Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the matter of	)	
	)	
Establishment of an Interference Temperature	)	
Metric to Quantify and Manage Interference	)	ET Docket No. 03-237
and to Expand Available Unlicensed Operation	)	
in Certain Fixed, Mobile, and Satellite	)	
Frequency Bands	)	

COMMENTS OF MOTOROLA, INC.

Steve B. Sharkey
Director, Spectrum and Standards Strategy

Robert D. Kubik, Ph.D.
Manager, Regulatory and Spectrum Policy

Motorola, Inc.
1350 I Street, NW
Suite 400
Washington, D.C. 20005

April 5, 2004

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SUMMARY

Motorola generally welcomes the Commission's exploration of new ideas and concepts as it attempts to provide avenues for the introduction of new technologies and services, as well as to provide greater certainty regarding the use of the radio spectrum. However, Motorola believes that there are significant technical challenges that would need to be overcome to realize implementation of the interference temperature concept in a way that provides the necessary protection to incumbent and primary services. As described in more detail below, challenges include, 1) the need to account for a wide variety of design characteristics of primary services and to not impede the ability of those systems to evolve system designs or technologies, 2) the difficulty of measuring the noise floor in frequency bands that are actively used by primary services, and 3) the inability of an unlicensed transmitter to determine the path conditions between it and a potential victim receiver operating on a primary basis.

The technology necessary for widespread implementation of this concept is beyond current state of the art, is prohibitively expensive, and would have a significant and unacceptable impact on primary services. Given that systems implemented under the interference temperature concept would have to operate at extremely low power to avoid interfering with existing and primary users, there appears to be little counter balancing benefit to pursing this concept at this time.

Implementation of interference temperature faces challenges in almost any frequency band, but those challenges are especially great in frequency bands used for mobile services due to the dynamic radio relationship between mobile receivers and transmitters. The uncertainty of implementation is exacerbated in bands used for public safety communications, where the criticality of communications justifies providing the highest levels of protection.

In support of its comments, Motorola provides two technical studies demonstrating the significant impact that the introduction of interfering sources would have on CDMA cellular systems and on fixed point-to-point operations.

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Motorola, Inc. ("Motorola") respectfully submits these comments in response to the Federal Communications Commission's ("FCC" or "Commission") *Notice of Inquiry* ("*NOI*") and *Notice of Proposed Rulemaking* ("*NPRM*") in the above captioned proceeding.[1] In this proceeding, the Commission is exploring options for developing a regulatory regime in assessing interference based on the actual radiofrequency ("RF") environment, as opposed to being based only on transmitter operations, and therefore seeks comment on a new analytical and regulatory model it calls the interference temperature metric.

In general, Motorola welcomes the Commission's exploration of new ideas and concepts as it attempts to provide avenues for the introduction of new technologies and services, as well as to provide greater certainty regarding the use of the radio spectrum. However, Motorola believes that there are significant technical challenges that would need to be overcome to realize

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[1] *Establishment of an Interference Temperature Metric to Quantify and Manage Interference and to Expand Available Unlicensed Operation in Certain Fixed, Mobile and Satellite Frequency Bands,* Notice of Inquiry and Notice of Proposed Rulemaking, FCC 03-289 (Nov. 28, 2003) ("*NOI*" or "*NPRM*").

implementation of the interference temperature concept in a way that provides the necessary protection to incumbent and primary services.

As described in more detail below, these challenges include, 1) the need to account for a wide variety of design characteristics of primary services and to not impede the ability of those systems to evolve system designs or technologies, 2) the difficulty of measuring the noise floor in frequency bands that are actively used by primary services, and 3) the inability of an unlicensed transmitter to determine the path conditions between it and a potential victim receiver operating on a primary basis. Further, the technology necessary for widespread implementation of this concept is beyond current state of the art, is prohibitively expensive, and would have a significant and unacceptable impact on primary services. Given that systems implemented under the interference temperature concept would have to operate at extremely low power to avoid interfering with existing and primary users, there appears to be little counter balancing benefit to pursing this concept at this time.

Implementation of interference temperature faces challenges in almost any frequency band, but those challenges are especially great in frequency bands used for mobile services due to the dynamic radio relationship between mobile receivers and transmitters. The uncertainty of implementation is exacerbated in bands used for public safety communications, where the criticality of communications justifies providing the highest levels of protection.

In support of these positions, Motorola provides two technical studies demonstrating the significant impact that the introduction of interfering sources would have on CDMA cellular systems and on fixed point-to-point operations.

I. IT IS PREMATURE TO IMPLEMENT THE INTERFERENCE TEMPERATURE MODEL.

The purpose of the subject *NOI* is to examine a potential "fundamental paradigm shift" in the Commission's approach to spectrum management by specifying a potentially more accurate measure of interference that takes into account the cumulative effects of all undesired RF energy.[2] In the Commission's view, the interference temperature metric would: 1) provide licensees with greater certainty regarding the maximum permissible interference and greater protections against harmful interference, and 2) identify spectrum opportunities for other transmitters in bands where the interference temperature threshold is not met.[3] The *NOI* seeks general comment on the potential of this new approach while the *NPRM* endeavors to implement the measure on a limited basis in two specific frequency bands.

In comments originally submitted in response to the Commission's Spectrum Policy Task Force Report, Motorola expressed caution on a number of elements of this concept.[4] Motorola emphasized that the primary objective of this examination must be to protect incumbents with primary rights from experiencing harmful interference.[5] Motorola also noted the complexity of

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2 *NOI* at ¶1. Motorola views the Interference Temperature metric as an extension of the concept of antenna noise temperature, which is a central component in radio science. When a receiving antenna is presented with a spatial energy density, it cannot distinguish between active and passive emissions; it simply integrates the incident energy density and produces a representation of that energy at its output. That an energy density can be used interchangeably with a temperature is well-accepted physics, and as such the Commission's extension of an interference temperature as a representation of an active emission of energy density is well founded in scientific principle. While Motorola does not dispute that an interference temperature can serve as a representation of an integrated average of the spatial energy density as observed by a receiver, Motorola is concerned about the practical effects of using this information for real-time spectrum management purposes.

3 *Id.*

4 Comments of Motorola, Inc., Spectrum Policy Task Force Report, ET Docket No. 02-135 (Jan. 27, 2003) ("Comments").

5 Comments at 13.

determining and controlling the influence of a transmitter's emissions upon a remotely located receiver.[6] Specifically, Motorola detailed a variety of technical hurdles, including the mobility and proximity of primary and secondary users, which must be overcome if the potential benefits of an interference temperature metric are ever to be realized.[7] In light of these observations, Motorola urged the Commission to further analyze and study the interference temperature concept while noting that, practically, an interference temperature metric may be a long way from being ready for deployment in the real world.[8] Motorola continues to believe that near-term implementation of interference temperature is not practical and that implementation will not provide the benefits of providing certainty for existing services or providing meaningful opportunities for new services that the Commission is seeking.

The instant *NOI* and *NPRM* ask a myriad of questions designed to stimulate debate on how an interference temperature metric can be established. While the Commission has provided a discussion on some of the challenges in implementing this concept, the industry is not sufficiently advanced to provide the real time monitoring of the noise floor that is necessary for a successful implementation of this concept.[9] The industry only now is starting to develop the types of sensory and control technologies that could even begin to govern the action of emitters in response to real-time interference temperature data. Technologies that will effectively protect licensees are, therefore, either beyond the current state-of-the-art or so prohibitively expensive that the Commission cannot reasonably expect consumers to buy equipment that utilizes these

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6 Comments at v.

7 Comments at A-4 – A-7.

8 Comments at 14.

9 *NOI* at ¶ 23.

technologies. As such, it is impractical to begin implementation of an interference temperature metric when the technologies that will adequately protect incumbent licensees do not exist.

Therefore, consideration of establishing interference temperature metrics in any specific frequency bands, including those discussed in the *NPRM*, is premature until the FCC and the broad telecommunications industries reach a consensus on whether and how the metric can be effectively implemented without placing incumbent communications systems at greater risk to harmful interference. Adequate consideration of all of the factors that could potentially affect the interference level imposed on licensees is essential to the effective implementation of an interference temperature metric. These factors vary on a band-by-band basis and a system-by-system basis and will change as primary systems continue to evolve.

