Intel's Call for Worldwide Spectrum Reform

The revolution in converging computation and communications is poised to bring amazing benefits to consumers worldwide. Intel is the world's largest semiconductor manufacturer and a leader in technical innovation. Since one of Intel's founders first articulated it over 30 years ago, Moore's Law has guided the semiconductor industry. Less well known, Intel is also a leading manufacturer of communications and networking chips. In the future, all computers will communicate and all communications devices will compute. Intel's mission is to drive or to accelerate that convergence through silicon-based integration.

We are at the dawning of what will likely be the most significant technical revolution in radio technology in 70 years. Put briefly, Moore's Law is going to meet Marconi's transmitter. Rapid improvements in microprocessors will soon make possible radios that are much smarter and more flexible than those in use today. In the not too distant future, any device that might benefit from being able to communicate will have a radio designed into it.

One of the biggest obstacles in the path of this revolution is the artificial scarcity created by the outdated spectrum management systems in most countries. Thus, improvements in spectrum management represent a substantial opportunity to promote technical innovation, foster competition and benefit consumers.

This paper summarizes some inefficiency created by current spectrum management techniques. Then it provides specific recommendations that spectrum policymakers could take to promote innovative new technologies and services such as Wi-Fi, WiMAX, UWB and other initiatives. Lastly, an appendix discussing Wi-Fi as a case study of spectrum reform is provided.

General Critique of Current Spectrum Management

The existing spectrum management approach was logical when created. It was based on a technology in which the tuning range of a radio was necessarily quite limited, and the designs of radio were fixed and tightly tied to the specifics of the application they were intended for. Today, the advent of incredible computational power in microprocessors and related semiconductors has revolutionized what is technically possible. In the U.S. a special Spectrum Policy Task Force to examined and recommend improvements for the United States spectrum policy. One of its key findings was that the current "command and control" spectrum management system is cumbersome, litigation-prone and politicized. Its tendency to "lock in" inefficient uses and technologies has become costly to the economy and has hindered the burgeoning demand for diverse wireless uses and has not taken advantage of the ability of technology to minimize interference. Moore's Law is moving us inexorably toward a technology in which extremely flexible and adaptable radio will become the standard. Shackling these advanced radios with the static spectrum management of the past will severely limit the benefits that can be gained from them.

Two promising spectrum management techniques can serve as a guide for further reform—the creation of largely unregulated, license-exempt frequency bands and the grant of increasing use and technical flexibility to exclusive licensees. These techniques give users more freedom to innovate and respond to changing market forces without seeking government approval. But they also require that government spectrum managers to specify interference protection requirements and other rights and obligations objectively and in a manner designed to foster industry planning and private cooperation. These reforms need not be mutually exclusive and should be considered simultaneously.

Spectrum Management Improvements

Three improvements are necessary. First, there is an immediate need to allocate additional 5 GHz spectrum for unregulated and unlicensed use to foster new applications and accommodate growth. Second, policymakers should expeditiously determine whether spectrum "non-interfering easements" for new technologies such as agile radios ("overlays") and ultra wideband ("underlays") could be created that would not impose significant interference on existing licensees. Third, more licensed spectrum should be made available for wireless broadband access such as WiMAX. Frequently, this will require reforming existing licensed spectrum to make it possible for market forces to move currently allocated spectrum to higher valued wireless data uses. In total, these reforms would create valuable new uses without creating significant interference to other users.

1. *Additional Unlicensed Spectrum at 5 GHz*

The recent World Radio Conference recognized that harmonized frequencies in the bands 5 150-5 350 MHz and 5 470-5 725 MHz for the mobile service would facilitate the introduction of wireless access systems (WAS) including radio local area networks (RLANs). The main obstacle to the allocation of this spectrum had been concerns with interference with military radars and fixed-satellite service. Studies were conducted showing that sharing between the radar and mobile services in the bands 5 250-5 350 and 5 470-5 725 MHz was possible with the application of agile radio technology such as dynamic frequency selection[1]. Accordingly, specific parameters, particular to the services potentially sharing the band, were agreed upon and a Resolution was adopted which greatly increased spectrum for these important services, without burdening the existing service.

It is important now that administrations quickly adopt rules to implement this beneficial ITU resolution. Rules have already been completed in the European Union and United states implementing this resolution.

