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I. INTRODUCTION

I am Kevin Kahn, Intel Senior Fellow and Director of Intel's Communications Technology Laboratory. In my current position, I manage a research and development lab that explores future technologies in optics as well as wired and wireless communications. During my 29 years at Intel, I have worked in a variety of areas including software design, processor and systems architecture, and data communications. Intel Fellows, our company's highest technical position, provide strategic technical guidance to the company. Therefore, I have been deeply involved in the development of Intel's technology policy positions in broadband and wireless communications. I have also served on advisory committees and panels at the Federal Communications Commission, the National Science Foundation, and the National Academy of Sciences.

It is an honor to appear before this Committee to testify on wireless issues and spectrum management reform, including the deployment of unlicensed wireless services.

II. NEED FOR SPECTRUM REFORM

All wireless technologies require radio spectrum. And, as innovative technologies are developed by companies like Intel, their success in the marketplace ultimately depends upon appropriate and sufficient radio spectrum being made available by government regulations. Thus, as demand grows for an established standard, such as Wi-Fi (IEEE 802.11), or as new standards based around new technology are readied for the marketplace, such as WiMAX (IEEE 802.16), regulations need to change to allow their use and broad acceptance. Standards provide international interoperability and the opportunity to achieve economies of scale and scope, but none of this is possible without the necessary spectrum.

Unfortunately, traditional means of spectrum management are inefficient and have resulted in large portions of our radio spectrum being allocated to specific technologies and services. The result is that today there is not sufficient room for new usage.

A. ARTIFICIAL SCARCITY

Indeed, spectrum is artificially scarce because under the current regulatory structure – which is primarily based on an outdated system of "command and control" spectrum management – much of our radio spectrum is locked into old uses and old technologies. More importantly, this antiquated spectrum management regime locks out new uses and technologies. As a consequence, available spectrum for new wireless technologies is artificially scarce and very expensive – a problem, which in recent years, has only become more severe.

The FCC, NTIA, and Congress are to be commended for their efforts at spectrum management reform to date including authorization of innovative technologies such as UWB, software defined radios, and cognitive radios; making more radio spectrum available for wireless technologies such as WiMAX, 3G, and Wi-Fi at 2 GHz, 5 GHz, and 70/80/90 GHz; and efforts to free up critical spectrum below 1GHz via the DTV legislation and the proposed TV "white spaces" rules and legislation.

These efforts recognize that, as innovation continuously advances, so must our approach to radio spectrum. Indeed, our national policy needs to advance so as not to suppress market forces. As the Technology CEO Council (or TCC) – the information technology industry's public policy advocacy organization comprising CEOs from Applied Materials, Dell, EMC, Hewlett-Packard, IBM, Intel, Motorola, NCR, and Unisys – states in its February 2006 paper "Freeing Our Unused Spectrum: Toward a 21st Century Telecom Policy":

> How we address and manage spectrum scarcity is one of the most important public policy challenges our country faces as we move deeper into the 21st century. Efficient spectrum policy can drive technological innovation and productivity and, thus, our entire economy. Indeed, if our nation manages its spectrum resources well, it will have a competitive advantage in the global market that will benefit all our citizens …"[1]

B. SPECTRUM REFORMS

For these reasons, Intel supports policies that maximize spectrum efficiency and reduce artificial spectrum scarcity. Widespread adoption of market-based spectrum policies will allow carriers and manufacturers to make market-driven deals to deploy WiMAX and other efficient new technologies.

1. TCC Recommendations

To this end, Intel believes that the solution to the current lack of spectrum for wireless and other technologies lies in the adoption of certain fundamental reforms – many of

[1] Technology CEO Council, "Freeing Our Unused Spectrum: Toward a 21st Century Telecom Policy," Feb. 2006, at 2 (available online at http://www.techceocouncil.org/index.php?option=content&task=view&id=248) ("TCC Paper").

which are set forth in the TCC paper as "recommendations" for maximizing our nation's spectrum efficiency and wireless potential. Among the TCC recommendations are the following:

(i) Undertake spectrum inventories to identify inefficient spectrum use. And then transfer underutilized federal government spectrum to commercial use or sharing such spectrum with commercial users.

(ii) Allow more flexibility within licensed use. (Licensed use refers to technology, such as TV and cellular, for which users must have an FCC license before using the spectrum to transmit a signal.) Licensed use is preferable in congested areas to assure quality of service and promote investment. Enabling flexible licenses that permit assignment, lease, or transfer of spectrum rights, as well as negotiation of interference rights, leads to increased innovation and spectrum efficiency.

