BEFORE THE
FEDERAL COMMUNICATIONS COMMISSION
WASHINGTON, D.C.

In the Matter of	
UNLICENSED OPERATION IN THE TV BROADCAST BANDS	ET Docket No. 04-186
ADDITIONAL SPECTRUM FOR UNLICENSED DEVICES BELOW 900 MHZ AND IN THE 3 GHZ BAND	ET Docket No. 02-380

COMMENTS OF MICROSOFT CORPORATION

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SUMMARY

The importance of both fixed and nomadic broadband service to our economy and to public safety is now self-evident. It is equally self-evident that such service should be affordable. There should be no "underserved" (and surely no unserved) communities in the United States. And this Commission, to its credit, has taken a variety of steps to help reach this goal. Nevertheless, there are communities less than sixty miles from Washington, D.C. where DSL and cable are not available, and will not be for the foreseeable future. Moreover, nomadic broadband – with its enormous public safety as well as commercial potential – is still rare despite the phenomenal success of Wi-Fi devices and hot spots.

Microsoft believes that one critical avenue to a future of ubiquitous broadband is the availability of unlicensed spectrum below 1 GHz. The superior propagation characteristics of such lower band spectrum can make the critical difference between success and failure for those seeking to provide wireless broadband services.

Fortunately, as the Commission has recognized, there is an enormous reservoir of unused lower band spectrum all across the country. There are unused television channels in every community that would be ideal for use by unlicensed broadband devices and service providers. Moreover, the technology already exists to allow these vacant channels to be used without causing harmful interference to broadcasters. Microsoft thus supports the Commission's proposal to allow unlicensed devices to operate on unused television channels. There are, however, several significant improvements the Commission should make to its proposal:

First, the Commission should avoid mandating the technology that either fixed or nomadic devices use to avoid operational broadcast channels. Rather, it should mandate the level of avoidance necessary to protect broadcasters, and let manufacturers choose the type of technology that best can meet those requirements.

Second, the Commission should permit unlicensed devices to operate on channels 2-4 and 14-20 where those channels are not being used for television broadcasting. Unlicensed devices are not likely to cause interference to the TV interface devices (such as VCRs) that operate on channels 2-4 or to the mobile radio services that use channels 14-20 in some locations.

Third, the Commission should adopt the same out-of-band emission rules that it has adopted for unlicensed devices in other bands. Significantly stricter rules – as the Commission seems to propose -- risk making the vacant TV channels *unusable* for broadband services.

Fourth, the Commission should encourage the voluntary use of spectrum sharing techniques among unlicensed devices by allowing devices that incorporate such techniques to operate at higher power. Smart spectrum sharing will assure maximum use of this valuable national resource.

By making vacant television channels available for unlicensed devices under the right conditions, the Commission could well be putting in place the final piece of the wireless broadband puzzle – and creating the necessary conditions for the development of truly ubiquitous broadband service.

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Advances in wireless technology will play an important role in closing the digital divide, particularly in rural and other unserved areas, and in supporting important, new broadband applications. Smart antennas and smart radios are already here. These technologies hold promise for using previously allocated and licensed – but not fully used – spectrum in exciting and much more efficient ways.

In this Notice of Proposed Rulemaking ("NPRM"), the Commission recognizes the potential for new technology to tap more fully this country's spectrum resources. To exploit this potential, the Commission proposes a new plan for broadband operators to use edge-of-the-art, unlicensed devices to make use of the vast amount of vacant television spectrum that for years has lain fallow across the country. Microsoft believes this proposed use of spectrum below 1 GHz might be the key to making true broadband technology available to much of this country and for new nomadic services. This NPRM is a watershed proposal and Microsoft endorses it fully.

DISCUSSION

Microsoft's interest is in fostering ubiquitous access to broadband technology. Given the country's demography and geography, it is not clear that people who live in traditionally underserved communities will get that access anytime soon. Nor is it clear that all parts of the country will enjoy the benefits of novel, nomadic broadband applications anytime soon (such as cost-effectively connecting a squad car at the scene of a crime to a town-wide public safety network). Fortunately, in this NPRM the Commission recognizes that advances in radio technology create opportunities to fill gaps in the nation's broadband coverage by taking advantage of unused spectrum.

Over time, the FCC has allowed limited re-use of vacant television spectrum. For example, the Commission has already seen fit to share television spectrum among land-mobile stations, radio astronomy and wireless medical equipment. Now, innovations in license-exempt broadband technology will allow vacant television channels to be used to extend dramatically the reach of broadband services. The range of broadband wireless devices in the television bands would be so much greater than similar devices operating in the 2.4 GHz and 5 GHz frequency bands that it can make a crucial difference in the availability of broadband services across the nation.

By allowing the deployment of such wireless devices, the Commission would achieve several important policy goals:

- ✓ Bringing more broadband to more users, including public safety and government users[1]
- ✓ Using grossly under-used spectrum more efficiently

[1] It is not only rural areas that suffer from a dearth of broadband options. In urban areas, access to service is difficult for many lower income residents. And throughout the nation, municipalities are having difficulty finding funds to handle increasing public safety demands. All are problems that may be alleviated by the growth of new wireless broadband offerings.

- ✓ Providing fertile ground for growing new spectrum efficient technologies using new technologies[2]

However, in several respects the NPRM is overly cautious. Microsoft believes there are steps – outlined below – the Commission can take that will help the Commission achieve its goal of using spectrum policy to accelerate broadband deployment nationwide, while protecting existing and future users from interference.

I. EVEN THOUGH WISPS ARE STARTING TO PROVIDE BROADBAND TO UNSERVED AREAS, USE OF TV SPECTRUM WILL OFFER SIGNIFICANT ADVANTAGES

In this NPRM, the Commission observes that allowing unlicensed devices to use vacant television spectrum will make more efficient use of that spectrum and will yield unlicensed networks that operate effectively at much greater ranges than devices operating today at higher frequencies. The Commission continues, "These new devices and services could also have significant benefits for economic development and for consumers and businesses by providing additional competition in the broadband market." And it also recognizes that in some areas there are virtually no broadband choices.[3]

The Commission is, of course, well aware of the many Wireless Internet Service Providers ("WISPs") that have found some success in deploying unlicensed equipment to provide broadband services where otherwise none are available. As Microsoft has noted previously, the "College Terrace Internet Cooperative" near Stanford University is a free,

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[2] For example, smart antenna and cognitive radio devices appear ideal for making use of spectrum that varies in frequency and bandwidth depending on geography.