Moreover, to fully realize the benefit of this new allocation, all countries should make these and other frequencies at 2.4 and 5 GHz available on an unlicensed or "license exempt" basis. As discussed below, these frequencies should not be encumbered with unnecessary restrictions on outdoor use or use for commercial purposes.

2. *Non-interfering Easements*

Following the success of the WRC, spectrum policy managers should also identify addition spectrum sharing using new technologies such as UWB and agile radios, which could be created without imposing significant interference on existing licensees. Much of the spectrum has already been allocated to dedicated uses, but at any instant little of the spectrum is typically being used, even in densely populated cities.

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[1] Dynamic frequency selection (DFS), described in ITU-R Recommendation M.1652 is a general term used to describe mitigation techniques whereby a device senses the radio spectrum for the presence or absence of a primary user to avoid co-channel interference.

Many applications use spectrum only intermittently or only in certain places, but foreclose all other uses because current radios have limited tuning range and use simple interference mitigation strategies. Moore's Law has begun to change that. Soon radios will be spectrally agile and very flexible in how they encode information in their signal. As a result, radio systems will be able to share the spectrum in much more efficient ways that will also mitigate interference, thereby greatly relieving spectrum scarcity.

For example, the FCC recently opened a Notice of Inquiry considering unlicensed use on broadcast television. To avoid interference from other TV stations into the current generation of television receivers, most of the TV channels in any geographical area are unused. Smart radio techniques, however, might permit unlicensed use, without any adverse impact on the TV reception and may also offer advantages to broadcasters.

The use of these bands is particularly important, as noted in the ITU-R, to many developing countries and countries with large areas of low-population density, for the cost-effective implementation of mobile services such as IMT-2000[2].

Indeed, because the channels "in use" seldom change, smart agile radios within current technical capability may be able share these frequencies by sensing their environment and adjusting their operating parameters accordingly. Another method under consideration is to use Global Positioning System receivers built into the unlicensed devices to determine the device location relative to fixed broadcast

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2 WRC'07 / Agenda 1.4 / RESOLUTION 228

transmitters. Experience in these bands could facilitate the development of more advanced applications where use varies much more rapidly over time and space.

For this approach to work, regulators will have to set interference limits for particular technologies specified in objective terms. Radio use of spectrum is not an "all or nothing" proposition. Depending on the technology, radios add to the background noise over which other radios must "shout" to be "heard." . Other radio technologies however may utilize more selective techniques to discriminate between the required signal and interference By analogy, someone whispering in the hallway creates far less "interference" than would someone shouting in the first row of this hearing room but the listener would require a highly directional earpiece. The regulator will have to determine the amount of interference that a particular radio system adds to the environment and when that is too much (that is, when it should move elsewhere). These limits could define the boundaries of a non-interfering easement. For example, a user of a particular frequency would be required to shut off within a specified time once it detects an incumbent user begins transmitting.

Together with limitations on the amount of power such underlay radios might use, this approach could allow valuable transmissions with virtually no impact on the allocated users of the various bands. Typically, spectrum regulations allow a person to scream in one city, a person to scream in a distant city and everyone else has to remain quiet. Clearly, there are better ways to utilize a valuable resource like spectrum. Given the pace of innovation in the electronics industry, we should begin reworking our regulatory structure to anticipate the future now.

3. ***Licensed Reforms***

More spectrum needs to be made available for implementation of wireless access systems (WAS), including radio local area networks (RLANs) using technology such as WiMAX. Various countries are considering allocations at 2.3, 2.5, 3.4 and 5 GHz bands. It is important that ample spectrum be made available on a globally harmonized manner.

In many cases existing licensees on particular bands should be given use and technical flexibility to permit them to move frequencies to new highly valued uses such as wireless broadband. But giving licensees flexibility is not enough. Spectrum managers will also need to:

- Set objective interference limits for each license's co-channel (geographical) and adjacent channel (frequency) boundaries. E.g., a licensee should not be limited to putting up a 200-foot antenna at particular coordinates emitting particular power. Instead, it should have operational flexibility (including moving from broadcast to mobile and portable uses) as long as it operates within specified power limits at its boundaries with its co-channel and adjacent channel neighbors.

- Exhaustively assign spectrum across their country. Where only urban areas ("holes") have been licensed on particular frequencies. The regulator needs to assign the spectrum in the rest of the country ("the Swiss cheese" or "remainders")

Finally, serious spectrum reform is going to require hard work. The technical questions are formidable. And incumbent users have a legitimate interest in assuring that their use is not significantly interfered with. But policy makers should always keep the consumer interest front and center. Some of the existing holders of spectrum or businesses that might face competition as a result of technological innovation may oppose these reforms. Protectionist efforts should be resisted. In the end, consumers and the broader public will benefit enormously if improved spectrum management techniques can eliminate the artificial scarcity created by the current system.

