Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Spectrum Policy Task Force Report	)	ET Docket N0. 02-135
	)	
	)	

Summary

Shared Spectrum favors adoption of the Spectrum Policy Task Force ("SPTF's") recommendations. (ET Docket No. 02-135, November 2002). Our spectrum occupancy measurements indicate that spectrum utilization is low. The real problem is not a spectrum shortage, but developing reliable spectrum access methods that enable new systems to co-exist with non-cooperative existing Primary users.

Shared Spectrum is developing an adaptive spectrum access approach based on the SPTF's concept of Interference Temperature. Analysis and simulations indicate that the method is effective in allowing secondary spectrum usage with minimal interference. We suggest adoption of statistical methods to specify Interference Temperature. It is not necessary to defer setting different threshold levels for each band, geographic region, or service until a noise survey is complete.

1 Introduction

Shared Spectrum is a newly formed company developing broadband wireless equipment optimized for secondary spectrum markets applications. As noted by the Commission[1], there is no equipment on the market now with the flexibility and capability to facilitate the use of available spectrum for a broad range of services. Our goal is to offer technology and equipment to fully realize the potential of the secondary spectrum market as rapidly as possible. The technology to accomplish this could be fielded in a few years, but regulatory issues (technical and spectrum availability) now limit its development.

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[1] *Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets*, FCC 00-402, Para. 4.

Shared Spectrum has conducted extensive spectrum occupancy surveys that indicate that spectrum utilization is low in most bands, even in urban areas. We believe that the problem is accessing spectrum, and not of spectrum shortage.

Shared Spectrum believes that advances in broadband wireless network technology being developed by the Department of Defense along with the Task Force's recommendations will provide a profound improvement to wireless communications over the next few years. These advances enable current and future wireless systems to avoid causing interference and to be tolerant of interference. The Task Force's concept of Interference Temperature enables dynamic, adaptive spectrum use that would solve the spectrum access problem. These new developments will lead to a very large increase in the widespread availability of high capacity wireless communications in both urban and rural regions and provide a significant cost reduction due to reduced spectrum acquisition costs. We applaud the Commission's forward thinking on this issue.

To accelerate these changes, the Commission should promote near-term testing and early type-acceptance of wireless systems that use the Interference Temperature concept for spectrum access. Also, the Interference Temperature should be defined with a "base" value and a certain number of allowable occurrences of specific amplitudes and durations that would not significantly degrade the level of service compared to other loss of service causes. The SPTF suggests that a noise survey be made before implementing a more quantitative approach to inference management, but we believe that initial conservative Interference Temperature threshold values could be adopted now and then increased when the noise studies are complete.

Shared Spectrum is developing an adaptive method to control transmitter power that would enable secondary use while maintaining a specified Interference Temperature at the Primary transceiver. We believe our progress in this area can contribute significantly to the practical implementation of the Interference Temperature concept introduced in the SPTF report. We also propose a statistical Interference Noise Temperature definition.

2 Adaptive, Interference Temperature Spectrum Access Methods

This section provides an overview of Shared Spectrum's approach to implement the SPTF's Interference Temperature method. The goal is for a Secondary System to access spectrum and to not degrade the performance of any Primary system by more than a set threshold. Our implementation is to permit the Secondary Network to introduce interference power to the Primary system below a certain level in dBm/Hz. This is consistent with the FCC's Part 15 rules on unintended emissions from electronic equipment, the rules on UWB devices, and the SPTF recommendations.

We are developing receive-only spectrum monitoring methods that can provide sufficient information to Secondary Network nodes to meet this goal without location or other information, provided the Primary signals are semi-duplex. Specifically, the node measures the received Primary in-band signal strength, and combines this information with prior knowledge of the transmitter's power in order to determine the maximum allowable secondary transmit power as shown in Figure 1 and described below.

$$P_{\text{max TX}} = P_{\text{allowable interference}} + P_{\text{primary}} - P_{\text{measured}}$$

