BASIC DETAILS

Consultation title: Digital Dividend: Cognitive Access, Consultation on licence-exempting cognitive devices using interleaved spectrum

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Name Michael Lynch

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Executive summary

Question 1. The executive summary sets out our proposals for licence-exempting cognitive devices using interleaved spectrum. Do you agree with these proposals?

The executive summary in section 1.5 states “The device must be able to determine with sufficiently certainty that the spectrum is not in use in the vicinity. Depending on how this is achieved, parameters such as sensing levels need to be set.” Furthermore, in Table 1, section 1.9 proposes the sensitivity thresholds to be “-114 dBm in 8 MHz channel (DTT) and -126 dBm in 200 kHz channel (wireless microphones)”. We believe these levels to be insufficient to fully protect broadcast incumbents, especially in the case of wireless microphone sensing We also believe that these levels may be impractical given the presence of anomalous propagation from distant broadcast signals that are way outside the broadcast service area and could mistakenly be detected, the presence of out-of-band emission from other electronic equipment in the TV bands, and the likelihood of denial of service by simple devices emulating DTT and wireless microphone transmissions. More details are given in the following responses.

In the case of wireless microphone sensing where the threshold is lowered to –126 dBm, this sensing threshold will already be 31 dB below the out-of-band emission level allowed in the U.S. in 200 kHz from an electronic device located at 10 m (re. FCC Part 15.209(a)). If the sensing scheme needs to be applied to the entire TV channel, the total allowed interfering power coming from this electronic device at 10 m would be 46 dB above the specified sensing threshold. This is a detection level difficult to achieve with current sensing technologies.

We believe that the sensing parameters and requirements set forth in section 1.5 may be insufficient and could lead to either potentially high level of interference to broadcast incumbents or very low probability of operation of low-power license-exempt devices in the TV bands, depending on the policy for RF sensing. For example, it may be (a) to allow operation of license-exempt devices in channels where DTT or wireless microphones cannot be detected, or (b) to preclude operation as soon as the RF energy in the TV channel, regardless of its source, exceeds the sensing threshold of the energy detector (i.e., SNR = -3.3 dB for 1 dB noise uncertainty[1]) even if the presence of a broadcast incumbent cannot be detected[2].

In the case of the more relaxed approach (a) to the consideration of sensing results, the license-exempt equipment will stop transmitting only when it has positively detected an incumbent in the TV channel. In other words, it will continue operation until an incumbent signal is detected even if the sensing environment has been degraded by the presence of other RF energy in the TV channel. The risk of interference to broadcast incumbents will become large in areas of higher ‘man-made noise’. Such a situation not only fails to protect the broadcast services but also places the consumers at a serious after-sales disadvantage over time, because the interference from license-exempt devices could occur at any time after the DTT receiver has been installed.

In the case of the more conservative approach (b) to the consideration of sensing results, where the license-exempt equipment will stop transmitting as soon as the amount of RF energy in the TV channel exceeds the sensing threshold of the feature detector (i.e., -10 dB to –25 dB) as

1 The performance of a sensing device will be verified in laboratory environment for certification. Typical signal feature detection processes can achieve positive detection of RF signals with known characteristics in the range of –10 dB to –25 dB SNR depending on the detection algorithm used and the sensing time used for integration. The SNR in laboratory environment will be the result of the thermal noise generated by the RF front-end of the sensing device. In practical situation, however, any RF energy present in the TV channel will add to this thermal noise and result in an increase of the total noise level, with the consequence of some desensitization of the sensing device.

2 See 22-06-0134-00-0000_Performance-of-the-power-detector-with-Noise-Uncertainty.ppt available on https://mentor.ieee.org/802.22/documents

well as the sensing threshold of the energy detector (i.e., SNR = -3.3 dB for 1 dB noise uncertainty), a distant high-power broadcast operation could, due to normal stochastic variations in signal propagation, result in a large amount of ‘false positive’ at the levels of sensing thresholds specified. Close-by electronic equipment could cause the same result.