The burden for establishing that there is no unacceptable interference should be placed on the new entrant. This approach is consistent with established policies, including the approach taken in making spectrum in the 5 GHz band available for unlicensed use. In the 5 GHz band, the Commission imposed technical restrictions on unlicensed services that would adequately protect incumbent licensees.[10] Although the same technical restrictions utilized in the 5 GHz band will not work in other bands, as demonstrated by the Motorola study in the attached appendix B, the Commission would need to impose similar restrictions or guidelines on unlicensed users that will ensure primary licensees' protection from unreasonable interference.[11]

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[10] Revisions of Parts 2 and 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) devices in the 5 GHz Band, Report and Order, FCC 03-287 (Nov. 18, 2003).

[11] The FCC must establish clear criteria to verify that unlicensed devices actually comply with their necessary obligations for monitoring the interference temperature and must take appropriate actions when the threshold is breached. If the Commission is unable to do so, it should defer implementation until such a time when it can practically enforce the established interference temperature.

The primary licensee, however, should be an active participant in determining whether unacceptable interference would occur. In order to adequately protect primary users, the Commission must fully understand all elements of those users' operations, including technical characteristics, operating environment, and service expectations. Only licensees are fully aware of the interference levels they can sustain. Their determination of the appropriate interference temperature should bear a significant amount of weight in the Commission's determination of appropriate interference metrics. The Commission should not undermine a licensee's ability to operate, or require licensees to bear a significant economic impact in order to accommodate underlay uses of spectrum pursuant to an interference temperature concept.

II. IT IS NOT PRACTICAL TO UNIVERSALLY IMPLEMENT THE INTERFERENCE TEMPERATURE METRIC.

The Commission must take into account many factors that vary service-by-service, system-by-system and band-by-band in trying to determine an appropriate interference temperature. These factors include the design of primary systems operating in the band and whether the band is used for mobile, fixed, broadcast, or satellite services, the antenna types and gains used, the modulations and technologies used and margins provided in the system design and the expected coverage area. Even if the Commission developed a band-specific interference temperature taking all of these factors into account, the Commission would also have to ensure that the interference temperature does not impede the ability of licensees to improve and evolve their systems or technology. Such flexibility is one of the core tenets of the Commission's spectrum management policy. It is therefore impossible for the Commission to dictate a single interference temperature metric for all bands and all users and even more difficult to develop an interference temperature that does not impede licensees' ability to innovate and improve their service while maximizing their own spectrum efficiency.

Implementing the interference temperature in frequency bands used by land mobile services is particularly challenging. Four characteristics of land mobile services would make it difficult to implement an interference temperature metric in these bands. First, as described below, the mobility of land mobile users makes it impossible to adequately model the interference environment on a dynamic basis. Second, certain technologies operating in bands allocated for land mobile services require significant bandwidth, particularly those that are designed to provide data services. Third, different technologies often operate in the land mobile bands. Fourth, the critical nature of public safety communications warrants the exclusion of any measures such as interference temperature being implemented in frequency bands used for public safety.

In the case of systems providing data services, additional interference would significantly decrease a given system's capacity and degrade the efficiency of the network by reducing throughput or the number of users that can be served, thereby limiting a licensee's ability to provide its intended service. For example, Motorola has assessed the potential impact to WCDMA operations at 850 MHz and has concluded that a 1 dB increase in interference to the thermal noise could decrease the uplink capacity by nearly 10 percent.[12] This would impact the reliability and availability of the service, would negatively impact the data rates available to users, or would require the licensee to spend millions of dollars to deploy additional infrastructure.

Differences in technology deployed will also impact the determination of the interference temperature. For example, both CDMA and GSM technologies operate in the PCS bands. These technologies have significantly different operating characteristics and utilize different types of

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[12] *See* attached Appendix A.

receivers. Such differences make it extremely difficult to develop an interference temperature metric that will protect all licensees. For these reasons, the use of an interference temperature metric in the land mobile bands to allow for underlay deployment of unlicensed transmitters is not appropriate for the foreseeable future.

The Commission should also exempt from consideration any frequency band used by public safety agencies. Clearly, the criticality of public safety communications requires the utmost protection. In the Spectrum Policy Task Force Report, the Commission acknowledged the essentiality of public safety communications and hence determined that spectrum currently set aside for public safety should remain subject to the command and control model of regulations.[13] The establishment of an interference temperature in public safety bands would undermine this determination and would put at risk the reliability of public safety spectrum. Hence, public safety spectrum should not even be considered for the interference temperature metric. Other critical spectrum uses related to homeland security should also be afforded similar consideration.

III. NOISE FLOOR MEASUREMENTS IN INCUMBENT FREQUENCY BANDS WILL BE EXTREMELY DIFFICULT TO ACQUIRE.

The *NOI* recognizes that the effectiveness of the interference temperature concept depends on "an understanding of the condition of the RF environment, *i.e.*, the noise floor."[14] Unfortunately, the only reliable way to measure a true noise floor without considering the contributions of primary services is to command every primary transmitter to be silenced. Only then could the noise floor be accurately measured, since only natural and unintentional man-

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13 *See* Spectrum Policy Task Force Report, FCC, ET Docket No. 02-135, at 21 (2002).

14 *NOI* at ¶24.

made emissions would be present. The intentional radiators would have to be silenced because, even if they could all be demodulated and have their relevant parameters (e.g., amplitude, phase) estimated, at weak signal levels there would be some (perhaps substantial) estimation error, and so some residue would remain after canceling the signals. This residue would give a false reading of the noise floor.

Of course, the consequence of such a shut down of incumbent operations is the loss of revenue or services to commercial operations or the disruption of other critical, private communications. These consequences are clearly unacceptable. While a system shut down could be scheduled during low usage hours, such a measurement may not be representative of noise levels during other times of the day. For example, ignition noise due to heavy traffic will be different at 3:00 AM than it is at rush hour. Industrial noise may also be lower at off-hours.

Even more problematic than getting a one time measurement of the noise floor would be the problem of an unlicensed device attempting to determine whether the interference temperature threshold has been met in a band, and therefore whether the device can transmit or not. If these unlicensed devices were monitoring emissions, they would include the emissions from primary services, as well as emissions that contribute to the interference temperature, making it difficult or impossible to transmit.

One could argue that it is possible for some systems to work short-duration measurement opportunities into their regular operations if there is unused capacity. For example, unused time slots in a TDMA system or down time in a packet system could be used to perform a measurement provided the measurement equipment could be synchronized with the system. But the timeslots would have to be vacant on the desired frequency (as well as adjacent and perhaps alternate channels) in the desired and all neighboring transmitters to ensure that there is no interference from other transmitters. This would require a tremendous amount of coordination that may not even be feasible given that the system architecture would not likely have accounted for this need. Already, higher speed data solutions are beginning to fill these gaps. CMRS operators and manufacturers are financially motivated to maximize the use of their channels by filling all unused timeslots. In systems that do not have the possibility of built-in opportunities, such as CDMA or other continuous waveforms, the only recourse is to power down the transmitters.

Conceivably, it may be possible to use the licensed receivers as the noise measurement devices. The receivers would be synchronized to the system and could listen to empty time slots in a TDMA system or down time in a packet system, but this would require several non-trivial modifications to the receivers' hardware and software.[15] However, if the licensed receivers were for continuous waveforms like CDMA, it would still be difficult to acquire a good noise floor measurement due to the difficulty of separating the environmental noise from noise due to system linear distortions (e.g. error vector magnitude from intersymbol interference due to receiver filtering, multi-path effects, etc.). This all assumes that interference from neighboring transmitters is not present, which is unlikely given the coordination challenges already pointed out above. For these reasons, Motorola believes that establishing benchmark noise floor readings in incumbent frequency bands will be extremely problematic.

[15] Hardware and software changes would be needed to enhance the receivers' ability to 1) perform accurate power measurements at the noise power level; 2) keep the receiver activated during times other than its required operating time, which will impact battery life if the unit is battery powered; and 3) perform the noise analysis and report its findings back to a central location. This latter issue will require modifications to the infrastructure software to accommodate and process this new information.

IV. IMPLEMENTATION OF THE INTERFERENCE TEMPERATURE METRIC RAISES TECHNICAL ISSUES THAT ARE NOT EASILY ADDRESSED BY EXISTING TECHNOLOGIES.

