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Spectrum Policy Task Force

Report of the Interference Protection Working Group

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Interference Protection
Working Group

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The findings and recommendations contained in this Report are those of the Interference Protection Working Group members, and do not necessarily reflect the views of the Commission, Commission management, or the Spectrum Policy Task Force.

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I. Introduction

The Interference Protection Working Group ("Working Group") of the Commission's Spectrum Policy Task Force is pleased to present its findings and recommendations.[1] The Working Group was established to assist the Task Force identify and address spectrum policy issues and challenges involving interference protection. To that end, it reviewed comments filed by parties responding to the Task Force's Public Notice of June 6, 2002, particularly comments relating to interference protection (ET-Docket No. 02-135). On August 2, 2002, it participated in a public workshop on Interference Protection ("Interference Protection Workshop") that addressed "Interference Challenges, Advanced Technology and A Better Process."[2] This report summarizes the Working Group's analyses and presents its findings and recommendations. Some recommendations are intended to enhance interference management in the near-term, while others address longer-term challenges.

Interference protection is central to effective spectrum management. Electromagnetic interference plays a pivotal role in the design and operation of telecommunications equipment and systems, and related costs. In today's radio frequency environment, interference generally limits the useable range or technical effectiveness of communications signals. Its effects on spectrum users and service providers range from annoyance, to economic harm, to threats to the safety of life and property. Interference protection is fundamentally related to spectrum rights and obligations. It also affects the efficiency of spectrum use. Regulatory interference protection standards that are too lax could prove detrimental to existing or planned services. Conversely, standards that are overly protective could prevent or impede the introduction of new services and technologies.

Interference protection has always been a core responsibility of the Commission. Section 303(f) of the Communications Act of 1934 as Amended directs the Commission to make regulations it deems necessary to prevent interference between stations, as the public interest shall require.[3] The Commission's strategic plan for the years 2003-2008 includes as a spectrum-related objective the "vigorous protection against harmful interference..."[4]

Interference protection is addressed in virtually all of the Commission-regulated services that use the radio spectrum. Historically, various approaches have evolved for managing interference. Typically, FCC rules and policies have been tailored to the expected uses and technical characteristics of particular services at the time of their creation. Most services have common elements aimed at interference protection such as limits on in-band power and out-of-band emissions. For many wireless and satellite services, the potential for interference is evaluated by outside frequency coordinators.

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[1] The Interference Protection Working Group is an interdisciplinary group of staff from across the Commission's Bureaus and Offices.
[2] A transcript of the public workshop is available at the Task Force's web site, http://www.fcc.gov/spft.
[3] 47 U.S.C. § 303 (f).
[4] *See Federal Communications Commission Strategic Plan FY 2003 – FY 2008*, available at http://www.fcc.gov/omd/strategicplan2003-2008.pfd.

Negotiated interference agreements among affected parties are also permitted in numerous services.

The record in this proceeding indicates that many of the Commission's rules and processes for managing interference have been generally successful. In recent years, few instances of systemic interference have been directly linked to Commission allocation or licensing processes.[5] Industry sources suggest that formal and informal frequency coordination processes have been effective.[6] The Commission has implemented new services by means of a variety of *ad hoc* approaches. Existing services have been able to grow and add new features resulting from the flexibility for licensees to make technical and operational changes.

II. Future Challenges Warranting Consideration of New Interference Protection Paradigms

As reflected by commenters and workshop participants, there are rising concerns that future spectrum demands will challenge current interference management paradigms. First, many radio communications services have grown substantially in recent years. For instance, Stratex Networks, Inc. comments that the 6, 11, 18 & 23 GHz bands in the Common Carrier and Operational Fixed Services in New York City, Los Angeles, Chicago, San Francisco, Philadelphia, Boston and Washington, D.C. have exhibited growth rates ranging from 15 percent to 900 percent.[7] The median growth rate for these cities and bands is 150%. Sprint comments that in the six years since they and other PCS licensees entered the market, "The number of mobile customers has nearly quadrupled, from 33.8 million in December 1995 to 128.4 million in December 2001.[8] According to Sprint, 58 percent of all Americans 12 and older now subscribe to a mobile service.

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[5] An example is the on-going conflict in the 800 MHz band, involving high power commercial radio transmitters and vulnerable mobile public safety receivers operating in close proximity on adjacent frequencies. The potential for interference between these services worsened as commercial licensees evolved the nature of their operations from SMR service (with relatively few stations serving wide areas) to a cellular service (with many stations serving smaller areas). The rules for interference that were established to manage interference in this band were developed years ago and currently do not appear to be sufficient. This conflict underscores the tension that can arise between flexible service offerings and the certainty of interference protection. *See* In the Matter of Improving Public Safety Communications in the 800 MHz Band and Consolidating the 900 MHz Industrial/Land Transportation and Business Pool Channels, *Notice of Proposed Rule Making* in WT Docket 02-55, 17 FCC Rcd 4873 (2001) (800 MHz Proceeding).

[6] For example, while acknowledging the interference conflict at 800 MHz, Glen Nash, past President of the APCO, Int., stated at the August 2, 2002, Interference Protection Workshop: "We really don't have a problem. Where we've gotten into trouble is when people don't want to play the game." Dr. Andrew Clegg of Cingular Wireless LLC added that interference provisions for the PCS service (power limit, boundary field strength limit and informal licensee coordination) work well and, in his opinion, could serve as a model for the future. Other participants at that workshop indicated that many interference problems are solved through cooperation among the parties through facilities adjustments. According to David Hageman of Poka Lambro Telcom, interference is not a major issue in rural areas.

[7] Comments of Ronald D. Coles on behalf of Stratex Networks, Inc. at 5. According to Stratex, anecdotal evidence indicates "that in major metropolitan areas it is becoming more difficult to coordinate frequency pairs in the preferred bands of 11 & 18 GHz."

[8] Comments of Sprint Corporation at 2.

A second challenge is presented by the explosive consumer demand for RF devices. The comments of the Consumer Electronics Association ("CEA") illustrate the large variety of very low power small-range RF devices in common use, including garage and car door openers, baby monitors, family radios, wireless headphones, and wireless Internet access devices using Wi-Fi™ or Bluetooth™ technologies.[9] According to CEA, the most common wireless device is the cordless phone, with 2001 sales of almost 36 million units.[10] By the end of the year more than 10 million computers are expected to use wireless networking technology and the wireless LAN industry is expected to reach a value of $5.2 billion by 2005.[11] CEA forecasts that, "As people become more mobile, moving from the office to the home, to the coffee shop, or to the airport, wireless networking application will become increasingly pervasive."[12]

The cumulative impact of the increasing volume and density of radio devices on the RF environment will challenge the Commission's current approaches to interference management.[13] Dr. Paul Steffes of Georgia Tech University, who is the past Chair of the Committee on Radio Frequencies, represented the interests of radio astronomy at the FCC's Interference Protection Workshop. He indicated that the radio astronomy community, which pays attention to the growth of spectrum use, has observed an explosion in spectrum use around the passive services. According to Dr. Steffes, "Just because we know the rate of growth is so significant, the minimal pressures now will become major pressures within the next four years."[14]

The National Aeronautics and Space Administration ("NASA") also comments on the burdens placed on the ability to manage the spectrum, due in part to the "tremendous" growth in personal communications devices and the increased congestion over the past ten years or so.[15] According to NASA, "All the best allocation and assignment processes which maximize the use of the RF spectrum are to no avail if the RF environment becomes corrupted and interference becomes 'harmful' to radio services depending on that spectrum for fulfillment of mission goals."[16]

Cingular Wireless LLC reports on some of the activities and findings of the FCC's Technological Advisory Council ("TAC")[17] that relate to the state of the RF noise environment.[18] Among the TAC findings cited by Cingular are the following:[19]

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9 Comments of CEA at 2-4.
10 *Id.*
11 *Id.*
12 *Id.*
13 At the Interference Protection Workshop, Dr. Clegg made the following statement about interference: "I think I can predict the future fairly confidently that we're going to see the same that we see today, but we're going to see a lot more of it…and it's going to be a gradual thing. It may not be so obvious on a day to day basis, but the interference will increase."
14 Interference Protection Workshop remarks of Dr. Paul Steffes.
15 Comments of NASA at 6.
16 *Id.*
17 The TAC was created for the purpose of advising the Commission on the impact of emerging technologies and other spectrum management issues.
18 Comments of Cingular Wireless LLC at 37-38.

> [There] "could be a very serious emerging problem caused by the explosive growth of both intentional and unintentional radio sources. The future could be very different from what we might expect from past experience. The key to getting our hands around this issue will be a good set of models for both intentional and unintentional radiators which can then be used to predict the evolution of the noise background." *Second Meeting Report of the TAC at 1, 9.*

> "[W]e could potentially be entering a period of rapid degradation of the noise environment. Such degradation would reduce our ability to meet the communications needs of the country. The principal negative impacts are likely to be reductions in the performance or reliability of wireless systems or increases in their costs." *Fourth Meeting Report of the TAC at 23 (Annex 4).*

Cingular Wireless comments that the Commission accepted TAC recommendation to undertake a multi-part study of the noise floor. Two of the seven findings of the first step of this study are given below: [20]

> "Until [noise floor] information is organized and analyzed, the FCC will not have a firm basis for deciding whether current noise standards are too tight, too loose, or maybe even just right." *Sixth Meeting Report of the TAC at 9.*

> "As we enter the new millennium, new noise sources are being developed (e.g., ultrawideband devices), and other electronic devices continue to proliferate as fast as the technology and the regulatory process will allow. Many of these other individual sources of "noise" may meet the current Federal Communications Commission (FCC) rules, but in great numbers they may negatively affect the overall electromagnetic noise environment. *Sixth Meeting Report of the TAC at 25*.

A third interference management challenge is presented by the migration from a relatively small number of waveforms to widely varying signal architectures and modulation types for voice, video, data and interactive services. Even single classes of users are now using a wide variety of digital technologies. Cingular Wireless notes that CMRS licensees "commonly use analog AMPS technology and four different digital technologies (TDMA, CDMA, GSM and iDEN)" and that other more advanced technologies will follow.[21]

Under the current interference management approaches, tension is likely to arise between the competing Commission objectives of flexible service offering and well-defined protection rights.[22] If flexible use is to be fully realized, it will become

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[19] *Id.*
[20] *Id.*
[21] *Id.* at 12.
[22] The potential for mutual interference among different waveforms sharing the same or adjacent spectrum has not been fully quantified. It is easier to design rules to protect transmissions with the same known waveforms than to protect a waveform of one type from many (possibly variable) waveforms.

increasingly difficult to pre-determine interference ranges. Worst-case propagation analysis may not always be applicable. Laboratory testing to demonstrate the spectrum sharing compatibility of two or more waveforms will become increasing complicated, time consuming and costly. [23] In Dr. Steffe's view:

> "The problem, of course, for the future is complexity. Obviously, the number of users and the management of the problem becomes dramatically enhanced…we were saying that it's [consideration of interference] at least a six dimensional problem, meaning spatial, x-y-z, frequency, time and waveform, and of course since the wave form can be infinitely complicated, you can make it an n-fold problem, which basically has more variables than you have numbers."[24]

Due to the complexity of interference issues and the RF environment, interference protection solutions may largely be technology driven. As a fourth challenge, the Commission will need to keep abreast of the rapidly advancing technology, in order to promote and empower its use. Due to advances in digital signal processing and antenna technology, communications systems and devices are becoming more tolerant of interference through their ability to sense and adapt to the RF environment. According to Dr. Raymond Pickhotz of George Washington University, it is important to recognize the impact of different kinds of interference, "not all of which are bad," on a particular technology.[25] Sources of signal impairment in wireless systems include internal (or self-generated interference), external interference and various sources of noise. Dr. Pickholtz indicated that in some systems of cooperative users (e.g., systems that use Code Division Multiple Access technology), "you can actually exploit the fact that there's a lot of *a priori* knowledge about the nature of the interference and either eliminate it or minimize it the point where it's not very important…[T]he concept here is that to the extent that you can avoid interference and not treat it as it if was noise you can increase the [system] capacity and therefore get more revenue…CDMA handsets use intersymbol interference to improve performance." [26] Dr. Pickholtz added that other types of interference, for example from external sources, may be similar to thermal noise, which cannot be mitigated by digital signal processing.

Thus, the Commission will be challenged to understand the rapidly changing communications technologies and the interactions of diverse signals. The Commission will also need to keep abreast of advances in spectrum monitoring and measurement technologies.

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[23] The compatibility of new technologies with those used by incumbents is often demonstrated by subjective and objective laboratory and/or field-testing. Separate tests are conducted to determine the impact of a new waveform on each existing waveform that will share the same or adjacent spectrum. As the number of available signal waveforms (and combinations thereof) continues to rise, the compatibility testing process will become increasingly unwieldy and, unless the process is streamlined in some fashion, it could jeopardize the ability of technologists to bring their products to market with their economic window of opportunity.

[24] Interference Protection Workshop remarks of Dr. Paul Steffes.

[25] Interference Protection Workshop remarks of Raymond Pickholtz.

[26] *Id.*

III. Nature of Recommendations

The Interference Protection Working Group recommends consideration of the following paradigms to supplement current interference management approaches, which the Working Group believes will significantly help the Commission meet its future challenges: Quantification of Acceptable Interference Levels, Transmitter Enhancement for Interference Control, Allocating Spectrum to Radiocommunications Services that are Grouped Together by Their Similar Technical Characteristics, Inclusion of Receiver Standards/Guidelines (through incentives, mandates, or a combination of these), and Improved Communications on Interference Issues with the Public. The Working Group submits it analyses, conclusions and recommendations for each of these.

IV. Quantification of Acceptable Interference Levels

A. Current regulations and statutes

Two key questions raised in the June 6, 2002, Public Notice are whether the Commission's current definitions of interference need to be changed and whether more explicit protection from harmful interference should be provided to incumbent spectrum users.[27] The Commission's Rules define four levels of interference:

> *Interference.* The effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radiocommunication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy.[28]
>
> *Harmful Interference.* Interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with these [International] Radio Regulations.[29]
>
> *Permissible Interference.* Observed or predicted *interference* which complies with quantitative interference and sharing criteria contained in these [International (FCC)] Regulations or in ITU-R Recommendations or in special agreements as provided for in these Regulations.[30]
>
> *Accepted Interference.* Interference at a higher level than defined as permissible interference and which has been agreed upon between two or more administrations without prejudice to other administrations.[31]

[27] *See* Public Notice, "Spectrum Policy Task Force Seeks Public Comment on Issues Related to Commission's Spectrum Policies," Questions 7 and 9, DA 02-1311 (June 6, 2002).
[28] 47 C.F.R. § 2.1(c); ITU RR 1.166.
[29] 47 C.F.R. § 2.1(c); ITU RR 1.169.
[30] 47 C.F.R. § 2.1(c); ITU RR 1.167.
[31] 47 C.F.R. § 2.1(c); ITU RR 1.168.

