which to transmit. Inspired by Spectrum Bridge's application, we have created a mock-up our proposed application, shown in Figures 2 and 3.

This application would use the location services (roughly, GPS) available on iPhones and Android devices to automatically determine the location of the venue. This would be sent to a TV whitespace database which would then feed back information on the current local channel availability and quality, shown in the middle column of Figures 2 and 3. In addition to the current channel quality, the database would also provide information on the channel quality that could result from venue registration, shown in the far right column of Figures 2 and 3. Note that operators of unlicensed microphones will see the screen in Figure 2. Users who sign in with the appropriate credentials (i.e. are confirmed operators of licensed microphones) will see a screen like that in Figure 3. This provides operators with a gentle reminder that unlicensed

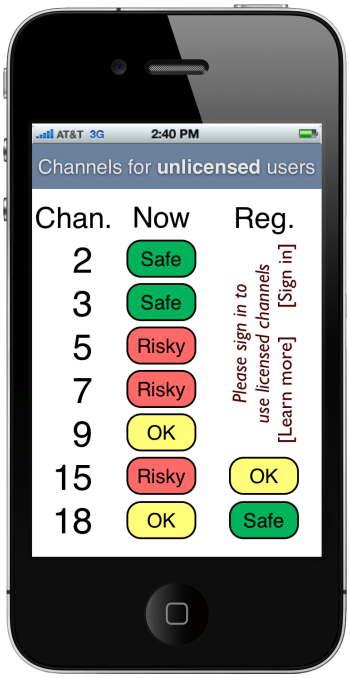

Fig. 2. Mockup of iPhone app for *unlicensed* wireless microphone operators.

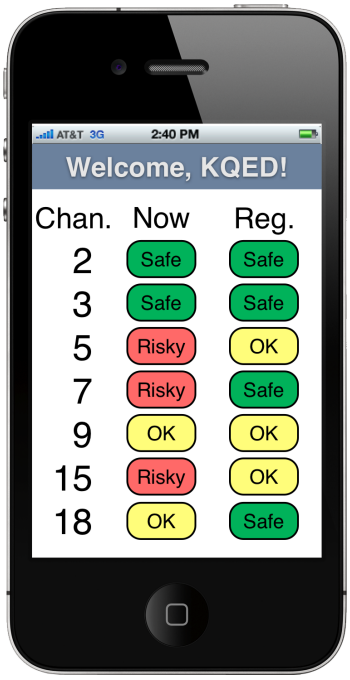

Fig. 3. Mockup of iPhone app for *licensed* wireless microphone operators.

microphones are not allowed to register on more than the two provided channels.

If the operator determines that he can operate reasonably without registration, then no further action is required. Until such time as it is necessary to register in the database, he can simply use this application to help inform his choice in channels, similar to the function that Spectrum Bridge provides with their application.

However, if he wishes to improve his operating conditions he can simply tap on the entry corresponding to the desired channel (e.g. the green "Safe" button for channel 18) to register his location (venue) in the database. The application then transmits this information to the TV whitespace database which acknowledges receipt and forwards the information to the other TV whitespace databases[10].

There are clearly some questions regarding the design of this application, for example:

- How long should the registration last? Some events last only a few hours while others last days.
- What area should be protected? Just 1 km around the location at which the request was sent?
- Should the reservation start immediately or after some delay? How long should this delay be?

However, the main point is that it is easy to create such an application which can be utilized by most Americans *today*. Furthermore, if demand is present, multiple similar applications can be created to suit the needs of different types of operators and venues.

Thus we have demonstrated one possible way to overcome the difficulties inherent in wireless microphone registration.

C. Additional benefits of a wireless microphone registration app

One issue which we have not yet seen addressed is the potential operation of the wireless microphones within auctioned bands. We are unaware of any mechanism by which wireless microphones will be migrated out of these bands, thus by default they will be technically able to cause interference to licensed users. If left completely unaddressed, this has the potential to decrease the value of these bands in the forward auction which in turn threatens the success of the entire auction.