5 GHz Unlicensed Allocation

Objective

Get harmonized unregulated 5 GHz spectrum globally.

Statement of Issue

The World Radio Conference of 2003 supported World Wide WLAN/RLAN operation in the 5 GHz frequency range. Individual countries must now implement this recommendation.

Policy Recommendations

Intel supports the expeditious implementation of the intent and content of the WRC decision. But some clarifications are required to outline the specific deviations required to optimize the overall decision.

Frequency (MHz)	Output Power (e.i.r.p.)	Restrictions	Power Spectral Density (mW/MHz)
5150 – 5250	200 mW	Indoor Only	10 (0.25 kHz per 25 kHz band) Note: FCC is 2.5 mW/MHz
5250 – 5350	1 W	Indoor/outdoor No Mask DFS/TPC*	50 Note: FCC is 12.5 mW/MHz
5470 – 5725	1 W (250 mW max Tx power)	Indoor/Outdoor DFS/TPC*	50
5725 – 5850	4 W (1 W max Tx power)	Indoor/Outdoor	50

Additionally, Intel

- Opposes mandatory technical standards (“etiquettes”) beyond power limitations and DFS and TPC requirements needed to protect authorized users.
- Supports minimizing user restrictions on outdoor usage, except in the 5.15-5.25 GHz band.

- Supports promotion of passive scanning.
- Supports allocation of spectrum for WAS, as opposed to specifically WLAN
- Opposes restrictions on modulation types.
- Supports conformance to harmonized RF safety requirements.
- Supports strong “harmonized” encryption routines.
- Opposes licensing of private or public access
- Supports development of a harmonized roaming standard

WiMAX Allocation

Objective

Make spectrum available for WiMAX use globally over a narrow range of frequencies.

Issue statement

WiMAX (the industry group associated with the family of 802.16 standards) can be used as an alternative to a wire or fiber for delivering longer range broadband access to a site. It can be used to provide backhaul for Wi-Fi, fixed broadband access to homes and businesses and eventually portable broadband service. Because WiMAX is not defined for use with particular frequency bands, an operator can use those bands, licensed or unlicensed, that are available. For example, 802.16a is optimized for operation in frequencies between 2 and 11 GHz. WiMAX could be used unlicensed bands particularly in rural and developing markets where there is less congestion. Typically, bands at 2.5 GHz and 3.4 GHz are available on a licensed basis for use with an access data service.

Policy Recommendations

Because of its potential to provide a valuable new source of broadband access, governments should make spectrum available for WiMAX use. Frequently, the best means of achieving this goal will be to allow users and licensees on existing spectrum the flexibility to use the 802.16 family of standards.

Current Proceedings

3.4 GHz allocations in various countries
2.3 GHz allocation in Korea
2.5 GHz allocation (MMDS/ITFS proceeding) in U.S.

Ultra Wide-Band

Objective

Enable the authorization of Ultra Wide-Band radios on a global basis.

Issue statement

UWB technology enables very large bandwidth transmission ~500 Mbps. It is only currently authorized in the US (at very low levels, below Part 15 limits) on 7 GHz (3.1-10 GHz) of spectrum. However even though operating at low levels, UWB is still authorized on spectrum licensed to other people. This has resulted in opposition from incumbents who fear they might see small amounts of interference in their bands.

Policy Recommendations

Because of its low transmit power, governments can and should authorize UWB on a license exempt basis.

Current proceedings

ITU-R Task Group 1/8 UWB compatibility study, CEPT compatibility study, ETSI System Reference Document, FCC: ET Docket No. 98-153

SDR (Software Defined Radio)

Objective

To create a new class of equipment which will allow manufacturers to develop reconfigurable transceivers that can be multi-service, multi-standard, multi-mode, and multi-band.

Issue statement

The FCC amended their equipment authorization rules to permit equipment manufacturers to make changes in the frequency, power and modulation parameters of software based radios without the need to file new equipment authorization applications with the Commission. The FCC issued this definition of an SDR solution:

> **Software Defined Radio:** A radio that includes a transmitter in which the operating parameters of frequency range, modulation type, or maximum output power (either radiated or conducted) can be altered by making a change in software without any changes to hardware components that affect the radio frequency emissions.