(iii) Give the FCC explicit authority to use certain market-based auction mechanisms, and reform the FCC's auction procedures. The FCC should be encouraged to use combinatorial or package bidding to facilitate optimal combinations of spectrum rights. The FCC also should consider whether market-based mechanisms, such as "two-sided auctions" and the use of "auction vouchers,"[2] could be adopted to encourage more efficient spectrum use. These mechanisms encourage users to transfer underutilized spectrum to those who can provide more valuable services.

(iv) Allow more unlicensed use in rural areas and where otherwise appropriate. (Unlicensed use refers to technology, such as Wi-Fi radios, for which manufacturers must have their devices certified by the FCC before deploying, but do not require users to have a license to use the spectrum.) As we have seen with Wi-Fi, permitting more unlicensed use spurs technological innovation and enables viral growth of new technologies.

All of these reforms are critical to 21st century spectrum management and innovation.

2. Flexible Licensed Use

Flexible licensed use means allowing existing licensees to use their spectrum in ways that utilize new technology without having to go back to the government to get permission for each new innovation. A standard requirement is that the new technology does not cause harmful interfere to existing licensed users, either by causing co-channel interference

[2] In two-sided auctions, spectrum voluntarily offered by incumbents is auctioned together with any unassigned spectrum. Bidders can efficiently aggregate spectrum that is currently highly fragmented by making all-or-nothing bids on packages of assigned and unassigned licenses. In voucher auctions, incumbents are given auction vouchers in exchange for turning back their licenses. The value of vouchers is determined in an auction of the returned spectrum and unassigned spectrum held by the government.

(interfering with others on the same frequency) or adjacent channel interference (interfering with others on different frequencies).

One example of allowing more flexible licensed use was in the FCC "wireless cable" proceeding. This proceeding dealt with spectrum in the 2.5 GHz range, which is adjacent to Wi-Fi. Licensees who were using their spectrum for one-way video broadcasting were permitted to use their spectrum for much higher-valued wireless broadband applications such as WiMAX. In congested urban areas, such licensed services may be the best way to proceed in order to encourage deployment, ensure optimal quality of service, and manage interference. WiMAX can be used to distribute signals to Wi-Fi hotspots or it can be used as a longer-reach fixed service. A desktop box with an antenna can become a digital subscriber line (DSL) alternative. WiMAX has enormous potential for benefiting consumers, but it cannot fulfill that potential without spectrum reforms.

Intel has similarly encouraged the FCC to allocate the 3650-3700 MHz band in a manner which would provide access to this spectrum for rural WISPs and promote efficient use of this spectrum in congested Metropolitan Service Areas (MSAs). Specifically, Intel has supported a compromise proposal whereby the FCC would prescribe non-exclusive licensed use in rural areas, and licensed use in the Top 50 MSAs – where exclusive use is necessary to promote investment and quality of service for long range services in congested areas.

3. Unlicensed Use

Allowing more unlicensed use is readily achievable through the exploitation of new technologies that enable unlicensed users to operate in the same spectrum as licensed users of traditional radio technology – without causing harmful interference to those users. Importantly, in May 2004, the FCC initiated the so-called "Vacant TV Channels" proceeding, in which it proposed to allow cognitive radios to overlay channels 2-51 of the TV spectrum. Cognitive radios can discern spectrum use at their location and modify their frequency and power to operate only in spectrum that is "vacant" at any given time.[3]

Intel filed Comments and Reply Comments in the FCC's "Vacant TV Channels" proceeding in November 2004 and January 2005, respectively.[4] Intel's filings strongly supported the Commission's proposal to permit operation by new unlicensed wireless devices in the TV "white spaces" – primarily in channels 21 through 51. We continue to work with the FCC to advance this proceeding.

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[3] TCC Paper at 5. Because spectrum use varies by time and location, cognitive radios can use vacant spectrum only temporarily and do so without interference to others, maximizing the number of users and services accessing given frequencies.

[4] Comments of Intel Corporation, *In the Matter of Unlicensed Operation in the TV Broadcast Bands; Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band*, ET Docket Nos. 04-186, 02-380, Nov. 30, 2004; Reply Comments of Intel Corporation, *In the Matter of Unlicensed Operation in the TV Broadcast Bands; Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band*, ET Docket Nos. 04-186, 02-380, Jan. 31, 2005.