[3] According to a recent article, once online, rural users' behavior is comparable to urban and suburban users. However, they are less likely to enjoy broadband connections. Elaborating, the article goes on to reveal that 19 percent of U.S. online rural residents have broadband connections at home, compared to 36 percent of urban residents and 32 percent of suburbanites. Roughly 25 percent of rural users did not think they were able to get a broadband connection in their community, compared to 5 percent of urban users, and 10 percent of those in the suburbs. *See Digital Dirt Road Divide*, Robyn Greenspan, (February 23, 2004) *available at* http://www.clickz.com/stats/sectors/demographics/article.php/3316541.

broadband Internet access network used by those living in that area. We have also often discussed Coffman Cove -- a remote Alaskan village has created its own broadband network using Wi-Fi equipment and satellites for traffic backhaul.[4] There is no doubt that WISPs are playing an increasing role in bringing affordable broadband to underserved areas. Indeed, there are more than 8,000 wireless ISPs in the U.S. using unlicensed frequencies -- most of them in rural areas – and about half have fewer than one hundred customers.[5]

But WISPs continue to face significant obstacles. Their infrastructure costs can be high, and their signal propagation and "spectrum quality" are low.[6] Last fall, at the Commission's "Rural Wireless ISP Showcase and Workshop,"[7] a number of presenters described these difficulties. For example, many WISPs currently operate on an unlicensed basis in the 2.4 GHz band. While their ability to provide commercial service in that band is noteworthy, they pointed out that the band is rife with unlicensed interferers like cordless phones, microwave ovens, and baby monitors. As the WISP workshop demonstrated, for WISPs to take wireless broadband to the next level of

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4 *See Broadband Comes to Coffman Cove,* ISP-Planet (May 27, 2003). The Commission itself has presented examples of WISP success stories. In a presentation before the "World Radio Conference on Rural Wireless Broadband using wireless LAN Technologies," the Commission tells the story of the "Tribal Digital Village." In this case, in San Diego County, California wireless broadband access is being brought to isolated Indian reservations scattered throughout desolate terrain near the Mexican border. *See Wireless Local Area Network (WLAN) Applications Around the World,* Lauren Maxim Van Wazer, Special Counsel, Office of Engineering and Technology, Federal Communications Commission (June 2003) *available at* http://www.fcc.gov/oet/projects/rural/wireless_LAN_seminar_LVW_6-03.ppt.

5 "Wi-Fi brings broadband to rural Washington," InfoWorld (August 23, 2004), available at http://www.infoworld.com/article/04/08/23/HNwifiwash_1.html.

6 Most desirable spectrum is encumbered. However, some frequencies are easier to access and use than other frequencies.

7 *See Rural Wireless ISP Showcase and Workshop,* November 4, 2003 (http://www.fcc.gov/osp/rural-wisp/welcome.html).

deployment, deployment hurdles must be overcome and the "quality" of spectrum must be improved both in terms of propagation and uncontrolled interferers.[8]

Compared to spectrum currently available for WISPs, the advantages of using television spectrum are readily apparent. For analysis purposes, we have identified five possible deployment modes for unlicensed devices in television spectrum: Rooftop WISP, Hot Spot WISP, Zero-Install WISP, Rooftop Mesh, and Indoor House-to-House Mesh.[9] The potential coverage range for each is stunningly robust, as shown in Table 1.

Table 1 – Coverage Range Summary (km)

	Rooftop WISP	Hotspot WISP	Zero-Install WISP	Rooftop Mesh	Indoor House-to-House Mesh
Low VHF	7.2 – 31.4	3.0 – 8.8	1.7 – 5.7	4.8 – 20.7	0.08 – 0.62
High VHF	3.9 – 20.7	1.6 – 5.3	0.9 – 3.4	2.7 – 13.2	0.06 – 0.39
UHF	1.7 – 12.4	0.9 – 3.3	0.6 – 2.3	1.3 – 7.7	0.05 – 0.35

[8] *See, e.g.,* Michael R. Anderson, *PDQLink, Wireless Technologies and Interference, FCC Showcase, November 4, 2004*. PDQLink also provides a sample monitoring session where over 50 potentially interfering sources were observed at a one location. http://www.fcc.gov/osp/rural-wisp/welcome.html.

[9] Rooftop WISP: the WISP installs tower mounted base stations to cover the service area. The tower antennas are 30 m above ground level. The subscriber units are roof mounted, nominally 10 m above ground level. Both the tower and subscriber stations have omni-directional coverage antennas with 6-dBi gain and 1 W transmit power (6 dBW EIRP).

Hot Spot WISP: the WISP installs a roof mounted base station nominally 10 m above ground level. The base station antennas have omni-directional coverage antennas with 6-dBi gain and 1 W transmit power (6 dBW EIRP). Subscriber units are PCMCIA cards with attached short (5" long), normal mode helix antennas and 100 mW transmit power. The base station controls the subscriber units' channel selections insuring that they only operate on vacant TV channels.

Zero-Install WISP: the WISP installs roof mounted base stations nominally 10 m above ground level. The base station antennas have omni-directional coverage antennas with 6-dBi gain and 1 W transmit power (6 dBW EIRP). Subscriber units are PCMCIA cards or PCI cards with attached short (5" long), normal mode helix antennas and 100 mW transmit power. The base stations control the subscriber units' channel selections insuring that they only operate on vacant TV channels.

Rooftop Mesh: these are peer-to-peer mesh networks with subscriber units that are professionally installed and roof mounted, nominally 10 m above ground level. They have omni-directional coverage antennas with 6-dBi gain and 1 W transmit power (6 dBW EIRP).

Indoor House-to-House Mesh: these are ad hoc peer-to-peer mesh networks. Subscriber units are PCMCIA cards or PCI cards with attached short (5" long), normal mode helix antennas and 100 mW transmit power. These units transmit if they receive a control signal from a TV station or FM broadcast station identifying vacant channels within their service areas. Alternatively, they could use GPS or other location sensing methods, or cognitive radio techniques, to identify vacant channels.

These ranges – showing that some WISP signals could travel over 31 kilometers – dwarf the ranges typically achieved by unlicensed devices in the 2.4 GHz and 5 GHz bands.