For the above reasons, it seems that the most viable solution to allow license-exempt device operation in the interleaved TV spectrum is a geolocation/database oriented approach. However, such a solution will only work for devices that are accessible over data networks such as the Internet. Small peer-to-peer operation without connection to a larger network could not be easily controlled by a geolocation/database approach. Given the unreliability resulting from RF sensing, both by mis-detecting incumbents and potentially creating interference, Ofcom may want to consider limiting the use of interleave DTT spectrum to license-exempt devices that can all directly or indirectly be connected to the Internet.

In section 1.6, a database polling approach seems to be assumed. With technology readily available today, the device need not pull data from the database. Rather, the device or the device network operator may register with a network of databases informing it of an area of interest so that the network of databases may push any changes affecting the specific area to the device or to the device network operator. Therefore, the update rate of the information from the database to the license-exempt devices connected to the Internet may not be an issue.

Geo-located databases also have the advantage that they closely conform to the current regulatory models, which address the protection of certain geographic area, not only areas in which DTT signals happen to be detected. Databases also have the marked advantage of allowing the regulator to remotely shut down an offending device, a network of devices, or a class of devices found to have manufacturing defects (such as a specific model form a specific manufacturer), etc.

The geolocation/database approach also allows the regulator to dynamically allocate and de-allocate spectrum over specific areas as well as across a whole country with a few keystrokes. It also relieves the constraint of being restricted to “relatively low power” in all cases, as power can be an output parameter from the database determined by a cognitive engine, known as a resolver, after due consideration of the terrain topology, time of day, weather, ionospheric conditions, etc., as well as area coexistence information, including update notices on an area of adjacent and co-channel incumbent and other license-exempt operations. A prime example of such dynamic parameters is the specification of taboo channels and out-of-band performance to protect existing receivers with a published gradual phase-out of such protections as receiver performance improves. This could lead to a much more efficient use of this scarce and valuable spectrum resource.

Such a database approach can be adopted for the protection of wireless microphones used in fixed or venue-type operation, and for Electronic News Gathering (ENG). Beyond the proposed country-wide channel 38 allocated to PMSE as indicated in its report, Ofcom should designate a few more DTT channels in certain areas for ENG and other fixed or venue-type operations. When access to the geolocation database fails, white space devices should not be using those channels dedicated to PMSE on a permanent basis.

To address the situation in which the designated channels are found to be too noisy to use, an alternative approach is being developed by the IEEE 802.22 WG, whereby a wireless microphone beacon operating as a FCC Part 74 device (PMSE) at 250 mW in a 77 kHz bandwidth in a specific microphone sub-channel would signal the presence of wireless microphone operation in the TV channel.[3] Special care was taken in selecting the appropriate modulation and bandwidth in order to allow a license-exempt device of up to 4 W EIRP to detect this beacon at a distance equivalent to its potential interference distance, assuming a reciprocal propagation path, since the beacon can be located close to the wireless microphone receivers.[4]

Finally, we do not believe that the use of the DTV interleaved spectrum should be limited to personal/portable devices. The IEEE 802.22 WG is developing a standard for fixed operation, especially in less populated rural areas where all the user terminals will be professionally installed and where EIRP up to 4 Watts can be used to extend the coverage distance to up to 30 km.

[3] P802.22.1/D4, "Part 22.1: Draft Standard to Enhanced Harmful Interference Protection for Low-Power Licensed Devices Operating in the TV Broadcast Bands," July 2008.

[4] Note that a 6 dB margin was included in the calculations to cover for eventual frequency selective fading affecting differently a 6 MHz wide license-exempt device and the 77 kHz beacon transmission. See document 22-09-0068-01-0000- Sensing performance from 802.22.1 wireless microphone beacon.doc available on https://mentor.ieee.org/802.22/documents)

Detection

Question 2. Do you agree that the sensitivity level for DTT should be -72 dBm?