The task of determining and controlling the influence of a transmitter's emissions upon a remotely located receiver is an enormously complex problem. Many unique circumstances must be taken into account when establishing both an interference temperature and the guidelines for monitoring compliance with that interference temperature. Motorola described a number of these challenges in a white paper submitted to the Spectrum Policy Task Force in October, 2002. These challenges include:

- ***Shadowing*:** Interference temperature measurements at a single location do not necessarily indicate the interference level at the primary user. Shadowing of the antenna of the measuring receiver may significantly attenuate the sources of interference. The effectiveness of the measuring receiver is a function of the details of the relative locations of the measuring receiver, interference sources, the primary user, and physical obstructions. In some cases, an obstruction will be between an interference source and a measuring receiver trying to monitor the interference temperature. This situation is illustrated in Figure A.

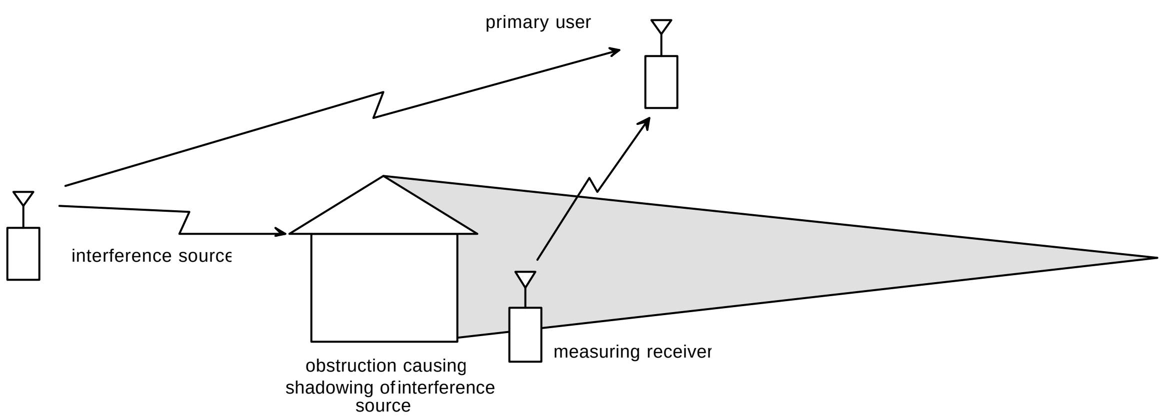

Figure A. Shadowing of the measuring receiver from the interference source may cause incorrect assessment of interference level.

- ***Antenna directionality and gains*:** Antenna patterns significantly impact the level of interference experienced by the primary user. Specifically, if the primary user utilizes a directional receive antenna, the measuring receiver estimating the interference temperature impact on the primary user requires knowledge of many aspects of the primary receiver including its pointing direction, the location, and information about the antenna pattern. If the measuring receiver also has an associated antenna gain in the temperature-monitoring receiver, the interference temperature level experienced by the primary user could vary significantly depending on the measuring receiver antenna pointing direction and the location of the measuring receiver. It would be virtually impossible for the Commission to take into consideration the antenna pattern of every single receiver used by every single licensee in establishing an interference temperature metric for a band and yet this is what would be required to ensure licensees the adequate interference protection to which they are entitled.

- ***Path loss*****:** The uncertainty of all the path losses; e.g. primary transmitter to primary receiver, primary transmitter to measuring receiver, interference sources to primary receiver and interference sources to measuring receiver, may greatly affect the measurement and impact of interference temperature at the primary receiver. Path loss depends on the terrain details and distance, both of which are most often not known. In determining an appropriate interference temperature it would be necessary to make assumptions regarding the path loss conditions. To provide appropriate and adequate protection to the primary user, these assumptions would have to be conservative, leading to very low usable power levels for the unlicensed devices.[16]

- ***Detector sensitivity*****:** Primary-user activity over the entire service area must be estimated. The number and locations of measuring receivers required to detect this activity is a function of the sensitivity of the measuring receivers themselves as well as the characteristics of the measuring receiver antennas. If the measuring receiver sensitivity was adequate, it is conceivable that a single measuring receiver co-located with the non-primary user's transmitter could be sufficient. However, it is unlikely that radiometric detection techniques could achieve the required sensitivity, so that a measuring receiver array would be required to adequately sense activity over the service area.[17]

- ***Transmission formats*****:** The detectability of signals is affected by modulation details. For example, it is possible to design waveforms that appear as thermal noise to the measuring receiver. Waveforms designed in this manner are called Low Probability of Detection (LPD) waveforms. Their use in a system may make it virtually impossible to discriminate between primary users' signals and actual interference temperature. Many next-generation cellular systems will use direct-sequence spread spectrum technology designed for operation at very low signal-to-noise power ratios

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[16] To this end, the Commission should also consider the fact that while many systems are predominantly interference-limited, there are often substantial regions in the coverage area where unfavorable propagation attenuates the signal sufficiently such that the desired communications become noise-limited. Introducing additional interference into such signal paths will result in a complete loss of coverage. Furthermore, new noise-limited zones can be created every day, with the construction of new buildings that can shadow communications, or penetration into new buildings, or buildings with newly applied materials (e.g., window coatings or treatments, aluminum siding, etc.). In other words, it is extremely problematic for the Commission to consider imposing a uniformly degraded noise floor.

[17] Detector sensitivity is, of course, also affected by the noise figure of the sensor radio frequency circuitry. Motorola notes that techniques are known that achieve detection sensitivities superior to the sensitivities of a classical radiometer.

> in the full trans-mission bandwidth. These waveforms will be difficult to detect using radiometric techniques. Also, non-continuous waveforms (e.g. TDMA) may be more difficult to detect than continuous waveforms. Problems will also be created if the primary user's receiver and the measuring receiver operate on different bandwidths. Consider the case in which the measuring receiver has a bandwidth larger than the primary user's receiver. In this case, random noise sources that contribute to the interference temperature measured by the measuring receiver will be averaged and reported over the bandwidth of the measuring receiver, rather than the bandwidth of the primary user's receiver. In such a case, the narrowband random noise sources would have a significantly greater impact on the primary user receiver than anticipated by the measuring receiver.

The net result of all of these variables is that it is impossible to predict whether dynamic interference temperature measurements precisely model the nearby radio environment. If they do not, then the primary user will likely experience significant interference that could potentially cripple, or at least substantially impair, its operations, a result that is unfair to primary licensees that have relied on the Commission's current interference protections.

V. NO VIABLE INTERFERENCE MONITORING SYSTEM HAS BEEN IDENTIFIED.

The Commission seeks comment on what type of network is needed to monitor the radio environment and how such information should be disseminated to unlicensed devices, raising three possible scenarios that could provide the necessary monitoring information, including suggestions that the monitoring process take place within an individual device and that a grid of monitoring stations be developed.[18] The simplest case presented, where the secondary device would measure interference temperature and make a go/no-go decision based on the measurement plus the device's own contribution, is not practical for all situations. The secondary device has little or no knowledge of the difference in propagation conditions between the two locations (assuming it knows the locations), and cannot know what kind of path losses its

[18] *NOI* at ¶ 11-12.

transmissions would experience. Nor could it know if another secondary user is already transmitting elsewhere and causing interference to the incumbent primary user, but whose contributions are not measurable at the secondary unit in question. Given that typical propagation studies show that power level measurements experience a standard deviation on the order of 6 – 8 dB at a given range[19] and considering that two propagation paths must be predicted, there is a possibility that the incumbent user could be experiencing a desired signal level that is tens of dB weaker than the secondary user's observation. Likewise, the secondary user's measurement of the interference could be equally erroneous. Extreme margins would have to be built in to ensure that no harmful interference is present at the incumbent receiver.

As we have mentioned in our previous reply to the Spectrum Policy Task Force, the suggestion that licensed services should somehow be responsible for broadcasting monitored information at its receiver locations for use by unlicensed devices is the most meaningful but also has the biggest impact on the incumbent in terms of hardware and/or software modifications. This is an unreasonable imposition, considering there is no benefit for the incumbent. Motorola questions the policy of requiring spectrum incumbents to absorb costs for the establishment of potentially interfering service offerings. Regarding a pervasive monitoring grid, even if a monitoring grid could be established, individual primary receivers may frequently experience higher levels of interference than the monitoring system would predict because they are seldom if ever co-located. In Motorola's view, the establishment of a monitoring network that would broadcast real-time noise floor information would be of limited value if it does not accurately represent the environment of the victim receivers.