While it is by no means a complete solution, we suggest that the registration application proposed above could also be used to notify wireless microphone operators that some channels are unavailable (perhaps by always reporting them as low-quality), thus helping to nudge their operation to more acceptable bands.

V. The guard bands must have spatial holes

Through the incentive auction, the FCC will soon create two guard bands, each 6 to 10 MHz wide, which separate up- and down-link spectrum from broadcast television in order to prevent harmful interference. The FCC intends[11] to allow unlicensed devices to transmit in these guard bands [1, ¶126]:

> ...this approach would create a uniform downlink band plan to help ensure interoperability, and nationwide guard bands that could be used by unlicensed white space devices, at least on a secondary basis. [1, ¶182]

What does operating on a secondary basis mean? In order to adequately protect licensed services (e.g. broadcast television and the winners of the forward auction) from undue amounts of interference, we must enforce some protected regions in space within the guard bands whenever a protected service is operating on an adjacent channel. The only alternative is to impose such an extremely low power limit that adjacent-channel interference is inconsequential; however, with the advent of the whitespace technology this is clearly wasting an opportunity.

We wholeheartedly support the FCC's decision to treat the guard bands as whitespace but we wish to remind all interested parties that one consequence of this decision is that the bands will *not* be guaranteed to be available nationwide[12]. The guard bands cannot be thought of as equivalent to the 2.4 GHz ISM band because of these numerous spatial holes.

A. Protected TV licensees

As is currently required in the TV whitespaces, unlicensed devices should not be allowed to operate in the 6 MHz adjacent to a broadcast TV station's channel while within its service area[13]. Therefore it is reasonable to require that devices operating in the guard bands will contact the TV whitespace databases; this then imposes no additional overhead for any of the involved parties.

B. Protecting the winners of the forward auction

For the purposes of this discussion, we will assume that the winners will deploy an LTE-like network[14].

1) Up-link: Protecting the up-link portion of an LTE-like network is simple: the receivers (i.e. cellular towers, pico- or femtocells) are at fixed locations and are long-lived enough that it is worth it to characterize the receiver specifications.

[10]The existence of multiple database providers [9] only slightly complicates the situation. These databases are already required to exchange information on a daily basis and this requires only a change in timescale.

[11]Although the quotation below comes from a section on an alternative band plan, we believe that the FCC intends for the guard bands to be used by whitespace devices rather than regular unlicensed devices. This is particularly evident in footnote 198 (from ¶126): "This unlicensed spectrum is in addition to (rather than in lieu of) the white space spectrum that exists today in the UHF band, and will continue to exist after the repacking of the broadcast services."

[12]Depending on the size of the guard bands, it may be possible to exclude devices on only a portion of a guard band, e.g. the 6 MHz nearest the relevant protected service. However, it is still possible for the entire guard band to be off-limits to whitespace devices at that location since protections may overlap, e.g. when a TV transmitter and an cellular tower are near one another.

[13]These should be the same protections afforded in the FCC's rules for the TV whitespaces. In particular, the separation distance—an additional spatial buffer between the service area and transmitting whitespace devices—ranges from 0.4 to 2.4 km, depending on the height of the whitespace device [4, §15.712].

[14]In this case, location estimates are essentially free: a cellular-style network and any device that has access to such a network will be able to estimate its location with reasonable fidelity.

From this, a reasonably-sized exclusion region can be created around each tower and registered in the database. The relatively static nature of these receivers keeps the overhead to a minimum.

2) Down-link: The problem of protecting the down-link portion of an LTE-like network is very similar to the problem of protected TV receivers: their exact locations are unknown but they are necessarily within some range of their tower(s) of interest. The sensible solution in this case is also the same as that for the TV receivers: create a protected region around the tower which is large enough to encompass all associated receivers plus an additional spatial buffer. Carriers, while planning their network, already compute these spatial footprints in order to determine their coverage maps so registering them in the whitespace database is not a burden for them.