Our understanding is that this value is used in Europe for the planning of DTT services and represents the minimum DTT received signal level that provides for reliable DTT service and for which the DTT receiver is entitled to protection. Our understanding is that below this received signal level, the DTT receiver is not expected to get protection from interference. Note that the corresponding value for the ATSC DTV system in North America is –84 dBm.

Question 3. Do you agree with an additional margin of 35 dB resulting in a sensitivity requirement for cognitive devices of -114 dBm?

More explanation is needed on the origin of the requirement for 35 dB to cover for the 'hidden node' effect. Clarification would be required as to how the numbers in Table 3 of the Report were determined. Were the measurements done at the fringe of the DTT coverage or inside the coverage as well?

This 35 dB for 99% does not correspond to what propagation models such as the ITU-R P.1546 will predict for such a situation. It would seem that this value represents the excess signal fading in various reception setting that can be found in a DTT coverage area rather than in the fringe area where the received signal level is close to the –72 dBm minimum level. A sensing threshold of –114 dBm is used in the FCC R&O 08-260 but this corresponds to protecting DTV reception down to –84 dBm.

Notwithstanding the above, if protection of DTT on co-channel and adjacent channels is based, as in the US, on avoiding interference to DTT reception when the DTT receiving installations are inside protected contours while interference can occur for DTT installation outside the protected contours, IEEE 802 believes that protection of DTT is better achieved by geolocation and database access than RF sensing since there is no clear relationship between DTT sensing results and the location of the sensing device, whether inside or outside the protected contour.

Furthermore, in order to secure a sufficiently large safety margin to avoid misdetection inside the protected contour, the sensing threshold needs to be at a very low level. This will tend to over-protect DTT receiving installations outside the protected contour as well as create large number of false positives, some due to distant DTT transmissions received sporadically far from their normal coverage areas. Other false positives will result from out-of-band emission from electronic devices for which (in the U.S.) the allowed level is 200 µV/m in 120 kHz at 3 m (according to the FCC Part 15.209a; we suspect that an equivalent level exists in the UK because similar electronic equipment is used). This level is 35 dB higher in 8 MHz and at 10 m than the –114 dBm sensing threshold.

Question 4. Do you agree with a maximum transmit power level of 13 dBm EIRP on adjacent channels and 20 dBm on non-adjacent channels?

We agree with these values as reference for personal/portable devices when RF sensing is used. However, in the case of Wireless Regional Area Network (WRAN) installations such as those envisaged by the IEEE 802.22 Working Group. with a professional installation required, many of the interference considerations would be addressed by the installer. We believe this should provide additional protection and suggest the reference limit for professionally installed, fixed user devices be +36 dBm EIRP for a potential reach of up to 30 km.

In the case of the use of a geolocation/database approach, we believe that the actual power limitation should be provided as an output of the database rather than pre-set in the equipment to leave more flexibility. For example, the regulators could alter the maximum allowed EIRP by region and over time to allow service by license-exempt devices for the benefit of people who would otherwise be deprived of it.

Question 5. Would it be appropriate to expect DTT equipment manufacturers to improve their receiver specifications over time? If so, what is the best mechanism to influence this?

Yes, we believe that DTT equipment manufacturers could improve the DTT tuner design with time to allow better and more efficient spectrum use.

Question 6. Do you agree that the reference receive level for wireless microphones should be -67 dBm?

Yes. In addition, as in the DTT case, it would seem appropriate to define the reference minimum receive level for wireless microphone operation above which protection is required.

Question 7. Do you agree with an additional margin of 59 dB for wireless microphones?

In the U.S. the record clearly indicates that -114dBm is too high a threshold to adequately protect incumbent services in the (http://www.fcc.gov/oet/projects/tvbanddevice/Welcome.html). The record also clearly indicates that -114dBm is too low a threshold for the reliable operation of personal/portable devices. There is no sensing threshold compromise that can resolve this conflict regarding wireless microphone detection.