In the meantime, Members of this Committee are seeking to expedite this process. In this regard, Intel commends Chairman Stevens and Senators Allen, Sununu, Kerry, Boxer, and Dorgan for sponsoring the "American Broadband for Communities Act" (ABC Act),[5] and the "Wireless Innovation Act of 2006" (WINN Act),[6] respectively. Intel also applauds Senator Smith's support of legislation directing the FCC to allow unlicensed use of the TV "white spaces."[7] The ABC Act and the WINN Act recognize the vast untapped potential of the TV "white spaces." Intel stands ready to work with the bills' sponsors and other members of this Committee and the Congress to move forward on this important issue. Given the timeliness of these bills and their importance to our country, I will devote the remainder of my testimony to detailed consideration of the most important issues in the TV "white spaces" debate.

III. TV "WHITE SPACES"

Requiring the FCC to make the TV "white spaces" available for unlicensed use – as contemplated by the ABC Act and the WINN Act – would be a big step forward in maximizing our nation's spectrum efficiency.

A. SIGNIFICANT "WHITE SPACE"

At almost any location in the U.S., many channels in the TV bands are not being used by licensed services. For example, Intel's internal analysis estimates that there is a *minimum* of 24 MHz of "white space" in channels 21-51, throughout the New York City TV market – the most congested market in the country.[8] In areas with fewer TV stations like Honolulu, Hawaii and Charleston, West Virginia, Intel estimates that there is a *minimum* of 114 and 126 MHz of "white space" in channels 21-51, respectively, throughout the TV market. And, in areas like Anchorage, Alaska and Billings, Montana, Intel estimates that there is a *minimum* of 156 and 174 MHz of "white space" in channels 21-51, respectively, throughout the TV market. These "white spaces" represent a significant amount of spectrum that could be easily detected and utilized by cognitive radios for a variety of valuable new wireless applications – thereby providing substantial consumer benefits.

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[5] S. 2332, "American Broadband for Communities Act," introduced on Feb. 17, 2006, by Chairman Ted Stevens (R-AK), 109th Congress, 2nd Session.

[6] S. 2327, "Wireless Innovation Act of 2006," introduced on Feb. 17, 2006, by Sens. George Allen (R-VA), John E. Sununu (R-NH), John F. Kerry (D-MA), and Barbara Boxer (D-CA), 109th Congress, 2nd Session.

[7] Remarks of Senator Gordon H. Smith (R-OR), before the American Electronics Association, Cyber Series Luncheon, Washington, DC, Feb. 8, 2006.

[8] Intel estimates that there is an average of 48 MHz of "white space" throughout the New York City TV market (DMA).

B. SUBSTANTIAL CONSUMER BENEFITS

Indeed, the TV "white spaces" could be used to provide significant benefits to consumers.

1. Rural Broadband

For example, this spectrum could offer enormous advantages for wide area wireless broadband services such as WiMAX in rural and other underserved areas. The highly favorable propagation characteristics of the TV spectrum – including the ability to pass through buildings, weather, and foliage – make transmission less dependent on line of sight and better for low-cost deployment in rural and bad weather areas. Compared to the 2.5 GHz frequencies – a likely alternative spectrum band for wireless broadband – the TV spectrum requires fewer antennas and uses less power for a given level of service quality to a given coverage area.

Given its propagation characteristics, the TV "white spaces" could be particularly useful in rural areas. In contrast, we estimate that the 2.5 GHz frequencies would require approximately four times as many base stations to achieve equal geographic area coverage, for a given air interface and bandwidth. The upshot is that opening the TV "white spaces" to unlicensed wireless broadband use could dramatically accelerate broadband deployment in this country. Indeed, the TV "white spaces" could be used to provide better broadband service or a first broadband service in many rural areas.

2. Cutting-Edge Consumer Applications

The TV "white spaces" could also be used to provide new, cutting-edge consumer applications that take advantage of this spectrum's improved signal reliability and range. Wireless local area networks using low power and battery operated devices could enable new capabilities that bring safety, convenience, and comfort to consumers in their homes and workplaces. For example, such devices could provide improved energy efficiency through intelligent home automation and power monitoring; home security with robust low power wireless video feeds; and other interesting new home entertainment applications. For example, companies such as Dell Inc. are considering some interesting applications for data and video distribution within the home.

3. Public Safety Uses

Additionally, in emergencies, the TV "white spaces" could be used to provide auxiliary services to augment public safety communications on licensed networks. For example, rescue efforts could be enhanced by placing remote video cameras at a disaster site to relay images to a command center; or using portable "helmet cams" to provide real-time, point-of-view command/control information.