C. Whitespace in the guard bands should merge with the TV whitespaces

The FCC remarks in footnote 198 (from [1, ¶126]): "This unlicensed spectrum [in the guard bands] is in addition to (rather than in lieu of) the white space spectrum that exists today in the UHF band, and will continue to exist after the repacking of the broadcast services." We interpret this to mean that the whitespace in the guard bands will be merged with the TV whitespaces and we wish to reinforce this idea. The whitespace in the guard bands cannot stand on its own for several reasons which we discuss below.

1) Coverage holes with no alternative are unacceptable: As argued above, the guard bands will necessarily have holes (as a consequence of providing adequate protection for licensed services) and therefore cannot provide full nationwide coverage *on their own*. In particular, coverage will be sparse in populated areas since there are more TV broadcast towers [10] and LTE-like networks in populated areas. With such holes, this spectrum will be attractive to only a very few manufacturers of unlicensed devices.

However, when coupled with the TV whitespaces we reach a critical mass of spectrum: with so much potential spectrum, no location will be completely bereft of whitespace. In particular, opening up the whitespaces in channel 37 will benefit metropolitan areas in which spectrum is typically scarce.

2) Aggregating whitespaces reduces overhead: Adding the whitespace in the guard bands to the TV whitespaces reduces the number of proceedings and simplifies the entire process. While the individual protections may differ (e.g. different protected regions and separation distances for LTE-like networks as opposed to TV licensees), using the same style and protocol allows for reuse of regulations and (more importantly) technology. These differences represent merely a slight change in the databases, *not* in the main text[15] of the regulations.

VI. Proposed modifications to regulations

We propose the following changes to the FCC's regulations [4], also given in Figure 4:

- Rather than reserving two channels nationwide for unlicensed microphones, just allow the operators of these devices to register on one of these two. Thus locations without currently operational unlicensed microphones would be available for whitespace on those two channels.
- Radioastronomy sites would be assigned a cochannel protected region which is large enough to avoid interference to their operations. These sites are already registered in the whitespace databases and protected regions could be easily modified if interference is observed.
- Locations where WMTS devices are operated (e.g. hospitals) would be assigned protection regions. These locations should already be registered with the FCC and could easily be added to the whitespace databases.
- The whitespace in the soon-to-be guard bands should be designated as part of the TV whitespaces. Furthermore, devices operating in the guard bands should be subject to adjacent-channel exclusions for protected services operating in nearby bands.

	Current FCC regulations	**Proposed regulations**
Television station protections	Protected region + separation margin cochannel and adjacent channel	*No change*
Wireless microphone protections	• Two channels nationwide • Venue registration	Venue registration only (extended to unlicensed on only these 2 channels)
Radioastronomy site protections	• Channel 37 nationwide • 2.4 km on all channels	• Large protected region on channel 37 • 2.4 km on all channels
WMTS (medical) protections	Channel 37 nationwide, except radioastronomy sites	Protected region on channel 37
PLMRS/CMRS protections	1-3 channels in each of 13 major metropolitan areas	*No change*
Proposed guard bands	Designated as whitespace	Part of the TV whitespaces and subject to adjacent-channel protections

Fig. 4. Table comparing the current and proposed protections.

VII. Impact of regulations on the whitespaces

The benefits of the whitespaces are already well-known to the reader: innovation spurred via a low barrier-to-entry courtesy of the fact that use of whitespace spectrum is free. However, it is also important to ensure that new entrants will have a large and inviting market for their products. To that end, we need to make sure that whitespace is readily available in populated areas such as the east and west coasts of the United States. We see in Figure 5 that these are precisely the regions which have the least available whitespace. In fact, roughly 3% of US residents currently have no access to whitespace channels.

As shown in Figure 6, some locations are losing up to 8 channels due to the metropolitan area exclusions:

> TVBDs may not operate at distances less than 134 km for co-channel operations and 131 km for ad-

[15] Instead, these changes could be reflected in updated or expanded tables of values, e.g. separation distances.