Question 8. Do you agree with a sensitivity requirement for -126 dB (in a 200 kHz channel) for wireless microphones?

Assuming a reciprocal transmission channel between a 100 mW license-exempt device and a 10 mW wireless microphone, the sensitivity requirement for the license-exempt device to sense the wireless microphone so that its sensing range is at least as large as its interfering range would need to be -115-10 = -125 dBm for an unfaded wireless microphone signal captured by the sensor. Reciprocity is assumed given that the location of the wireless microphone is likely to be close to the location of the wireless microphone receiver compared to the distance to the license-exempt device. If this is not the case, an additional margin will be needed to cover for the fact that there could be more attenuation on the path between the license-exempt device and the wireless microphone, in comparison to the path to the wireless microphone receiver.

Because of the impracticality of the above low detection thresholds, in our view, there is only one realistic means to protect wireless microphone operation while allowing reasonably effective operation of license-exempt devices in the interleaved spectrum: the use of geolocation for the license-exempt devices associated with access to a database recording all protected channels reserved for DTT services, ENG, and wireless microphone operation. For ENG in normal circumstances, all wireless microphone operation would be documented prior to their operation so that the push-technology proposed for dissemination of timely information from the database can create the required local protection ‘bubble’ before wireless microphone operation starts. Ofcom should designate a few DTT channels in any area for ENG and other fixed or venue-type operations, and ensure that they become well-known channels in an area. When access to the geolocation database fails, white space devices will not be using those channels because those channels are always protected 24 x 7.

Question 9. Do you agree with a maximum transmit power level in line with that for DTT? Are there likely to be any issues associated with front end overload?

Having different maximum transmit power based on DTT and PMSE protection would not make much practical sense. The single limit should be dictated by the most demanding protection.

Front-end overload as such should not be a major concern for the transmit power considered. However, third-order intermodulation beats in the DTT receiver front-end (i.e., 2a-b and a-b+c tone combinations) may become a problem in some specific cases. Considering that a DTT receiver may operate in an environment with high signal level from high power DTT transmitters, the presence of a nearby license-exempt device may generate an intermod product that falls in the channel to which the DTT receiver is tuned. This will be related very closely to the physical location of the DTT receiver relative to high power DTT transmitters and the location of nearby license-exempt devices. With the geolocation of these license-exempt devices and access to a database, such consideration of third-order intermodulation beats could easily be taken into account. For example, if channel N is available from a distant DTT transmitter and needs to be protected in an area, and if a high power transmitter operating on channel N+2 is located in this same area, the database may preclude the use of channel N+4 by license-exempt devices located within a radius of, say, 3 km from the high power DTT transmitter to avoid the generation of interference in the DTT receiver front end on channel N. This distance can be modified in the database over time with improvement in linearity of the typical DTT receivers.

Question 10. Do you agree that the sensitivity level for mobile television receivers should be -86.5 dBm?

No. Although the sensitivity of mobile DTT receivers could be increased by the use of more robust modulation, the operating margin will need to be larger because of the higher variability of the channel in mobile situation. In the US, the M/H ATSC services is designed based on a sensitivity level of -94 dBm

Question 11. Do you agree with an additional margin of 20 dB for mobile television?

No. No analysis was conducted to determine a number.

Question 12. Is it likely that mobile television will be deployed in the interleaved spectrum? If so, would it be proportionate to provide full protection from cognitive access?

Yes. The US contemplates the use of mobile television within the Broadcast service (as an inband system). As a primary service, protection will have to be afforded to the mobile broadcast service.

Question 13. Should we take cooperative detection into account now, or await further developments and consult further as the means for its deployment become clearer?