In addition, with the better propagation available in the TV bands, higher data rates are sustainable at greater distances when compared to the 2.4 GHz and 5 GHz bands. As a radio signal propagates away from the transmitter, the data rate drops as the distance from the transmitter increases and the signal becomes weaker. Table 2 provides representative data rates achievable in the TV bands with various modulations.[10]

Table 2 – Data Rates Supported by 802.16a in a 6 MHz Channel

			Guard Factor			
Modulation	Code Rate	Receiver Sensitivity	1/32	1/16	1/8	1/4
BPSK	1/2	-88 dBm	2.5 Mbps	2.4 Mbps	2.3 Mbps	2.1 Mbps
QPSK	1/2	-85 dBm	5.0 Mbps	4.9 Mbps	4.6 Mbps	4.1 Mbps
	3/4	-83 dBm	7.5 Mbps	7.3 Mbps	6.9 Mbps	6.2 Mbps
16-QAM	1/2	-78 dBm	10.0 Mbps	9.7 Mbps	9.2 Mbps	8.3 Mbps
	3/4	-76 dBm	15.0 Mbps	14.6 Mbps	13.8 Mbps	12.4 Mbps
64-QAM	2/3	-72 dBm	20.0 Mbps	19.4 Mbps	18.3 Mbps	16.5 Mbps
	3/4	-70 dBm	22.5 Mbps	21.9 Mbps	20.6 Mbps	18.6 Mbps

These tables demonstrate that lower frequencies with better propagation characteristics are simply better suited for creating cost-effective, robust wireless broadband. The bottom line is that, with these advantages, a WISP using spectrum below 1 GHz would need about 1/3 fewer base stations than, and about 50% of the capital investment of, a

[10] For this table, 802.16a is used as an example air interface. For a 6 MHz TV channel bandwidth, 802.16a specifies a sampling factor of 86/75. The resulting sampling frequency, sub carrier spacing, and useful symbol time are 6.88 MHz, 26.875 kHz, and 37.2 µsec, respectively. Four guard factors are supported, 1/32, 1/16 1/8, and 1/4, depending on the amount of multi-path mitigation required. The resulting guard times are 1.2 µsec, 2.3 µsec, 4.7 µsec, and 9.3 µsec, respectively. The raw bit rates, including MAC and preamble overheads, which can be supported in a single 6 MHz channel, are shown in Table 2 for each of the specified modulation and coding combinations, and for each of the guard factors. Receiver sensitivity is also shown assuming a 7 dB noise figure and 5 dB of implementation losses.

WISP using the 2.4 GHz or the 5 GH bands. That, in turn, could make all the difference in providing cost-effective broadband to unserved and underserved areas of the country.

II. UNUSED TELEVISION BROADCAST SPECTRUM IS AVAILABLE

In its NPRM, the Commission observes that it would seem feasible for unlicensed transmitters to operate on vacant television channels that cannot be used by broadcasters in a given area due to interference concerns.[11] Because of frequency-dependent interference relationships among broadcast television operations in a given geographic area, once operations are established on certain channels, other channels cannot be used in that area. And because television service areas in one city often overlap with those in another (*e.g.*, Washington and Baltimore), there is a "daisy chain" of channel exclusions that extends over large regions. As a result of the relationships between broadcast stations, on a geographic basis, much of the broadcast television spectrum goes unused. Further, as the Commission states in its NPRM, many usable TV channels are simply unassigned in certain locations and, therefore, could be made available for unlicensed operations.[12] Microsoft agrees with the Commission that with proper interference controls unlicensed broadband networks can use significant amounts of vacant television spectrum.

III. TECHNICAL RULES CAN PROTECT INCUMBENT OPERATORS WHILE PERMITTING UNLICENSED OPERATIONS

The Commission wants to ensure that unlicensed use of vacant TV channels does not disrupt incumbent operations – particularly television broadcast operations – and does

[11] NPRM at ¶13.

[12] Id.

not adversely affect the transition from analog to digital television (DTV transition).[13] Microsoft generally agrees with the Commission's proposed technical criteria for determining when unlicensed devices can use a TV channel.[14] However, in some instances, Microsoft believes the Commission's interference control proposals are unnecessarily limiting. In these instances, fuller use of the bands by unlicensed devices would ease the growth of broadband networks while still protecting broadcast television and other incumbent services.

The Commission proposes channel avoidance as its primary interference control mechanism.[15] In other words, in a given area unlicensed devices may only operate on unused TV channels. In addition, the Commission proposes two general categories of unlicensed TV band devices – personal/portable devices and fixed/access devices.[16] Personal/portable devices would consist of devices like notebook computer NIC cards and self-installed wireless connections. Fixed/access devices would consist of devices operated from a distant, fixed location, much as WISPs operate in other spectrum. The Commission makes this distinction because it believes different implementations may require different interference avoidance techniques, though it also is trying to adopt technical requirements that are *simple* and *reliable*.[17]

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13 *See, e.g.,* NPRM at ¶15.

14 *See* NPRM at ¶¶29-32. The Commission proposes technical criteria to determine when a TV channel can be considered "vacant" for use by unlicensed devices. Under this proposal a TV channel would be considered vacant if the desired-to-undesired signal ratios (or D/U ratio) shown in the table in paragraph 30 of the NPRM between co-channel and adjacent channel television operations and a "fixed/access" unlicensed device, or co-channel only for a "personal/portable" unlicensed device, are met at all points within the service area of the protected television operation. The Commission also proposes that unlicensed devices do not operate within the protected service contour of *any* co-channel TV operation (NPRM at ¶32.).

15 NPRM at ¶17.

16 NPRM at ¶19.

17 Id.

The Commission further proposes two primary tools (position determination and control signals) for ensuring that unlicensed TV band devices operate only on vacant channels, and it suggests a third (cognitive radio).[18] We urge a more flexible approach than outlined in the NPRM; specifically:

- The Commission proposes to use the control signal approach for personal/portable devices[19] and the position determination approach for fixed/access devices. We believe both approaches can be viable options for both types of devices.[20]
- That said, a mandatory control channel requirement for personal/portable devices could severely (and needlessly) constrain the development of networks among personal/portable devices, and it could preclude use of those networks in remote areas where no control channel is available.
- As important, we believe the Commission should accommodate sensing techniques that could be used to ensure that unlicensed networks only operate on unused TV channels.
- The Commission should encourage the voluntary use of other spectrum sharing techniques among unlicensed devices by allowing devices that incorporate such techniques to operate at higher power.

A. Position Determination

The Commission proposes that fixed/access unlicensed devices incorporate a method (like a GPS receiver) to determine its location with a minimum accuracy of 10 meters.[21] Using positioning information, the devices then would be required to access a database and computational software to determine the TV channels that are vacant at its location and operate only on vacant channels. Microsoft does not object to this general approach for fixed/access devices (though 10-meter accuracy seems to be unduly

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18 NPRM at ¶¶20 and 28.