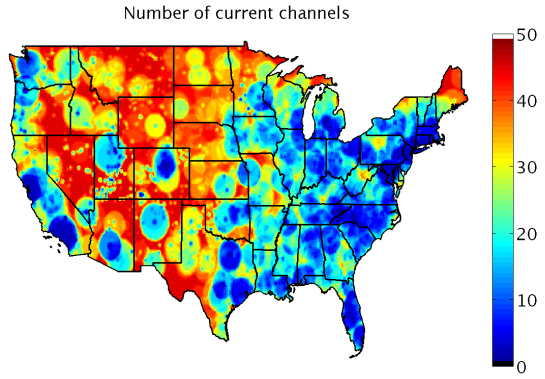

Fig. 5. Number of whitespace channels currently available.

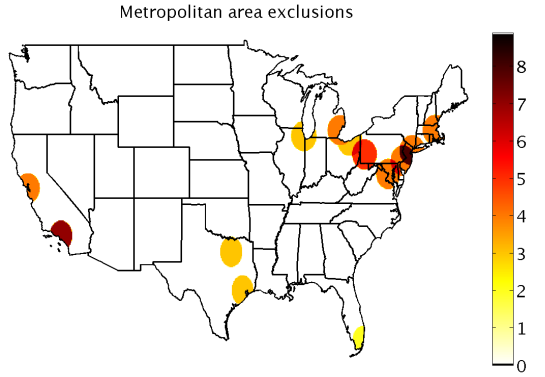

Fig. 6. Number of channels excluded specifically by the metropolitan area exclusions.

> jacent channel operations from the coordinates of the metropolitan areas and on the channels listed in §90.303(a)[16] of this chapter. For PLMRS/CMRS operations authorized by waiver outside of the metropolitan areas listed in §90.303(a) of this chapter, co-channel and adjacent channel TVBDs may not operate closer than 54 km and 51 km, respectively from a base station. [3, §15.712(d)]

The FCC's wireless microphone protections further reduce whitespace availability by reserving two channels (approximately) nationwide for unlicensed microphones:

> All TVBDs are permitted to operate available channels in the frequency bands 512-608 MHz (TV channels 21-36) and 614-698 MHz (TV channels 38-51), subject to the interference protection requirements in §§15.711 and 15.712, except that the operations of TVBDs is prohibited on the first channel above and the first channel below TV channel 37 (608-614 MHz) that are available, i.e. not occupied by an authorized service. If a channel is not available both above and below channel 37, operation is prohibited on the first two channels nearest to channel 37. These channels will be identified and protected in the TV bands database(s). [3, §15.707(a)]

Analysis of the modifications proposed above (*excluding* the guard bands since their size is currently unknown nor do we know the deployments of the primary systems which will impose spatial exclusions on them) yields the following results, represented by the blue lines in Figures 7 and 8:

- Up to 10 million people (mostly in New York City and Miami) would now be able to use the whitespaces.
- Only approximately 650 people (in a rural area in central California) would remain without whitespace access of any kind.
- Over 30% of people would see *at least* a 50% increase in the number of whitespace channels (fractional gain = 0.5).
- Over 10% of people would see *at least* a doubling of the number of whitespace channels (fractional gain = 1).

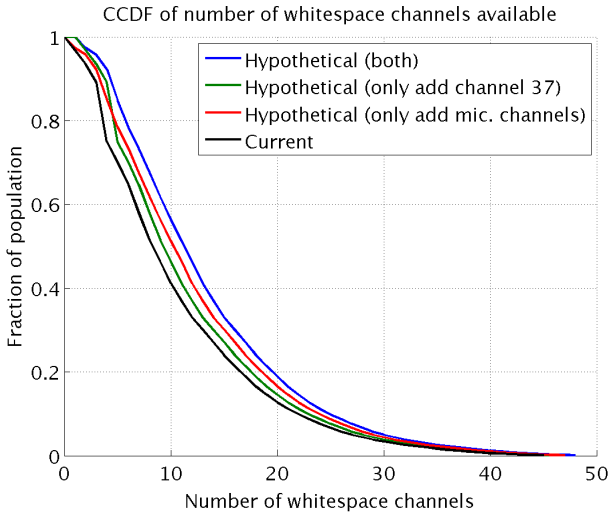

Fig. 7. Number of channels available under each scheme.