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[19] Motorola, Inc., "Proposed Revision to Recommendation ITU-R P.1411-1: Suburban Multipath Propagation and Path Loss Characteristics in the 3.7 GHz Band", ITU-R WP3K, Document 3K/49-E, Geneva, Switzerland, May 2002.

VI. FURTHER CONSIDERATION OF THE NOTICE OF PROPOSED RULE MAKING IS PREMATURE.

The Commission should not establish interference temperature thresholds at this time. As described above, the establishment of an interference temperature for any single frequency requires a careful balancing of a multitude of factors, and the implementation of such a metric that failed to take into consideration a crucial factor could cause substantial damage to a licensee's operations. To date, little analytical work has been done and there have been very few real world tests that indicate the actual effect such a regulatory regime will have on incumbent users' operations. Furthermore, licensees have not yet determined, based on their individual operating characteristics, what interference levels are acceptable and will enable them to continue to operate effectively.

The proposals in the *NPRM* rely on work in other bands, specifically the 5 GHz band. This work, however, is not directly applicable to the 6525-6700 MHz, 12.75-13.15 GHz, and 13.2125-13.25 GHz bands. As demonstrated by the attached Motorola study, the application of DFS parameters designed to protect high power radars in the 5 GHz band will result in significantly different outcomes when applied to systems in the 6525-6700 MHz band.[20] Specifically, this study found that, when applying the same DFS parameters, the interference experienced by operators in the 6 GHz band is more than 60 dB higher than the interference experienced by operators in the 5 GHz band. Clearly, the characteristics of these two bands and the licensees operating in these bands are significantly different and the positive results from use in one band cannot be used as a basis for establishing an interference temperature level in the other.

[20] *See* attached Appendix B.

VII. CONCLUSION

Given the technical difficulties in implementing an interference temperature, and the potentially severe consequences on existing services, Motorola respectfully urges the Commission not to proceed with implementation of interference temperature concept at this time.

Respectfully submitted,

/S/ Steve B. Sharkey
Steve B. Sharkey
Director, Spectrum and Standards Strategy

Robert D. Kubik
Manager, Spectrum and Regulatory Policy

Motorola, Inc.
1350 I Street, N.W.
Washington, D.C. 20005
(202) 371-6900

April 5, 2004

APPENDIX A

INTERFERENCE TEMPERATURE IMPACT OF ADDITIONAL INTERFERENCE ON WCDMA FDD SYSTEM CAPACITY

This appendix provides a preliminary investigation of the capacity loss for a macro WCDMA-FDD system within the 850 MHz USA cellular allocations [824-849 MHz and 869-894 MHz], when it faces additional interference. The 3GPP RAN WG4 ad hoc group hosted by T1 P1.2[21] studied requirements for the migration of UMTS into the 850 MHz US cellular band at Cingular Wireless's request. Cingular Wireless, Motorola, Nokia, Qualcomm, Lucent and Ericsson were among the participants to approve the methodology and the parameters.

1. ASSUMPTIONS

1.1. Methodology

In this preliminary investigation, we considered a WCDMA-FDD system in the 850 MHz band. The 3GPP-approved system level Monte-Carlo methodology has been used to assess the effect of additional interference onto system capacity. The Monte-Carlo technique is a statistical technique that functions by considering many independent instants in time. For each instant, or simulation trial, a scenario is built up using a number of different random variables (e.g. the positions of the users in the system). If a sufficient number of trials is considered then the probability of a certain event occurring (such as the probability that a user is interfered) can be estimated with a high level of accuracy.

A methodology and a set of assumptions for simulation of WCDMA systems are described in 3GPP TR 25.942 [1]. This study has used as much as possible the 3GPP RAN WG4 assumptions. The assumptions are detailed in Section 5 Annex B.

Simulation parameters for the 850 MHz US cellular bands 3GPP RAN4 Work Item have been reused here [2].

1.2. Additional Interference

The objective is to determine the capacity loss for uplink of a WCDMA system deployed as described in Section 5 Annex A when additional interference (modeled as a thermal noise increase) is introduced. Nominal capacities are first found by running the simulations without any additional interference. The impact of additional interference on these results is then assessed.

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21 T1 P1.2 is a working group of T1 P1 sub-committee, which is a part of T1 committee. Committee T1 is sponsored by the Alliance for Telecommunications Industry Solutions and accredited by the American National Standards Institute to create network interconnections and interoperability standards for the United States. T1P1 sub-committee: Wireless/Mobile Services and Systems; T1P1.2 working group: GSM/3G Radio

2. WCDMA UPLINK CAPACITY LOSS

Figure 1 below shows the uplink capacity loss as a function of the additional interference (difference between the I_{add}+N term and the thermal noise N, where I_{add} is the additional interference modeled as an increase in thermal noise).

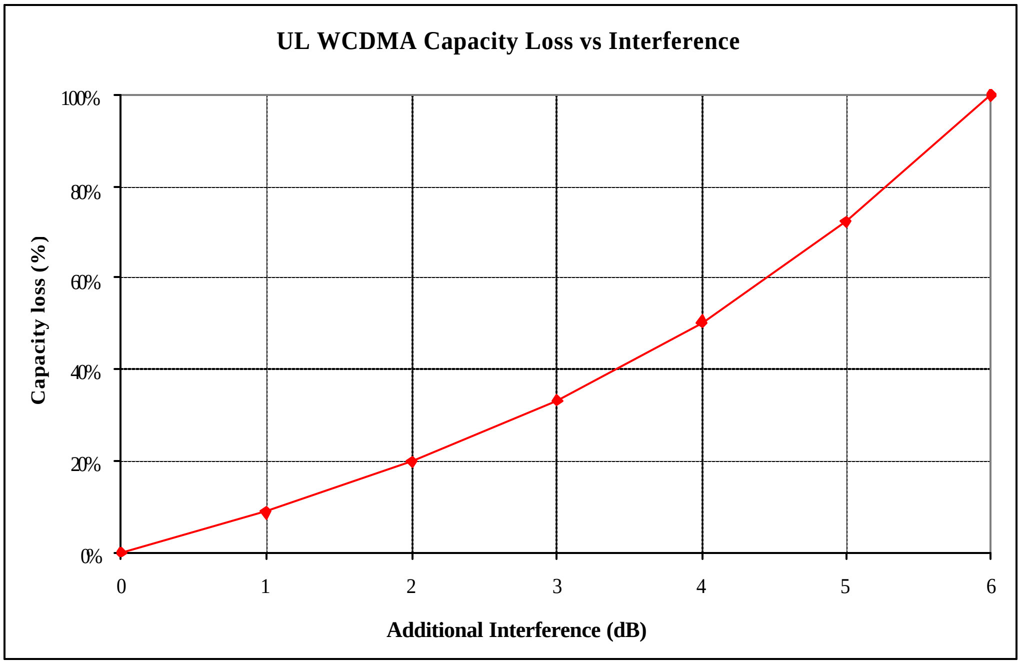

Figure 1 – Uplink Capacity Loss

A low additional interference level (such that I_{add}+N is 1 dB above the thermal noise) would lead to capacity losses lower than 10 %. Nevertheless, increasing the additional interference has an impact on the capacity. In uplink, the capacity criterion used is 6 dB of noise rise [1], i.e. intra-system interference tolerated by base stations (BSs) when operating without any external interference is 6 dB. Therefore, when an additional interference I_{add} is introduced, the WCDMA uplink intra-system interference tolerated is reduced, as the total interference tolerated by BSs stays equal to 6 dB. This is why the introduction of an additional interference has an impact on UL capacity loss. Having an I_{add}+N level 6 dB above the thermal noise would be sufficient to reduce the capacity to zero. Indeed, since the system operates at 6 dB above the thermal noise, if the external interference is such that the I_{add}+N term is itself 6 dB above the thermal noise, then there would be no room for intra-system interference, i.e. intra-system traffic.

3. CONCLUSIONS

Based on the methodology and assumptions in Annex A and Annex B, it has been shown that even a single digit increase in the noise level would have a significant impact on the uplink of a WCDMA system operating at 850 MHz.

