Table 4.

Radio Astronomy Observatory	Latitude	Longitude	Elevation
Allen Telescope Array	40° 49' 04'' N	121° 28' 24'' W	1043 m
Arecibo Observatory	18° 20' 46'' N	066° 45' 11'' W	496 m
Green Bank Telescope	38° 25' 59'' N	079° 50' 24'' W	825 m
Very Large Array	34° 04' 44'' N	107° 37' 04'' W	2126 m
Very Long Baseline Array Stations			
Pie Town, AZ	34° 18' 04'' N	108° 07' 07'' W	2371 m
Kitt Peak, AZ	31° 57' 22'' N	111° 36' 42'' W	1916 m
Los Alamos, NM	35° 46' 30'' N	106° 14' 42'' W	1967 m
Ft. Davis, TX	30° 38' 06'' N	103° 56' 39'' W	1615 m
N. Liberty, IA	41° 46' 17'' N	091° 34' 26'' W	241 m
Brewster, WA	48° 07' 53'' N	119° 40' 55'' W	255 m
Owens Valley, CA	37° 13' 54'' N	118° 16' 34'' W	1207 m
St. Croix, VI	17° 45' 31'' N	064° 35' 03'' W	16 m
Hancock, NH	42° 56' 01'' N	071° 59' 12'' W	309 m
Mauna Kea, HI	19° 48' 16'' N	155° 27' 29'' W	3720 m

Table 5 lists the major cities in proximity to observatories and their distances from the radio astronomy sites that are observing the methanol spectral line.

Table 5.

Observatory	Distance to Major U.S. Cities
Allen Telescope Array	Sacramento 250 km; San Francisco 350 km
Green Bank Telescope	Pittsburgh 230 km; Washington DC 250 km; Richmond 240 km
Very Large Array	Albuquerque 150 km; EL Paso 270 km; Tucson 270 km; Phoenix 410 km
Very Long Baseline Array Stations	
Pie Town, AZ	Albuquerque 160 km; EL Paso 320 km; Tucson 350 km; Phoenix 360 km
Kitt Peak, AZ	Tucson 70 km; Phoenix 180 km; Los Angeles 630 km
Los Alamos, NM	Albuquerque 80 km; EL Paso 440 km; Amarillo 410 km
Ft. Davis, TX	EL Paso 270 km
N. Liberty, IA	Chicago 320 km; Milwaukee 330 km; Des Moines 170 km
Brewster, WA	Seattle 210 km; Tacoma 250 km; Spokane 180 km
Owens Valley, CA	San Bernardino 350 km; Sacramento 320 km; Fresno 140 km; Bakersfield 220 km; Las Vegas 290 km
Hancock, NH	Boston 110 km; New York 300 km
Mauna Kea, HI	Honolulu 290 km

As shown in Table 5, many of the radio astronomy observatories observing the methanol spectral line are located in remote areas, in radio quiet zones, or in the mountains where they are afforded a great deal of protection from ground-based interfering sources. NTIA believes the geo-location technology that unlicensed devices can employ to facilitate sharing with the FS can also be employed to protect the radio astronomy observatories listed in Table 4.

IX. GEO-LOCATION TECHNOLOGY CAN BE USED TO PREVENT UNCOORDINATED USE OF SPECTRUM WITHIN RADIO QUIET ZONES, AND COORDINATION ZONES.

Radio quiet zones and coordination zones are intended to provide protection to passive sensing of the electromagnetic spectrum. The nature and intent of these zones are directly in conflict with the notion of opportunistic use of spectrum using the interference temperature model. These zones were created to minimize potential interference to radio astronomy or other facilities that require low-noise environments and are highly sensitive to RF interference. The low-noise environments that are created to protect these facilities are the same environments that opportunistic use of spectrum under the interference temperature model could attempt to exploit. Higher-powered unlicensed use under the interference temperature model could present difficulty in protecting these locations from interference. Because there is no transmitted signal from these stations, real-time sensing of the RF environment cannot indicate the need for protecting these services. Geo-location technologies could provide a basis for protecting these sensitive facilities from harmful interference, while still allowing opportunistic use of the spectrum in areas that are sufficiently distant from the facilities.

The National Radio Quiet Zone (NRQZ) was established to protect the National Radio Astronomy Observatory in Green Bank, West Virginia and the Naval Radio Research Observatory in Sugar Grove, West Virginia from possible harmful interference. The NRQZ is the area bounded by 39°15' N on the north, 78°30' W on the east, 37°15' N on the south, and 80°30' W on the west. The reference point that is used for calculating the potential for interference is the prime focus of the Green Bank Telescope (GBT). The location (NAD83) of the GBT prime focus is 38°25'59.2" N latitude, 79°50'23.4" W longitude. The ground elevation is 776 m, and the height is 139.6 m above ground level. For successful coordination in the NRQZ, the calculated power density of the transmitter at the reference point should be less than:

- 1 x 10^{-8} W/m^2 for frequencies below 54 MHz
- 1 x 10^{-12} W/m^2 for frequencies from 54 MHz to 108 MHz
- 1 x 10^{-14} W/m^2 for frequencies from 108 MHz to 470 MHz
- 1 x 10^{-17} W/m^2 for frequencies from 470 MHz to 1000 MHz
- f^2 (in GHz) x 10^{-17} W/m^2 for frequencies above 1000 MHz

In frequency bands that are allocated to the radio astronomy service, the criteria of ITU-R Recommendation RA.769-1 are applied.[45]