Policy Recommendations

The FCC created a Class III permissive change procedure for SDR solutions. This procedure is used when a manufacturer changes software that affects the radio's frequency, output power, modulation type, or maximum field strength outside of the parameters previously approved. Using this procedure, an applicant can submit test data showing that the equipment complies with the applicable requirements for the service(s) or rule parts under which the equipment will operate with the new software.

Current proceedings

FCC: NOI (3/17/00), R&O (9/13/01) ET Docket No. 00-47

Unlicensed Use of TV Spectrum

Objective

Provide the ability to reuse the TV broadcast spectrum by unlicensed devices on a "non-interfering" basis.

Issue statement

TV broadcast licensees have exclusive rights within in a Grade B contour surrounding their transmitter. Using current technology, devices can be built that can discover which channels are vacant and then use them on a non-interfering basis with existing services.

Policy Recommendations

Governments should determine whether and how unlicensed devices might be able share use of the TV spectrum on a non-interfering basis. The current allocation process results in many channels being unassigned at the local level. The fixed and well understood nature of the TV transmitters makes it possible for unlicensed devices based on existing technology to coexist even using conservative operating assumptions. Given the attractive propagation characteristics of the TV broadcast bands, their use by unlicensed devices could quickly generate substantial benefits to consumers and businesses including the acceleration of the deployment of broadband services.

Governments should expeditiously begin examining whether to permit unlicensed use of the broadcast television frequencies. At a minimum, such examinations should consider and quickly resolve those issues necessary to enable wireless broadband operation in the TV bands.

Current proceedings

FCC: TV Broadcast Notice of Inquiry: ET Docket No. 02-380

Cognitive Radio Initiative

Objective

Bringing Cognitive radios to the consumer space will create better spectrum utilization by exploiting the "time" factor in communications. Solutions would be able to sense vacant spectrum and use this "white space" on an opportunistic basis creating the ability to have a "real-time' secondary market leasing structure.

Issue statement

Cognitive radio technologies can enable a radio device and its antenna to adapt its spectrum use in response to its operating environment. As set out in the FCC's Spectrum Policy Task Force Report, cognitive radios constitute one set of leading edge technologies that promise more efficient use of spectrum. Often taking advantage of the neglected "time" element associated with spectrum availability, cognitive radio technology can provide a variety of options for a radio device/antenna to identify spectrum, that is, available for use that would otherwise be unused but classed as unavailable today. DARPA has initiated a program for cognitive radios, called the XG Program. BBN is writing the initial architectural, framework, and software structure documents.

Policy Recommendations

No specific policy recommendations for cognitive radios exist at this time. Governments should begin to identify potential changes to the technical rules, policies and procedures that could facilitate the development of cognitive radios. They should also consider related issues such as Interference Temperature., a method of determining the availability of a channel.

Current proceedings

FCC: Workshop (5/19/03); ET Docket No. 03-108

Appendix

Spectrum Reform Benefits—the Wi-Fi Case Study

All of the benefits from innovative spectrum usage are illustrated by the marketplace and technical success of Wi-Fi. Wi-Fi is the name that the Wireless Ethernet Compatibility Alliance (now the Wi-Fi Alliance) gave to the wireless standards collectively known as 802.11—defined by the Institute for Electrical and Electronic Engineers (IEEE). Wi-Fi devices operate today in the 2.4 and 5 GHz unlicensed bands. The key to Wi-Fi's astonishing success has been the regulatory regime that prevails in these bands – which allows anyone to sell and use equipment in these bands without first obtaining a license from the government, provided only that the equipment meet certain technical specifications. This regime allowed manufacturers enormous freedom to innovate and to respond to changing market forces – knowing that no government licensing process would create a roadblock between their technology and consumers. This regime also allowed consumers, schools and businesses to build their own Wi-Fi networks by spending their own money as quickly or as slowly as they wished, without the need for government approval or having to navigate any kind of licensing process.

As result of the freedom enjoyed both by technology manufacturers and technology users, the pace of Wi-Fi innovation has been brisk. The speed of Wi-Fi equipment has jumped from 1-2 Mbps to 54 Mbps. The range of the equipment has also improved, while its costs have plummeted. Products have moved from 4 to 5 chip solutions in 1999 to the 2-chip solutions prevalent today with much more of the radio frequency circuits integrated, allowing broad expansion into a number of products. In 1999, only 802.11b PC cards and enterprise access points were available. Today, users can choose between 802.11a, 802.11b, or dual-band (802.11a and 802.11b) products for enterprise, small offices, or homes.