The red and green lines in Figures 7 and 8 represent the individual effects of modifying *either* the channel 37 rules *or* the wireless microphone rules (but not both simultaneously). Notice that adding back the microphone channels has a more significant impact than opening up channel 37. This is because most places will gain two channels from a change in wireless microphone rules whereas they can gain a maximum of one channel by using the whitespace on channel 37.

VIII. Methodology and Assumptions

A. Wireless microphone channels

There appears to be a potential contradiction regarding which channels will be reserved for wireless microphones. In the discussion, it is stated that "[the FCC is] herein expanding the reservation of two channels in the range 14-51 to all markets nationwide" [3, ¶29]. However, [3, §15.707(a)]

[16]This document can be found at http://www.hallikainen.org/FCC/FccRules/2008/90/303/section.pdf (footnote added by authors of this report).

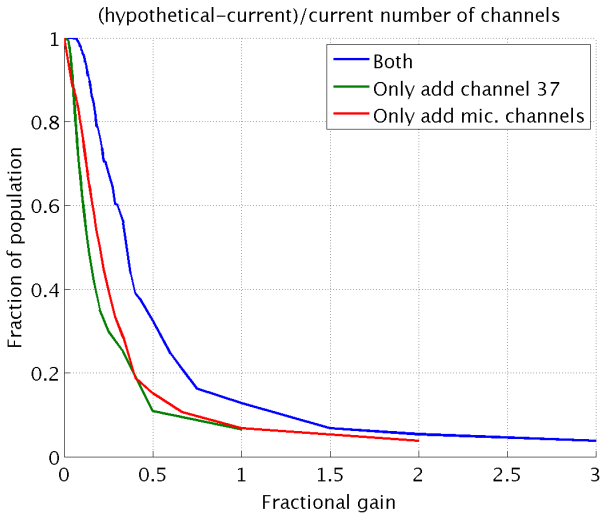

Fig. 8. Fractional gain in the number of channels.

(quoted in the previous section) seems to imply the reserved channels are in the range 21-51.

For the purposes of this report, we assume that channels 2-13 are *never* reserved for unlicensed wireless microphones, even in the cases where this means that fewer than two channels are reserved for these microphones.

B. Wireless microphone channels and PLMRS/CMRS exclusions

In the discussion in [3, ¶29], the FCC notes that it is "expanding the reservation of two channels in the range 14-51 to all markets nationwide" which could be taken to imply that locations with PLMRS/CMRS exclusions will reserve no further channels for unlicensed wireless microphones.

However, the regulations themselves state wireless microphone channels should be reserved on available channels [3, §15.707(a)] (also quoted in the previous section). "Available" is defined [3, §15.703(a)], in part, as "acceptable for use by an unlicensed device" and subject to §15.711, which includes the PLMRS/CMRS exclusions [3, §15.711(d)]. Thus these rules are additive and may reserve up to a total of 5 channels.

For the purposes of this report, we use the latter of these two interpretations.

IX. Future work and other questions

The analysis presented above is not intended to be 100% complete or accurate. In particular, the following questions remain unanswered:

- How large will the guard bands be?
- How much white space will be left in the guard bands once all major players have their equipment in place?
- What kind of protection do WMTS devices need? What about radioastronomy sites?
- Exactly how much which space will be left in channel 37 once we protect these sites and devices?
- How much whitespace will be available once wireless microphone operators routinely register their devices?

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