The Table Mountain Radio Receiving Zone (TMRZ) of the Research Laboratories of the Department of Commerce is used for research concerned with low signal levels, such as from deep-space, extraterrestrial low-signal satellites, or very sensitive receiver techniques, to be conducted without the potential for interference found in most areas of the nation. NTIA's Institute for Telecommunication Sciences (ITS) has maintained oversight of the TMRZ to ensure the levels of unwanted RF energy within the site conform with federal regulations and the site remains a valuable national research asset. The TMRZ facility is essential to research in the area of very wideband receiver technology and radio wave propagation. The federal government has a number of permanent facilities used for ongoing research projects at the TMRZ. In addition to ITS, the facilities at the TMRZ support research and development activities being performed by the National Institute of Standards and Technology, the National Atmospheric and Oceanic Administration, the United States Geological Survey, as well as other federal agencies, research

45. *See* http://www.gb.nrao.edu/nrqz/nrqz.html for additional information.

universities, and telecommunication and technology industries. To ensure that the capabilities of the site (1800 acres in the vicinity of 40°07'50" N latitude, 105°15'40" W longitude) remain conducive to this type of research, the field strengths received from radiated signals should be limited to the values shown in Table 6.[46]

Table 6.

Frequency Range	Field Strength (mV/m) in authorized bandwidth of service	Power flux density* (dBW/m^2) in authorized bandwidth of service
Below 540 kHz	10	-65.8
540 to 1600 kHz	20	-59.8
1.6 to 470 MHz	10	-65.8
470 to 890 MHz	30	-54.2**
Above 890 MHz	1	-85.8**

* Equivalent values of power flux density are calculated assuming free space characteristic impedance of 376.7=120π ohms.
** Space stations shall conform to the power flux density limits at the earth's surface specified in appropriate parts of the Commission's rules, but in no case should exceed the above levels in any 4 kHz band for all angles of arrival.

Additionally, the following guidelines are given for determining whether coordination is necessary:

- All stations within 2.4 km (1.5 miles).
- Stations within 4.8 km (3 miles) with 50 watts or more average effective radiated power (ERP) in the primary plane of polarization in the azimuthal direction of the TMRZ.
- Stations within 16.1 km (10 miles) with 1 kW or more average ERP in the primary plane of polarization in the azimuthal direction of the TMRZ.
- Stations within 80.5 km (50 miles) with 25 kW or more average ERP in the primary plane of polarization in the azimuthal direction of the TMRZ.[47]

The Arecibo Coordination Zone was created to protect the radio astronomy operations at the Arecibo Observatory. The coordination zone consists of the islands of Puerto Rico,

46. *See* 47 C.F.R. § 21.113(b).

47. *See* 47 C.F.R. § 21.113(b)(1).

Desecheo, Mona, Vieques, and Culebra. The interference guidelines shown in Table 7 are used in coordination efforts within the Arecibo Coordination Zone.

Table 7.

Frequency (MHz)	Bandwidth (MHz)	Threshold level of spectral power flux density ($dBW/m^2/Hz$)
13.36-13.41	0.05	-248
25.55-25.67	0.12	-249
73.0-74.6	1.6	-258
322.0-328.6	6.6	-258
406.1-410.0	3.9	-255
425.0-435.0	10.0	-255
608.0-614.0	6.0	-253
1332-1400	70.0	-255
1400-1427	27.0	-255
1610.6-1613.8	3.2	-238
1660-1670	10	-251
2370-2390	20.0	-247
2690-2700	10.0	-247
4800-4990	190.0	-241
4990-5000	10.0	-241
10600-10700	100.0	-240

The radio quiet zones and radio receiving zones are currently protected by coordination requirements and maximum allowable field strength requirements. These coordination and analyses efforts are performed on a case-by-case basis by personnel from the affected facility and the applicant desiring to make use of the spectrum in these areas. NTIA believes that new technologies could allow this analysis to take place on a real-time basis within a device (whether licensed or unlicensed) and that coordination with the affected facility might not be necessary for unlicensed devices employing geo-location technologies.

X. THE PARAMETERS OF THE REFERENCE RECEIVER USED TO ESTABLISH THE INTERFERENCE TEMPERATURE LIMITS COULD BE DEVELOPED IN THE COMMISSION'S RULEMAKING PROCEEDING ON RECEIVER STANDARDS.

In the NOI, the Commission requests comment on the receiver performance parameters that should be considered in setting the interference temperature limits.[48] Specifically, the Commission requests information on whether there are minimum receiver performance criteria that should be considered as a reference in setting interference temperature limits and how should the specifications for such a receiver should be developed. The Commission also seeks comment on whether a worst receiver available for a service, or an average receiver should be used in determining the interference temperature limits.[49]

A receiver used for a specific radio service is required to receive and process a wide range of signal powers, but in most cases it is important that they be capable of receiving distant signals whose power has been attenuated during transmission. There are several parameters that can be used to define the minimum performance of a reference receiver for the purpose of establishing interference temperature limits: sensitivity, noise figure, and selectivity. The sensitivity is one of the most important receiver characteristics and defines the weakest signal power that may be processed satisfactorily. The noise figure is the amount of noise (in decibels) that the receiver adds to the input noise within its noise bandwidth.[50] The selectivity is the

48. NOI/NPRM at ¶ 21.

49. *Id.*

50. In practice, the 3 dB bandwidth of the filter used to determine the receiver selectivity is assumed to be the receiver's noise bandwidth.

property of the receiver that allows it to separate a signal or signals at one frequency from those at all other frequencies. These parameters are related, and changes in one will likely result in changes to the others. For example, selectivity can be enhanced by adding greater filtering to the RF input of the receiver. This will also result in greater loss at the desired frequency, causing a reduction in sensitivity.

Although the parameters discussed above are applicable to all receivers, the actual values of these parameters will vary dramatically for each authorized radio service. For example, receivers operating in the RNSS have noise figures on the order of 2 to 3 dB and are capable of receiving signals below their thermal noise floor, whereas, land mobile receivers typically have noise figures of 8 to 10 dB and a sensitivity at or above their thermal noise floor. Thus, it is clear that the performance parameters used in determining the reference receiver to establish the interference temperature limit will vary depending upon the radio service(s) operating in a specific frequency band.