These preliminary investigations show that the level of additional interference that can be tolerated by radio systems would depend upon the metrics developed to assess capacity of these systems (in this case, 6 dB noise rise for WCDMA uplink). These metrics would also depend on the radio systems, services and assumptions being considered.

The level of additional interference that can be tolerated would also depend upon geographical distribution of users. In this study, capacity metrics are averaged over the system. It is to be noted that the additional interference that can therefore be tolerated could be different according to the localized intra-system interference levels.

The additional interference that can be tolerated depends on many factors, making the definition and application of an interference temperature metric quite complex. Further study would be needed to fully understand all of the aspects involved.

4. REFERENCES

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[2] UMTS at 850 – Interference and Band plan considerations – 3GPP RAN WG4 Tdoc(03)558 – Contribution from T1 P1.2.

[3] A simplified Analytical Model for Predicting Path Loss in Urban and Suburban Environments – Howard H. Xia – IEEE Transactions on Vehicular Technology, Vol. 16, No. 4, November 1997.

[4] Microcellular Propagation Characteristics for Personal Communications in Urban and Suburban environments – Howard H. Xia – IEEE Transactions on Vehicular Technology, Vol. 43, No. 3, August 1994.

5. ANNEX A: METHODOLOGY

A methodology and a set of assumptions for simulation of WCDMA systems are described in 3GPP document TR 25.942 [1]. This study has considered as much as possible the 3GPP RAN WG4 assumptions:

The WCDMA network has been simulated according to the macro deployment and 3-sectorized cells have been used. 48-sector layout has been chosen (as shown in the figure below). As each cell consists of 3 sectors, this means that the pattern is in fact composed of 16 cells.

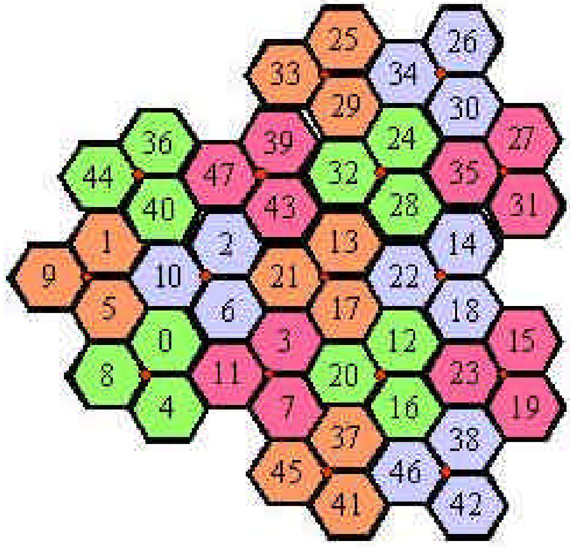

Figure 2 – The fundamental 48-sector structure assumed

For each trial, users are distributed across the cellular system using a uniform distribution.

Users are initially assigned to one or two base stations. Each user is able to enter soft handover if the link budget from two or more base stations appears attractive, a soft handover window being used. The window size defines the difference between the strongest received signal and the weakest allowed. On the uplink, switching selection diversity is assumed at the base station.

Once each mobile station has had its base station(s) assigned then the uplink received signal strength at each base station is calculated. The received signal consists of the desired and interfering signal strengths. The interfering signal (intra-system interference) consists of:

- Interference generated by other communication links in the same cell.
- Interference generated by communication links in all of the surrounding cells.

The C/I-based power control algorithm is an iterative process that converges positively when each communication link achieves its target C/I ratio. The algorithm assumed uses an adaptive step size. For each iteration, the power supplied to each link is updated with a value dependant upon the difference between the current C/I and C/I_{target}.

Once power control has converged the system is assumed to be in a realistic steady state and various records are made. The capacity of the system can be defined in a number of ways, by using the System Outage criterion or the Noise Rise criterion.

The Noise Rise criterion is commonly used to characterize uplink CDMA system performance. In general, noise rise refers to the sum of signals from all mobile stations that is above the thermal noise received at the base station receiver.

6. ANNEX B: SUMMARY OF SIMULATION ASSUMPTIONS

The simulation parameters below are in accordance with the UMTS850 simulation assumptions in 3GPP RAN4 [2] (themselves mostly based on 3GPP TR 25.942 [1]).

	WCDMA-FDD
Deployment scenarios	Uplink: 6 dB noise rise criterion Network in macro layer
	Tri-sectored BS antennas 48 sectors with wrap-around Maximum antenna gain = 14 dBi Sector radius of 1847 m
Services	Speech 12.2 kbps (chip rate 3.84 Mcps) Eb/N0 target (uplink): 6.1 dB Processing gain = 26.8 dB Thermal Noise (uplink) = -103 dBm
Propagation	The Xia propagation model is used for MS-BS case. Suburban environment is considered.[2][3][4] $Pathloss = 40(1-0.004\cdot\Delta h_b)\log10(R)-18\log10(\Delta h_b)+21\log10(f)+71.7dB$ Where: R is distance in km between the Mobile Station and the Base Station ?hb is Base Station antenna height relative to average rooftop; Δhb = 39.7 m assumed for suburban area f is frequency in MHz.
Cell selection	As per TR 25.942 v5.0.0
SIR calculation	As per TR 25.942 v5.0.0: Uplink: Computation of the ratio between the wanted signal (considered UE) and the sum of received signals from all other UEs (intra-system interference) at the BS (the highest C/I ratio is selected in case of soft handover).
Power control assumptions	As per TR 25.942 v5.0.0 MS max power: 21 dBm MS min power: -50 dBm

APPENDIX B

STUDY OF DFS PARAMETERS AND THEIR IMPACT ON FIXED SERVICE LINKS IN 6525-6700 MHZ

1. Introduction

This appendix evaluates the interference potential using the same methodology employed in the ITU studies that proposed values for DFS in order to protect radar systems operating in the 5250-5725 MHz band.[22] This analysis evaluates the impact of applying those same DFS requirements to provide protection of fixed links operating in the 6525-6700 MHz band.

1.1. Interference Methodology

The methodology employed to evaluate interference into radar systems operating in the 5250-5725 MHz band is based on a Monte Carlo approach. Multiple trials were employed to gain information on the peak interference resulting from the various distributions of unlicensed devices while taking into account geography and radar antenna beam dynamics. The described methodology follows that used in the DFS analysis with the exception that radar systems are now replaced with fixed systems.

1.2. Scenario Description

The scenario considered Wireless Access System (WAS) devices distributed in a city environment consisting of an urban zone, a suburban zone and a rural zone (see Figure 3). The Fixed Service (FS) link is also assumed to be located in either the urban, suburban or rural zone. Each zone has its own 3D distribution of WAS devices where the height was also assumed to vary uniformly by zone. In order to simulate one trial the following steps are taken:

1 Randomly distribute the WAS devices about the urban, suburban and rural zones.
2 Randomly place the FS in the zone under study; the azimuth pointing direction of the FS link is randomly selected with no elevation angle.
3 Compute the interference level received by each WAS device to check if DFS has engaged. If the received power level is above threshold, then turn off WAS device.
4 Compute the aggregate interference level received by the FS link from all WAS devices, which do not have DFS engaged and store for later analysis.

Multiple trials are then performed to capture the random nature of the interference. Parameters such as the FS link pointing direction, the location of the FS link within the zone under study and

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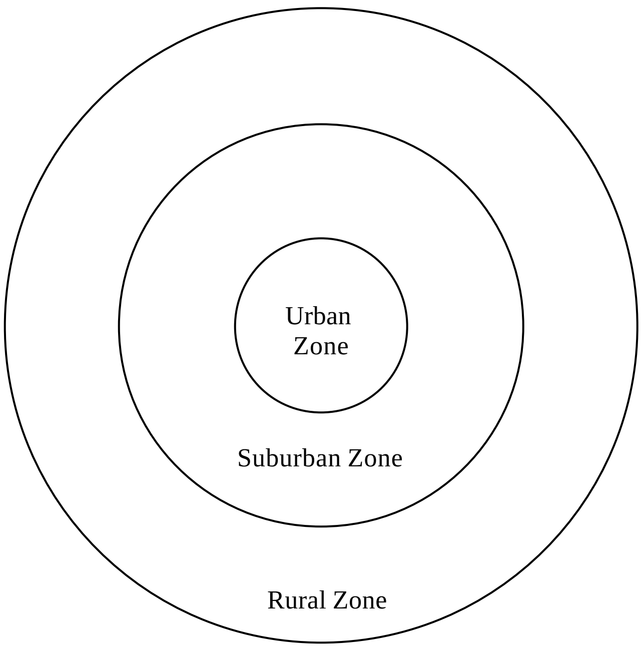
22 *See* Analysis of potential sharing between radiodetermination systems and wireless access systems (WAS) in the 5250-5350 and 5470-5725 MHz bands, United States of America, Document 8A-9B/153-B, 13 September 2002.

the distribution of the WAS devices all contribute to a distribution of interference levels experience by the FS link.