These definitions of interference, which are decades old, are also found in the international radio regulations. The terms *permissible interference* and *accepted interference* are used in the international coordination of frequency assignments between administrations.[32] The Commission's service rules for a number of radio services include the definition of harmful interference given in § 2.1(c).[33]

The terms *interference* and *harmful interference* also are found in the Communications Act of 1934 as Amended:

- **Sec. 302 [47 U.S.C. 302(a)] Devices which interfere with radio reception.**
"(a) The Commission may, consistent with the public interest, convenience, and necessity, make reasonable regulations, (1) governing the interference potential of devices which in their operation are capable of emitting radio frequency energy by radiation, conduction, or other means in sufficient degree to cause **harmful interference** to radio communications; and (2)…" (emphasis supplied).

- **Sec. 303 [47 U.S.C. 303] General powers of the Commission.**
"Except as otherwise provided in this Act, the Commission from time to time, as public convenience, interest or necessity requires shall —

* * * * *

(f) Make such regulations not inconsistent with law as it may deem necessary to prevent **interference** between stations and to carry out provisions of the Act: *Provided, however,…* (emphasis supplied).

* * * * *

(y) Have authority to allocate electromagnetic spectrum so as to provide flexibility of use, if –

(1) such use is consistent with international agreements to which the United States is a party;
and
(2) the Commission finds, after notice and an opportunity for public comment, that –
(A) such an allocation would be in the public interest;
(B) such use would not deter investment in communications services, or technology development; and
(C) such use would not result in **harmful interference** among users." (emphasis supplied).

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32 *See* Comments of the Satellite Industry Association at 10, which note that the term "acceptable interference" can be used in the coordination process to define limits to protect against unacceptable interference.

33 *See*, for example, 47 C.F.R. §§ 21.2, 90.7 and 101.3, which give the definition for *harmful interference* for the Domestic Public Fixed Service (Multipoint Distribution Service), Private Land Mobile, and Fixed Microwave Services, respectively. Means of applying this definition vary with the nature of the service; for example, the definition is applied differently depending on whether a particular spectrum band is available for exclusive or shared use. Note also that 47 C.F.R. § 15.5(b) conditions the operation of unlicensed intentional and unintentional radiators on not causing *harmful interference* to an authorized radio station.

The means of interference protection vary for different radio services. The most common elements are limits on transmitted in-band power and out-of-band emissions. Outside frequency coordination is employed in many wireless telecommunication and satellite services and in the broadcast auxiliary services. Negotiated interference agreements are permitted in many services.

The service rules vary considerably regarding how interference is quantified, predicted or otherwise managed. Several examples illustrate the different approaches. Licensees in the PCS and some Private Land Mobile Services must limit their signal strength to prescribed values along their geographic boundaries to protect licensees in adjacent areas. Some land mobile services use minimum station separations corresponding to different power and antenna height combinations. The extent of interference protection afforded to analog television broadcast stations is defined by minimum station separations between stations assumed to be operating with the maximum allowable combination of antenna height and power. Power flux density limits are commonly used as a means of protection in many Satellite services.

The rules for some services prescribe detailed criteria for predicting interference at protected service locations. For example, the service populations of digital television stations are protected on the basis of calculations of desired-to-undesired signal strength ratios at locations where service is predicted to occur in the absence of interference. The Multipoint Distribution Service rules prescribe a rigorous interference methodology for two-way communications systems, based in part on an assumed statistical distribution of the subscriber locations. The frequency coordination process for some point-to-point microwave operations considers harmful interference to occur if a transmitter would "degrade the threshold of a victim receiver by no more than 1 dB."[34]

B. Views expressed in the public record

Definitions of "interference" and "harmful interference": Commenters are divided on the need for new definitions of *interference* and *harmful interference.* Some favor retaining the current definitions. The comments of Nortel Networks reflect several of the reasons given by commenters supporting this position:

> [the] "current definitions are generic, and allow appropriate interpretation on a case-by-case basis …More rigid definitions may inhibit the industry and stifle innovation… 'Harmful interference' is interpreted relative to past performance, and since performance is constantly changing, any technical definition would have to change constantly, as well"… and "Nortel urges that the Commission maintain consistency with international definitions." [35]

[34] Comment of Comsearch at 7-8.

[35] Comments of Nortel Networks at 1. *See also*, for example, the Comments of Wayne Longman at 15-16, who contends that a quantified definition would "cause more disputes than it resolves"; Comments of NASA at 7, which state that "considering new definitions could be detrimental to commercial as well as Federal agencies that rely on such technical criteria for design and development of new radio systems;" and the Comments of Telesat Canada at 3.

Several commenters point out that the generic definition of "harmful interference" allows the Commission to interpret its meaning differently for particular radio services. According to Verizon Wireless, "It is not the definition of 'harmful interference' that is in need of change but the way in which the Commission enforces its rules or establishes policies regarding interference."[36]

Other commenters urge the Commission to clarify or change the current definition of *harmful interference*. Sprint contends the current definition has several weaknesses: it is highly subjective - the terms "serious degradation" and "repeated interruptions" are not defined and are open to *ad hoc* interpretation; it does not sufficiently address the current RF environment and modern technology (i.e., adaptive capabilities of modern communications systems); and that the definition is too general.[37] According to Sprint, "The specific definition of 'harmful interference' should depend on the nature of the victim service and the function it is intended to serve."[38] Xtreme Spectrum contends that the current definition of *harmful interference* causes uncertainty and suggests that the definition's subjective nature accounted for much of the controversy in the ultra-wideband proceeding.[39] As a better approach, it recommends a system of interference protection based on quantitative measures of harmful interference (degradation or interruption) a given service can tolerate.

The Satellite Industry Association ("SIA") comments that harmful interference is an extreme level and that just because interference does not rise to this level, it cannot be concluded that the interference is acceptable to the victim.[40] According to SIA, attempts to quantify the level of harmful interference would not be useful. Rather, efforts should be made to ensure that levels of interference will not result in service interruption or degradation, a level characterized as "acceptable" interference – the level operators would coordinate among themselves. SIA suggests that, when adopting spectrum sharing criteria, the Commission use the terms "permissible or acceptable" interference.[41]

Steve Baruch expressed a somewhat similar view at the Commission's Interference Protection Workshop. He indicated that a level of interference could be harmful or not harmful depending on the victim and that attempts to quantify *harmful interference* amount to identifying acceptable or tolerable levels of interference to parties sharing the spectrum. According to Mr. Baruch, "You can identify objective limits of what would be tolerable, but not would be harmful."

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[36] Comments of Verizon Wireless at 7. *See also* Comments of the Satellite Industry Association at 10; and Comments of Cingular Wireless LLC at 40.
[37] Comments of Sprint at 13-17. *See also* Comments of National Public Radio at 14.
[38] *Id.* at 15.
[39] Comments of Xtreme Spectrum, Inc. at 6-9. According to Xtreme Spectrum, "In the ultra-wide band proceeding the parties generally concurred on the appropriate techniques for predicting interference, but differed greatly on what assumptions to use – and consequently differed on whether interference would or would not occur in practice." *Id.* at 8.
[40] Comments of the Satellite Industry Association at 10-11.
[41] *Id.*

Need for more explicit interference protections: As noted, some parties recommend that more explicit protections be built into the definitions of interference. Others urge the Commission to give careful consideration to the condition of the RF noise floor.[42] According to Cingular Wireless:

> "…increasing the noise floor by even a few dB may adversely impact existing licensed systems and their customers in a number of ways, such as: (1) coverage, (2) system capacity, (3) reliability of data throughput, and (4) quality of voice service. To overcome these effects, licensees may have to reconfigure previously optimized systems and deploy additional facilities to regain what the noise floor increase erased. Thus, the incumbent's service should be considered 'seriously degraded, obstructed, or repeatedly interrupted,' constituting harmful interference, as a result of the newly authorized spectrum assignment."[43]

Cingular Wireless also notes that the Commission could set signal strength limits that would "establish a rebuttable presumption against interference or noninterference with respect to particular technologies and services, taking into account industry standards, prevailing noise levels, receiver characteristics and other factors."[44]

At the Interference Protection Workshop David Hageman urged a common approach for measuring interference compliance:

> "I think that if you're going to do something that way, you need to have clearly defined measurements. You need to come up with some way that the common person out there, the small carrier, can take a spectrum analyzer or some common piece of equipment with some standard things that they have and say I'll stick this antenna up and I'll make this measurement and I'll turn this knob and set that switch and, bang, here's my level. And it meets it or it doesn't. And it needs to be the same for every one." [45]

Several commenters recommend that the Commission pay attention to the cumulative or aggregate effects of interference from multiple RF emitters.[46] For example, according to the Association for Maximum Service Television and the National Association of Broadcasters:

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[42] *See*, for example, Comments of Cingular Wireless LLC at 41; Comments of Dominion Resources, Inc. at 5-6; Comments of NASA at 7; and AT&T Wireless Service at 15.
[43] Comments of Cingular Wireless LLC at 41.
[44] *Id.* at 43. *See also* the Comments of Motorola, Inc. at 17 ("The level of interference that can be tolerated may vary depending on the nature of the service involved."); and the Comments of Dr. Charles L. Jackson at 2 ("If licenses contained clauses stating that licensees would have to accept up to some specific level of co-channel and adjacent channel energy, then some such disputes would be easier to resolve, or might not be disputes at all.")
[45] In this context, Mr. Hageman reflected on a past experience in which he was informed that there are multiple formulas for calculating a field strength limit at a service area boundary.
[46] Comments of Telesat Canada at 2; Comments of Bell South at 7.

"The Commission typically conducts an *ad hoc*, case-by-case interference analysis and considers the harmful interference caused on an incremental basis. Thus, even if each new spectrum use does not cause significant interference to existing spectrum users, the *cumulative* effect of all the new spectrum uses authorized in recent years has degraded the quality of the spectrum for all users."[47]

As another means of more explicit protection, a commenter suggests that as spectrum demand increases, incumbent users be required or provided incentives to migrate to the use of more robust and spectrally efficient technologies, accompanied by required use interference avoidance and mitigation techniques.[48]

Finally, some commenters discuss the need for more explicit protection in terms of "interference rights"; contending, for example, that incumbent users should not be subjected to additional unwanted interference.[49]

C. Conclusions

1. <u>There is a need to quantify acceptable levels of actual interference</u>:

The previous section highlighted future challenges to the effectiveness of the current interference management paradigms, as the Commission seeks to accommodate the high demand for spectrum-based services and devices for both licensed and unlicensed services. Approaches such as predictive modeling, laboratory compatibility testing of signal waveforms and spectrum use decisions based on knowledge of the local environment – standing alone – will be increasingly strained by the increasing intensity of spectrum use and the changing nature of the RF environment, especially in urban areas of the country. The radio environment will be increasingly characterized by flexible service offerings with a multitude of signal waveforms and by higher densities of low power RF emitters with small signal ranges. The cumulative effects of these devices and other sources of RF energy will raise the noise floor and could threaten the reliability of existing communication services.

As a result of these factors, it will not always be possible to guarantee well-defined interference protection rights based on comprehensive predictive analyses. Nor will current interference management approaches inform the Commission of the intensity of spectrum use or the condition of the RF noise floor as it considers spectrum for new technologies or to accommodate the growth of existing services.[50]

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[47] Comments of MSTV/NAB at 12-13.
[48] Comments of Carl Stevenson.
[49] *See,* for example, the Comments of AT&T Wireless Service at 14; Comments of SIA at 13-14; and the Comments of Wayne Longman at 16.
[50] Since most of the favored spectrum bands are already in use, much of the future demand may be in the form of requests to share spectrum with incumbent licensees, for example, by placing very low power RF devices "underneath" the much higher emission levels of incumbent users.

The Working Group concludes that the current definitions of interference in Part 2 of the Commission's Rules adequately address the broad and changing technical and operational characteristics of the many radio services.[51] Rather than change the definitions, the Working Group recommends that the Commission consider addressing its long-term interference management and spectrum policy challenges by supplementing its transmitter-centric approach with a new paradigm based on (1) real-time measurements of spectrum use and the RF environment and (2) adaptive responses of transmitters and receivers to these measurements. As set forth below, maximum acceptable levels of interference could be established to provide well-defined protection rights to incumbents. Such threshold levels could also be used as a basis for permitting additional spectrum access to new RF-based technologies and services.

Commenters and workshop participants indicate that technology for sensing and reacting to the interference environment is now available.[52] For example, according to Sprint, "the IS-95 code-division multiple access ("CDMA") air interface used in PCS and cellular networks uses transmit power control on both uplink and downlink transmissions…If the interference at the receiver is increased, the transmitter will increase its power output to compensate – up to a limit." Personal Telecom Tech, Inc. comments that "Frequency-agile technology via software-defined radio technology can be used to monitor power in spectrum bands and thus determine where channels might not be used or not available for licensed services due to buildout and deployment or environmental or topological considerations." The next section of the Working Group report discusses how interference measurements could be combined with adaptive transmitter control technology to limit interference to within established levels.

2. <u>As a long-term strategy, the Commission should consider use of the "Interference Temperature" metric as a means of quantifying and managing interference</u>:

As introduced in this report, "interference temperature" is a measure of the RF power available at a receiving antenna to be delivered to a receiver – power generated by other emitters and noise sources.[53] More specifically, it is the temperature equivalent of the RF power available at a receiving antenna per unit bandwidth, measured in units of

[51] The definitions in Section 2.1(c) of the Commission's Rules are sufficient for their intended purpose, provided they clearly state that means of interference protection may be tailored to specific services. We agree with commenters that any efforts to effect significant changes to these definitions should be well coordinated with all affected stake holders. The Commission may wish to consider a larger role domestically for the definitions of "permissible" and "acceptable" interference, in the manner in which these are used in the Satellite services.

[52] Comments of Personal Telecom Tech, Inc. at 2. Further, Jack Rosa of HYPRES, Inc. stated the following at the Interference Protection Workshop: "If you had a fast enough machine you could monitor the spectrum continuously. You could put in intelligent controllers, so-called bandwidth on demand. That technology can be accomplished now." A variety of devices are now commonly used to measure RF energy. The key is to integrate these devices with high speed frequency monitoring technology.

[53] The related term "noise temperature" is used by radio astronomers as a measure of the intensity of radiations from space. The noise temperature concept is also used in the satellite industry in connection with determinations of the need for international frequency coordination.

°Kelvin.[54] As conceptualized by the Working Group, the terms "interference temperature" and "antenna temperature" are synonymous.[55] The term "interference temperature" is more descriptive for interference management.[56]

Use of the interference temperature concept would be more amenable to an RF environment having the properties of additive Gaussian white noise; *i.e.*, with signals having uniform power spectral density over their frequency bandwidth. For such signals, the received power at the output terminals of the antenna could be calculated as the product of the interference temperature, the bandwidth and Boltzman's Constant.[57]

As illustrated in Figure 1, interference temperature measurements could be taken at receiver locations throughout the service areas of protected communications systems, thus estimating the real-time conditions of the RF environment.

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[54] Interference temperature can be calculated as the power received by an antenna (watts) divided by the associated RF bandwidth (hertz) and a term known as Boltzman's Constant (equal to 1.3807 watt-sec/°Kelvin). Alternatively, it can be calculated as the power flux density available at a receiving antenna (watts per meter squared), multiplied by the effective capture area of the antenna (meter squared), with this quantity divided by the associated RF bandwidth (hertz) and Boltzman's Constant. An "interference temperature density" could also be defined as the interference temperature per unit area, expressed in units of °Kelvin per meter squared and calculated as the interference temperature divided by the effective capture area of the receiving antenna -- determined by the antenna gain and the received frequency. Interference temperature density could be measured for particular frequencies using a reference antenna with known gain. Thereafter, it could be treated as a signal propagation variable independent of receiving antenna characteristics.