To establish the interference temperature limits, a reference receiver model must be developed for each radio service. It is difficult to determine whether the reference receiver should be based on parameters representing an "average" or "worst" receiver until these terms are defined. It is also important to realize that what one group would consider to be a worst receiver (e.g., low immunity to interference) another group would consider to be a "best" receiver due to its greater sensitivity. For this discussion, a reference receiver based on the average receiver has parameters that are in between the minimum and maximum values of receivers operating in a radio service. For example, if the noise figure of receivers operating in a frequency band varies from 4 to 8 dB, a value of 6 dB is used to define the noise figure of the average reference receiver. A reference receiver based on a worst receiver would use parameters representing the most sensitive (e.g., lowest measured noise levels) values of a receiver operating in a radio service. Using the previous example, a reference receiver based on a worst receiver would use a value of 4 dB to define noise figure of the reference receiver. Based on these definitions, it is clear that if the reference receiver is defined based on average parameters, the measured noise levels will be higher and there is a risk that all of the receivers in a given radio service will not be adequately protected. Therefore, NTIA recommends that the parameters for the reference receiver to be used in establishing the interference temperature limits should be based on the most sensitive parameters of the receivers operating in the authorized radio services.

There are many national and international standards bodies that have been involved in developing receiver standards that the Commission should take into consideration in defining the parameters for the reference receivers. These standards bodies, include but are not limited to, the Telecommunications Industry Association (TIA), the Consumer Electronics Association (CEA), RTCA, Inc.,[51] the ITU-R, the International Civil Aviation Organization (ICAO), the European Telecommunications Standard Institute (ETSI), and the International Electrotechnical Commission (IEC). NTIA has recently published a study on receiver standards, documenting currently existing domestic and international receiver standards.[52] NTIA recommends that the Commission consider the information contained in this report in developing the reference receiver performance parameters.

51. Formerly the Radio Technical Commission for Aeronautics (RTCA).

52. National Telecommunications and Information Administration, NTIA Report 03-404, *Receiver Spectrum*

In response to the SPTF recommendation to consider applying receiver performance requirements, the Commission issued a NOI seeking public comments on the following areas: current receiver environment; performance and standards; possibilities of improving receiver immunity; potential approaches to achieving desired levels of performance; considerations that should guide the Commission's approach; and issues relating to the possible incorporation of receiver immunity performance incentives, guidelines, or standards.[53] Based on the results of this NOI, the Commission has started developing a public record of the technical issues related to receiver performance standards. NTIA recommends that the Commission issue a follow-on NPRM that builds upon the existing public record to determine the receiver performance parameters to be used in establishing interference temperature limits.

XI. SPATIAL, ANGULAR, TEMPORAL, AND FREQUENCY FACTORS MUST BE CONSIDERED IN ACCURATELY MEASURING THE INTERFERENCE TEMPERATURE LIMITS.

One of the goals of the interference temperature limits is to protect a licensed user's receiver from an unlicensed user that is transmitting on the same frequency. As discussed in the NOI, the Commission requests comment on two approaches that could be used in measuring the interference temperature levels: real-time measurements, and measurements from multiple fixed monitoring (reference) sites.[54]

In order to provide a meaningful measurement of the interference temperature, the signal levels measured by the real-time (i.e., integrated within the unlicensed device) or fixed (i.e.,

---

Standards Phase 1 – Summary of Research into Existing Standards (November 2003).

53. *Interference Immunity Performance Specifications for Radio Receivers*, ET Docket No. 03-65, Notice of Inquiry, 18 F.C.C. Rcd. 6039 (2003).

54. NOI/NPRM at ¶ 22.

dedicated reference equipment) monitoring site receivers must be representative of the signal levels that a licensed user's receiver operating within the frequency band of interest would encounter. Several technical factors can have a significant impact on the signal levels measured by real-time or fixed monitoring station receivers: antenna height, antenna gain pattern, antenna polarization, and bandwidth.

Using an improper antenna height for the real-time or monitoring network receivers could result in either an under estimation or over estimation of the received signal levels used to determine the interference temperature levels. For example, if the monitoring network receivers are at ground-level but the licensed user's receiver is elevated (e.g., a base station tower), then the propagation loss between the potential interferer and an elevated user will be different than the loss between two ground-level users. In this situation, the monitored and reported interference temperature levels would differ significantly from the interference temperature observed by the licensed user, making compliance with the established limits difficult if not impossible to enforce. This problem could be addressed by assuming a worst-case, from an interference perspective, propagation loss environment such as free space. However, this brings up the fundamental issue of range estimation between a potentially unlicensed interferer and a licensed user, which will vary for different licensed services and unlicensed device applications.

When the licensed user and the monitoring receiver have antennas with similar gain patterns, the reported measured interference temperature levels would be an adequate representation of the RF environment. If the licensed user's antenna has a different antenna gain pattern than the monitoring antenna, the interference temperature measurements obtained using the monitoring antenna would not reflect the actual interference experienced by the licensed user. For example, when the interference temperature monitoring device is equipped with an omnidirectional antenna, the resulting reported interference temperature level would appear to be uniform, and any directional variations would tend to be smoothed out. However, if the licensed user has a directional or higher gain receive antenna, then the interference temperature experienced by the licensed user would be lower than the level measured by the monitoring receiver in some directions.[55] The potential for such variations would need to be considered when establishing an interference temperature limit to ensure that the limit appropriately represents the worst case (from an interference perspective) operating environment of the licensed receivers.