Section 1.3 describes the WAS and FS interaction, and Section 1.4 describes the WAS distribution.



Zone	Radius (km)	WAS User Density (%)	Building Height (m)
Urban	4	60	30
Suburban	12	30	6
Rural	25	10	6

Urban Zone: Highest density region in a city, typically consisting of multiple story buildings. Location where majority of WAS devices are deployed.

Suburban Zone: Medium density region about a city, typically consisting of residential users and small businesses.

Rural Zone: Low density, typically consisting of widely spaced residential users.

Figure 3: Geographic simulation area.

1.3. Fixed System – Wireless Access System interaction

Fixed System (FS) and Wireless Access Systems (WAS) devices operating co-channel in proximity could produce a scenario where mutual interference is experienced. A DFS algorithm may provide a means of mitigating this interference by causing the WAS devices to migrate to another channel once a FS has been detected on the currently active WAS channel. This simulation first considers the interference caused by the FS to the WAS device at the output of the WAS antenna. This interference to the j^{th} WAS is evaluated by using equation (1) below:

$$I_j^{WAS} = P_T + G_{Fj} + G_{Wj} - L_T - L_R - L_{P,FSj} - L_{P,RTj}^{T} - FDR \qquad (1)$$

Where:

I_j^{WAS} = Interference power received by the j^{th} WAS device (dBm)

P_T = Peak power of the FS link (dBm)

G_{Fj} = Antenna gain of the FS link in direction of the j^{th} WAS device (dBi)

G_{Wj} = Antenna gain of the j^{th} WAS device in direction of the FS site (dBi)

L_T = FS link insertion loss (dB)

L_R = WAS device insertion loss (dB)

$L^T_{P,RTj}$ = Propagation loss from the FS transmitter to the j^{th} WAS device (dB)

= $32.44 + 20 * \log(f) + LE * \log(d)$

in which

f = Frequency (MHz)

d = Distance (km)

LE = Loss Exponent, uniformly distributed between 20 and 35

$L_{P,RTj}$ = Building and non-specific terrain losses to the j^{th} WAS device (dB)

= Uniformly distributed between 0 dB and 20 dB

FDR = Frequency dependent rejection (dB).

Frequency Dependent Rejection (FDR) accounts for the fact that only a portion of the undesired transmitter energy at the receiver input will be available at the detector. FDR is a calculation of the amount of undesired transmitter energy that is rejected by a victim receiver. This concept is described in Recommendation ITU-R SM.337-4 Annex 1.

FDR can be stated mathematically as:

$$FDR = 10 \log_{10} \left[\frac{\int_0^\infty p(f - f_{tx}) df}{\int_0^\infty p(f - f_{tx}) h(f - f_{rx}) df} \right] \tag{2}$$

where

f_{tx} = Undesired transmitter tuned frequency

f_{rx} = Victim receiver tuned frequency

$p(f - f_{tx})$ = Normalized emission spectrum of the undesired transmitter

$h(f - f_{rx})$ = Normalized transfer function of the victim receiver

f = Absolute frequency.

In the special case of an undesired transmitter operating co-channel to a victim receiver, the following simplified form may be used:

$$FDR = \max\left(0, 10 \log_{10}\left(\frac{B_{tx}}{B_{rx}}\right)\right) \tag{3}$$

where

B_{tx} = Emission bandwidth of the transmitter

B_{rx} = Input bandwidth of the receiver.

This equation is calculated for each WAS device in the distribution. The value obtained is then compared to the DFS detection threshold under investigation. Any WAS device for which the threshold has been exceeded will begin to move to another channel, and thus is not considered further (for the remainder of the simulation trial run). The calculation of interference to the FS receiver from the j^{th} WAS device is given by equation (4):

$$I_j^{FS} = P_{Tj} + G_{Wj} + G_{Fj} - L_T - L_R - L_{P,FSj} - L_{P,RTj} - FDR \quad (4)$$

where:

I_j^{FS} = Interference to the FS receiver from the j^{th} WAS device (dBm)

P_{Tj} = Peak power of the j^{th} WAS device (dBm)

$L_{P,RTj}^{T}$ = Propagation loss from the j^{th} WAS device to the FS receiver (dB).

This value is calculated for each WAS device being considered in the simulation that has not detected energy from the FS in excess of the DFS detection threshold. These values are then used in the calculation of the aggregate interference to the FS by the WAS devices using equation (5):

$$I^{AGG} = \sum_{j=1}^{N} I_j^{FS} \quad (5)$$

where:

I^{AGG} = Aggregate interference to the FS from the WAS devices (Watts)

N = Number of WAS devices remaining in the simulation

I_j^{FS} = Interference into the FS from j^{th} WAS device (Watts).

Note: It is necessary to convert the interference power calculated in equation (4) from dBm to Watts before calculating equation (5).

1.4. WAS Distribution

This simulation uses a computer model that creates a data structure containing all of the WAS devices to be considered operating co-channel to the FS system at any given time. The data structure contains the pertinent parameters of each individual WAS device that are necessary for determination of the interference power level in the FS receiver caused by each WAS device. Specifically, the data structure contains the following elements:

- Region (Urban, Suburban, or Rural)
- User Class (Corporate, Public Access, or Residential)
- Power Level (0.05 Watts to 1 W)
- Location (x, y and z dimensions)

These parameters are assigned in the simulation input section. All of these assignments are made by generating uniformly distributed random numbers, and then applying a weighting function to assign the appropriate proportion of each element to the WAS devices. For example, since it is desired to distribute WAS devices in the urban zone from a height of 0 m to a height of 30 m, the following steps could be followed:

1. Generate a random number between 0 and 1.
2. The height of the device is found by multiplying the random number by 30.
3. Repeat steps 1-3 for each WAS device to be considered.

A similar approach is taken in assigning all of the elements of the WAS data structure. An example of a physical distribution of the WAS devices is shown in Figure 4.