[55] The idea of an interference temperature as a measure of the antenna "noise" power in a particular band and location is well established. *See*, for example, Wolfram Research at http://scienceworld.wolfram.com/physics/AntennaTemperature.html.

[56] Interference temperature is a component of the total noise temperature of a receiving system, which also includes the thermal noise generated within the receiver. The publication, "Telecommunications: Glossary of Telecommunications Terms," prepared by the National Communications System's Technology & Standards Division and Published by the General Services Administration defines "noise temperature" as follows: "At a pair of terminals, the temperature of a passive system having an available noise power per unit bandwidth at a specified frequency equal to that of the actual terminals of a network (the underlined terms are, in turn, also defined; for example, noise power is the "Interfering and unwanted power in an electrical device or system"). *See* http://www.its.bldrdoc.gov/fs-1037/dir-024/_3565.htm.

[57] The spectral characteristics of non-Gaussian signals generally are not scalable; *e.g.*, the total power in a frequency bandwidth cannot readily be extrapolated from the power level for a sub interval of that bandwidth. Thus, if an interference temperature "thermometer" measured the temperature of a portion of the bandwidth of such a communications system, that value could not be assumed to be constant over the entire bandwidth. The thermometer would need to measure frequency intervals comprising the whole bandwidth and use the largest measured temperature value to characterize the environment for the particular receiver.

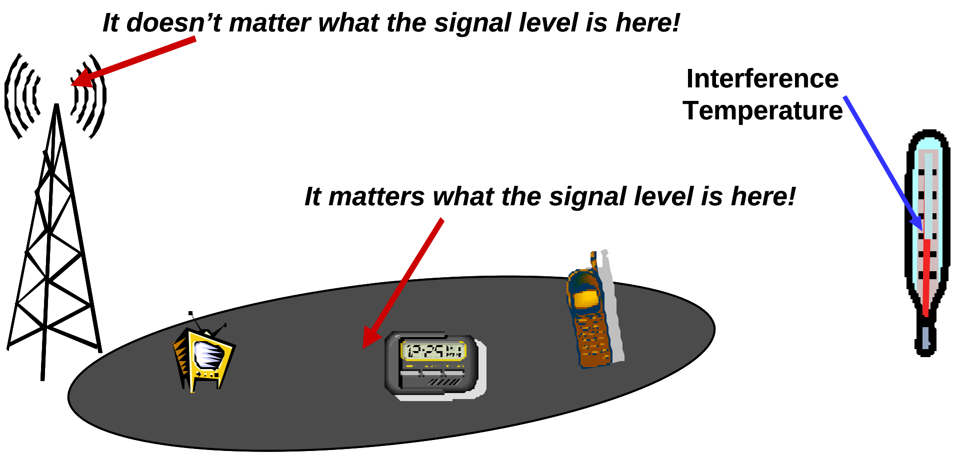

Figure 1

Like other representations of radio signals, instantaneous values of interference temperature would vary with time and, thus, would need to be treated statistically. The Working Group envisions that interference "thermometers" could continuously monitor particular frequency bands, measure and record interference temperature values and compute appropriate aggregate value(s). These real-time values could govern the operation of nearby RF emitters. Measurement devices could be designed with the option to include or exclude the on-channel energy contributions of particular signals with known characteristics; *e.g.*, the emissions of users in geographic areas and bands where spectrum is assigned to licensees for exclusive use.[58]

The Commission could use the interference temperature metric to set maximum acceptable levels of interference, thus establishing a "worst case" environment in which a receiver would operate. Interference temperature thresholds could thus be used, where appropriate, to define interference protection rights. Several commenters support capping interference levels.[59] Threshold levels could be set for different bands, geographic regions or services after the Commission has reviewed the condition of the RF

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[58] It may be technically complex to estimate the interference temperature excluding the licensed desired users. A simple measurement in this case would overestimate the actual interference temperature, but may be adequate in many cases because it would err on the side of preventing unwanted interference.

[59] *See*, for example, the Comments of Sky Tower; Comments of CTIA at 12 (suggesting a "zoning-like" model for determining what is acceptable interference); Comments of Sprint at 17 (suggesting a "harmful interference" threshold to cap the "total interference effect from all overlaid or coexisting systems. Once the interference effect reaches the cap, no more secondary devices or systems would be authorized to share the affected band.").

environment.[60] These levels could serve as benchmarks to guide engineering tradeoffs for radio equipment and system designers.[61]

D. Recommendations

- The Working Group recommends that, as a long-term strategy, the Commission consider the interference temperature metric for quantifying and managing interference, together with established "acceptable" levels of interference.

- The Working Group recommends that the Commission promote and hasten the transition from analog to digital transmission techniques and, if necessary, effect this transition by rule. Digital operations are generally more resistant to interference and would enhance use of the interference temperature metric.

V. Transmitter Enhancement for Interference Control

A. Current regulations

The Commission's Rules prescribe upper limits for in-band transmitter power and out-of-band emissions for the majority of spectrum uses. Automatic transmitter power control ("ATPC") to ensure transmission of the minimum power necessary for reliable communications is generally not required. The rules do provide that all satellite earth stations in the 20/30 GHz band "shall employ uplink adaptive power control or other methods of fade compensation such that the earth station transmissions shall be conducted at the power level required to meet the desired link performance while reducing the level of mutual interference between networks."[62] Earth stations in the Fixed Satellite Service operating in the 13.77 to 13.78 GHz band may use ATPC to increase power to compensate for rain attenuation.[63] Additionally, the Commission recently adopted rules to permit licensees in the radio and television broadcast auxiliary and cable relay services to use ATPC.[64]

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[60] In considering candidate bands for interference temperature thresholds, the Commission should take into account such other factors as the nature and extent of incumbency and the nature of the spectrum use. For example, it may not be appropriate to use the concept for certain public safety services.

[61] Acceptable "interference temperature" limits could, in effect, provide implicit receiver standards, because equipment manufacturers would have the option of designing receivers to operate in "worst case" RF environments.

[62] 47 C.F.R. § 25.204 (g). In ATPC systems, when a receiver detects a decrease in the necessary signal strength, it sends a control signal to the transmitter to increase power.

[63] 47 C.F.R. § 25.204 (f).

[64] *See* Revisions to Broadcast Auxiliary Service Rules in Part 74 and Conforming Technical Rules for Broadcast Auxiliary Service, Cable Television Relay Service and Fixed Services in Parts 74, 78 and 101 of the Commission's Rules, FCC 02-298, *Report and Order* in ET Docket No. 01-75, adopted October 30, 2002.

B. Views expressed in the public record

The record in this proceeding indicates that ATPC and other adaptive technologies are now in use. At the Interference Protection Workshop, Dr. Andrew Clegg stated that his company, Cingular Wireless, has "already deployed power control as tightly as we can…" Sprint comments that its CDMA PCS and cellular systems use transmitter power control for uplink and downlink transmissions.[65] As an alternative to power control, it comments that wireless local area network standards IEEE 802.11(a) and (b) provide for data rate adaptation, whereby reductions in the signal to interference ratio due to interference can be compensated by a reduction in the transmitted data rate.[66]

Commenters and workshop participants report that advances in cognitive radios, antennas and signal processing and coding are evolving and may soon become practical and without the high costs usually associated with implementing new technologies.[67] According to Vanu, Inc., a soft-ware defined radio ("SDR") proponent:

> "SDR will permit devices to alter the signal processing they are performing in order to get the best performance for the current conditions. For example, under poor signal to noise conditions, aggressive forward error correction may be called for. As conditions improve, the error correction could be modified in order to get improved data rates. Without the flexibility to make these changes quickly and inexpensively, the benefits of adaptation for the current operating environment could not be realized….SDR will at times be helpful in addressing harmful interference issues as quickly and efficiently as possible"[68]

Dr. David Reed offers further perspective on emerging technology:

> "[W]e must recognize that in the not-too-distant future, all radio systems will be based on digital signal processing, and thus will approach 'Cognitive Radio' capability. By cooperatively sensing and manipulating their electromagnetic environment, a network of software defined radio transceivers can adapt to their physical environment to match demand much closer to the capacity achievable by joint action of a group of radios."[69]

HYPRES, Inc., another SDR proponent, describes an automated system to dynamically monitor broad areas of spectrum and to "pass details of observed signal characteristics to central controllers for evaluation."[70] HYPRES suggests that the Commission consider implementing a monitoring capability to provide data for spectrum management. It notes that among the techniques made possible by the related technology

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[65] Comments of Sprint at 14.
[66] *Id.* at 15.
[67] According to remarks made by Jack Rosa of HYPRES, Inc. at the Interference Protection Workshop, indications are that the next generation of technology will cost "dramatically less" than current systems based on current technology.
[68] Comments of Vanu, Inc. at 4-5.
[69] Comments of David Reed at 8-9.
[70] Comments of HYPRES, Inc. at 2-3.

is the "spotting [of] interfering emitters to support adaptive cancellation and/or null steering of adaptive antennas."[71]

C. Conclusions

The Working Group believes that signal sensing and adaptive technology, such as that now used for ATPC, will become increasing sophisticated and could play a major role in the self-regulation of interference. Such technology could be used in conjunction with the interference temperature metric to ensure that the condition of the RF environment does not exceed permissible levels.

1. The Commission should make clear that its spectrum policies are based on "interference-limited" rather than "ambient noise-limited" environments.[72]

An interference-limited policy reflects typical RF environments, enhances frequency re-use, and would facilitate use of the interference temperature metric and established acceptable interference limits.

2. The Commission should consider extended use of environmental sensing and control technology, including technology that could be used in conjunction with the interference temperature metric.

The comments of Dr. David Reed in this regard are insightful:

> "As long as the regulatory process (including litigation and lobbing, and even secondary markets) focuses on defining interference without reference to the actual dynamics of systems, there will be no means in the reduction of 'actual' interference (as opposed to the current measure of 'imaginary' interference)."[73]

The Working Group describes an approach in which transmitters and receivers using advancing technologies could interact with the RF environment. In addition to the interference temperature metric, there are three major elements: (1) the information an emitter would need to adapt to the environment to ensure that a maximum acceptable interference threshold is not exceeded, (2) the manner of acquiring interference temperature data and delivering this data to the emitter, and (3) the responses of the emitter to the data.

An RF emitter would need to know the interference temperature (or, alternatively, the interference temperature density) at locations within its nominal signal range. This data could be acquired in several ways. It could be measured directly by the emitter; *e.g.*, for low power devices with very small signal ranges. More generally, a grid of spectrum

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71 *Id.* at 3.

72 In a noise-limited environment, the range of a signal is determined in the assumed absence of interfering signals. In an interference-limited environment, the range is determined in the presence of interfering signals.

73 Comments of David Reed at 16-19.

monitoring stations could be established that would continuously scan the RF environment for particular frequency bands, process the data and broadcast packetized interference temperature data from omni-directional antennas transmitting on dedicated frequencies. Data packets could also include the geographic location of the interference temperature measurement, the associated frequency or frequency band and the measurement bandwidth. As another means of data delivery, transmitters and receivers operating in the environment – for example, in "an adaptive *ad hoc* wireless network" – could be equipped with interference temperature "thermometers" and GPS sensors to determine measurement locations. The devices in the network would constantly measure interference temperature and route real-time data packets through the network. RF devices not in the network could also be equipped to measure and send this information.

For devices required to conform to interference temperature thresholds, responses could include a reduction in transmitter power, antenna beam re-shaping, selection of a different transmitting frequency or a "stand down" decision to wait until the environment adjusted to permit a transmission that would not cause an acceptable interference levelto be exceeded within the emitter's nominal signal range. The sensory/control system could thus provide a self-enforcing mechanism to ensure the integrity of the interference temperature limit for that frequency band, service and geographic area. As an additional benefit, such an approach could provide data to update a Commission data base on the condition of the RF noise floor.

Potentially significant benefits of using the interference temperature metric with sensory/control devices are illustrated in Figures 2 and 3.

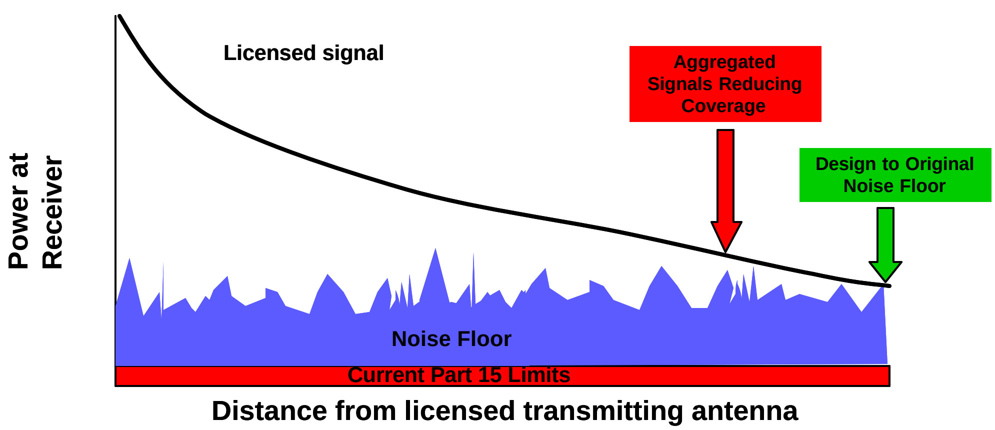

Figure 2

Figure 2 depicts a communications system designed to operate within a signal range at which the received power level approaches the noise floor that existed when the system was established. As additional interfering signals are added – for example, due to further aggregation of unlicensed devices or out of band emissions from new users – the noise floor can rise unpredictably. As a result, service reliability and signal coverage could be increasingly worsened without warning to the system licensee.

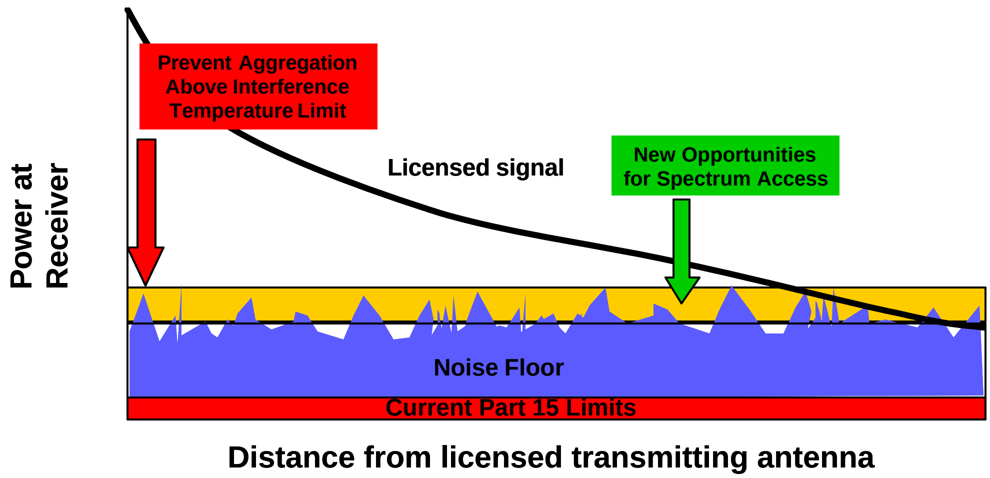

Figure 3

In Figure 3, the evisceration of service is capped by an "acceptable" interference temperature. In those portions of the signal path for which the temperature limit has not been exceeded, opportunities would exist for additional spectrum use; *e.g.*, by low power "underlay" emitters equipped with interference temperature "thermometers" and transmission "controlling" devices. In the long-term, this approach could also possibly be used as an alternate means of regulating out-of-band transmitter emissions; *i.e.*, in lieu of more expensive transmitter filtering.