Similar to the antenna gain variations, problems would be created if the licensed user's receiver and the monitoring receiver operate with different intermediate frequency (IF) bandwidths. For example, if the licensed user's receiver IF bandwidth is narrow (e.g., 25 kHz) and the bandwidth of the interference temperature monitoring receiver is wide (e.g., 5 MHz), there is a 23 dB difference in the noise floor between these two bandwidths. If there are discrete spurious sources that are contributing to the interference temperature, this would be averaged and reported over the wider bandwidth of the monitoring receiver. Over most of the band, the actual interference temperature would be somewhat lower than the reported (average) interference temperature. However, on the particular channel that contains the spurious sources, the interference temperature could be considerably worse than the reported average level. The problem of taking the bandwidth into account when measuring the interference temperature is further complicated by systems that employ adaptive bandwidth technology to increase the

55. The problem encountered with the antenna pattern is made more difficult when steerable or adaptive antennas are employed.

throughput.[56] If the interference temperature is to accurately represent the interference encountered by a licensed receiver, it should take into account the impact of bandwidth disparities.

The polarization of the interference temperature monitoring system is another factor that could greatly underestimate the measured signal levels. The most common polarizations are linear (horizontal or vertical), circular (left hand and right hand) or elliptical. If the polarization of the monitoring system's receive antenna is different from the polarization of the transmitted signals in the environment a polarization mismatch loss is encountered.[57] Table 8 provides a summary of the mismatch losses for different combinations of antenna polarizations.[58]

Table 8.

Polarization		
Monitoring Antenna	**Transmitted Signal**	**Polarization Mismatch Loss**
Horizontal	Vertical	Greater than 20 dB
Horizontal	Circular	3 dB
Vertical	Horizontal	Greater than 20 dB
Vertical	Circular	3 dB
Circular	Horizontal	3 dB
Circular	Vertical	3 dB
Circular (Left Hand)	Circular (Right Hand)	Greater than 25 dB
Circular (Right Hand)	Circular (Left Hand)	Greater than 25 dB

As it can be seen from Table 8, the error resulting from using different polarizations for the monitoring system can result in a significant underestimation of the measured signal. It should also be pointed out that the polarization of an antenna remains relatively constant throughout the main lobe of the antenna pattern, but can vary considerably in the minor lobes,

56. A variable bandwidth radio system monitors the frequency band and automatically increases the bandwidth and the corresponding throughput when the channels become available.

57. Polarization mismatch loss is the ratio at a receiving point between received power in the expected polarization and received power in a polarization orthogonal to it from a wave transmitted with a different polarization.

58. American National Standard, ANSI C95.3-1973, *Techniques and Instrumentation for the Measurement of Potentially Hazardous Electromagnetic Radiation at Microwave Frequencies*, at 12 (April 20, 1973).

which could result in additional measurement errors.[59]

Taking the above factors into consideration, achieving finer resolution to account for minimum receiver bandwidths or minimum receive antenna beamwidths would appear to be necessary to ensure that an interference temperature limit is established that provides adequate protection to all licensed user's receivers. However, if an interference temperature monitoring receiver utilizes narrow bandwidths and beamwidths, the increases in the number of observation points, both in frequency and azimuth sweeps, would greatly increase the total sweep time and would introduce latency in the update rate for unlicensed transmitters depending on real-time information from the monitoring stations. For example, increasing the total sweep time would increase the likelihood that maximum actual interference temperature values are not measured in a time-varying environment, such as for packet data systems, systems using antennas employing beam forming techniques, or frequency hopping systems. This would further extend the time delay before interference above the interference temperature limit is detected and action is taken by the unlicensed device.

Real-time or fixed interference temperature monitoring receivers could encounter spatial, angular, temporal, and frequency limitations. Some of these limitations can be addressed by establishing antenna heights, bandwidths, and antenna gain patterns and polarizations for the monitoring receivers that are representative of the licensed user's receiver. However, if frequency and angular increments are too small, a time delay in measured interference temperature levels may be introduced, where the licensed user would not be adequately protected on a real-time basis. For mobile real-time monitoring systems and mobile licensed users, it is not clear how the technical limitations raised above can be addressed. However, NTIA believes that

---

59. *Antenna Analysis*, E. A. Wolff, at 17 (1966).

it is possible to resolve many of these technical issues if the locations of both the monitoring system and licensed user are fixed.

XII. DOMESTICALLY AND INTERNATIONALLY DEVELOPED STANDARDS COULD BE USED FOR DEFINING THE PERMISSIBLE INTERFERENCE LEVELS FOR EACH RADIO SERVICE.

In the NOI, the Commission requests comment on whether a modest rise in the noise floor of a receiver as envisioned by the interference temperature model, would generally not cause harmful interference as defined under their definition of harmful interference.[60] Comments are sought on how much interference can be tolerated before it is considered harmful for a given radio service in a given frequency band. If the determination of harmful interference is based on a specific quality of service level, the Commission seeks comment on the rationale used to justify this level. The Commission also requests that commenting parties identify the specific frequency bands and services associated with these levels.[61]

The interference temperature metric as defined in the NOI is merely a measuring tool. It could be used to identify how much interference exists in a particular band at a particular time in a given geographical area. However, it does not determine whether the measured level of interference is too high, too low, or just right. In order to use the interference temperature metric, this determination will have to be made in many frequency bands across the RF spectrum. To accomplish this in a way that promotes spectrum efficiency, provides protection to incumbents, and that is predictable and non-arbitrary, a permissible interference standard is needed, not just a new technical metric. The need for a permissible interference standard is

---

60. NOI/NPRM at ¶ 27.

61. *Id.* at ¶ 28.

discussed in an article submitted as part of the public record for the SPTF.[62] This article identifies the lack of permissible interference standards in the Commission's Rules as a problem and proposes that such standards be developed, and suggests a framework to accomplish this objective. This is consistent with the Commission's stated objective of providing radio service licensees with greater certainty regarding the maximum permissible interference in the frequency bands in which they operate.[63]