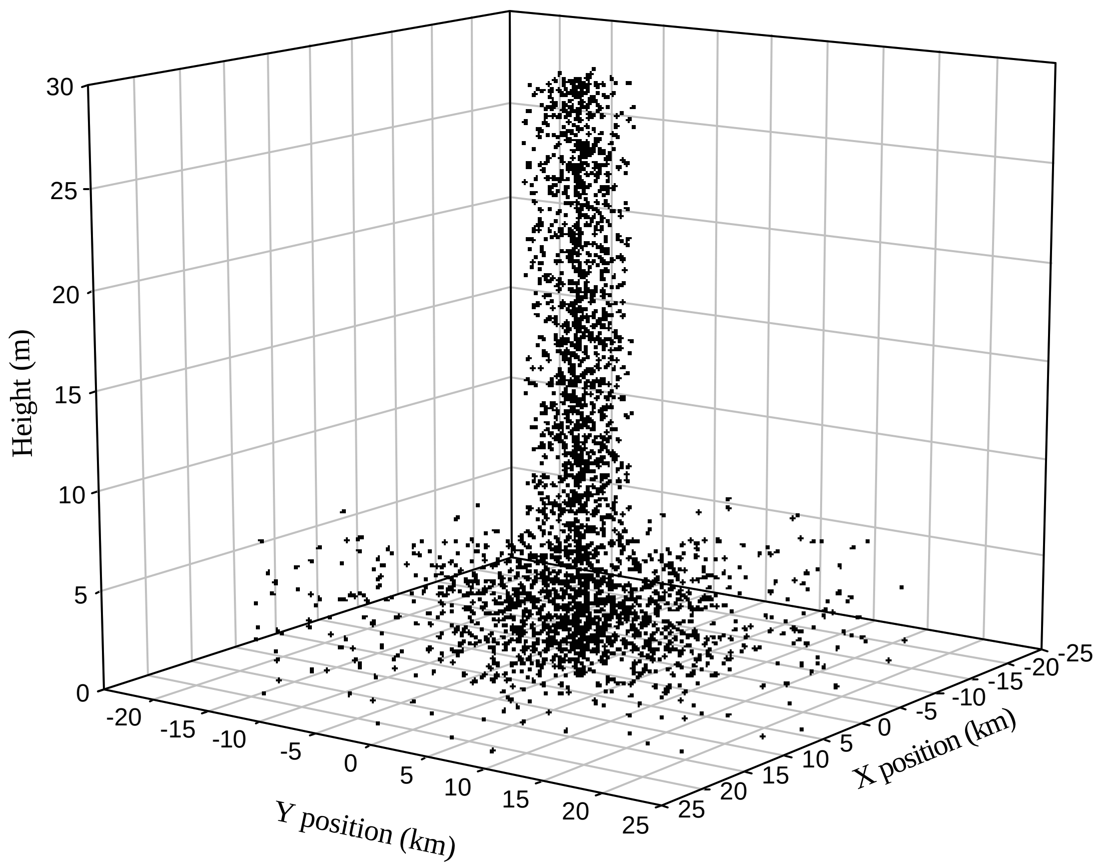


Figure 4: Example of a physical distribution of 2753 WAS devices

This figure demonstrates the three different regions *(i.e.* the dense urban core, the surrounding suburban region, and the outlying rural region). It also demonstrates the different maximum heights of each class of user in the sharing scenario. The urban users can be identified as having the highest altitude. The suburban users are most easily identified as having a reduced concentration of WAS devices. The rural users are best identified as those in the sparsely populated regions. It is important to note that this figure is not to scale. The height is greatly exaggerated to demonstrate the different user class heights.

2. Simulation Input Parameters

The parameters used in this simulation for the WAS devices can be found in ITU-R recommendation M.1652.[23] The parameters for FS links are generally taken from FCC part 101.

2.1. WAS Input Parameters

- A total of 2 753 WAS devices operating on a co-channel basis with a fixed system at a given moment was utilized.
- A smooth Earth line-of-sight calculation was utilized. Any WAS devices beyond the line-of-sight were discounted.
- WAS power distribution in Table 1 was utilized.
- The transmit bandwidth was 18 MHz and the insertion loss was 2 dB.

Table 1: WAS power distribution

Power level (EIRP)	1 W	200 mW	100 mW	50 mW
WAS users (%)	5	25	40	30

The WAS azimuth antenna pattern is omnidirectional. The WAS antenna elevation pattern was determined by examination of typical WAS antenna patterns. The pattern used is described below in Table 2.

Table 2: WAS elevation antenna pattern

Elevation angle (degrees)	**Gain (dBi)**
$45 < \varphi \leq 90$	–4
$35 < \varphi \leq 45$	–3
$0 < \varphi \leq 35$	0
$-15 < \varphi \leq 0$	–1
$-30 < \varphi \leq -15$	–4
$-60 < \varphi \leq -30$	–6
$-90 < \varphi \leq -60$	–5

[23] *See* Dynamic frequency selection (DFS) in wireless access systems including radio local area networks for the purpose of protecting the radiodetermination service in the 5 GHz band, ITU-R Recommendation M.1652, 2003.

For most devices to radiate 1 W e.i.r.p., an antenna gain of 6 dBi will typically be required. For this pattern the following description is given in accordance with Recommendation ITU-R F.1336:

$$G(\theta) = \max\left[G_1(\theta), G_2(\theta)\right] \tag{6}$$

$$G_1(\theta) = G_0 - 12\left(\frac{\theta}{\theta_3}\right)^2$$

$$G_2(\theta) = G_0 - 12 + 10\log\left[\left(\max\left\{\frac{|\theta|}{\theta_3}, 1\right\}\right)^{-1.5} + k\right]$$

$$\theta_3 = 107.6 \times 10^{-0.1 G_0}$$

where:

$G(\theta)$ = antenna gain (dBi)

θ = elevation angle (degrees)

k = 0.5 and

G_0 = 6 dBi.

2.2. FS Input Parameters

Shown below in Table 3 are the transmit parameters from Part 101 for fixed microwave services operating in 6525-6875 MHz. For purposes of this analysis it is assumed that the FS transmitter is operating at 6555 MHz, the transmitter is operating in frequency duplex division mode, and the channel bandwidth is 10 MHz.

The FS receiver is randomly located in the zone under study and the FS transmitter is located on average 27.1 km away, a statistical value selected by reviewing the FCC ULS database for FS links within 100 mile radius of Dallas Texas. The distance is selected using a random variable with a normal distribution having a mean of 27.1 km and a standard deviation of 12.7 km.[24] Furthermore a significant number of links seem be using Andrew Systems PAR8-65 on either the transmit or receive side of the link; that antenna is compliant with category A FCC requirements and the pattern is used in this analysis. The radiated power was set to the maximum permitted level of 55 dBW EIRP; this was done to ensure that the maximum number of devices will be triggered by the DFS mechanism. Typical links will have power levels significantly lower than that used in this simulation. The following assumptions are made with regards to the analysis: the peak antenna gain is 40.9 dBi, the insertion loss is 2 dB, the noise figure is 7 dB, and the antenna height is 10 meters.

[24] The data indicated that the shortest link is 0.4 km, any trials on the random variable which returned a value less than 0.4 km are disregarded for this analysis.

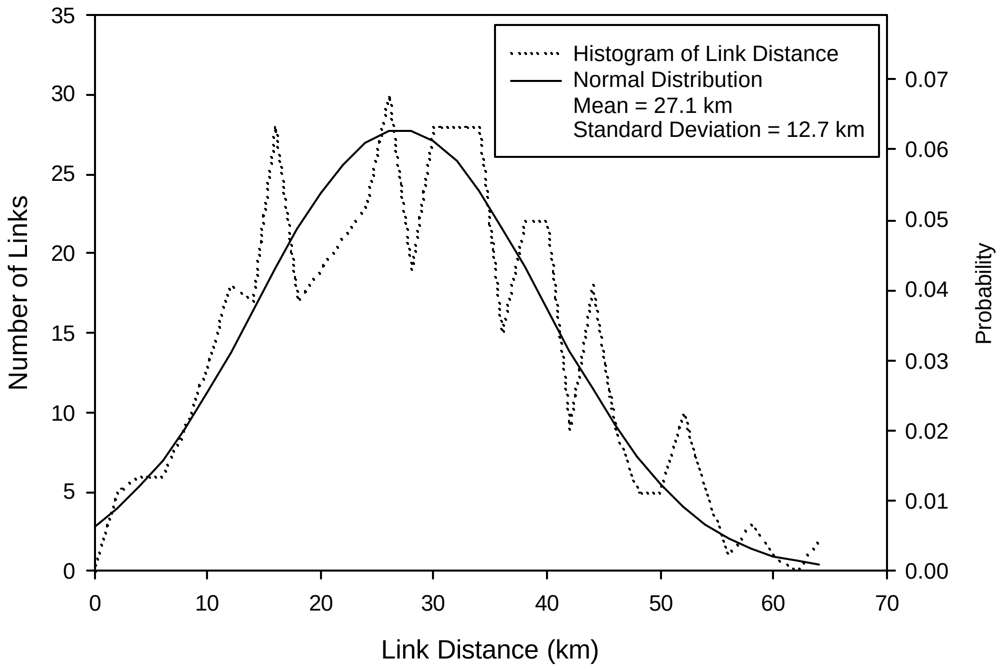


Figure 5: Distribution of links within 100 Miles of Dallas Texas.

Table 3: FS Parameters

Parameter	**FCC Rule Section**	**Value**
Transmitter Power Levels	47 CFR 101.113(a)	55 dBW EIRP
Antenna Requirements	47 CFR 101.115 – authorized after June 1, 1997	Andrew Systems PAR8-65 antenna compliant with category A requirements
Channel Bandwidth	47 CFR 101.147(l)	400 kHz, 800 kHz, 1.25 MHz, 2.5 MHz, 3.75 MHz, 5 MHz, 10 MHz

3. Simulation Results

Shown in Figure 6 through Figure 8 are the distributions of the interference level as related to the thermal noise of the FS link discussed above. The simulation was performed with 10,000 trials in each zone. The results were then grouped into bins of 1 dB width. Figure 9 is a representation of one trial from the simulation. Devices that had DFS triggered were primarily those that fall in line between the transmitter and the receiver.