19 NPRM at ¶21.

20 Or in some cases, a combination of a control signal from an appropriate source coupled with position determination may be appropriate. For example, if required to use control signals, a mesh network might function best if position determination is used to tell the device to ignore a control signal - passed through the mesh – that provides channel information that would not apply to that device.

21 NPRM at ¶26.

stringent and is likely to drive up equipment costs unnecessarily). Nonetheless, if control signals (provided by whatever means) will be part of the Commission's interference avoidance plan for personal/portable devices, there is no reason why static fixed/access devices cannot also use those signals.

Conversely, given the low cost of GPS chipsets, position determination could also be a viable alternative for personal/portable devices in certain deployment scenarios. In the same manner that the Commission proposes for fixed/access devices, a GPS equipped portable device could determine its location, access a stored database to identify vacant TV channels in the vicinity of its location, and limit its transmissions to only those channels. The device could automatically update its stored database whenever it is connected to the Internet. If the age of its internal database exceeded a threshold, the device could disable itself until its database is refreshed appropriately (e.g., by a wireline Internet connection). This type of operation may be of particular interest for temporary, outdoor networks.[22]

As an alternative to automatic location determination and computational methods to determine vacant channels, the Commission proposes to require a professional installer to determine the device's geographic location, determine vacant TV channels and then configure the device to use only vacant channels. Armed with all of this information, the installer would report his findings to a third party – like a frequency coordinator – who would maintain a database of the device's coordinates and available channels in the vicinity of the device's location.[23]

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[22] However, whether for fixed/access or personal/portable devices, Microsoft reminds the Commission that GPS functionality is severely limited for indoor applications.

[23] NPRM at ¶26.

Microsoft urges that this proposal be abandoned or, at most, made optional. This proposal is, essentially, the type of site survey and coordination requirement imposed on microwave services. While that process is appropriate for high-powered, licensed microwave operations sharing frequencies, it is inappropriate for low-power unlicensed devices. Mandating third-party installation of unlicensed devices will needlessly complicate, and increase the cost of, the deployment process (we estimate a typical "truck roll" to the customer's premises costs on average $300 today). Since the technology exists to protect occupied TV channels *automatically,* it would be unwise to mandate the use of a less sophisticated, more expensive means of protection.

B. Control Signal

As noted in the margin above, GPS location-determination is not an answer for all situations; nor is requiring the use of a control signal. The idea behind the NPRM's control signal proposal is that the signal would provide assurance that unlicensed portable devices will operate only on unused TV channels. As the Commission recognizes, there are a number of ways this control signal might be provided,[24] and the appropriate method may depend on the unlicensed network topology. If the devices were part of a point-to-multipoint network (*e.g.,* a hot spot WISP network), for example, it would be efficient to have the base station provide a control signal to its client devices.[25]

Though Microsoft does not object to this approach as *an option*, we believe that a channel detection and avoidance mechanism built into the unlicensed devices themselves will ultimately prove to be the easiest, most effective, and least burdensome way to

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[24] NPRM at ¶24.

[25] Since just about every unlicensed device used for broadband in the TV band will have some kind of connection to the Internet, the necessary control signal information could be obtained from a continuously updated database. For example, it could be the Commission's TV database.

protect broadcasters. Moreover, there are situations where a control signal mechanism may be at odds with the type of network being deployed and/or the Commission's policy goals. Specifically, a control signal requirement could prove problematic for mesh networks of personal/portable devices and for networks operating in remote areas where no control signal might be available.

We think of mesh networks as ones where there are at least three nodes with at least two paths to communicate between nodes. At the extreme, every node is directly connected with every other node. However, that topology is not practical for wireless mesh networks, which rely on peer-to-peer communications; where a "hop" through node "B" may be needed to carry communications from node "A" to node "C." Essentially, each device in a mesh network serves as an access point, client device and router. The beauty of this topology is that as each user adds a device to the mesh, the network grows "organically' without the need to add additional base stations, routers and other infrastructure. Consequently, at very little cost, mesh networks can grow to serve underserved neighborhoods (rural, suburban or urban) and then grow further to connect neighborhoods.[26]

But applying the control signal approach to mesh networks could be difficult and may impair deployment. Because communications and network information in a mesh network is passed from peer to peer, a control signal could be passed to devices in the far reaches of the mesh that cannot effect TV operations in the area where the control signal originated. The effect is that some devices may be instructed to avoid usable TV

[26] An example of an operating mesh networks can be found in this recent Business Week article: http://www.businessweek.com/technology/content/jul2004/tc2004072_3482_tc119.htm.

channels. The result is that devices will not use spectrum that is really usable which can cause a decrease in capacity, slow traffic rates or both.[27]

Dependency on a control channel also could frustrate deployment of wireless broadband networks in locations where no control channel is available. In remote locations already alluded to above – e.g., the Alaskan bush country and isolated Native American communities – one cannot presuppose the existence of an Internet service provider (or other commercial venture) that would have the wherewithal to find a control channel and bring it online. Perversely, then, the proposed control channel requirement could preclude use of vacant channels right where those channels are the most prevalent and where the need for affordable broadband capability is the most significant.[28]

C. Cognitive Radio/Spectrum Sensing

Microsoft believes there is a better approach – one that will not frustrate the development of mesh networks and one that could be utilized by other deployments as well. In paragraph 28 of the NPRM, the Commission seeks comments and suggestions on "whether we should permit fixed/access devices to use a spectrum sensing approach, as an alternative to the geo-location approach described above."[29] This approach may be

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[27] This false spectrum unavailability message could be particularly harmful to mesh devices as they devote capacity to both a communication and a routing function.

[28] The Commission also seeks comment on how often control signals should be updated and transmitted to reflect changes in TV station operations due to the DTV transition and new stations coming on line. As Intel noted, "The TV bands at issue in this proceeding are a primary service that has been analyzed and characterized for half a century of operation." *See* Reply Comment of Intel Corporation, ET Docket No. 02-380 at 19. This means there is never a lack of up-to-the minute data available. With reliable data and a relatively static broadcast environment, avoiding co-channel operation with a known television broadcast environment is a relatively simply task (as compared, for example, to avoiding a stealthy frequency-hopping radar). To the extent control signals are used, Microsoft believes that a daily update of control signal information would be perfectly adequate.

[29] NPRM at ¶28.

the *best* and most effective of the three the Commission suggests for *both* fixed/access devices and for personal/portable devices as well.