One of the key steps in any interference, electromagnetic compatibility, or sharing assessment is identifying an appropriate level of permissible interference. The identification of the appropriate level is often confusing, time consuming, with no single reference source from which to draw. Complications arise because of the divergent needs of incumbents and proposed entrants into any frequency band. The complexity of this process is further complicated by the numerous terms used regarding interference. For example, various fora including the NTIA, the Commission, and the ITU-R define five terms relative to interference: Interference, Permissible Interference, Accepted Interference, Harmful Interference, and Protection Ratios. Other terms that are commonly used, but not specifically defined are Allowable Performance Degradation, Interference Protection Criteria, and Spectrum Sharing Criteria. Since the spectrum sharing criteria normally depend upon specifics of the interfering and interfered-with systems, as well as the types of interfering signals, a very large number of combinations are possible.

62. R. Paul Margie, *Efficiency, Predictability, and the Need for an Approved Interference Standard at the FCC*, 2003 Telecommunications Policy Research Conference (September 2003) (This article is available at http://stlr.stanford/stlr/articles/03_stlr_5/index.htm) ("Margie Article").

63. NOI/NPRM at ¶ 1.

Permissible interference levels can be specified for aggregate (e.g., total from all sources of interference) or single-entry interference. For a given radio service and type of system (e.g., communications, radar), the parameters listed in Table 9 should be considered in developing the aggregate and single-entry permissible interference levels. The parameters listed in Table 9 will vary depending on the radio service operating in a given frequency band. For example, in developing permissible interference levels in the frequency bands used by the aeronautical radio navigation service, the power thresholds would not be permitted to vary based upon time duration of the interference, due to the safety-of-life functions of this service. On the other hand, in the frequency bands used by the FS, power thresholds can be based on long-term and short-term time percentages of interference.

Table 9.

Parameter	**Typical Units**	**Description**
Power Threshold	dBm, dBW, dB	Two or more levels of interfering signal power (I), interference-to-noise-ratio power ratios (I/N), or signal – or carrier-to interference power ratios (S/I or C/I)
Reference Bandwidth	Hz, kHz, MHz	Bandwidth in which interfering signal power should be calculated or measured.
Percentage of Time	Percent	For each power threshold, the percentage of time during which the threshold should in the case of S/I or C/I or should not in the case of I or I/N, be exceeded.
Percentage of Locations	Percent	For each power threshold, the percentage of locations at which the threshold should in the case of S/I or C/I or should not in the case of I or I/N, be exceeded. Used in some radio services to protect operations within a service area.
Special Conditions	Various	Information needed for interpretation or application of the thresholds, including as a minimum whether the permissible interference is for aggregate or single-entry interference. The type of interfering signal for which the permissible interference level pertains to the I/N, S/I, or C/I thresholds the definition of the N, S, C reference levels. This may include the duration for which permissible interference can be exceeded; specific category of victim or interfering stations; and frequency off-tuning associated with the power thresholds.

It is possible to describe potentially interfering signals using a number of generic categories. Table 10 provides a list of the generic categories that can be used to describe potentially interfering signals. The permissible interference levels for a system operating in a given radio service can vary depending on the types of interfering signal being received. For example, GPS receivers operating in the RNSS are more susceptible to continuous wave (CW) signals compared to noise-like signals and are less susceptible to interference from low-duty cycle pulsed signals. This susceptibility to CW and robustness to pulsed interfering signals is directly related to the signal structure of the GPS navigation signal.

Table 10.

Type of Interfering Signal	Definition
Continuous Wave	A continuous signal with a bandwidth much smaller than the receiver baseband (output bandwidth).
Noise-Like	A continuous signal that resembles Gaussian white noise over the radio frequency bandwidth of the receiver (uniform power spectral density) or produces the same effect as such a signal.
Pulsed	A signal that is turned on and off over time defined by the time on (pulse width) and the repetition rate of the pulses. The pulses may occur at a constant or changing repetition rate.
Impulse	A signal with very short duration pulses, generally less than 0.1 -2 nanoseconds in duration and occurring at constant or changing repetition rates.
Same as Desired Signal	A signal with modulation parameters that are the same as the desired signal except the baseband information content (carrier frequencies may differ).

NTIA recently completed the first phase of a study that reviewed existing standards and identified available interference protection criteria (IPC) for the various radio services in the 30 MHz to 30 GHz frequency range.[64] The study considered national and international standards from the following organizations: ITU-R, TIA, RTCA, ICAO, ETSI, IEC, International Maritime Organization, World Meteorological Organization, European Radiocommunications Organization, Radio Technical Commission Maritime, Aerospace and Flight Test Telemetry

64. NTIA expects to publish the results of this study later this summer.

Coordination Committee, Institute for Electronic and Electrical Engineers, United Kingdom Radiocommunications Agency, and Eurocontrol. Based on its review, NTIA determined that for many of the radio services, the IPC values contained in the various publications were incomplete and varied due to the specific type of interfering signal being received. During the second phase of the NTIA study, emphasis will be placed on developing IPC or other criteria for frequency sharing situations of practical importance. NTIA expects to publish these findings as well.

The Margie Article identified the need to establish consistent permissible interference standards, and recommended that the Commission initiate a NOI on the subject.[65] NTIA agrees with this suggestion and recommends that the results of the first phase of the NTIA study on IPC values for specific radio services be included as part of the NOI. The first phase of the NTIA study represents a comprehensive review of existing national and international standards and can serve as a solid basis for the Commission to begin building a public record with the goal of establishing maximum permissible interference levels to promote predictability and certainty for both licensed and unlicensed spectrum users.