3. Interference management could be enhanced to the extent the strengths of emitter-generated signals are spatially uniform over nominal signal ranges.

The Working Group believes that signal strength uniformity could enhance interference management and, in particular, the accuracy of the environmental sensory/control approach; for example, by avoiding complications caused by RF "hot spots." Antenna technology now exists to facilitate signal strength uniformity. Use of low power distributed transmission networks, in combination with beam shaping antennas, could also serve this purpose.

4. Effective interference mitigation could also be advanced through use of modern transmitter output filtering and related digital signal processing capabilities.

Use of such technologies could increase the "purity" of transmitted signals and reduce interference caused by adjacent channel "splatter". In this regard, the Working Group concludes that it would be appropriate for the Commission to consider the gradual tightening of out-of-band emission limits in its rules for the various radio services.

D. Recommendations

- The Working recommends that the Commission affirm that its interference management policies will be generally based on interference-limited RF environments.

- The Working Group recommends that the Commission promote transmitter enhancements as a means of interference management; for example, increased use of automatic transmitter power control.

- As a long-term strategy, the Working Group recommends that Commission consider augmenting existing interference management approaches by promoting the use of self-enforcing environmental sensing and adaptive transmitter control technology, in conjunction with use of the interference temperature metric.

- The Working Group recommends that the Commission promote the use of technologies that enhance the spatial uniformity of signal levels.

- The Working Group recommends that the Commission begin to examine the out-of-band emission limits in its rules in light of modern technology and related costs, with a view toward gradually tightening existing limits.

VI. Allocating Spectrum to Radiocommunications Services that are Grouped Together by Their Similar Technical Characteristics

The Commission's mission is "to promote the public interest through a fully competitive marketplace -- with access for all Americans to communications services -- in a cost-effective, efficient, and transparent regulatory environment." To realize this mission, spectrum managers should allocate spectrum to radiocommunication services within the same frequency band or to services in adjacent frequency bands in a way that places the fewest technical and regulatory constraints on all of the services in that spectrum. With fewer constraints, licensees will have the flexibility to deploy equipment in a cost-effective manner that has the greatest promise of consumer acceptance of new and innovative communication services. The Commission can foster spectrum efficiency and flexibility by allocating spectrum to radiocommunication services that are grouped together by their similar technical characteristics.

A. International Telecommunication Union (ITU) and FCC Spectrum Allocation Processes

Implementation of a new radiocommunications system requires substantial lead time for design and implementation particularly if the system requires a new service allocation and interference protection. Protection from interfering sources, both in-band and adjacent band, requires that service allocations are made whereby the systems operating in the spectrum are technically compatible. Technical compatibility among the radiocommunication systems leads to more efficient use of the spectrum and less constraints on the systems operating within a particular service allocation. This portion of the report summarizes the current international and domestic service allocation processes, finds that the Commission does already promote the "zoning" approach to spectrum allocations internationally, and concludes that a similar approach should be considered domestically in order to promote its goals of placing the fewest operating constraints on new systems without disrupting the operating environment that currently operating radiocommunication systems rely on.

1. <u>International approach to spectrum allocations</u>.

International spectrum allocations are made to radiocommunication services such as Broadcasting or Fixed-Satellite, not to systems. Service allocations are broad in scope. The Commission participates in the ITU spectrum allocation process with other U.S. Government agencies, the U.S. industry, and foreign administrations. The Commission considers industry proposals and positions that focus on future spectrum uses and it tries to reconcile the many competing interests associated with a new spectrum allocation keeping in mind the practicality of the operating constraints on the systems operating in the allocations.

Article 5 of the International Radio Regulations contains the International Table of Frequency Allocations. This table has been developed over the past century[74] under the auspices of the ITU. Over the years a multi-step technical approach has evolved to determine which radiocommunication services are able to share spectrum with other services. Generally, the steps are as follows:

i) <u>Technical description of service</u>. A detailed description of the technical parameters of the new service are developed and introduced into the appropriate ITU technical study group. These parameters include, but are not limited to, items such as the expected transmit power, antenna gain, geographic service area, receiver sensitivity, types of modulation employed and the types of applications proposed. This information is necessary to introduce the technical concepts of the new service to other members of the study group.

ii) <u>Selecting applicable frequency range</u>. Some wireless systems can only be implemented at a specific frequency or range of frequencies.[75] Other systems, due to atmospheric propagation affects and/or the current state of technology, can be implemented over a fairly wide frequency range such as 1-3 GHz. Generally, two frequency ranges are considered. One in which the system is capable of being implemented and, two, a preferred frequency range within which the future system operators would realize fewer constraints on system implementation.

iii) <u>Spectrum sharing studies</u>. Much of the frequency spectrum that is technically suitable for the implementation of a new communication system is already occupied by

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[74] As an example of the progress in radio technology, the Final Acts of the 1949 ITU Radio Conference contain, in Article 5, a Table of Frequency Allocations from 10 kHz to 10.5 MHz. The current Article 5 extends from 9 kHz to 275 GHz.

[75] Some types of earth-resource and radio astronomy sensing detect the emissions of atoms or molecules that only occur at specific frequencies. Other types of sensing, such as sea surface wave height are best accomplished over fairly narrow bands of frequencies.

existing systems in a service allocation. Ideally, all of the currently operating or proposed systems within the preferred frequency range of the new application will be studied to see if co-frequency sharing is technically feasible. These studies result in the development of sharing constraints that would have to be placed upon both the existing and the new services in order for all of them to operate in the same frequency band. In almost all cases, co-frequency operation of two different radio services will result in constraints being placed upon both services.

iv) Allocation changes. When the constraints are acceptable to all services involved in the spectrum sharing study, and the technical studies are completed, an ITU Recommendation is adopted by the administrations that describes the sharing constraints placed on the new and existing systems. ITU Recommendations are used by the ITU World Radiocommunication Conferences (WRC) as technical input to effect changes to the International Table of Frequency Allocations and by administrations to coordinate the operations of their radiocommunications systems.

One of the positive aspects of the ITU process for new and modified spectrum allocations is the amount of detailed analysis that is conducted to evaluate the system sharing possibilities prior to allocation. The studies are carried out by technical experts from a number of administrations and the resulting ITU Recommendation has a high probability of being correct in its conclusions and having international acceptance of the technology and constraints before new systems are implemented. The trade-off is that the ITU allocation process can take years to complete which creates a delay for international or regional deployment of new systems.

2. Domestic approach to spectrum allocations.

The Commission's allocation process also allocates spectrum to services, not to systems. Since its allocation process is not system or technology specific, a competitive marketplace is fostered by the Commission. Either on its own, or in response to a petition from the public, the Commission issues a rulemaking proceeding to allocate spectrum, it studies the technical aspects of the proposed services competing for new allocations and, through a transparent regulatory process, it strikes a balance among the services in allocating spectrum. In many instances, the domestic spectrum allocations are similar to, if not the same as, those that are internationally or regionally allocated. In those instances, the Commission takes full advantage of the technical studies conducted in the ITU process that led to the international frequency allocations. To a great extent, therefore, the Commission does already group service allocations based on technical characteristics of in-band and adjacent band services.

In some instances, however, the domestic allocations are significantly different than the international or regional frequency allocations. In some cases, too, the international process has not been completed but the time is ripe to implement a new service in the U.S. In other cases, the desire to sell new equipment outside of the U.S. may not exist or there may not be a requirement for international protection from interference. In these cases, the time associated with the domestic allocation process is the driving factor in the amount of lead-time that a new system would need for design and implementation. The lead-time includes the technical compatibility studies necessary to support the service allocation.

During the domestic allocation process, the technical specifics of a new system or technology usually are provided to the Commission in the form of a petition for service rulemaking or in the form of a system license application. In deciding which competing systems will operate in a particular allocation, the Commission evaluates the technical characteristics of the systems that propose to operate in the service allocation from a potential inter-service and inter-system interference standpoint. After it adopts the technical rules for a service, the operating constraints that would need to be accepted by all services in the allocation (and at times, in the adjacent allocation) are defined. At this stage, the Commission essentially determines the amount of technical flexibility a particular system or systems will have within the service allocation. The Commission also develops license conditions and operating provisions that are placed on the system authorization consistent with the service rules for the allocation. The sharing arrangements in several frequency allocations are described in Appendix A to provide examples of how grouping like users in certain allocations has led to competition within a service, technical flexibility and efficient use of the spectrum.

B. Findings and Conclusions

Interference control is complicated by the mismatch between technical characteristics of systems close in frequency. Authorization of technically compatible systems within international and domestic spectrum allocations will promote the systems' technical flexibility, efficient spectrum usage, and provide radiocommunication system manufacturers an opportunity to more readily deploy equipment throughout the U.S. and abroad. For services that are global in nature, where U.S. manufacturers desire to deploy equipment abroad, or where cross-border coordination of a system is necessary, the Commission has promoted the "zoning" approach to spectrum allocations internationally. Commission staff participates in the international allocations processes and study group activities. A review of several services in various exclusive and shared allocations in Appendix A reveals that the Commission, to a great extent, does already take a "zoning" approach to domestic spectrum allocations as well.

The zoning approach leads to fewer constraints on the systems operating in the exclusive or shared allocations which provides greater technical flexibility for the services to develop, grow and evolve. In some cases (e.g. fixed-satellite) coordinated approaches to spectrum access have been developed whereby a system may operate without coordination if it operates below an established interference threshold. In a few other instances, the Commission has taken an ad hoc approach to spectrum allocations. The tradeoff made by the Commission in order to provide for a new service was to add more constraints to the existing and new services in the allocation. As more radiocommunication systems serve end users directly, and as the density of the user population increases, it will become even more important for the Commission to group spectrum allocations based on mutually-compatible technical characteristics of the services.

C. Recommendations

The Commission has had success in its "zoning" approach to grouping together systems with similar technical characteristics. In this regard, the Commission has, to a significant extent, grouped allocations based on mutually-compatible technical characteristics. It should continue this policy with respect to allocation of spectrum for new uses and also consider creating incentives to evolve dissimilar uses to compatible groupings. In this vein, the Working Group recommends that the Commission:

> **[1]** continue to foster the "zoning" approach to spectrum allocations internationally and regionally. The Commission should continue to participate in the international spectrum allocation processes, working with other U.S. Government agencies, U.S. industry, and foreign administrations, to develop technical criteria for intra-system and inter-system interference mitigation and spectrum sharing;
>
> **[2]** develop service rules for systems and authorize those systems to use the frequency allocations in a way that least constrains all users of the spectrum [domestic and international] thereby increasing system technical flexibility and spectrum efficiency; and
>
> **[3]** use its spectrum rulemakings and service rules findings and conclusions, where appropriate, to support additional or modified international or regional frequency allocations in the ITU process.

VII. Receiver Standards/Guidelines

A. Background

For more than six decades, the Commission's general policy for managing or eliminating interference has been to control transmission parameters, mostly power and height, but sometimes antennas. For the most part, the earlier state of spectrum use and receivers allowed for such a general spectrum policy. Receiver quality, oftentimes, became an afterthought. When the need to evaluate interference at the receiver level does arise, the Commission either applies a set of worst case receiver parameters or uses general receiver characteristics for its determinations. This policy is reasonable for a spectrum environment that processes numerous fixed and high power services and a limited number of mobile and low power services.

The transformation of the spectrum environment to more cellular-like usage, with lower power levels and mobile use, necessitates that the Commission revisit its general policy requirements. As interference issues become more complex and the number of users and emitters proliferates, the Working Group believes the Commission will need to address receiver interference concerns and specific receiver evaluation criteria. Further, consideration should be given to new and more novel approaches to spectrum access, usage, and management to include adaptive receivers and future advanced receivers capable of monitoring interference temperature as a spectrum policy.

As part of its assigned tasks, the Working Group considered the following receiver-related questions:

- Should the Commission promulgate rules on receiver standards or request that the telecommunications industries voluntarily establish receiver standards and/or guidelines?
- Should the Commission adopt minimum receiver performance standards and encourage the markets to build and deploy higher quality receivers above our minimum threshold?
- Should the Commission define a quality of service threshold based on operational requirements for each service?
- Should the Commission promote the development of receivers to foster the concept of interference temperature?

B. Discussion

From a simplistic and physical standpoint, any transmission facility requires a transmitter, a medium for transmission, and a receiver. Focus on receiver characteristics has not been high in past spectrum use concerns, hence, a shift in focus is in order. The Working Group believes that receiver reception factors, including sensitivity, selectivity, and interference tolerance, need to play a prominent role in spectrum policy.

The record, including a number of commenters to the Task Force's public notice (PN commenters)[76] and participants in the Working Group's public workshop supported the need for receiver standards, guidelines, or incentives to evaluate harmful interference. Both the PN commenters and the workshop participants assert that from a technical standpoint, interference acceptability and susceptibility, as well as increased spectrum efficiency, are highly dependent on the quality and sensitivity of the receiver used. Spectrum sharing feasibility studies are made easier if, at least, the minimum performance characteristics of receivers operating in a band are known. They noted, however, that unless the characteristics of the receiver can be dictated by the service provider (e.g. cellular telephones), the provider has no control over the quality of the receiver (e.g. broadcasters). The commenters further noted that rapidly advancing technology such as software-defined radio and adaptive receivers that can filter and excise interference effectively should be factored in spectrum policy considerations.[77]

The PN commenters also generally favored the development, adoption, and implementation of receiver standards/guidelines/incentives (receiver standards), or, in the alternative, minimum receiver performance requirements. Their views are

[76] *See Public Notice,* "Spectrum Policy Task Force Seeks Public Comment on Issues Related to Commission's Spectrum Policies," DA 02-1311 (June 6, 2002) (PN).

[77] Comments of HYPRES, Inc. at 5.

buttressed by those of the workshop participants held by the other three Spectrum Policy Task Force Working Groups.

On receiver standards, participating parties, both those favoring and those opposing Commission adoption of receiver standards or minimum receiver performance requirements, acknowledged that receiver performance characteristics are essential to interference evaluation, feasibility studies, and the design of new and improved systems.[78] The parties supporting Commission adoption of receiver standards or minimum receiver performance requirements indicated that receiver standards would promote spectrum sharing and system interoperability, and provide common performance values that all equipment manufacturers must meet.[79]

The opposing parties stated that receiver standards would stifle innovation and negate the natural progression of technology, could eliminate lowest cost receivers from the marketplace, and could force consumers to purchase higher priced receivers.[80] They also pointed out that the rapidly changing technology landscape would result in receiver standards that would require constant Commission monitoring and maintenance.[81] Even those parties opposing receiver standards, however, did support, in varying degrees, the adoption of minimum receiver performance requirements.