Spectrum sensing is already a reality. In the 5 GHz bands, new unlicensed devices, using a technique called dynamic frequency selection (DFS), will be required to determine when radar is operating on a particular channel and then avoid that channel. These devices will be required to accomplish this channel avoidance under conditions of spectrum use that will be far more dynamic and challenging than anything that will ever occur in the TV bands. DFS could be incorporated into devices operating in TV bands to avoid occupied TV channels regardless of their location.[30]

Even as this proceeding unfolds, manufacturers are testing and may be deploying DFS functionality to avoid channels occupied by radar in the 5 GHz band. The 5 GHz experience reveals that the basic techniques for implementing channel avoidance in low cost devices are available. Essentially, manufacturers would program an unlicensed TV band device to operate only on vacant channels by incorporating sensing capabilities to detect TV signals in its area of operation. Devices would contain an antenna and a receiver capable of detecting signals down to a given threshold level to determine if a particular TV channel is occupied. If no signal were detected above threshold, the channel would be considered vacant.[31]

The Commission has expressed a concern about spectrum-sensing techniques because a situation might arise where an unlicensed device is shielded from a TV transmitter but is still within range of television receivers. The Commission fears the

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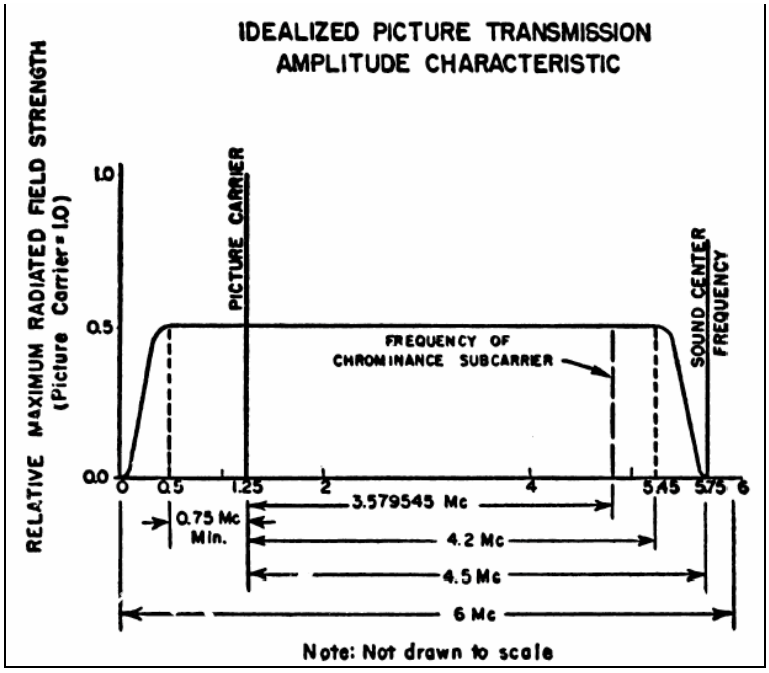
[30] In fact, identifying a TV signal is a lot easier than detecting a military radar signal.

[31] This functionality could be extended to include the ability to move off of a channel should an authorized TV operation suddenly commence service on that channel (e.g., if a station receives temporary authority to operate on a previously vacant frequency or from a different location).

unlicensed device will not sense that the channel is occupied and, thus, may begin operating and interfere with nearby television receivers.[32] But this "hidden-node" problem is solvable. The spectral features of a television signal can be used to mitigate the problem. Figure 1, below, shows an analog TV signal. The picture carrier, located 1.25 MHz above the lower edge of the channel, has significantly higher amplitude then any other component of the signal. The sound carrier, located 5.75 MHz above the lower edge of the channel, has the next highest amplitude. Either of these signals can be readily detected (and thus avoided) even when the analog TV signal is well below threshold.

Figure 1 – NTSC Spectrum[33]



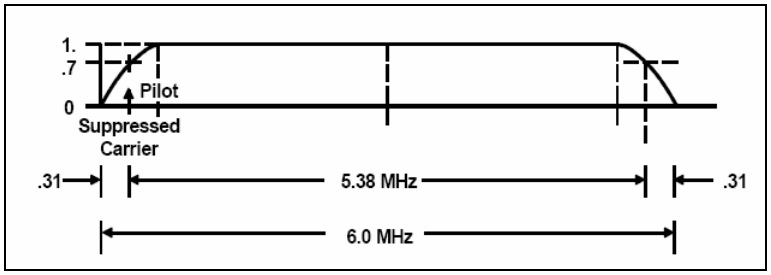
The same approach, though slightly more difficult, can also work with DTV signals. The DTV signal is illustrated in Figure 2, below. It is flat with the exception of

[32] NPRM at fn. 34.

[33] 47 C.F.R 73.699 Figure 5.

the pilot carrier located 0.31 MHz above the lower edge of the channel with power -11.3 dB relative to the average total signal power. The signal to noise ratio (S/N) at threshold is 14.9 dB. Thus, if the DTV receiver is able to recover the signal, the pilot S/N in the 6 MHz channel bandwidth must be at least 3.6 dB. This is equivalent to a pilot carrier to noise density ratio of 71.4 dB-Hz. So, in a 1 kHz bandwidth, the pilot S/N is 41.4 dB. Even if a hidden node situation resulted in 35 dB of blockage, it would still be easy for the sensing receiver to detect the pilot and declare the channel occupied.

Figure 2 - DTV Spectrum[34]



In sum, Microsoft believes that the Commission can – as it tentatively concludes – rely on new methods for avoiding interference, and that it can do so with respect to both fixed/access devices and personal/portable devices. The Commission need not feel compelled to overload licensed-exempt designers by requiring them to integrate an array of interference avoidance techniques into what are supposed to be low-cost devices. Indeed, doing so could undermine the entire purpose of this proceeding. Instead, if the Commission takes a hard look at the operational nature and power levels of broadband devices that would use television spectrum -- and also the operational nature of the television service (where frequency use is fairly static and protected service areas well known) it will find there are a variety of

[34] ATSC Standard: Digital Television Standard (A/53), Revision C Including Amendment No. 1; 13 July 2004.

techniques available to protect the television spectrum. The Commission's goal should be to adopt the least costly interference avoidance techniques necessary to protect television operations.

D. Additional Spectrum Sharing Techniques

The Commission notes that unlicensed devices operating pursuant to Part 15 of its rules receive no protection from other unlicensed devices. It seeks comment on whether voluntary standards to support sharing among unlicensed devices are needed.[35] Microsoft strongly believes such standards hold value not only for easing sharing among unlicensed devices, but also because techniques embodied in a voluntary standard can facilitate interference avoidance.