XIII. DEFINING INTERFERENCE TEMPERATURE IN TERMS OF SIGNAL-TO-NOISE RATIO COULD PROVIDE GREATER FLEXIBILITY AND CERTAINTY THAT BOTH INCUMBENT AND FUTURE SPECTRUM USERS DESIRE.

In the NOI, the Commission requests comment on what elements should be considered in setting interference temperature limits for different bands and locations.[66] The Commission suggests several factors such as type and criticality of service, its susceptibility to interference, types of licensees, state of the development of technology, and propagation characteristics of the

65. Margie Article at 38.

66. NOI/NPRM at ¶ 21.

frequency band that could be considered in setting interference temperature limits for a band. The Commission seeks comment on whether these factors are appropriate as well as whether other criteria should be addressed.[67]

For many active services, such as the broadcast service, existence (or lack thereof) of a desired signal at some level above the measured noise floor can be used as an indication of spectrum utilization. Desired signal strengths that are well in excess of maximum noise levels (high S/N) might allow opportunistic underlay by unlicensed devices with a lower potential of causing harmful interference to the licensed user. Non-existence of a desired signal above the noise floor indicates that the spectrum is not currently being used in the location of the measurement. Therefore no harmful interference could occur and opportunistic use could be permitted. The geographic area in between these two extremes, however, is the area where receivers are most vulnerable to interference (marginal S/N). Passive services, services using low received signal strengths, such as satellite downlinks, and mobile services which do not always operate in the same geographic region are not likely to lend themselves to this approach.

Appendix D investigates opportunities that can exist for unlicensed use in certain areas, while protecting the locations that are potentially more sensitive to interference. These areas of opportunity could be utilized by unlicensed devices that are capable of measuring the RF environment, and making a determination to transmit based on whether excess margin or insufficient desired signal exists, or a determination to not transmit if the desired signal level is such that an increase in noise could potentially disrupt communications. NTIA believes that defining the interference temperature in terms of the available S/N could provide greater flexibility and certainty for both incumbent and future spectrum users.

67. *Id.*

XIV. IN ORDER TO MAXIMIZE THE USEFULNESS OF MEASURED INTERFERENCE TEMPERATURE LEVELS, THE PARAMETERS OF THE MEASUREMENT SYSTEM SHOULD BE STANDARDIZED.

In the NOI, the Commission requests comment on the approaches to be used for measuring the interference temperature on a real-time basis, and in the case of interference temperature derived from measurements at multiple fixed sites, communicating that information to unlicensed devices that are required to protect the limit.[68] The Commission also seeks comment on the measurement system(s) and procedures to be employed in measuring the interference temperature.[69]

In the NOI, the Commission describes how they envision that the measured interference temperature levels can be used in underlaying unlicensed device operations. For example, the interference temperature measurements performed by multiple fixed monitoring stations can be combined at a central location. The combined data can then be distributed to unlicensed devices that in turn could modify their operating characteristics (e.g., frequency, power) in response to the RF environment that is represented by the interference temperature. Since the measured interference temperature levels can be used to modify, on a real-time basis, the characteristics of an unlicensed device that could have a direct effect on its compatibility with licensed users, the properties of the measurement system must be defined in sufficient detail to ensure that the appropriate interference temperature limits are applied to protect all licensed receivers.

The Naval Postgraduate School performed a literature and research study for the Commission on the impact of noise on wireless communications.[70] As part of this study,

---

68. *Id.* at ¶ 22.

69. *Id.*

70. Naval Postgraduate School, NPS-EC-02-004, *Literature Search and Review of the Impact of Noise on Wireless Communications* (March 2002) ("Naval Postgraduate School Report").

different approaches to perform noise measurements were examined. Based on their assessment, it is clear that in the design of a measurement system there are a number of diverse factors that must be considered.

NTIA believes that the interference temperature measurement system should be a spectrum analyzer (SA) based system that is computer controlled. A specialized front-end should be implemented before the SA that includes an effective bandpass filter and a low noise preamplifier. The low noise preamplifier is used to increase the dynamic range of the measurement system and the bandpass filter is used to protect the low noise preamplifier from being saturated by strong out-of-band signals. The critical parameters of the interference temperature measurement system include detector function, measurement bandwidth, noise figure, sensitivity, measurement time, and the measurement antenna.

A detailed discussion of each of the critical parameters of the interference temperature measurement system is provided in Appendix C. NTIA recommends that the interference temperature measurements be made using both peak and root-mean-square (RMS) detector functions. As discussed in Appendix C, the RMS detector provides a true representation of the average power and the interference impact to most licensed receivers can be quantified in terms of average power. The resolution bandwidth (RBW) of the measurement system should be consistent with the IF bandwidth(s) of the licensed receiver(s) operating in the frequency band being monitored. The video bandwidth employed should be as wide or wider than the RBW to avoid the problems associated with video averaging that are discussed in Appendix C. The preamplifier used in the front-end of the SA based interference temperature measurement system establishes the measurement system's noise figure, sensitivity, and dynamic range. As with the bandwidth, the noise figure of the measurement system used to perform the interference temperature measurements should be representative of that used by the licensed receivers operating in the measured frequency band. In frequency bands where the signal activity is highly dynamic (e.g., land mobile bands), a swept frequency approach can be used to monitor the band. However, in frequency bands where the signals occur on a periodic basis (e.g., radiolocation bands), a stepped frequency approach may be more appropriate. The measurement interval to be used in either the stepped or swept frequency approach is difficult to estimate without prior knowledge of the RF signal environment that is being monitored or the receivers that are to be protected. For example, it may be possible to estimate the measurement interval based on the characteristics of the licensed signals (e.g., symbol length in a digital system), but in general it will be necessary to perform preliminary measurements in a frequency band to determine the appropriate measurement interval to be employed. The antenna to be used to measure the interference temperature levels should have a gain pattern that is consistent with the antennas employed by the licensed user operating in the frequency band being monitored. A discussion of the different types of commercially available measurement antennas is provided in Appendix C. Since noise measurements are statistical in nature, first order statistics such as amplitude probability distributions (APDs) could be used to characterize and understand the effect of the measured signals on the licensed receivers. Higher order statistics can also be used to further characterize the RF signal environment. This would require use of a spectrum analyzer capable of sampling the time waveform of the received signal(s), and possibly other more specialized equipment.