The benefit of cooperative detection is very much dependent on the number, location and distance between license-exempt devices within a given area. Although the probability of detection increases rapidly with the number of sensors, the ITU-R P.1546 propagation model indicates that these sensors need to be typically at a minimum distance of 500 m from each other to be considered statistically independent. This mode of operation would require star or mesh type of network topology, which may not always be the case for personal/portable license-exempt devices. In a star network, the operator will need to select the sensors to be considered very carefully. Taking advantage of cooperative sensing would also mean changing the sensing threshold depending on the number of devices that can contribute to the detection. This unfortunately seems to be a rather complex approach for personal/portable devices.

Geolocation databases

Question 14. How could the database approach accommodate ENG and other similar applications?

Well-known push technology used on the Internet is expected to be used to update the nearby license-exempt devices to clear the channels if they are connected to the Internet.

The database approach would allow for this, whereby an authorised person defines and enters in the database the frequency range to be provided protection, the geographical area over which the protection is to be offered and the time period at which it applies.

As discussed in our response to question 8, there must be a few designated channels that ENG can use on a contingency basis. Because these channels, beyond the proposed channel 38, are in the database, they do not have to be the same few channels throughout the country, but can be picked to suit local conditions and ENG practices.

Question 15. What positional accuracy should be specified?

The positional accuracy for WRAN systems should be specified by the regulatory body. Since the type of operation and ENG equipment used in each administration may be different, it is more prudent that such action be left to the regulators. However, in the case of peer-to-peer type operation where there is no real ‘network, or operator, it would be wise to define an agree-upon reference positional accuracy so that the separation distances on which the database operate are increased by this reference distance to ensure protection to the broadcast incumbents. The proposed 100 metres accuracy seems to be reasonable.

Question 16. How rapidly should the database be updated? What should its minimum availability be? What protocols should be used for database enquiries?

Depending on the service to be protected, the update rate will be different. In the case of DTT protection, the update can be rather slow, even more than one hour as proposed. If it is for PMSE, it would need to be near real-time.

Our recommendation is to use known Internet push technologies for the database to bring updates on channel availability to affected license-exempt devices. We believe that 24 hours can lead to an extended duration of uncontrollable interference. We believe that this grace period defeats the proposed ability to resolve interference issues by having a database administrator issue a “no channels available” message. In our recommendation, the requirement for daily contact with the TV bands database is replaced by the requirement for master mode devices to verify their Internet connectivity hourly or cease operation. There are a broad range of standards-based paging and messaging technologies available that the TV bands database could use to push messages that reflect changes in channel availability to master mode devices for near real time updates.

Proper security and authentication protocol such as SSL at the transport layer should be used to access the database to assure that the device is communicating with a verified and approved database.

Question 17. Is funding likely to be needed to enable the database approach to work? If so, where should this funding come from?

No comment.

Question 18. Should the capability to use the database for spectrum management purposes be retained? Under what circumstances might its use be appropriate?

Yes. We believe the retention of the use of the database for spectrum management is of value. It will allow the regulators to implement evolving regulations and audit incumbent protection claims as well as database network operators to validate their database contents.

Question 19. Should any special measures be taken to facilitate the deployment of cognitive base stations?

In the case of a star network topology, the base stations would play a key role in providing protection to incumbents. If RF sensing is retained as a means of protection, sensing by the base station would be crucial because of the typically higher elevation of its antennas, allowing a larger reach. However, if the base station EIRP is allowed to be higher than that of the personal/portable devices, the interference radius may become larger than its sensing range, so sensing by the personal/portable devices will then be needed to augment the reliability. In the case of a geolocation/database solution, the database could become the node for the database access and be the best place to locate the local resolver. The personal/portable devices tethered to the base station would be able to rely on it to interface with the database, and their cognitive function could be reduced to providing only their geolocation while the database would control the channels that they can use as well as their maximum EIRP by capping the range of their Transmit Power Control.