Although unlicensed devices are expected to endure interference from other devices, there is a logical limit to this expectation. Obviously, incessant interference can render the device effectively inoperative. Industry's challenge, and one we believe the Commission should engage in, is to prevent this possibility. It would be a true public policy tragedy if the vacant TV channels suffered from the proverbial tragedy of the commons; if the highly useful spectrum the Commission proposes to re-purpose in this proceeding were rendered "junk spectrum" by excessive operation of "impolite" devices. Pro-active use of spectrum sharing rules would stave off this possibility.

It is important to consider this potential problem in advance – before it is experienced broadly in the marketplace. Once the tragedy is upon us, further deployment of unlicensed broadband devices will be stymied both by actual, dissatisfying user experiences and by publicity that the hoped-for benefits of the new devices are not there.

[35] NPRM at ¶47.

DFS, now used to avoid radar operations, was designed as part of the 802.11 standard to ease sharing among unlicensed devices. But other techniques have been developed and are being improved upon. For instance, device manufacturers could cluster their choice of operating frequency so that narrowband operations are separated from broadband operations; devices might observe a common power spectral density limit (i.e., less time in the air would mean more power); devices could employ listen-before-talk techniques; and/or the maximum time a station can transmit or otherwise occupy the medium could be limited.

Moreover, these techniques would be particularly useful in the TV bands, with their superior propagation characteristics – since any single unlicensed device is more likely to be within the area of operation of other unlicensed devices than would be the case at higher frequencies.[36] Microsoft also suggests that the Commission consider a regime in which devices implementing spectrum-sharing techniques are allowed to operate at higher power. Not only would this encourage the use of spectrum sharing techniques, but the higher the power of a device the greater the usefulness of incorporating spectrum-sharing techniques in that device.[37] If the Commission is ever again to encourage the use of spectrum-sharing techniques among unlicensed devices, this is the spectrum in which it should do so.

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[36] Assuming, of course, that deployment is held constant.

[37] The Commission has asked in a number of proceedings whether it should mandate "spectrum etiquette" rules to promote greater unlicensed device co-existence. Microsoft has long supported such spectrum-sharing techniques. But even mentioning such techniques have caused some members of industry to cringe. Microsoft believes, however, that if done correctly, spectrum-sharing rules can be successfully implemented. They need be neither stale nor inflexible.

IV. THE COMMISSION SHOULD CONSIDER EXPANDING THE CHANNELS PERMISSIBLE FOR UNLICENSED USE

The Commission says it wants to "allow unlicensed devices to access the largest practicable number of the 68 television channels."[38] Microsoft applauds this goal. But the Commission then goes on to exclude channels 2-4, channels 14-20 in areas where land mobile operations are permitted, channel 37 and channels 52-69 from possible unlicensed use. Microsoft understands that researchers use channel 37 for sensitive radio astronomy operations, and that the Commission has recently reallocated channels 52-69 from television broadcasting to other services. But Microsoft believes the exclusion of channels 2-4 and 14-20 is unnecessary.

A. Channels 2-4

The Commission observes that channels 2-4 are used for – or are adjacent to – output channels used for TV interface devices such as VCRs, DVDs and satellite terminal devices.[39] Due to the fear that unlicensed devices operating on channels 2-4 may cause interference to TV interface devices, the Commission proposes to prohibit unlicensed operation on these channels.[40]

This is an overly conservative proposal. TV interface devices are usually connected to TV receivers by coax cable; typically providing 60 dB of interference rejection. For an unlicensed device to interfere with these TV interface devices, a user would have to place the device virtually on top of the TV receiver. Consumers are familiar with, and know how to resolve, this type of "obvious cause and effect" interference. For example, just about everyone with 2.4 GHz cordless phones and a 2.4

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38 NPRM at ¶33.

39 NPRM at ¶34.

40 Id.

GHz Wi-Fi setup has learned that if the two systems are operated close to one another, interference occurs. The solution, of course, is to increase the separation between the systems.[41] Similarly, if interference between a TV band license exempt device and a TV interface device were to occur, consumers will quickly figure out (or could be instructed) to take mitigation measures such as moving the unlicensed device away from the television receiver or even buying more heavily shielded video cables. Consequently, Microsoft believes that unlicensed devices can use channels 2-4 without adversely affecting TV interface devices.

B. Channels 14-20

In 13 metropolitan areas, channels in the range 14 through 20 are used by the public land mobile radio service (PLMRS) and the commercial mobile radio service (CMRS). The Commission notes that PLMRS and CMRS base stations are assigned within 80 km of the center of the cities and mobile units may be operated up to 48 km away from associated base stations. Thus, in the 13 metropolitan areas where this use is allowed, mobile stations may be operating up to 128 km from the city centers.[42]

The Commission proposes to apply to unlicensed devices the same criteria it applies for protecting land mobile operations from potential LPTV interference. Thus, unlicensed TV band devices would be prohibited from operating within 134 km or 131 km from the city center coordinates – on a co-channel and adjacent channel basis respectively, of the metropolitan areas where PLMRS/CMRS services operate.[43] This proposal would give PLMRS and CMRS operations the same level of protection they

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41 In addition, just about every 2.4 GHz Wi-Fi manual warns of this potential for interference and provides possible mitigation measures.

42 NPRM at ¶36.

43 Id.

currently enjoy from LPTV. However, given the low duty cycle nature and comparatively low power levels of likely unlicensed services in these bands compared to the often 100% duty cycle of LPTV, this too seems unduly conservative and constraining.

V. OTHER ISSUES

The Commission raises a number of other issues in the NPRM the resolution of which will allow it to proceed with making vacant TV channels available for unlicensed broadband use. Specifically, the Commission inquires about RF exposure matters,[44] the protection of wireless microphone operations,[45] out of band emission limits[46] and unlicensed use in border areas.[47] While we address each of these in sequence, we are most concerned that the Commission not adopt overly restrictive out of band emission limits. Such limits could undermine the overall goal of this proceeding.

A. Routine Evaluation for RF Exposure

The Commission proposes to permit fixed/access unlicensed devices to operate at up to 4 watts EIRP.[48] Though the Commission states its belief that the power and antenna rules it proposes to adopt will resolve RF safety concerns, it nevertheless seeks comment on whether TV band unlicensed devices should be subject to routine evaluation for RF exposure.[49] Microsoft believes these devices should be exempt from routine evaluation for RF exposure.