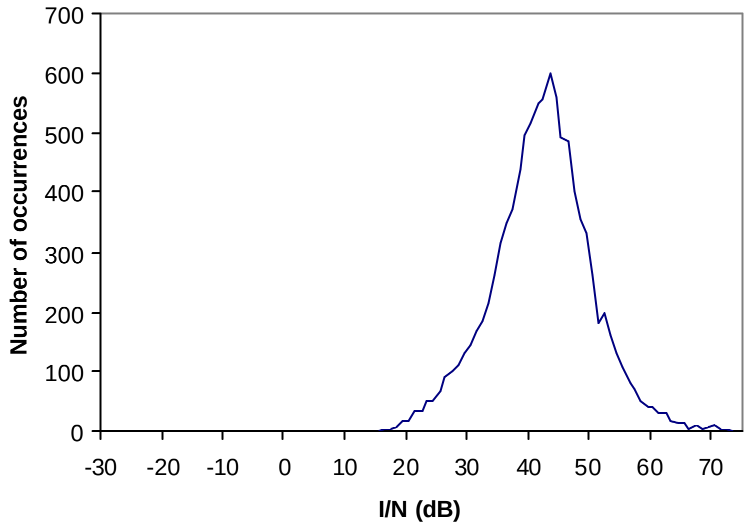


Figure 6: I/N distribution for FS link located in urban zone.

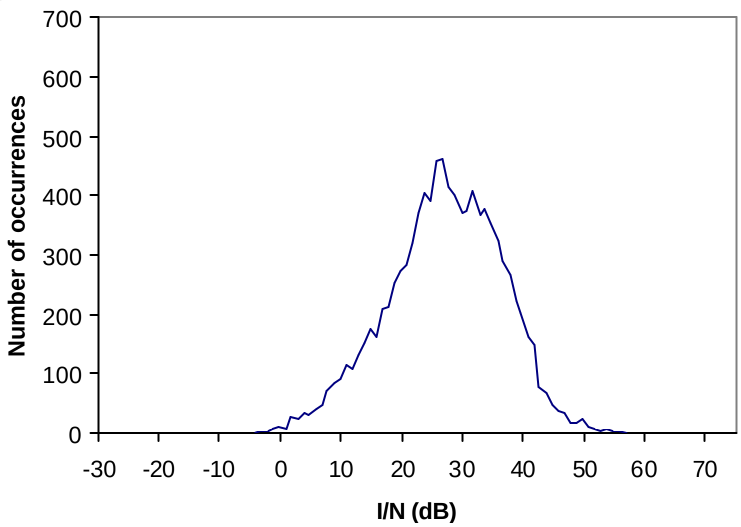


Figure 7: I/N distribution for FS link located in suburban zone.

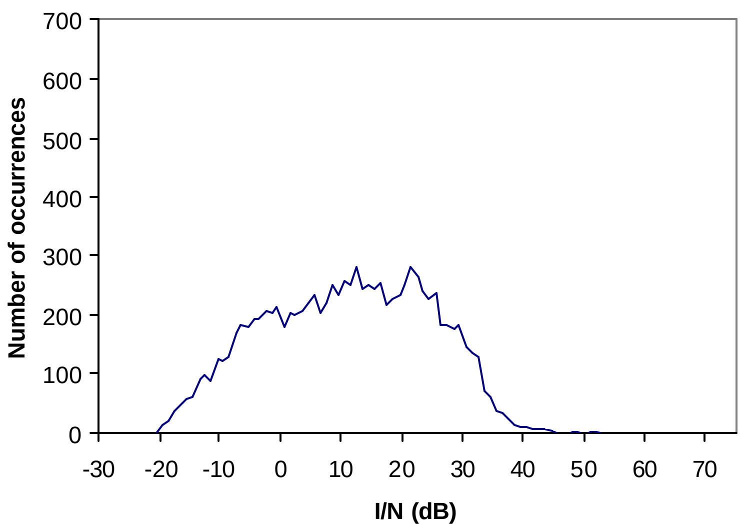


Figure 8: I/N distribution for FS link located in rural zone.

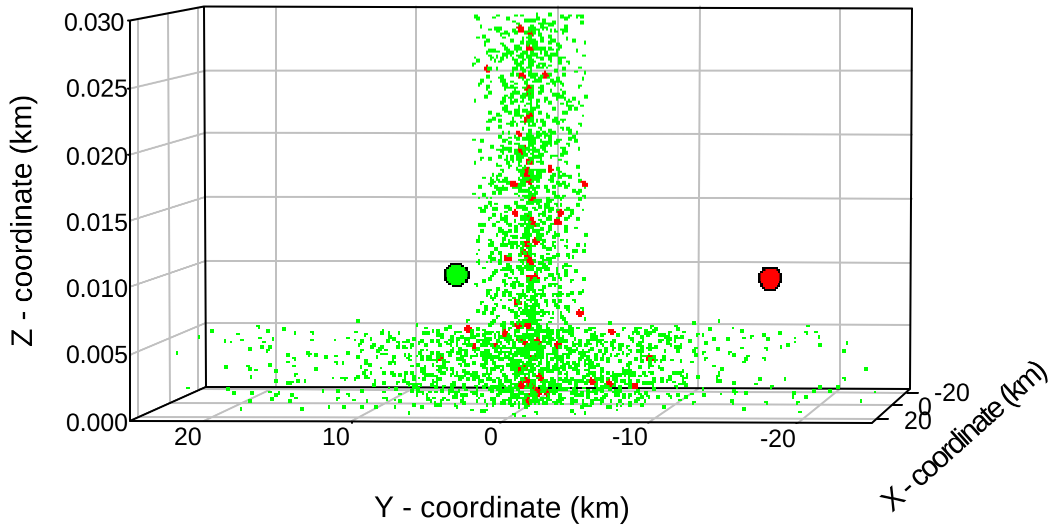


Figure 9a: Distribution geometry of a single trial. The large red circle is the transmitter and the large green circle is receiver. The small red dots are devices where DFS has been triggered, and the small green dots are devices where DFS has not been triggered.

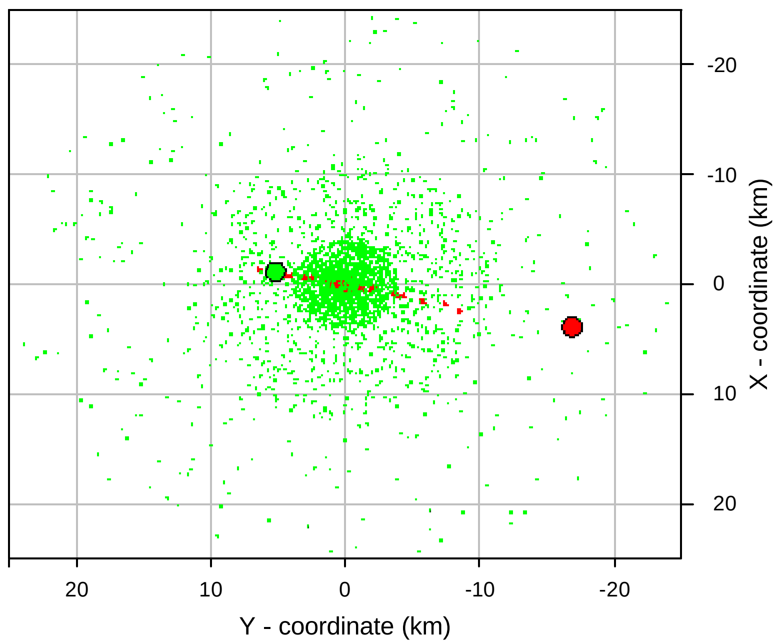


Figure 9b: Top view of single trial. The legend is same as in Figure 9a.

4. Conclusion

The simulation results indicate that interference 60 dB above the thermal noise of the FS links may be experienced by the operators in the 6 GHz band based on the DFS parameters proposed by the Commission[25]. The work done in the 5 GHz band was based on trying to achieve a protection level of I/N of -6 dB. This work indicates levels of interference nearly 76 dB higher.

25 *See NOI* at ¶44.

This result indicates that application of DFS parameters designed to protect high power radars operating in the 5 GHz band will result in significantly different results when applied to systems with dissimilar characteristics.