If adoption of either receiver standards or minimum receiver performance requirements is contemplated, working group participants suggested consideration of the following parameters. They include selectivity, susceptibility, dynamic range, local oscillator phase noise, data throughput, unwanted emissions, various carrier-to-noise or carrier-to-interference metrics, equipment performance labeling, tuned filtering, and interference suppression and rejection.[82]

Parties supporting receiver standards believe that long-term protection of legacy receivers stifles innovation and delays public acceptance and purchase of new technology, and that legacy receivers should not receive long-term or indefinite protection.[83] A few commenters suggested that a date-certain protection sunset for legacy receivers, based on equipment life cycles and amortization schedules, should be

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[78] Comments of Aeronautical Radio, Inc. at 4; Comments of Cingular Wireless LLC at 52; and, Comments of National Public Radio at 17.

[79] Late-Filed Comments of IEEE 802.18 Radio Regulatory Technical Advisory Group, IEEE 802.11, 802.15, and 802.16 Working Groups, and the IEEE 802 Metropolitan Network Standards Committee at 10; and Comments of Public Safety Wireless Network Program at 11.

[80] Comments of BellSouth Corporation at 12; Comments of Charles L. Jackson at 3; Comments of Nortel Networks at 6; and Comments of Wayne Longman at 19.

[81] Comments of BellSouth Corporation at 12.

[82] Late-Filed Comments of IEEE 802.18 Radio Regulatory Technical Advisory Group, IEEE 802.11, 802.15, and 802.16 Working Groups, and the IEEE 802 Metropolitan Network Standards Committee at 10; Comments of Dr. William C. Y. Lee, LinkAir Communications, Inc. at 4; and Comments of Nortel Networks at 8.

[83] Reply Comments of American Mobile Telecommunications Association at 8; and Comments of Marlon K. Schafer at 5.

imposed.[84] Others suggested that receiver certifications be time-limited (perhaps five to seven years), and that at the end of the certification period, the receiver manufacturer should be required to cease manufacture of the obsolete equipment.[85] Virtually all public participants agreed that there should be differing receiver standards among various radio services, and that services could be grouped by spectral characteristics, the application using the service, the bandwidth required by the application, and the application's potential for spectrum efficiency and sharing.[86]

In addition to the above, commenters specifically recommended the following:

- The Commission should initiate an evaluation of the performance characteristics of current receivers, particularly interference immunity, in order to provide an accurate assessment of the current operating environment on which to base new standards/guidelines/incentives or minimum receiver performance requirements.[87]
- The Commission should convene an industry panel to devise a plan for the resale, trade-in, and recycling of legacy receivers to stimulate public acceptance of new technologies.[88]
- The Commission should require product labeling that contains evaluation of product performance against objective performance benchmarks.[89]

C. Recommendations

The public record voiced a need for further action on receiver standards by the Commission. As discussed above, the Working Group has been considering the concept of interference temperature as another means of improving spectrum access and the creation of receivers capable of monitoring interference temperature needs to follow.

1. The Working Group recommends that the Commission initiate a *Notice of Inquiry* (NOI) addressing the adoption and implementation of either receiver standards/guidelines/incentives or minimum receiver performance requirements in the very near future. It suggests that the NOI seek comments on: how to characterize the current receiver environment; whether the Commission has the authority to issue receiver standards; what minimum performance parameters need to be considered; how to group differing receiver standards for different radio services; how recent receiver

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84 Late-Filed Comments of IEEE 802.18 Radio Regulatory Technical Advisory Group, IEEE 802.11, 802.15, and 802.16 Working Groups, and the IEEE 802 Metropolitan Network Standards Committee at 11.

85 Comments of David R. Hughes, Old Colorado City Communications Company at 3.

86 Comments of Ericsson Inc. at 7; Late-Filed Comments of IEEE 802.18 Radio Regulatory Technical Advisory Group, IEEE 802.11, 802.15, and 802.16 Working Groups, and the IEEE 802 Metropolitan Network Standards Committee at 11; Comments of Dr. William C. Y. Lee, LinkAir Communications, Inc. at 4; Comments of Marlon K. Schafer at 5; and Comments of Public Safety Wireless Network Program at 11.

87 Comments of National Public Radio at 21.

88 Comments of Citizens Media Corp/Allston-Brighton Free Radio at 13.

89 Comments of National Public Radio at 19.

developments such as software-defined radios could decrease current interference constraints; the level of protection and the length of time protection is afforded to legacy receivers, particularly those deployed by Public Safety and rural users; how receiver standards, if adopted, might stifle innovation; and how to contend with the possible potential negative effect of eliminating the lowest cost receivers from the marketplace.

2. The Working Group also recommends that the Commission pursue a detailed study of the advantages and disadvantages of using interference temperature as a means of addressing spectrum access and interference acceptance in the future. Future studies should include a comprehensive assessment of the interference(noise) temperature for all regions of the country. This assessment necessarily would be time consuming and expensive. While resource intensive, such an assessment could reap enormous spectrum access benefits and improvements for the telecom industry. As such, the telecom industry may consider funding or assisting in the funding of the assessment. If this interference temperature assessment is successful, the Commission should take prompt regulatory action to incorporate the use of interference temperature as part of its future spectrum policy. In this regard, for those receivers that the Commission might choose to be subjected to interference temperature limits, the Working Group recommends that the Commission either propose performance requirements for interference temperature capable receivers or request that the industry adopt and implement such standards.

3. Aside from the NOI and unrelated to interference temperature, the Working Group recommends that the FCC either commission a study group or issue a contracting proposal for an evaluation of the performance characteristics of current receivers to provide a better assessment of the current interference environment. This assessment could be used to improve the Commission's spectrum allotment policies or assist in the future development of receiver standards.

4. The Working Group also suggests that parallel to the NOI, the Commission convene industry committees to seek the creation of voluntary industry standards, guidelines or labeling for advancing receiver standards. If consensus is reached, the Commission could initiate a rulemaking to embrace the standards, either through a labeling or certification program or as part of the Commission's Rules.

5. The Working Group further suggests that the Commission urge the telecommunications industries to devise a plan to expedite legacy receiver replacement, perhaps by implementing the resale/trade-in/recycle plan suggested by the public. In the alternative, as an incentive to the deployment of more advanced receivers and the replacement of legacy receivers, the Commission could allow additional flexibility or increased power for those services or users deploying more advanced receivers.

In short, the time for intensive study and review of both current and future receivers is now.

VIII. Communications with the Public on Interference Issues

A. Introduction

The ability of the new radio-based technologies to become realities in the marketplace depends to an important extent on the terms and descriptions of interference. Disputes as to what may or may not constitute an effect of one service on another has been made at times more difficult to resolve because of informal and inconsistent language describing interference and its impact. In addition, entrepreneurs and others seeking to implement new systems or improvements to existing systems have found it difficult to determine which rules are appropriate candidates for revision and what the changes would be. Beyond the regulatory language and rules addressing interference, the actual experience of licensees and others engaged in the process of fielding new or changed communications systems constitutes an important asset that should be more easily available to others seeking to establish radio-based services.

B. Discussion

The Working Group sees a need to consider several focused efforts to make the Commission's interference rules, policies, processes and available tools more transparent, that is, more comprehensible, consistent, and easy to use.

1. Harmonizing Interference Language (Technical Terms and Units)

The rules governing interference for the wide variety of radio-based communications regulated by the FCC today are the result of a process that has evolved over time and that addresses the specific services involved and circumstances of the potential interference situations. Historically, the Commission has developed the technical interference criteria contained in the various parts of its rules on an industry by industry and service by service basis, responding to the particular situation presented by those seeking to establish new services and reacting to the concerns of potentially affected existing services. Each industry and to some extent each service within an industry has its own engineering "culture," that is, a body of conventional technical practices and terminology widely used by planners and licensees within that particular service.

The resulting treatment of interference for the *ad hoc* situations presented to the FCC has led to the successful implementation of a wide variety of radio-based systems in operation today. The existing language, however, addressing interference is highly diverse and not always consistent. This resulting body of interference language has become a daunting challenge for those seeking to learn how they should consider the lessons of the past in order to plan for the future.

The interference management rules governing a particular radio service have been adopted in a public proceeding based on a record containing technical material submitted by stakeholders of the pertinent industry and other potentially affected parties. The specific criteria are often the result a compromise between competing goals of a satisfactory level of performance for the licensees and an acceptable level of impact on others in nearby frequency bands or geographic locations. The circumstances for the determination of each new service are frequently unique to the situation brought to the FCC by petitioners seeking to alter the status quo in order to permit them to operate under the revised rules. The language addressing interference differs from service to service and reflects the nature of the service, the sharing situation, and the expectations of the community.

The technical interference criteria contained in the Commission's rules are fundamentally based on considerations of power and propagation in broad frequency classifications (*i.e.* high frequency (HF), very high frequency (VHF), ultra high frequency (UHF), *etc.*) The criteria in the rules also reflect operating considerations, such as whether the service is a fixed or mobile service. For example, interference criteria for mobile units generally incorporate an additional margin to account for signal fading resulting from the motion of the mobile unit. The technical criteria also reflect an expectation of the quality of service that will be demanded by licensees. Some services can be completely functional in the presence of a low level of interference, whereas users of other services, particularly public safety services, subscriber services, and broadcast services, have an expectation of a greater freedom from interference.

Even within a particular service the language describing interference may be variable and inconsistent. For example, rules defining interference levels may have initially been established for analog systems and not comparably revised for the advent of digital systems. Over time estimated propagation distances and hence expectations of impact may have changed due to the wide-spread availability of more accurate propagation models. In addition newly implemented services similar to an earlier generation of systems may have the expectation of more technical freedom and flexibility and hence have simpler interference rules.

The wide differences in approaches to interference management in the FCC's rules also shows up in the technical parameters that are used to describe performance and impact. The differences in units, methods and metrics for interference management that exist between the various services can be categorized as major differences, minor differences and inconsistencies. The major differences arise when the service quality or reliability goals for the services differ, or when concerns for administrative efficiency outweigh those for more accurate technical assignment (*e.g.*, if a large number of license application filings is expected). A different approach may also be appropriate where a service is presumed to be interference-limited rather than noise-limited under the expected operating radio frequency environment. Another factor resulting in major differences is whether the service is structured as a broadband or narrowband service. Broadband services must rely far more heavily on frequency use coordination between licensees to manage interference than do narrowband services. As a result, FCC technical rules for broadband services focus on signal coverage parameters rather than desired-to-undesired signal ratios. Broadband services also incorporate technical flexibility as well as service flexibility, which may limit the usefulness of such ratios.

Minor differences arise when services utilize a similar approach (*e.g.*, minimum D/U ratio), but employ different propagation models for the same general frequency range. In the UHF range, the Commission has approved or required the use of methods derived from three somewhat different sets of empirically derived field strength curves—R6602, Carey (ITU) and Okimura—for essentially similar services. For example, the historical and current practice is to use Carey-based tools for CMRS systems licensed under Part 22 and methods based on R6602 for similar CMRS licensed under Part 90. Furthermore, Okimura based criteria are used for other service types of stations, such as for paging systems as opposed to two-way radios for both Part 22 and Part 90. Finally, inconsistencies may appear to exist where the FCC's rules contain different expressions of engineering units that have been derived from different considerations of power, relative power, or electric field. These differences reflect the different approaches to describing and characterizing interference and its impact that are peculiar to the specific situation such as for broadcast or mobile services, for example, D/U and C/I, or dBμ and dBμV/m.

When the FCC makes a determination to implement a new or changed service, it correctly focuses on the interference situations presented by the parties and also on the context of the existing rules and services for impacted services. The resulting record of interference language in the rules today, however, for the many FCC-regulated services has become unnecessarily varied and is not always consistent—service to service. It has not been a focused goal of the FCC to treat its own rules objectively as a source of information on approaches to interference—its definition, management and control. Although the record stands as an authoritative body of rules on interference, it appears that these interference rules could be made more user-friendly; and it may be an appropriate and useful expenditure of the FCC's resources to review its rules on interference with the objective of harmonizing the language of interference to the extent possible. While important distinctions should always be made, there is a benefit to using more uniform language when describing interference and its impact. It is noted that the process of biennially reviewing and streamlining the FCC's rules is an existing process that could be tasked with an additional goal of harmonizing the interference rules. Where possible, consistencies and inconsistencies in the technical parameters and units could be highlighted and explained. In addition the FCC should be conscious of the international environment for the language describing interference and seek to harmonize our descriptions with those of other administrations.

2. Ensuring Consistent and Appropriate Use of Interference Language (Non-Technical Qualifiers)

The same variability in language on interference that pervades the FCC's rulemaking proceedings and the resulting rules also gives rise to inconsistent discussion of the impact of interference from a non-technical perspective. While in principle technical terminology may be made more objectively uniform, where possible, especially if the technical assumptions and conditions are specified, the terminology addressing the resulting impact of signal degradation on a user or subscriber may be regarded as subjective.

In its June 2002 public notice, the SPTF signaled its openness on the interest in, or need for, new definitions of "interference" and "harmful interference." In response, the majority of parties commenting on this issue argue that no change in the definitions is needed. Those arguing that the current definitions are too subjective and open to interpretation are outnumbered by those who believe that formal revision of the definitions would lead to constraints on technical innovation and to more interference disputes. However, a consensus among both sets of commenters is that the *usage* of these terms by the FCC is unclear.

Commenters on both sides raise issues with the current definitions and their use in the FCC's rules. They argue that the use of the terms "interference" and "harmful interference" is too informal and inconsistent. Sprint asserts that "there can be no serious dispute over the need for the Commission to confirm and clarify the scope of harmful interference, if not codify those clarifications in the rules or in notes to the rules."[90] The Information Technology Industry Council recommends, "in order for the Commission to be able to solve actual harmful interference situations, the Commission needs to better define the distinction between interference and harmful interference."[91] PanAmSat's comments propose an alternative to redefining the terms: "The Commission should not redefine the terms "interference" and "harmful interference," or attempt to quantify what constitutes harmful interference, but should clarify the use of those terms in its rules."[92]

Bringing in the international perspective, the Satellite Industry Association (SIA) elaborates on the appropriate use of the terms "harmful," "accepted," and "permissible" interference in the context of adopting sharing criteria:

> "The definitions for 'interference' and 'harmful interference' have been established and agreed to within the ITU for some time. In addition, there are also established definitions for 'permissible interference' and 'accepted interference.'… It is not clear what purpose would be served by redefining any of these terms. Instead the Commission should make clear the use of these terms in its regulations. Harmful interference is an extreme level of interference that is rarely seen when properly functioning radio equipment is used in a frequency band by services or systems that operate on a co-primary basis. At the same time, it is clear that just because interference between such services or systems in a band does not rise to the high level of 'harmful interference' it cannot be reasonably concluded that the interference is subjectively acceptable or tolerable to the victim service or users. As a result, the Commission's, and even the ITU's, attempts to quantify the level that constitutes harmful interference are really not a useful exercise. The key is to find ways to ensure that the level of interference ... is not and will not be at a level that will result in the interruption or degradation of one of the services using the band. Therefore, the level of interference that is appropriate for allowance from

90 Sprint Comments at 12.
91 Information Technology Industry Council Comments at 9.
92 PanAmSat Reply Comments at 2.

> one service into another is always less than harmful interference. That is where the term acceptable interference should be used … For the Commission's purposes, the object of most spectrum sharing rulemaking proceedings – at least those not involving assessment of interference to a safety service – should be to identify the level of permissible interference… [T]he Commission should, when adopting sharing criteria, use the terms permissible or acceptable interference."[93]

Although distinctions between of levels of interference will continue to be discussed, the Working Group believes that the qualifiers describing the impact of the interference should be more consistent and appropriate, as the FCC discusses its interference decisions and describes its interference rules.