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44 NPRM at ¶25.

45 NPRM at ¶38.

46 NPRM at ¶39.

47 NPRM at ¶46.

48 NPRM at ¶25. Essentially, the Commission proposes to apply the technical provisions of 47 C.F.R. §15.247.

49 *See* 47 C.F.R. §§1.1307(b) and 2.1091.

The Commission has devised two categories of environmental situations to evaluate potential RF exposure hazards and set RF exposure limits — an occupational controlled environment and a public/uncontrolled environment. The occupational/controlled limits apply in situations where people are exposed to RF radiation as a consequence of their employment and are fully aware of the potential for exposure and can exercise measures to limit their exposure. The public/uncontrolled limits apply in situations where the general public may be exposed to RF radiation, or in employment situations where employees may not be fully aware of the potential for RF exposure or where they cannot exercise control over it. For each environment the Commission has set maximum permissible exposure (MPE) limits.[50]

The maximum permissible exposure (MPE) limits for the TV channels proposed for unlicensed devices are shown in Table 3.

Table 3 - Maximum Permissible Exposure Limits

		Occupational / Controlled		**Public / Uncontrolled**	
Channels	Frequency (MHz)	Power Density (mW/cm^2)	Averaging Time (min)	Power Density (mW/cm^2)	Averaging Time (min)
5 – 6	76 – 88	1	6	0.2	30
7 – 13	174 – 216	1	6	0.2	30
14 – 36	470 – 608	f/300	6	f/1500	30
38 – 51	614 – 698	f/300	6	f/1500	30

The Tell cylindrical model[51] gives the average power density near a vertical dipole antenna as:

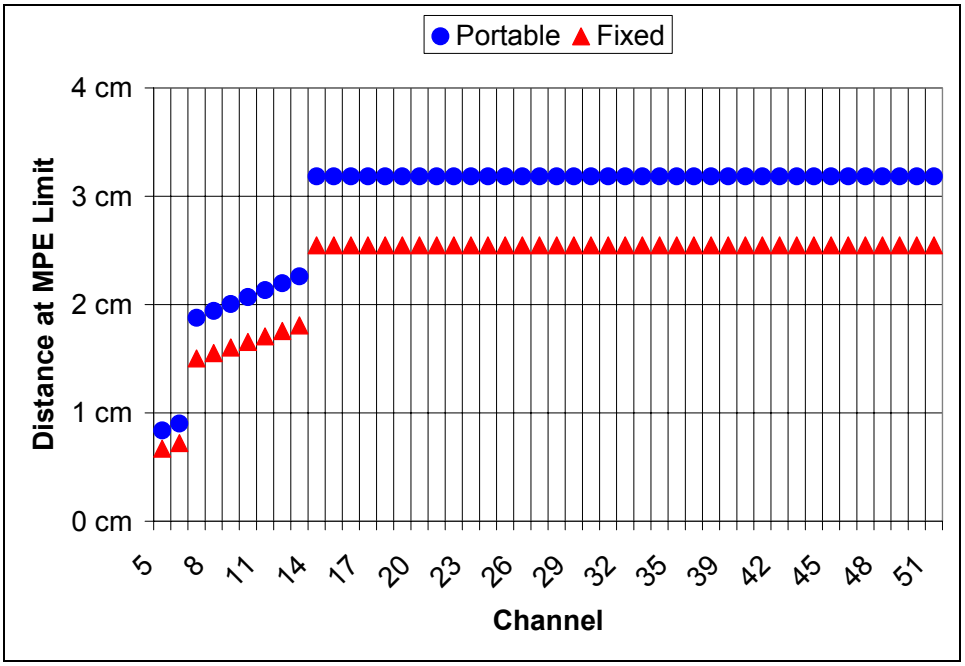
$S(mW/cm^2) = P / [2\pi \times d \times h]$

where: P is the transmit power (mW)
d is the distance from the antenna (cm)
h is the antenna length (cm).

[50] *See* 47 C.F.R. §1.1310.

[51] *See* Tell, R.A., "Engineering Services for Measurement and Analysis of Radiofrequency (RF) Fields," Richard Tell Associates, Inc., Las Vegas, NV (1995).

Figure 3 shows the distance from the antenna at which the power density drops below the MPE limit for each of the TV channels for each of the two cases. The first case, "Portable," is for public/uncontrolled exposure from a device with 100 mW transmit power and a λ/4 vertical antenna.[52] To reach the MPE limit, an individual would have to remain within 1 inch (7 inches for a high power device) of the device antenna when the device is operating at full power and 100% duty cycle for a period of 30 minutes. The likelihood of this happening in the real world approaches zero.[53]



• **Figure 3 - Distance at MPE Power Density Limit**

The second case, "Fixed," is for RF exposure from a device with 1 W transmit power and a 5λ/8 vertical antenna in an occupational/controlled environment. Fixed devices will typically be tower or roof mounted, so using occupational/controlled MPE

[52] Portable devices will be used in home and office environments, so the pubic/uncontrolled MPE limits are appropriate.

[53] Wholly apart of the inability of anyone over six years of age to hover two inches from a piece of electronic equipment for 30 minutes without moving, unlicensed broadband devices do not operate anywhere near 100% duty cycle.

limits is appropriate. To reach the MPE limit, an individual would have to remain within one inch (six inches for a high power device) of the antenna of a device operating at maximum transmit power and at 100% duty cycle for a period of 6 minutes. Again, this is not likely to happen in the real world.

The Commission routinely exempts mobile devices[54] in bands below 1.5 GHz that radiate less than 1.76 dBW ERP (3.9 dBW EIRP) from environmental evaluation for RF exposure.[55] Under the Commission's proposals, portable unlicensed TV band devices are limited to 0.6 dBW EIRP (3.6 dBW EIRP for a hypothetical high power device). Currently, the Commission does not require environmental evaluation for RF exposure for TV band devices (that operate pursuant to Part 74 of the Commission's rules) that operate with less than 100 W ERP (102 W EIRP).[56] Under the Commission's proposals, fixed unlicensed TV band devices are limited to 6 W EIRP (36 W EIRP for a hypothetical high power device). For both the portable and fixed devices, and even for hypothetical "high-power" devices, it is most unlikely that anyone will ever receive RF exposure above the MPE limits. Further, in all cases unlicensed TV band devices radiate well below the limits at which the Commission routinely exempts devices from RF exposure evaluation. Consequently, there is no safety reason for requiring routine evaluation for RF exposure for unlicensed TV band devices.