The pace of Wi-Fi deployment and the expansion of Wi-Fi product lines has also been brisk. Wi-Fi products have extended beyond PC cards and access points to PDAs, printers, and a host of consumer electronic goods. In addition to providing portable Internet access, Wi-Fi home networks are enabling consumers to use multiple computers with their broadband connections and peripherals. One company already incorporates a Wi-Fi (802.11a) transmitter in its personal media center allowing video streaming to TVs. These technological innovations have and will continue to generate a strong consumer response. Although 802.11 products did not begin shipping in significant volume until 1999, the growth has been staggering. Sales have increased from 7.9 million wireless LAN chipsets in 2001 to a projected 23-25 million chipsets in 2002, according to Allied Business Intelligence.[3] Gartner estimated that over $2 billion worth of wireless LAN equipment was sold last year.[4] In-Stat projects that the Wi-Fi hardware market will grow to nearly $4 billion in 2004.[5]

The Wi-Fi Alliance, the leading Wi-Fi trade organization, has grown to over 200 companies and certified over 500 products in just three years. PublicInternetProject.org detected the presence of nearly 14,000 access points in Manhattan alone.[6] According to the Yankee Group, over 700,000 U.S. companies are now using more than one million access points.[7] Public access locations are multiplying worldwide from airports to hotels to neighborhood coffee shops, and most recently, onboard commercial aircraft. In the United States, AT&T Wireless, Wayport, T-Mobile and others sell access for notebook users with wireless networking capability.

This process is just the beginning. Many in the high-tech community believe this technology – and the license exempt regulatory model – can be used to create wireless broadband networks to the home. From Athens, Georgia to Wellington, New Zealand, "WLAN clouds" providing wireless access for entire neighborhoods are appearing. Korea, already the world's broadband leader, also seems ready to lead in wireless networking. Leading Korean telecom providers have rolled out over 10,000 public access locations since their launch last year. The 2003 World Radio Conference, held in Geneva June 2003, made a global spectrum allocation at 5 GHz for wireless data networking. From the UK to France to Hong Kong, regulators have already considered, or are now considering, the ability of this technology to provide a wireless broadband connection to the home or office. The Wi-Fi Alliance recently announced the creation of Wi-Fi Zone, a logo program/ database directory for Wi-Fi public access worldwide.[8]

Intel has been a leader in the effort to accelerate Wi-Fi adoption worldwide. We will

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[3] http://www.alliedworld.com/prhtml/wlic03pr.pdf.html

[4] "Wireless LAN Equipment: Worldwide, 2001-2007", Gartner, January 2003.

[5] "It's Cheap and It Works: Wi-Fi Brings Wireless Networking to the Masses", Instat, December 2002.

[6] http://publicinternetproject.org/research/research_sum.html

[7] http://www.nwfusion.com/news/2002/0801wlan.html

[8] http://www.wi-fizone.org

continue to actively participate in multiple standards bodies that are working on further improving this technology. We have introduced Intel Centrino™ Mobile Technology branded products, which include a microprocessor (code-named "Banias"), related chipsets, and Wireless LAN networking capability. These components are designed, optimized and validated by Intel to maximize the wireless mobile computing experience. Over the past three years, Intel has increased our investment in wireless technologies fourfold. In addition to our research and development investments, Intel Capital's Communications Fund plans to invest $150 million in wireless networking technologies. These investments are accelerating the deployment of Wi-Fi networks and remove technical barriers to Wi-Fi growth and adoption.

Especially noteworthy, recent Wi-Fi-related innovations may accelerate broadband adoption nationwide. Cometa plans on creating a network of wireless LAN access points in the top 50 metropolitan service areas in the U.S. so that users will always be within five minutes of connectivity. Additional locations will be added as customer and usage grows. Technologies like Vivato's smart antennas offer promise by extending the range of wireless Internet access to up to 4 miles. In the future, mesh configurations of access points could enable Wi-Fi to deliver Internet access over even longer distances in competition with DSL and cable modem service. Wi-Fi is a success because the unlicensed bands allow technologists to innovate and consumers, businesses, schools and carriers to build their own networks at their own speed without government intervention.