A systematic review of the interference rules and definitions would be required to ensure such consistency. The interference definitions scattered throughout the rule parts may be standardized to reflect the language of the definitions from Section 2.1 of the FCC's rules or the ITU Radio Regulations. In addition, undefined qualifiers such as "objectionable" may be replaced with standard qualifiers or re-defined to remove ambiguity and subjectivity. Instances of the terms "harmful," "accepted," and "permissible" interference could be reviewed to ensure that their use matches the meanings of their respective definitions. The FCC may also seek to add qualifiers where such an addition may usefully clarify the meaning.

Short of redefining interference broadly, the consistent and appropriate use of qualifiers would remove some ambiguity for licensees, applicants, industry, and the general public who are trying to comply with interference rules. The Working Group believes that clarifying the use of interference qualifiers and ensuring consistency is a suitable compromise between the extremes of redefining interference and taking no action with the definitions.

3. Facilitating Access to the FCC's Rules on Interference

Title 47 of the Code of Federal Regulations contains the rules governing interference for FCC-regulated services. These rules however are spread throughout a number of different rule parts comprising five volumes and over 3600 pages. Beyond the problems cited in the preceding paragraphs on the technical and non-technical language on the definition and management of interference, the body of regulations governing interference for all services is vast in scope and voluminous in size. Moreover, the actual interference rules themselves are not easily identified and isolated in the context of all the rules governing a particular service. For example, for certain services interference may be indirectly governed by specifying minimum separation distances or limitations on transmitter power and antenna height—without ever mentioning the word "interference" or referring to levels of interference.

[93] Satellite Industry Association Comments at 10-11.

In order to assist those seeking to understand the interference determinations for the existing services, it seems appropriate for the FCC to provide a roadmap or directed guide that would facilitate access to rules governing interference for any regulated service. Providing the interference rules for all services in all frequency bands regulated by the FCC in *a consolidated summary* may be helpful to licensees when evaluating actual interference from other users or determining their own requirements.

Rules governing interference protection may include, depending on the service, a combination of service contours, interference contours, emission masks, transient frequency behavior, directional antennas, out-of-band emission limits, power limit, antenna height restrictions, and other criteria. Procedures to measure interference-related parameters may also be contained in the rules. For example, certain rules may specify technical relationships and limitations by means of equations, propagation models, or measurement procedures. The direct availability of the rules governing interference may help to more quickly resolve interference disputes or determine the potential for interference and could service as an aid to frequency coordination. A consolidated summary may also prove useful to licensees who may not know exactly which services are in shared or adjacent bands or the corresponding FCC rules that regulate these services.

There are also additional interference requirements that may not be contained in the section of 47 CFR that contain a given service's technical rules. In 47 CFR Parts 1 and 2 certain requirements and procedures are specified that pertain to a number of services in various rule parts. For example, Section 1.924 of the rules contains procedures and associated field strength limits licensees should be aware of to protect radio astronomy sites, FCC field offices and sensitive Government facilities. Licensees may not be aware of such requirements because the governing rules are not directly included in their services' rule parts. In addition, Section 1.923 states that some channel assignments and/or usage may be subject to provisions and requirements of treaties and other international agreements between the United States and Canada and Mexico. This general requirement is more typically contained in 47 CFR Part 1 rather than in the applicable rule part. (The treaties and agreements are not actually contained in the rules. Certain agreements with Canada and Mexico are contained within the International Bureau's web site http://www.fcc.gov/ib/sand/agree/. This is not an inclusive list however, as many agreements were approved decades ago[94].)

An analogy to a consolidated summary of rules governing interference may be made to OET Bulletin 65, which contains the general rules on limits for the absorption of electromagnetic radiation by humans. This bulletin, and its many supplements and annexes, may be analogous to a summary of interference rules, but on a much smaller

94 For example, *see Agreement Concerning the Coordination and Use of Radio Frequencies Above Thirty Megacycles per Second, with Annex, as amended*, Exchange of Notes at Ottawa, Canada, October 24, 1962, Entered into force October 24, 1962. See *also* USA: T*reaties and Other International Acts Series* (TIAS) 5205; CAN: *Canada Treaty Series* (CTS) 1962 No. 15; *Agreement Revision Technical Annex to the Agreement of October 24, 1962* (TIAS 5205/CTS 1962 No. 15) Effected by Exchange of Notes at Ottawa, Canada, June 16 and 24, 1965, Entered into force June 24, 1965. USA:TIAS 5833/CAN: CTS 1962 No. 15, as amended June 24, 1965.

scale, in that it addresses all FCC-regulated services in specifying acceptable measurement procedures for compliance with the standard for absorption of radiation.

A single document containing the consolidated summary of interference rules would be physically large, and maintaining its currency could require a considerable expenditure of time and other resources. The FCC is necessarily continually in the process of revising its existing rules and establishing new ones, and the potential exists for differences to develop between the rules as contained in 47 CFR and those as summarized in a separate document. Therefore, a practical means to maintain a consolidated summary of the interference rules may be to establish a web site that provides links to the appropriate sections of the most recent version 47 CFR and other useful information such as access to propagation models in current use. An electronic implementation of the consolidated summary of the interference rules comprising a series of links to the most recent version of the Rules may be the most efficient way to keep the summary up to date. For instance, the United States Government Printing Office periodically updates 47 CFR and houses the single source the FCC rules at its web site, http://www.access.gpo.gov/ecfr/.

4. Facilitating Access to Successful Practices for Interference Resolution

In an ideal world new services following the technical specifications and the service rules developed through the FCC's processes and promulgated in 47 Code of Federal Regulations (Telecommunications) would be designed, licensed, and implemented, without interference to existing licensees in neighboring frequency bands and geographic areas. In reality, however, practical systems are developed and fielded with an appreciation of the fact that transmissions from actual equipment in operation may be received by neighboring licensees for a variety of reasons including the non-ideal nature of transmitters, antennas, and receivers, the details of their relative positioning, and the statistical nature of electromagnetic propagation. Increasingly, the FCC has come to depend on the efforts of new and existing licensees and even third parties to make practical systems function together without improperly affecting each other, especially in shared bands. Indeed, the FCC has long depended on the efforts of third parties such as frequency coordinators for certain bands to assist new entrants by selecting appropriate frequencies and locations using detailed and complete data bases of licensee information including the technical specifications and actual locations of the transmitters and receivers. Fixed microwave facilities, private mobile radio services, and satellite earth-stations are examples. Importantly, the FCC in permitting increasingly flexible services such as Personal Communications Services has come to assume that licensees or their agents will seek to coordinate their system implementations and subsequent changes directly with each other rather than seek FCC intervention. PCS licensees have strongly supported this approach and have made it work.

Realizing the importance of the efforts of licensees themselves and of third parties to supplement the effectiveness of defined interference limitations and the technical and operational service rules, the Spectrum Policy Task Force raised the question of the desirability of facilitating privately negotiated solutions to interference problems. Such an approach could bring to the process of resolution of interference—from both a planning and an operational perspective—economic considerations of the impact of interference. Many commenters viewed positively efforts by the Commission to support such direct negotiated solutions. A general sense from the comments is that if private parties have sufficient information at their disposal, and if the Commission's rules regarding licensee rights with respect to possible interference are clear, the preferred approach is to try to resolve interference problems directly among the affected parties. Only if such efforts fail should the interference problem be referred to the Commission for resolution. Parties feel that private negotiations will lead, in most cases, to a much faster and more acceptable resolution of interference problems than using the Commission's regulatory processes.

In view of the fact that the total compendium of the FCC's rules in 47 CFR is not a complete handbook on how to implement practical communications systems, the experience of licensees and third parties across the several communications communities regulated by the FCC should be viewed as a valuable asset that could be used more widely. Accordingly, a "handbook" identifying successful practices, standards associations, key technical bulletins from the industry associations, and other aids in the resolution of interference could supplement the effectiveness of 47 CFR for interference management. Such a gathering of successful practices, a "best practices handbook," would be especially useful to those outside the existing communications communities seeking access to the electromagnetic spectrum for the first time with potentially innovative technologies. A "best practices handbook" for interference management would be a compendium of available information broadly related to the subject of interference management. Such a compendium need not be an actual physical document and could be realized as a web site containing important documents and standards addressing interference and links to other sites with relevant information on interference management for specific licensee communities. In this way, the information could be continuously and efficiently updated, and users could be assured that they were accessing the latest available information. Included in such a handbook could be such material as current industry guidelines used to coordinate spectrum use and manage co-channel and adjacent-channel interference problems for each service or group of services, examples of successful interference management negotiations, a list of steps parties should take to resolve interference problems; a list of steps parties could take to demonstrate that a proposed service will not pose undue interference on incumbent licensees, relevant technical bulletins issued by the FCC or technical standards bodies, a list of frequency coordination organizations, including links to their web sites, and a discussion of the FCC's licensee databases, including general instructions on how to conduct searches for co-channel licensees, for example, within a specified geographic area.

The handbook could be a vehicle to assemble and organize relevant interference management information in one virtual location to assist parties to help themselves to resolve problems independently, without direct FCC involvement. An example of the successful use of an actual best practices guide is a document developed in 2000 by several trade associations, an equipment manufacturer, and a wireless service provider to suggest ways to reduce or eliminate interference between public safety and CMRS radio systems. Subsequently, the Commission issued a News Release describing the guide and providing a copy of the full publication by means of a link to an electronic version. It is anticipated that a best practice handbook for interference management would include a link to this guide as well as any similar guides that may be relevant to interference management.

C. Recommendations

The Working Group recognizes the importance of the public's access to comprehensible and useful information and practices on interference management and has the following recommendations that address broadly (1) the language of interference and (2) the rules and practices governing interference management:

- Initiate a review and revision of the FCC's rules, possibly in conjunction with the existing biennial reviews, with the goals of
  - Harmonizing interference language, focusing on technical terms and units, and
  - Ensuring consistent and appropriate use of interference language, focusing on non-technical qualifiers.

- Organize and make public in documentation or at a web site, for the purpose of facilitating public access, a comprehensive and authoritative gathering of
  - The rules on interference for all the FCC's radio-based services and
  - The practices and procedures for interference resolution.

IX. Acknowledgements

The members of the Interference Protection Working Group wish to thank the participants in the public workshop on Interference Protection held on August 2, 2002. The wide-ranging views of these professionals reflect the deep experience of a diversity of communications communities and disciplines and have significantly informed the public discussion on the subject of interference.

APPENDIX A

Allocating Spectrum to Radiocommunication Services that are Grouped Together by their Similar Technical Characteristics

Exclusive Use of Service Allocations Based on Technical Characteristics

Radiocommunication services are able to operate in adjacent frequency bands through the use of power limits, out-of-band emission limits, and use of receivers that are able to filter out unacceptable interference from systems operating in adjacent frequency allocations. Other portions of this report focus on the specific technical characteristics that can be used for groupings or "zoning" based on a system's sensitivity to interference and how in-band signals are transmitted.[95] We focus here on the services that are allocated the same spectrum and have regulatory status in that spectrum.

Terrestrial Broadcasting Services

AM radio stations operate in the Broadcasting Service allocations from 535 kHz - 1705 kHz. AM stations are assigned frequencies on a non-interfering basis using desired-to-undesired signal ratios and power limits. There are four classes of AM stations with permissible powers between 0.25 kW and 50 kW. FM radio stations operate in the Broadcasting Service allocation from 88 -108 MHz. The Commission authorizes commercial and noncommercial educational (NCE) full-service stations, and low power FM (LPFM), FM translator, and FM booster secondary stations in this exclusive spectrum. Only commercial FM stations (92.1 MHZ to 107.9 MHZ) are assigned channels based on geographic allotments. Commercial FM stations are assigned these channels using minimum distance separation requirements that are based on desired-to-undesired signal ratios. There are seven classes of commercial FM stations (Class A, B1,B, C3, C2, C1, C) that are based on power (maximum permissible ERP is 100 kW) and antenna height (maximum permissible antenna HAAT is 600 meters) requirements. NCE FM stations are assigned channels on a non-interfering basis using desired-to-undesired signal ratios and power and antenna height limits. Based on power and antenna height authorized, NCE FM stations are assigned the same classes as commercial FM stations. There are two classes of LPFM stations (LP100 - 100 watts max ERP and 30 meters max antenna HAAT, LP10 - 10 watts max ERP and 30 meters max antenna HAAT) which are assigned channels using minimum distance separation requirements that are based on desired-to-undesired signal ratios. FM translator and FM booster stations are assigned channels on a non-interfering basis using desired-to-undesired signal ratios. AM and FM radio technology has substantially evolved over several decades. The exclusive Broadcasting allocations have provided this service the opportunity to explore ways to overlay digital radio technology in the same allocations (e.g. In-band, On Channel (IBOC) and In-band, Adjacent Channel (IBAC)). The constraints on the development of the digital systems have been inter-system related, not inter-service

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[95] These two areas are evaluated in other sections of this report on "Including receiver tolerances in the regulations" and "Enhancing transmitter interference control," respectively.

related. The addition of inter-service constraints would likely have resulted in further difficulties in developing the digital overlay techniques that are now being evaluated.

Broadcast television is allocated spectrum from 54 MHz to 806 MHz. The Commission authorizes full-service commercial and noncommercial TV broadcast stations, and low power TV (LPTV), TV translator, and TV booster secondary stations throughout the allocation. Only full-service commercial and noncommercial FM stations are assigned based on geographic allotments made to communities using minimum distance separation requirements that are based on desired-to-undesired signal ratios. Secondary LPTV, TV translator, and TV booster stations are assigned, for the most part, on a non-interfering basis using desired-to-undesired signal ratios. Broadcast TV has exclusive use of the Broadcasting Service allocation on channels 2 through 13 (54 MHZ to 216 MHZ) and channels 21 to 69 (512 MHZ to 806 MHZ), but must share spectrum on channels 14 through 20 (470 MHZ to 512 MHZ) with Public Mobile Services (Part 22) and Private Land Mobile Radio Services (Part 90). Broadcast auxiliary services also operate in the shared spectrum and are assigned frequencies on a non-interfering basis. The Commission continues to encourage Digital Television implementation in the exclusive Broadcasting Service allocation. The exclusive allocation has provided for digital television service rules that are less constrained than if the allocation were shared with other services.