The database network should describe protection contours rather than signal levels. The resolver, taking into account base station antenna pattern, height, etc, should compute and decide on the actual permissible radiated power in any given direction. This decoupling would simplify the database network, as it would not concern itself with transmitter specific parameters but rather with describing the protection to be given. A network operator, being responsible for any damage caused to others, would have to operate the resolver before any network device can effectively transmit. Special measures would therefore not be required.

Beacon reception

We don't believe that a beacon network as proposed by Ofcom is a good approach. The initial TV White Space NOI issued by the FCC in 2004[5] had proposed such a generic beacon to be carried by existing broadcast infrastructure such as FM transmitters but this solution has, since then, been set aside in the discussion.

Question 20. Where might the funding come from to cover the cost of provision of a beacon frequency?

No comment.

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[5] US FCC, ET Docket 04-186: Notice of Proposed Rule Making, In the Matter of "Unlicensed Operation in the TV Broadcast Bands", Released May 25, 2004

Question 21. Is a reliability of 99.99% in any one location appropriate? Does reliability need to be specified in any further detail?

No comment.

Comparing the different options

Question 22. Do you agree with our proposal to enable both detection and geolocation as alternative approaches to cognitive access?

No. We believe that both detection and geolocation methods cooperate to enhance and improve reliability of cognitive spectrum access for protection of incumbents and better use of the spectrum. However, at this time, the detection approach alone is unworkable in the real world because of the extremely low sensing thresholds proposed.

Other important parameters

Question 23. Should we restrict cognitive use of the interleaved spectrum at the edge of these bands? If so, what form should these restrictions take?

No. We believe protection requirements should be defined by the regulators and executed by the database network rather than implemented from the start.

Question 24. Do you agree that there should be no limits on bandwidth?

We recommend that the total power and power spectral density be limited such as to prevent a narrowband transmitter from gaining dominance over others by concentrating all the admissible power over a very narrow bandwidth. We also recommend that provisions be made to allow wide band and narrow band devices to communicate together for coexistence and band sharing. Defining a maximum power spectrum density limit (e.g., 8 dBm per 3 kHz as per Part 15.247e in the US) would cover for such case.

We believe that the maximum channel bandwidth for license-exempt devices should be aligned with the current TV channel raster to allow Ofcom to allot, at will, spectrum back to DTT broadcast services or to allot spectrum for license-exempt devices when not needed for broadcasting.

Question 25. Do you agree that a maximum time between checks for channel Availability should be 1s?

IEEE 802 believes that 1 hour is sufficient between checks by white space devices for channel availability with the database, noting that the push mechanism will provide near real-time updates when changes occur.

Question 26. Do you agree that the out-of-band performance should be -44 dBm?

It does not seem to be realistic to require tighter out-of-band emission level from license-exempt devices than from other electronic equipment.

Question 27. Is a maximum transmission time of 400ms and a minimum silence time

of 100ms appropriate?

It would appear that RF sensing to protect broadcast incumbents cannot work with the TDM structure proposed by Ofcom.

Question 28. Is it appropriate to allow “slave” operation where a “master” device has used a geolocation database to verify spectrum availability?

Yes, we believe this to be appropriate, provided that the master device has access to the incumbent database through a resolver and that the protection distance used in the resolver takes into account the range of the master station. In the case where the range of the master station may be large, the operator may have an incentive to geo-locate the slave devices in order to allow operation in some areas by some “slave” devices while banning transmission for other “slave” in other areas. This is the model used in the 802.22 WRAN standard development which is based on a fixed license-exempt device implementation in the TV bands with “slave” devices being able to operate at up to 4 Watt EIRP to provide a coverage of up to 30 km radius.

However, this ‘delegation’ of the incumbent protection responsibility to the master device does not work when RF sensing is used. Each slave device will have to do its own sensing. A specific example of this is when the master device is a server located in the basement of a house while its “slave” devices can be located anywhere inside and outside but close to the house. RF sensing by the master device would not be sufficient to protect broadcast incumbents such as nearby wireless microphones that could be interfered with by the devices outside the house.