NTIA believes that the criticality of defining the measurement system parameters is directly related to how the interference temperature measurements are going to be used. For example, if the measured interference temperature levels are to be used to gain a gross understanding of the signal occupancy in a frequency band, then some of the measurement system parameters may be less important. However, the Commission indicates in the NOI that the measured interference temperature levels can be used by unlicensed devices to control their operating characteristics. In this situation, the parameters of the measurement system become more critical and must be considered very carefully to ensure that interference temperature measurements adequately protect the licensed receivers. Therefore, NTIA recommends that the parameters of the interference temperature measurement system that are discussed above be identified for each frequency band and standardized. NTIA believes that standardizing the measurement system will maximize the usefulness of the measurements.

XV. BEFORE IMPLEMENTING THE INTERFERENCE TEMPERATURE MODEL, THE RIGHTS AND RESPONSIBILITIES OF BOTH LICENSED AND UNLICENSED SPECTRUM USERS MUST BE DEFINED.

The SPTF Report addresses the subject of spectrum rights and responsibilities and recommends that the Commission define these rights and responsibilities for all spectrum users, particularly with respect to interference and interference protection, and those rights and responsibilities should be considered and established to the extent possible and practical.[71] In the NOI, the Commission seeks comment as to how this objective can be accomplished and avoid long, drawn out interference disputes without detrimentally affecting reasonable expectations of all interested parties, including expectations regarding the Commission's use of its authority to impose conditions, modify licenses and take other steps to promote greater access to, and more efficient use of the spectrum.[72]

---

71. SPTF Report at 18.

72. NOI/NPRM at ¶ 19.

Throughout the Commission's SPTF and NTIA's Spectrum Summit, providing predictability and certainty for licensed and unlicensed, as well as incumbent and new users of the spectrum, was identified as a critical goal to effectively manage the RF spectrum. Providing predictability and certainty to all spectrum users can only be accomplished if the rights and responsibilities of spectrum users are clearly defined. Several examples exist where the lack of definition in the rights and responsibilities of the incumbent and new spectrum users appear to have resulted in problems with deployment of new commercial services, including the General Wireless Communications Service (GWCS), the Wireless Communications Service (WCS), and the 700 MHz Commercial Mobile Radio Service (CMRS). For GWCS and WCS, flexibility of use was stressed over clearly defined service rules, which resulted in spectrum below 5 GHz where little or no commercial applications have been deployed.[73] In the case of 700 MHz CMRS, the uncertainty regarding when and how the broadcasters were to vacate the spectrum has resulted in delays of the auction and deployment of commercial services.

One of the major findings and recommendations of the SPTF was that regulatory models must be based on clear definitions of the rights and responsibilities of both licensed and unlicensed spectrum users, particularly with respect to interference and interference protection.[74] The SPTF also concluded that there are certain common elements that the Commission should incorporate into its spectrum policy regardless of the regulatory model that is used, including clear and exhaustive definition of spectrum users' rights and responsibilities.[75] It is expected that clear definitions of rights and responsibilities of spectrum users would simplify the rulemaking

---

73. The GWCS auction was indefinitely postponed due to lack of interest and the WCS auction generated minor interest and licenses were awarded for as low as $1.

74. SPTF Report at 3.

75. *Id.* at 4.

process, and could prevent heated public disputes over potential interference.[76] In addition to these recommendations of the SPTF, spectrum rights were also a major point of discussion in the NTIA Spectrum Summit.[77]

NTIA believes that a clear definition of both spectrum rights and responsibilities would facilitate a simplified technical process for considering new services, whether licensed or unlicensed, in many frequency bands. Clearly defined rights and responsibilities will also simplify the analysis of whether new unlicensed services can and should be introduced in licensed bands. NTIA recommends that before the interference temperature model is implemented, the rights and responsibilities of spectrum users be addressed. This could be accomplished as part of the ongoing interference temperature rulemaking proceeding or as part of the recommended NOI to identify permissible interference levels.

XVI. TO EFFECTIVELY IMPLEMENT THE INTERFERENCE TEMPERATURE MODEL, REPRESENTATIVE OPERATIONAL SCENARIOS MUST BE DEVELOPED FOR EACH RADIO SERVICE.

In the NOI, the Commission seeks comment on what assumptions should be made regarding operating scenarios to be used when performing interference studies assessing how much interference can be tolerated before it is considered harmful. The Commission also seeks comment on whether a statistical approach can be developed to arrive at the interference temperature limits. If a statistical approach can be developed, commenters should identify what parameters need to be developed. The commenters should also explain how such a statistical

76. *See* Testimony of Dr. Paul Kolodzy, Former Director of the Spectrum Policy Task Force, Federal Communications Commission, Before the U.S. Senate Committee on Commerce, Science and Transportation, Thursday, March 6, 2003.

77. *See* Keynote Address of Assistant Secretary Nancy J. Victory, Before the Federal Communications Bar Association (FCBA), Spectrum Policy Summit & CLE, Washington, DC, April 16, 2002.

approach would be applied.[78]

In assessing potential interference to receivers from transmitters, a source-path-receiver analysis is often performed. The basic parameters that must be defined for this type of analysis include the maximum permissible interference level, the output power and antenna gain of the potentially interfering transmitter, the propagation path defined by a minimum separation distance between the transmitter and receiver, and the gain of the receive antenna in the direction of the potentially interfering transmitter. Collectively, this information defines an operational scenario, which establishes how close the transmitter and receiver may come to one another under actual operating conditions, and likely orientation of the antennas. This information is used to determine the appropriate model to use in computing the propagation loss. The operational scenario can also be used to determine the applicability of other factors such as building attenuation, allowance for multiple transmitters, and safety margins.