Terrestrial Mobile Services

Mobile services are provided terrestrially in a wide variety of frequency bands, predominantly less than 2 GHz, allocated to the Mobile (and frequently Fixed) Services, for a wide variety of private and commercial purposes. The earliest mobile services were in support of public safety purposes and eventually evolved into the larger class of non-commercial, land mobile radio services, which today are usually not inter-connected to the public switched telephone network. This larger class is dominated by private land mobile services (Part 90), but also includes aviation (Part 80) and maritime (Part 87) services. Private land mobile radio services, which support the radio needs of private companies, as opposed to companies that offer communications services to the public, and other organizations such as state and local governments, generally share the frequencies that they occupy below 470 MHz. They have non-exclusive access to the channels through coordinators and may be assigned to time-share certain channels that are being used by other private users. For private services that use bands generally above 800 MHz, access to the spectrum is on an exclusive, “first come, first served” basis. Licenses for these services are generally site-based, that is, an applicant is granted the exclusive right to use the certain frequencies within an area determined by a base station location and a radius of operations for the mobile units. Other channels in the same geographic area may be assigned to other applicants through a coordinator for the services who maintains a database of the assignments. The same channel may be re-used by another licensee, if it is determined that the inter-site distance is sufficiently large so that the services would not interfere with each other; for example, 70 miles separation is required for private services at 800 MHz, because of the high power of the base station transmitters.

Commercial mobile radio services, on the other hand, are generally provided on a for-profit basis and offer inter-connection to the public switched telephone network (PSTN). The commercial mobile services of today have evolved from efforts to extend the PSTN to people in moving vehicles allowing them to talk to land-based telephone subscribers. The cellular concept evolved in a major movement away from the large separation distances required by private mobile services, which serve their mobiles with a single, high-powered transmitter. This concept involved the re-use of the same channels through smaller radius cells with lower-powered base stations and mobiles. The first important commercial radio service was cellular radiotelephone service. Starting in the 1980s, the FCC assigned equal amounts of spectrum on an exclusive basis to two cellular systems in each geographic area. These early assignments established a duopoly of carriers and involved licensing the single wireline common carrier in each area, but then making another license available, through administrative hearings and, later, lotteries. The two cellular providers were to compete in their offerings of cellular service to the public and initially used the same mandated analog technical standard developed by the industry and placed into the rules by the FCC. The rules for the exclusive use by the licensees included the identification of separate bands for the two competing entities, power and height standards, and emission limitations for the base station and mobile unit transmitters. These limitations were largely to assure that the cellular concept was implemented rather than the earlier concept of higher power base stations serving large areas. In order to protect other cellular licensees on the same bands, but in adjacent geographic areas, the licensees were permitted direct coordination with their neighbors in order to assure that the channels selected by the neighboring cellular licensees would not cause interference.

In its first major move to establish technical flexibility, the FCC in the late 1980s relaxed the rules for the cellular radiotelephone service and permitted the licensees the use of technologies alternative to the analog standard. (Although alternative technologies such as digital transmission techniques were permitted, the carriers were required to maintain a level of analog service in order to keep open the option of a nation-wide common standard. The FCC is currently considering the removal of this analog requirement.) By giving the cellular licensees the flexibility to use alternative transmission standards, the FCC enabled the move to digital mobile services. The FCC encouraged the cellular industry to act on its own and declined to participate in the industry standard-setting process to develop alternative digital standards, allowing the industry to determine its own best standards to best serve its business concept of service to the public. Out of this process digital mobile systems were developed and fielded for next-generation Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (CDMA) systems. The CDMA standards developed in this process have evolved become the basis for the advanced communications services being considered for much of the world today. In addition to this technical flexibility for the cellular service, the FCC also granted service flexibility by facilitating other uses of the cellular frequencies than for the mobile service. Fixed services may be offered by the licensee. Data services, permitting early access to computer networks, were also enabled for the mobile user through the use of cellular-delivered, packet-data (CDPD) service. The freedom given to the exclusive licensees of the cellular frequency bands for flexible use of alternative digital technical systems and of alternative service offerings is limited by the requirement that other cellular operators not experience interference to their services.

In contrast to the cellular service, which started out with a detailed technical standard for a specific and well-defined concept of mobile service, the Personal Communications Services (PCS) at 1850-1990 MHz was conceived from its beginning on the basis of technical flexibility to the licensee to choose the transmission standard that would best achieve the licensee's own concept of service. The purpose of the service was left to the licensee and was not specified in the minimal regulations, but only had to be consistent with the frequency allocation of Mobile or Fixed Services. The sizes of the spectrum blocks were sufficiently large to permit the licensees to subdivide the frequencies in order to offer alternative services. PCS licenses were assigned by competitive bidding, which was authorized by Congress in 1993. Accordingly, the licenses went to the highest bidder, thus allowing exclusive use of the spectrum under a flexible regime that would allow the licensee to respond to the market demands for service. Changes in the marketplace for communications services could in principle be undertaken without going to the FCC to initiate a rulemaking to implement new technical or service rules. The PCS technical rules specified no standard for channelization or for transmission and only gave height and power and emission limitations for the base stations and a maximum field strength to be maintained at the boundary of the service area. This field strength level could be re-negotiated by the neighboring licensees. Within the licensee's service area, the licensee is free to use the technology of its choice to offer the service it deems appropriate, consistent with the few limitations that were imposed. Fewer constraints on the terrestrial mobile (and fixed) services led to greater technical flexibility within the service. The Commission is now considering how to implement 3rd Generation mobile services where even more technical flexibility is envisioned.

Satellite Services

Satellite systems are used to provide fixed, mobile, broadcasting and other types of commercial services. The antenna patterns of satellites (international and domestic) generally overlap each other in the same geographic service area. The isolation among the satellite systems comes from orbital location separation, antenna beam separation, frequency assignment separation, or a combination of these. We evaluate these concepts and how they have been applied by the Commission to services that have similar technical characteristics. In many instances, satellite services are grouped together based on their similar technical characteristics. Many of the intra-service coordination mechanisms described below result from such groupings.

Fixed Satellite Service (FSS) - Geostationary(GSO/ FSS) sharing. GSO/GSO FSS sharing has been accomplished through orbital arc separation and the management of noise temperature (noise power) contributions from other GSO FSS networks. First, the amount of orbital arc separation between GSO FSS satellites was derived from extensive studies based on analysis of management of noise temperature from contributions of adjacent systems in the GSO arc. The Commission has adopted rules requiring an orbital separation of 2 degrees (2-degree spacing) for GSO FSS systems sharing the same spectrum and serving the U.S. This has provided for closer orbital spacing than generally used internationally and "packed" the GSO arc over the U.S. more densely. This has led to a rather competitive GSO FSS marketplace in the U.S. However, under this condition GSO systems are required to meet certain technical requirements including antenna directivity, off axis performance, EIRP limits and power levels at the GSO arc in order to minimize interference to adjacent GSO systems. This sharing orbital arc sharing mechanism provides an efficient way for utilizing the orbital arc and spectrum while providing sufficient system flexibility to GSO FSS operators.

The Commission's 2-degree spacing policy is based on the management of noise temperature among GSO FSS systems sharing the same spectrum. This concept is based on the premise that the noise temperature of a system is subject to increase as the level of interfering emissions from other systems increases. It is, therefore, applied irrespective of the modulation characteristics. Additionally, the ITU has relied on this concept for administrations, including the US administration, to follow to determine the potential for interference among GSO networks. Specifically, the ratio of the apparent increase in the equivalent satellite link noise temperature resulting from interfering emissions to the equivalent satellite link noise temperature (?T/T) is determined. If the ratio exceeds 6 percent, as determined by the ITU, then there exist the potential for interference and coordination is required between the GSO FSS systems. The equivalent satellite link noise temperature is referred at the output of the receiving antenna. For a bent pipe transponder (non-processing transponder) system the analysis encompasses both the uplink and downlink noise contributions. For a base-band transponder (signal processing transponder) system each portion of the link (i.e. uplink and downlink) is treated independently. This ?T/T approach to satellite coordination is made possible through grouping FSS systems with similar technical characteristics in the same service allocation.

Very Small Aperture Terminals (VSATs). In 1986 the Commission established rules for the licensing of very small aperture (VSAT) satellite earth stations in the 12/14 GHz bands.[96] Since then, VSAT operations have been widely deployed across the United States. VSAT systems are private networks that use a large main antenna to communicate by satellite link to a large number of smaller remote earth stations. The hub station controls all remote transmissions. The Commission provided for "blanket" licensing of VSATs by creating an exclusive allocation for the GSO FSS and VSAT operations. The FSS allocations that are used for VSAT operations have no terrestrial operations in them and, therefore, coordination among the operations is not necessary. This has led to much technical flexibility and growth in the service. The Ku-band FSS satellite networks are used for voice, data, facsimile and video transmission, satellite control signals and, also, broadcasting to consumers in what is called the "Direct-to-

[96] *In the Matter of Routine Licensing of Large Networks of Small Antenna Earth Stations Operating in the 12/14 GHz Frequency Bands*, Declaratory Ruling (rel. April 9, 1986) (VSAT Order). The 11.7-12.2 GHz Ku-band Fixed Satellite Service (FSS) downlink is associated with uplink spectrum at 14.0-14.5 GHz.

Home"[97] (DTH) GSO/Fixed Satellite Service. This should not be confused with the BSS described below. The allocations are now used to provide internet and video services directly to end users via smaller antennas than originally envisioned that are more marketable to consumers.

Broadcasting Satellite Service (BSS). In the 1980's, satellite technology advanced to the point where the direct to home Broadcast Satellite Services (BSS) could become a reality. The member states of the ITU realized that the ability to broadcast to the people of their countries could be extremely important and, in-order to ensure that all countries had access to this service, ordered the ITU to draft a technical plan whereby every administration could receive BSS TV services. The BSS plans took into account the requirements of all of the member states and, based upon assumed technical parameters and agreed upon interference allotments, attempted to fulfill everyone's BSS requirements. The ITU first developed a BSS plan for Regions 1 and 3[98]. Later, a Region 2[99] plan was developed that included the US requirements. In the ITU Region 2 the BSS Plan used 12.2 – 12.7 GHz for the satellite-to-user frequency band. At the same time the ITU recommended that the 12.2-12.7 GHz band be cleared of the existing fixed services because it was expected that fixed service systems would give interference to the ubiquitously deployed home BSS receivers. The exclusive BSS allocation allows satellite systems to share the spectrum through a geographic and orbital separation allotment plan that provides administrations access to particular orbital slots and channels in the plan. By limiting the operating constraints to inter-system sharing, U.S. BSS networks have adapted to the plan and use higher powered satellites to serve small antennas (i.e. smaller than 1.2 m VSAT antennas) that have much less gain but are more marketable to consumers.

Mobile Satellite Service (MSS). Exclusive spectrum and exclusive frequency assignments within the spectrum have been made by the Commission to provide for the implementation of MSS systems. In order to use omnidirectional antennas on the mobile satellite handsets, frequency separation among the satellite systems is necessary. Separate frequency assignments allow for higher power satellites to deliver signals to handsets with low antenna gain (e.g. omnidirectional antennas) and higher gain antennas on the satellites to receive weaker signals from the handsets. Like PCS and other emerging technologies, the exclusive MSS frequency assignments allow for smaller, less power consuming end user equipment that is marketable to consumers. The size of the mobile earth terminals (METs) must be small enough to have consumer acceptance. This could not be accomplished by PCS or MSS with directional antennas on the mobile terminals. The frequency and geographic isolation tradeoff in order to implement these services, therefore, leads to exclusive spectrum for the services whereby the systems have technically similar and compatible characteristics and the constraints are limited to intra-service sharing of the spectrum. Specifically, the Commission has allocated the 1525-

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[97] DTH-FSS originated in the 4/6 GHz, C-band frequencies and was later deployed in the Ku-band frequencies. Millions of home subscribers still receive programming in these frequency bands.

[98] ITU-R Region 1 is comprised of Europe, Russia and Africa. ITU-R Region 3 is comprised of Asia and Australia.

[99] ITU-R Region 2 comprises North and South America.

1559 MHz/1626.5-1660.5 MHz (L-band), 1610-1626.5 MHz/2483.5-2500 MHz (Big LEO band), and 1990-2025 MHz and 2165-2200 MHz (2 GHz MSS) bands for MSS system implementation.

L-band MSS. The L-band allocation was made by the Commission in 1986 and it concluded that, because of the difficulties in sharing the spectrum, the spectrum available in the L-band could support only one U.S. space station licensee. Currently, that U.S. MSS system is operating in portions of the L-band spectrum. Spectrum sharing problems arose because of the combined use of regional coverage antennas on the L-Band satellites and near-omni-directional antennas on the user terminals. The use of near omni-directional antenna was required to reduce the size of the user terminal but the lack of antenna discrimination prevented the isolation among the different L-Band MSS systems thereby reducing the total number of systems that could be implemented in the spectrum. For these same reasons, L-band MSS systems do not share the L-band service allocation with other services.

Big LEO MSS. The 1992 World Administrative Radio Conference (WARC-92) allocated the 1610-1626.5 MHz band on a co-primary basis with other satellite services for MSS operations in the Earth-to-space direction. WARC-92 also allocated the 2483.5-2500 MHz band on a co-primary basis for MSS operations in the space-to-Earth direction (the "Big LEO" bands). On a secondary basis, WARC-92 further allocated the 1613.8-1626.5 MHz band for MSS operations in the space-to-Earth direction. In 1994, the Commission allocated exclusive spectrum (with the exception of Radioastronomy in the 1610.6-1613.8 MHz band) and issued service rules for Big LEO MSS. Furthermore, the Commission designated the 1621.35-1626.5 MHz band exclusively to time division multiple access/frequency division multiple access (TDMA/FDMA) operations and the 1610-1621.35 MHz and 2483.5-2500 MHz bands for code division multiple access (CDMA) operations because of the inability of CDMA systems and TDMA/FDMA systems to share the same frequencies. Nonetheless, these constraints were intra-service related and were much less constraining on the deployment of the two MSS systems in operation today than inter-service constraints may have been on these systems.

2 GHz MSS. WRC-92 also allocated 1980-2010 MHz and 2170-2200 MHz bands to MSS on a global basis. Additionally, WRC-95 adjusted the allocations to include the 2010-2025 MHz and 2160-2170 MHz bands for MSS in ITU Region 2, effective January 1, 2005 in the United States and Canada effective January 1, 2000. In 1997, the Commission allocated the 1990-2025 MHz (uplink) and 2165-2200 MHz (downlink) bands to MSS in United States, it adopted 2 GHz MSS service rules in August, 2000, and issued MSS licenses in June, 2001. The 2 GHz MSS allocations are shared with terrestrial systems, however, and exclusive MSS use of the allocations is premised on the MSS licensees, according to service rule requirements, relocating the incumbent terrestrial systems.

Fixed Satellite Service (FSS) - Non-Geostationary Fixed Satellite Service (NGSO/ FSS) sharing. Service allocations typically do not distinguish among the different service delivery options available to the operators.[100] In the 1990s, a variation in the use of the FSS spectrum was initiated. It was proposed that constellations of Non-Geostationary (NGSO) satellites in the Ku-band frequencies (11 and 12 GHz band downlink, 14 GHz band uplink), under certain conditions, could share the same spectrum with the GSO FSS and the DBS systems. These systems now have international and domestic allocations in the 11.7-12.7 GHz range. NGSO FSS systems had a high potential to cause unacceptable interference to operational and planned GSO FSS systems. Initial sharing proposals from the NGSO community were based on non operation of NGSO systems within a defined orbital separation from the GSO arc. This was intended to limit the potential for in-line event interference. The initial proposals indicated that the NGSO systems could share without impact on the GSO networks and that the GSO networks would not be aware of the NGSO systems operations. However, the potential interference increases with the implementation of additional NGSO systems.