C. NO HARMFUL INTERFERENCE

All of these innovative unlicensed applications are possible without causing harmful interference to authorized users. Indeed, Intel filed detailed technical analyses with its FCC Comments and Reply Comments demonstrating that unlicensed use of the TV "white spaces" is both achievable and practical. These analyses clearly refute the misleading and incorrect claims made by TV licensees that unlicensed use will interfere with their operations.

Furthermore, as both the ABC Act and the WINN Act contemplate, before any new unlicensed devices could be deployed in the TV "white spaces," they would have to go through the FCC's rigorous certification process – a process that has been used for years to authorize new devices in this country. Pursuant to the certification process, the device manufacturer will have to demonstrate that the device meets the technical requirements for unlicensed devices to operate in the TV "white spaces." These technical requirements, including interference criteria, are set forth by the FCC's Office of Engineering and Technology. No new device could be deployed without first complying with the FCC's certification process.

1. TV Reception

Permitting new unlicensed wireless devices to share the TV bands would not cause harmful interference to TV reception. To begin, the potential for harmful interference to TV reception by high power "fixed/access" services such as WiMAX is not a concern. Not only are the locations of TV stations known, but also the unlicensed devices can utilize various mechanisms (*e.g.*, frequency coordination, professional installation, and output power control) to preclude any harmful interference to TV receivers.

Moreover, claims that new unlicensed "personal/portable" devices operating in the TV "white spaces" would cause harmful interference to authorized services from out-of-band emission is misleading. Because radiated emissions outside the channel of operation are unintended and unwanted emissions, these devices are not designed to maximize their emissions level. In fact, the actual radiated level emitted by an unlicensed device will almost always be far below the permitted maximum.

In addition, only approximately 15 percent of U.S. homes rely solely upon an over-the-air TV signal. The majority of these over-the-air viewers live in areas of strong signal strength (where the received signal would easily overcome radiated emissions from other household electronics). The remainder of over-the-air viewers – those located in areas of marginal signal strength – receive their signal using an individual- or MATV-based antenna system, which is far removed from the proposed unlicensed devices (and thus is less likely to be susceptible to harmful interference). Further, tens of millions of TV viewers and their neighbors already operate similar electronic devices, which would cause the same type of supposed harmful interference to TV receivers as the unlicensed devices in question – and, yet, such interference has not been an issue.

For example, numerous devices found in the average American home, such as cordless telephones, Wi-Fi cards, and Bluetooth solutions, are subject to the same levels for unwanted emissions in the TV bands. Operation of these devices has proven to be compatible with TV viewing in American homes for years. Moreover, devices operating in the TV bands, such as common door openers and remote controls, are permitted far higher emissions levels than those allowed under the FCC's proposed rules. Even with these increased emissions levels, the operation of door openers, remote controls, and similar devices does not cause harmful interference to TV reception.

The radiated emissions limits set forth in the FCC's proposed rules for unlicensed operation in the TV "white spaces" already apply to a variety of digital devices, such as personal computers and electronic toys. Operation of these digital devices does not interfere with TV viewing. Furthermore, the limits for these digital devices, as would be found in some office-type environments, have emissions levels that are higher than the level for the proposed unlicensed devices. Even in this environment, both over-the-air and cable- and VCR-connected television receivers operate successfully.

2. Direct Pick Up

Direct pick up (DPU) is the amount of signal a television tuner receives over-the-air, in the absence of an external antenna. The potential for DPU interference in cable-ready television receiving equipment from new unlicensed wireless devices is highly improbable today. In fact, the immunity level for such receiving equipment – *i.e.*, the power level above which interference is perceptible to the viewer – was developed years ago (when TV sets were generally poorly shielded) in order to minimize the effect of interference to cable television (CATV) viewing from over-the-air TV stations.

Indeed, this immunity level was specified more than 20 years ago to accommodate the susceptibility of some older TV set/receiver designs that were prevalent when the rule was written. So-called old school "hot/cold chassis" designs are inherently more susceptible to DPU interference, as the input connection is partially unshielded. The most vulnerable targets for DPU interference are the handful of remaining older TV sets connected to set-top boxes and tuned to channels 3 or 4. However, TV set-top boxes and newer TV receivers do not use the "hot/cold chassis" design; rather, they have fully shielded tuners – which render them nearly invulnerable to DPU interference.