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54 Mobile devices are those for use in situations where a separation distance of at least 20 centimeters (7.9 inches) is normally maintained between the transmitter's radiating structure(s) and the body of the user or nearby persons. *See* 47 C.F.R. §2.1091(b).

55 *See* 47 C.F.R §2.1091(c).

56 *See* 47 CFR §1.1307.

B. Wireless Microphone Operations

The Commission states that the operational characteristics of wireless microphone operations are such that the likelihood of interference is minimal.[57] Nevertheless, it seeks comment on whether measures are needed to protect wireless microphone operations, including setting aside channels in each market for their use. Microsoft does not believe such significant measures are necessary for protecting wireless microphones.

First, wireless microphones are permitted relatively high output power (50 mW in the VHF band and 250 mW in the UHF band), particularly in light of the range over which they typically operate (hundreds of feet at the most). This results in a significant signal margin at the wireless microphone receiver. Second, the vast majority of wireless microphones use FM modulation. FM receivers exhibit a "capture effect" in which they respond to only the strongest signal received on the frequency to which the operator tunes the receiver while simultaneously rejecting any weaker interfering signals. Third, wireless microphones are narrowband – limited to 200-kHz operating bandwidth - so they only "see" a small fraction (3%) of the power from a 6-MHz wide unlicensed emission. Consequently, the likelihood of interference from unlicensed device signals is so low that interference mitigation measures are unnecessary.

C. Out of Band Emission Limits

The Commission proposes to require unlicensed devices operating in television spectrum to comply with the out-of-band emission ("OOB") limits that apply to other Part 15 digital modulation devices.[58] It reasons that since it is proposing power and

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[57] NPRM at ¶38.

[58] *See* 47 C.F.R. §15.247(c).

antenna limits for unlicensed TV band devices that are similar to those for current Part 15 digital modulation devices, it should adopt the same OOB emissions rules that apply to those devices. Microsoft agrees fully with this reasoning.

Unfortunately, the proposed rule the Commission has developed yields a different and unacceptable result. The Commission proposes the following rule:

> [I]n any 100 kHz bandwidth outside the frequency band in which the device is operating, the RF power must be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of desired power. Attenuation below the general limits specified in 15.209(a) is not required. Radiated emissions that fall outside the TV broadcast channel(s) where the device operates must comply with the radiated emission limits specified in 15.209(a)."[59]

This proposal, in fact, differs significantly from the existing rule governing Part 15 digital modulation devices – *and applying the Section 15.209(a) out-of-band limits as proposed in the last sentence could eliminate the possibility of using the TV spectrum for broadband services.*

First, the proposed rule appears to be self-contradictory and differs from the existing Part 15 rules. The first part of the proposed rule suggests that outside of its occupied channel the device must attenuate its highest 100 kHz bandwidth power level by 20 dB. This is consistent with the current out-of-band emission rule for Part 15 digital transmission devices. But the last part of the proposed rule appears to require devices to meet the Section 15.209(a) OOB limits – even for out-of-band emissions that occur within the TV bands. This part of the proposed rule constitutes a significant departure from the existing rule it purportedly proposes to emulate.[60]

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[59] NPRM at Appendix B, Section 15.244(d).

[60] "We propose to require that unlicensed devices operating in TV bands comply with the *same* out-of-band emission limits that apply to other Part 15 digital transmission system transmitters." (*emphasis added*) NPRM at ¶39.

Second, to comply with the 15.209(a) limits within available (for unlicensed device use) TV bands, the device's transmit signal would have to be reduced outside the channels where the device operates by: 91 dB across channels 5 and 6; 88 dB across channels 7 through 13; and 85 dB across the available UHF channels. This degree of attenuation would limit the effective, useable bandwidth of the occupied channel so dramatically that broadband services would be unsustainable. That is because to comply with such strict OOB limits, the signal roll-off must be so steep that too little of the 6 MHz active channel would be available for service. Microsoft suggests the Commission simply adopt the essence of its own proposal to *"require that unlicensed devices operating in TV bands comply with the same out-of-band emission limits that apply to other Part 15 digital transmission system transmitters*" by adopting the following rule text based on Section 15.247 (c):[61]

> In any 100 kHz bandwidth outside the frequency band in which the device is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement. Attenuation below the general limits specified in §15.209(a) is not required. Radiated emissions that fall in the restricted bands as defined in §15.205(a) shall comply with the radiated emission limits specified in §15.209(a).

This rule both would protect adjacent channel broadcast operations and allow the use of vacant TV channels for broadband service.

D. Unlicensed Use in Border Areas

Consistent with border exclusion zones agreements for low power television (LPTV) assignments, the Commission proposes that unlicensed fixed/access TV band

[61] In practice to limit self-interference devices may employ an RF SAW filter to reduce transmit power by about 50 dB in immediately adjacent frequencies and transmit power control ("TPC") to limit transmit power to that which is actually needed. Combined, these techniques would result in adjacent channel OOB emission characteristics more benign than those permitted by the current digital transmission OOB rule (Section 15.247(c) and (d)) and will fully protect adjacent channel broadcast operations.

devices be prohibited from operating within 32 km of the Mexican border for VHF channels, and within 40 km for UHF channels. It also proposes that these devices be prohibited from operating within 60 km of the Canadian border.[62] It seeks comment on methods to ensure that unlicensed TV band devices do not operate within these border areas.

Microsoft believes the Commission's proposed approach to border issues is needlessly traditional and overly cautious. This approach treats unlicensed devices as if they were broadcast stations. But, of course, they are not and there is no reason to treat them similarly. First, unlicensed devices and television stations operate at enormously disparate power levels. Second, the unlicensed device-to-television system interference mechanism is different than the television-to-television interference mechanism – so even if exclusion zones for unlicensed devices were appropriate, the use of the exclusion zones designed for broadcast stations is not. Third, and most importantly, whatever mix of technical and operational constraints are adopted for unlicensed devices transmitting on vacant U.S. television channels can easily be adapted to protect Canadian and Mexican stations as well. No exclusions zones are required.

CONCLUSION

The Commission's proposal to allow unlicensed devices to operate in vacant television channels has the potential to alter dramatically the provision of broadband service in this country. If this proposal is adopted with the right technical and operational rules, it could jump-start the provision of both fixed and nomadic wireless broadband services – both for commercial and public safety purposes. It could help make real the

[62] NPRM at ¶46.

promise of ubiquitous broadband, and unleash a new round of innovation in broadband technology and services.

Respectfully Submitted,

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