Previously, the GSO FSS interference environment was defined by the characteristics of the particular satellite networks in the GSO arc (GSO satellite sharing was based on orbital position, knowledge of antenna directivity and off axis gain characteristics, as well as power density levels – See earlier discussion of ?T/T). Now after more than 6 years of technical studies, a sharing solution was reached that provides for NGSO system operations without overly constraining incumbent GSO FSS systems.[101] The solution defined for the GSO community an aggregate interference that could be designed around by their future systems to accept the anticipated level of interference. Furthermore, the GSO FSS would have to limit its antenna off axis EIRP levels for future networks. The NGSO community as a result has a defined interference environment that is produced by the operational GSO FSS systems that it can design around.

Constraints were placed on the GSO FSS operations (and FS operations in the shared allocations) in the Ku-bands in the U.S. in order to increase in spectrum utilization within the FSS by NGSO systems. The price paid to maximize the use of the "white space" in the spectrum was that the incumbent GSO FSS operations (and terrestrial system operations in the shared bands) are more constrained in that they must take measures to protect the NGSO systems and accept more interfering power from them. The flexibility lost by the GSO FSS is that a possible reduction in antenna size or use of higher power levels in the future (which may be needed for higher level modulation to support new applications) were sacrificed to accommodate the new use of the FSS and FS allocations. The interactions between GSO and NGSO systems are being further considered in higher frequency bands such as 20/30 GHz (Ka-band) and 30/40 GHz (V-band).

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[100] The service allocation is technology neutral. For example, the allocation does not limit the frequency band to a particular modulation or orbital altitude.

[101] The sharing criteria resulted in limits to aggregate and single entry Equivalent Power Flux Density (EPFD) both in the uplink and downlink directions from the NGSO systems. This was a defined value which represents the combined radiation levels from the NGSO systems into any GSO receive antenna either at an Earth station or satellite.

Shared Use of Service Allocations

The C-band and Ku-band Fixed Satellite and Fixed Service Allocations. It is possible, too, for various services to share the same spectrum when their technical characteristics are different but compatible. For instance, in the United States, the 4/6 GHz spectrum (C-band) and 11/14 GHz spectrum (Ku-band) is allocated on a co-primary basis to the terrestrial Fixed Service (FS) and the Fixed-Satellite Service (FSS). Since 1974, thousands of terrestrial microwave stations and satellite earth stations have been coordinated and licensed by the Commission in the C-band alone. Within the FS, the bands are used for both commercial and private microwave communications. In the FSS, the 4 GHz and 11 GHz portions of the C-band and Ku-band are used for space-to-Earth (downlink) applications including direct-to-home video programming. The 6 GHz and 14 GHz portions of the bands are used for Earth-to-space (uplink) communications. International allocations are similar to the U.S. allocations. The stations of the two services use directional antennas which can be coordinated to use the same frequency assignments through geographic separation. Both services continue to coordinate the use of the "white space" in the C-band and Ku-band to maximize the use of the frequencies. Indeed, the service rules for FS and FSS systems in the shared frequency bands require advanced (prior to license application) frequency coordination between the fixed earth stations and microwave stations. The constraints are limited, however, to those that are necessary to complete the coordination of the systems (i.e. the constraints placed on the stations are limited to those necessary to resolve mutually unacceptable interference and the constraints may be more or less for different stations).

More recently, the Commission has adopted service rules and a licensing approach for C-band Small Aperture Terminals (CSATs). CSATs are similar to Ku-band VSATs (described earlier) in that they consist of networks of smaller remote earth stations that communicate via satellite to a large main antenna or hub. The hub station controls all remote transmissions. Because the C-band is used heavily by the Fixed Service, unlike the exclusive Ku-band FSS allocations for VSATs, technical constraints and coordination procedures were placed on CSAT operations. CSATs are limited to a portion of the shared allocation and to communications over a limited number of satellites. By adopting these limits, a streamlined licensing approach was made possible for CSAT licensees to more readily deploy networks of CSAT remote antennas while protecting the FS from unacceptable interference and preserving the C-band for future terrestrial FS growth.

Ku-band BSS, NGSO FSS and FS sharing. Use among systems in a shared allocation will become more and more constrained as system requirements call for complex sharing arrangements for all of the allocated services to have access to the spectrum. As more services are delivered directly to end users (the users can be anywhere in the geographic service area and the user density in the geographic area is high) the demand for uncoordinated access to the spectrum increases for ubiquitous deployment of systems. Furthermore, the licensing method used for ubiquitous terrestrial services authorizes the service provider on an 'area wide' basis the flexibility to install systems within a given geographic area. Any interference generated within the system is under control of the single operating entity. By the same token, ubiquitous space services that meet certain criteria can be provided ‘blanket’ licenses where the criteria applied to the space system prevents interference from occurring and allows the earth terminals to be placed at any location within the satellite service area. If transmitters of one system are randomly placed among the receivers of another system through wide-area or blanket licensing, interference will occur. Therefore, sharing between two ubiquitous services in the same geographic areas is, in general, not feasible.

Furthermore, it is costly for ubiquitous services to have constraints on the placement of terminals because of the needed ability to serve customers that may be anywhere within the licensed geographic service area. Operating constraints such as transmitter power or placement limit the operators’ flexibility to provide true ubiquitous service. For example, the Direct Broadcast Service (DBS) is a BSS service in the U.S. which is ubiquitous. Geostationary (GSO) DBS satellites deliver broadcast signals to users through out the U.S. The DBS receivers all use high gain antennas that generally point in a southerly direction and can be located anywhere in the country. The NGSO/FSS proposed to take advantage of these operating characteristics and limit the interference power that it would produce at a DBS receiver from a constellation of satellites delivering broadband data in the same frequency band. This sharing situation results in power constraints on the NGSO/FSS and an increase in the interference normally received by a DBS user.

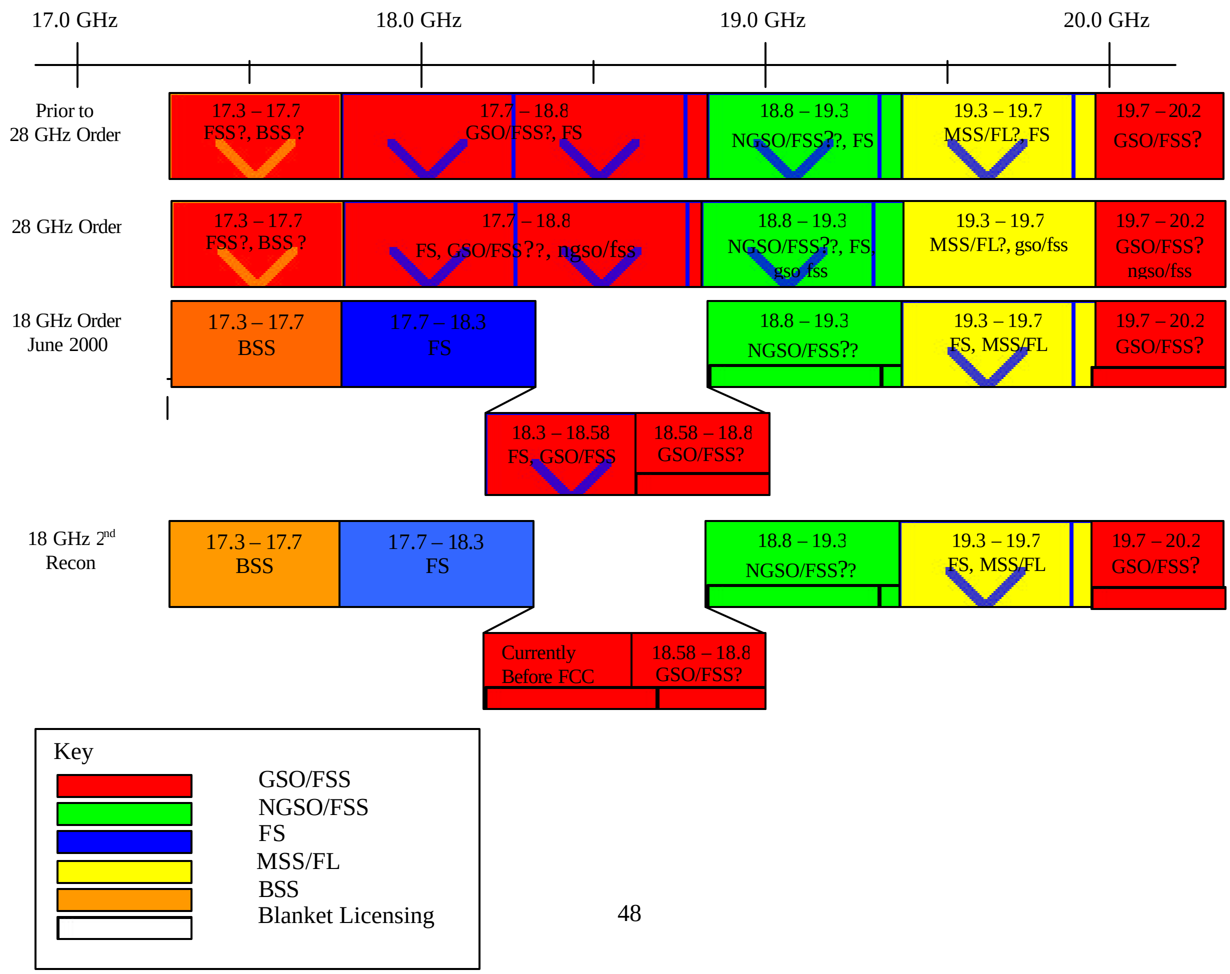
Recently, another service, MVDDS, proposed to operate in the FSS and BSS frequency bands. MVDDS is a terrestrial point-to-multipoint service. In this case, the Commission adopted rules that will permit the three ubiquitous services to exist in the same band by placing constraints on the MVDDS transmitters and defining areas where NGSO/FSS stations are not permitted to operate. It also adopted a “first-in” arrangement whereby the MVDDS operator must not operate within 10 km of an NGSO receiver and the NGSO operator must accept interference from preexisting MVDDS transmitters. Additionally, the MVDDS operator must notify the NGSO operator of the location of the MVDDS transmitters so that the NGSO operators can avoid them. In sum, the introduction of MVDDS resulted in power constraints on the MVDDS to protect both the DBS and NGSO FSS systems, the possible exclusion of the NGSO/FSS from areas near an MVDDS antenna, and DBS receivers will need to accept additional interference.

In general, the tradeoff for introducing more services into an allocation is to limit some of the technical flexibilities of all the systems in the allocation. As the sharing situation becomes more complex, more constraints must be placed on newly introduced services and on the existing services as well. Wide-area and blanket licensing is also constrained due to the need to accommodate the “first-in” stations of the other service. At this stage, the services are no longer truly ubiquitous.

Sharing possibilities in the Ku-band among ubiquitous services have been explored but in the Ka-band and V-band, the Commission has taken a different approach. The approach has led to fewer technical and regulatory constraints on the services but the cost associated with the flexibility to have blanket licensing and wide area licensing comes at the price of exclusive service allocations. In the Ka-band and V-band, it is proposed that ubiquitous point to multipoint services with small antennas with little or no sidelobe attenuation would have highly dense deployment of transmitters and receivers. If both services are to operate in same frequency band, many more constraints on both services would have to be in place to avoid mutually unacceptable interference. An alternative would be to allocate spectrum exclusively to each of the particular services and limit constraints to intra-service operations. This provides certainty to licensee and provides for more technical flexibility within the service.

Ka-band FSS and FS sharing. From 1997 to the present, the Commission has modified the frequency allocations and developed service rules (including rules for relocation of incumbent systems) throughout the 17-20 GHz range of frequencies. The allocation changes and service rules adopted by the Commission define the sharing possibilities among the various satellite services and terrestrial services. The following figure shows how the service allocations have changed in recent years.

The main reason for the band arrangement is that both the satellite and the fixed services had requirements for ubiquitous deployment of end-user stations. There is great difficulty in having two truly ubiquitous services sharing the same spectrum as discussed earlier. In this case the ubiquitous services included the BSS, NGSO/FSS and GSO/FSS. The FSS proposed to provide service to businesses and households from low-orbit and geostationary satellites. The FS allocation is mainly used to provide wireless cable distribution. The BSS proposals are to transmit to the satellites from feeder-link earth stations and downlink to ubiquitous home receivers in the 17.3-17.7 GHz band.



The amount of spectrum that is shared among the terrestrial and satellite services has been significantly reduced. By separating the band into allocations to services that have similar technical characteristics, blanket licensing and wide-area licensing for the FSS and FS, respectively, is made possible for the services over most of the spectrum.[102] This permits the service operators to deploy user terminals without having to coordinate with each other. This can only be done without interference constraints relating to inter-service sharing (i.e. in bands free of other services). This required the Commission to adopt rules for relocation of incumbent systems at the expense of the new system operators.

V-band FSS and FS sharing. Prior to 1994, most of the millimeter wave technology in the V-band was funded by the U.S. Government for military and scientific purposes. There was little commercial use of the band, but as technology has evolved, the Commission has initiated several proceedings to make portions of the V-band available for commercial use. Proposals for new technologies increased the demand for spectrum allocations in the 36-51 GHz band and led to complicated spectrum sharing arrangements. The Commission proceedings addressed the potential interference problems between terrestrial wireless systems and satellite services recognizing the limited possibilities of high-density terrestrial wireless systems and high-density satellite systems sharing the same frequency bands.

The Commission recognized, too, that sharing between services intended for communications with ubiquitous consumer terminals, would likely result in undue technical constraints on one or both of the services. These technical constraints would not permit terrestrial fixed wireless systems (FS) or FSS to achieve their full potentials. After several years of domestic proceedings and World Radiocommunication Conferences (WRCs), the Commission released a Further Notice of Proposed Rulemaking in May 2001 that proposes to re-designate portions of the V-band spectrum for FS and FSS, and it creates and shifts allocations of the services. The proposed changes reflect the "soft segmentation approach" developed by the U.S. delegation to the WRC-2000 and adopted by the WRC-2000. The "soft-segmentation" sharing arrangement was also incorporated in the International Radio Regulations. The soft segmentation approach generally favors wireless services in the spectrum below 40 GHz and favors satellite services in the spectrum above 40 GHz by requiring more stringent satellite power limits in the spectrum below 40 GHz. The U.S. is attempting to harmonize its spectrum allocations with the international and regional allocations in order to promote cross-border arrangements that would enhance the delivery of all V-band services to consumers.

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[102] The MSS/FL allocation from 19.3-19.7 GHz does not involve ubiquitous services and therefore sharing with the FS is possible. Mobile satellite service Feeder-links only involve a few earth stations that use large, highly directive, antennas. These earth stations can share with the FS via standard a frequency coordination approach and wide FS station deployment is still possible.