Moreover, local TV stations – the reason for immunity levels – and the new devices in question are quite different in a very important way. Users cannot change the fixed location of licensed high power local TV stations. In contrast, operators of new "personal/ portable" devices can and will reconfigure, relocate, or simply disable their equipment to avoid DPU interference in their CATV receiving equipment (similar to how consumers handle cell phone interference with TV and computer equipment today). Thus, the immunity level requirements are not necessary with respect to "personal/ portable" devices – because any potential for interference is in the user's control – and thus easily avoided.

Also, industry experience demonstrates the extent of the improbability of DPU interference today. Over the past nine years, as DTV stations have commenced operation, approximately 1550 new high power broadcast TV stations have begun transmitting, essentially simultaneously. Yet, reports of DPU interference to CATV viewing equipment from even these new powerful transmitters have been negligible.

3. Cable and Satellite

In addition, allowing new unlicensed wireless devices to share the TV broadcast spectrum would not cause harmful interference to cable or satellite TV service. Indeed, because the CATV signal is typically terminated at both ends, there is no interference to CATV operation using RG-6 cable for distribution throughout the home. (RG-6 cable is the most widely used cable for home installation of cable TV and satellite TV systems.) Interfering signal ingress only occurs when one end of the cable is not connected – an unrealistic scenario.

And where a house has multiple CATV outlets in several rooms and some of the outlets are not used, the unused outlets are typically terminated with screw-in terminators. Even where unused outlets are not terminated in this manner and signal ingress occurs to the unused outlets, such ingress will not cause harmful interference to the outlets that are connected to TV receivers because of the high degree of isolation between outputs. Indeed, most multiple outlets are connected to a CATV feed via directional couplers. These couplers have a high degree of isolation between their "tap" and "output" connections. Furthermore, even where simple hybrid signal splitters are used to connect multiple outlets to a CATV feed, the splitters exhibit high isolation between outputs – and thus does not cause harmful interference to the connected CATV outlets.

Finally, the operation of new unlicensed "personal/portable" devices in the TV bands would not cause harmful interference to DBS systems. The TV bands in question encompass frequencies below 698 MHz, whereas DBS satellite systems use frequencies in the range of 1 GHz to 2.2 GHz on the downlink cable between the DBS Low Noise Block Converter/Feedhorn on the dish antenna and the DBS set-top box. Thus, the proposed unlicensed devices and DBS services use different bands, such that the operation of unlicensed devices in the TV "white spaces" would have no effect on – much less cause possible ingress to – DBS systems.

D. MILITARY AND DEFENSE RADAR

Notably, spectrum sharing similar to that proposed in the TV "white spaces" bills, is already occurring in far more complex scenarios. For example, the 5 GHz band – which is used to transmit classified military and defense radar signals – now shares spectrum with unlicensed 802.11a (Wi-Fi) radio technology. Such radios switch frequencies when the presence of radar is detected, thus continuing operation without causing interference to the classified signals. Recognizing the benefits of wireless broadband networks at 5 GHz, the FCC worked with NTIA, the Defense Department, and the private sector to

allow these sophisticated unlicensed devices to share the 5 GHz band with highly sensitive military and government systems.

This example powerfully demonstrates the public benefits gained when government and commercial spectrum users collaborate to adopt innovative technological approaches to spectrum sharing. Through this collaboration, the private sector was afforded a new unlicensed platform on which to innovate – without interfering with critical military needs. Significantly, the 5 GHz example of spectrum sharing is considerably more challenging than the TV "white spaces" scenario. Indeed, military signals in the 5 GHz band are intended to *not* be detected by other technologies, whereas TV stations are fixed and *easily* detectable by cognitive radios.

IV. CONCLUSION

In sum, Intel, like consumers, wants broadband and other new technologies to become widespread, high quality, and affordable. Over the years, we have consistently supported policies that encouraged wired and wireless broadband investment and competition. We believe that is what will give consumers the broadband and technologies that they want. In that regard, we believe that modernization of the nation's spectrum management system is essential to ensure that the Commission's policies evolve with the consumer-driven evolution of new wireless technologies, devices, and services.

Allowing more flexible licensed use, as well as more unlicensed use (*e.g.*, in the TV "white spaces"), will enable spectrum users and companies like Intel to innovate and respond to market forces without having to go back to the government and get regulations changed to accommodate every new innovation. Spectrum reforms will enable cutting-edge technologies, as well as higher-powered new uses of existing technologies. With a progressive approach to our spectrum policy, we can drive the innovation that keeps the U.S. economy dynamic and competitive.