The operational scenarios considered using the source-path-receiver approach typically assume that the parameters (e.g., transmitter power, antenna gain) are represented by a single fixed value. However, a probabilistic approach can also be employed, in which the analysis treats the parameters as statistical quantities, each defined by a mean and deviation around the mean. This analysis method could be employed by choosing or deriving a Probability Distribution Function (PDF) for each parameter. The joint PDF can be computed by convolving the individual PDFs with one another. The main difficulty with this approach is collecting a sufficient amount of data to accurately develop the PDFs for the parameters in the analysis. For radio services that require a high degree of confidence in the analysis results, such as the aeronautical radionavigation service, there is little benefit in employing this approach since the

78. NOI/NPRM at ¶ 28.

higher probabilities as defined by the PDF (*e.g.*, 99.99999%) must be used to develop the statistics for the analysis parameters.

Analyzing operational scenarios with consideration of locations of licensed receivers and unlicensed transmitters has been a major difficulty in past rulemaking proceedings.[79] In particular, analyses considering mobile services (licensed and unlicensed), where the locations of the transmitters are unknown, rely upon assumptions concerning separation distances that might or might not be appropriate. Such radiocommunication services might be better analyzed by considering interference scenarios, and the probability that harmful interference will occur, by employing Monte Carlo analysis techniques.[80] Using Monte Carlo analysis techniques, the worst-case scenarios, as well as less conservative scenarios, can be taken into account in assessing potential interference to a receiver. This approach was used in the 5 GHz U-NII R&O, where the location of the radar receiver, unlicensed device transmitter locations, and shielding losses were treated as random variables. Using this approach, propagation effects for locations that accounted for nearly free-space propagation, as well as other locations that warranted greater propagation losses due to terrain and shielding effects, were taken into consideration in assessing potential interference to radar receivers.

In assessing potential interference to receivers using the interference temperature model, it will be necessary to develop radio service specific operational scenarios. Currently most of the efforts in developing documented operational scenarios for assessing potential interference to receivers have been limited to the aviation industry. For example, RTCA Special Committee

79. The Margie Article contains a discussion of how vagueness and inconsistency in the rulemaking process affected the Multichannel Video Distribution and Data Service and Ultrawideband technologies rulemaking proceedings. *See* Margie Article at 20.

80. The Monte Carlo method has been used for the simulation of random processes and is based upon the principle of taking samples of random variables from their defined probability density functions.

159 (SC-159) Working Group 6 (WG 6) developed an operational scenario used to assess potential interference to aviation GPS receivers used for a Category I precision approach from MSS mobile earth terminals (METs).[81] In this operational scenario, a minimum separation distance of 100 feet was established and the free space model was determined to be appropriate to compute the propagation loss. The GPS receive antenna was assumed to be located on top of the aircraft and the antenna gain in the direction of the MET taking into account shielding from the aircraft was established. The maximum permissible interference level was based on a GPS receiver operating in the tracking mode, receiving a signal from a low elevation satellite, and a noise-like interfering signal. A safety margin was also included in the analysis to account for uncertainties such as multipath, receiver implementation losses, and variations in the antenna gain. This operational scenario only considered interference from a single interfering transmitter and did not consider interference from multiple transmitters of the same radio service or transmitters from multiple radio services. RTCA SC-159 WG 6 has expanded the scope of their work to include additional aviation scenarios as well as potential interference from multiple interfering transmitters within the same radio service and from transmitters in multiple radio services.[82] In order to develop interference temperature limits for each radio service, the operational scenarios and appropriate assumptions for each will need to be developed. These operational scenarios will be different for each radio service and must include information regarding transmitter and receiver parameters such as locations, transmitter power, transmit and receive antenna gains and any other radio service specific parameters (e.g., safety margin for

81. Document No. RTCA/DO-235, *Assessment of Radio Frequency Interference Relevant to the GNSS* (January 27, 1997).

82. Document No. RTCA/DO-235A, *Assessment of Radio Frequency Interference Relevant to the GNSS* (December 5, 2002).

aviation). NTIA believes that operational scenarios employing statistical techniques can be used for considering aggregate interference especially when the number and location of the transmitters are unknown. However, it must be realized that if a licensed service is to provide consumers with robust, reliable services, the probability of interference occurring must be kept low. NTIA recommends that operational scenarios be developed for each radio service to be used in determining the interference temperature limits. NTIA believes that adoption of radio specific operational scenarios in conjunction with maximum permissible interference levels will provide the certainty and predictability that incumbent and new users of the spectrum desire and is consistent with the recommendations of the Commission's SPTF.

XVII. THE INTERFERENCE TEMPERATURE LIMITS MUST PROTECT BOTH IN-BAND AND ADJACENT BAND SPECTRUM USERS.

In the NOI, the Commission's request for comments only addresses interference to in-band spectrum users and does not specifically address issues related to users operating in the adjacent bands. In the NPRM, the Commission does address the issue of out-of-band emissions. Specifically, the Commission recognizes the need to assure that increased operation of unlicensed devices enabled under the interference temperature model will not result in harmful out-of-band interference.[83]

Currently, adjacent band operations are protected by unwanted (i.e., out-of-band and spurious) emission limits that are either described as an absolute power or EIRP level, or as a reduction in power level as the frequency becomes farther removed from the fundamental frequency of the emission. Adequate measures of adjacent band energy must be included in the interference temperature model if the adjacent band users are to benefit from the same levels of

83. NOI/NPRM at ¶ 49.