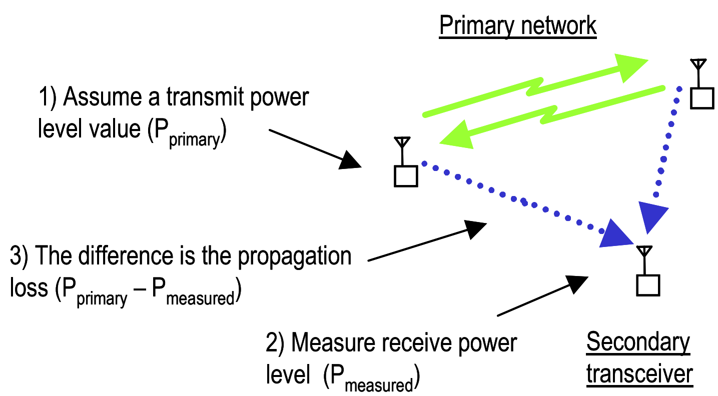

Figure 1 The propagation loss between the Secondary Network and Primary nodes and the allowable interference level determines the maximum power the Secondary Network node can transmit. The propagation loss is estimated by measuring the received power level and using prior knowledge of the Primary TX power level.

2.1 Issues and Features of the Shared Spectrum Approach

Shared Spectrum's approach mitigates the well-known "Hidden Terminal Problem." If a Primary terminal has high propagation loss to the Secondary transceiver and is not detected, then the approach determines the maximum allowable power level to avoid the Secondary transceiver to cause interference to the "hidden" Primary terminal. Each Secondary transceiver determines their own maximum transmitter power using their own measurements.   No single Secondary transceiver declares the spectrum available using only local measurements because this would cause a Hidden Terminal Problem.

The method maintains an exclusion zone that matches that required by the Primary network. Each Secondary transmitter reduces its maximum power level until it doesn't cause interference to any of the Primary users as shown in Figure 2. The resulting spectrum "boundary" forms an exclusion zone that matches the Primary user's region.

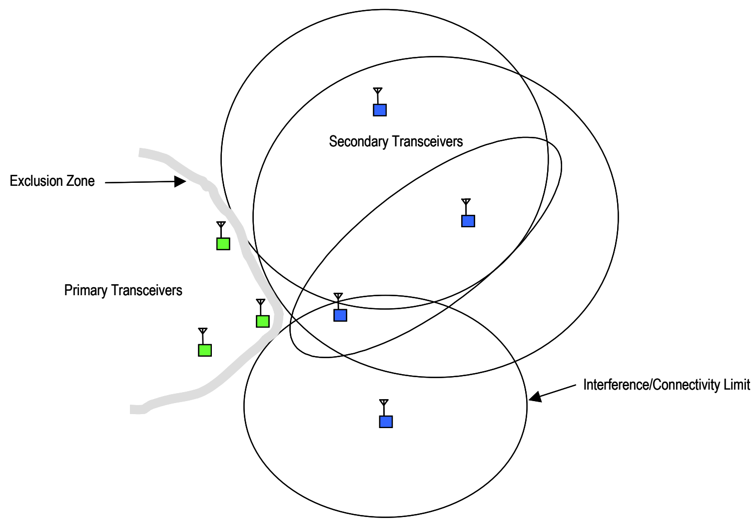

Figure 2 Exclusion zone determined by the adaptive method matches the Primary user's needs.

Under many circumstances antenna directionality and gain effects can be included in the adaptive algorithm. The measured signal level has these effects included and they are the same for the transmitted path because of reciprocity. Antenna gain and propagation effects will cause significant differences in the calculated net propagation loss based on measurements at one frequency and the actual propagation losses measured at another frequency.   Our approach mitigates this effect by making measurements over a time period where multi-path effects between channels can be represented statistically.

2.2 Improvements

Our approach uses several improvements and refinements to this basic method:

- **Adjacent Channel and Inter-modulation Effects-** Additional algorithms extending the above principle are used to account for adjacent channel and inter-modulation effects.
- **Improved Sensitivity -** Our approach uses special detection methods to improve the Secondary Network reception sensitivity and, thus, increases the dynamic range of Interference Temperature management, and permits more flexibility in Secondary Network transmitted power level.
- **"Look-Through"** - If the Secondary transceiver is part of a network with uncoordinated transmissions, then reception of the Primary signals by the Secondary Network nodes may be blocked under high duty cycles conditions. We use a method to mitigate this problem.
- **Time Lag Effects** – Changes in propagation conditions can occur quickly and there are short time delays due to receiver scanning, sampling, and data processing. These are overcome by introducing variable margins in the power algorithm.
- **Cumulative Effects** – If a large number of Secondary Transmitters operate in the region using the above method to set their maximum transmit power level, then the cumulative effect of these transmissions will cause the net Interference Temperature at the Primary receivers to increase. Our approach mitigates this vulnerability through statistical methods of Secondary Transceivers monitoring maximum power control.
- **Post Detection Actions** – We are developing several methods to reduce unintended interference and to reduce hardware costs by using cooperative Secondary Network behavior.

3 Probabilistic Definition of Interference Noise Temperature

We agree with the SPTF recommendations on page 34 of the report. The most important issue is to quantify acceptable levels of interference through the "interference temperature" concept. The Interference Temperature needs to have a statistical definition to accommodate practical spectrum access methods that will cause a small and insignificant, but still measurable interference level. The allowable interference durations need to be selected so they will not significantly degrade the Primary system's level of service compared to other loss of service causes.

Unlike the present definition of Interference Noise Temperature, the interference caused by an adaptive spectrum access method will a have a non-Gaussian temporal and amplitude distribution, and will be limited in bandwidth. There are several causes of the interference caused by an adaptive system. The adaptive algorithms described above will occasionally under- estimate the propagation losses due to abrupt propagation changes and cause interference. Primary systems will sometimes suddenly “turn on” in an area where Secondary operation is underway, and it will take a finite amount of time for the Secondary system to detect and react to this. Primary systems will sometimes have very low duty cycles and the Secondary systems entering the region will cause some interference until the Primary system transmits.

The level of interference, the occurrence rate, and durations should introduce a short-term loss of service to the Primary user that is less than current causes such as thermal noise fluctuations, man-made noise bursts, equipment faults, software faults, traffic overload, and others. These effects vary widely with spectrum band, location, Primary equipment type, mobility and other factors.

The Interference Temperature statistics should take into account the Interfering signal’s bandwidth as well as the temporal distribution. Noise temperature is an attractive approach because it is bandwidth and frequency insensitive. However, the loss of service to the Primary user at a certain Interference Temperature is less for interference over 1 MHz (and blocking a few channels) than over a 100 MHz (and blocking many channels). Shared Spectrum advocates the use of statistical representations that capture the ability to manage to a probability of harmful interference within both the time and spectral domains.

In Table 1 is shown a notional Interference Temperature limitation that a Secondary system would have to meet to operate within a band that is used by a Primary system. The “base” Interference Noise Temperature is 5 dB above 273^{o}K. The Secondary system is allowed a certain number of 0.1 second and 1 second long periods of interference at different levels above the “base” Interference Noise Temperature. There are limits for a single Primary channel and for the entire band in total.

Table 1 Notional Allowable Interference Noise Temperature Levels, Occurrence Rate, and Maximum Duration

Interference Noise Temperature Level (dB relative to 273 ^{o}K)	Maximum Duration (seconds)	Maximum Occurrences Per Hour in any One Primary Channel	Maximum Occurrences Per Hour Per Band
<5 dB	Unlimited	Unlimited	Unlimited
5 dB to 25 dB	0.1 second	10	50
5 dB to 25 dB	1 seconds	5	25
>25 dB	0.1 second	5	25
>25 dB	1 second	2	10

4 Don't Defer Adoption of Quantitative Approach to Interference Management

The SPTF recommends adopting standard methods to measure the noise floor, conducting long-term noise floor measurements[2] and recommends setting Interference Temperature threshold after the review of the condition of the RF environment in each band.[3]

Shared Spectrum submits that measurements of the noise floor would be helpful, but that the present spectrum users will correctly argue for Interference Temperature thresholds near the noise figures of the receiver pre-amplifiers in their systems. Completion of a noise survey will provide evidence to increase the threshold several dB, but this increase is not a key factor in the adoption of new spectrum access techniques. The Commission should adopt initial Interference Temperature thresholds of several dB above thermal noise, and eventually increase these values as the noise survey results become available.

We urge the Commission to start now to set different threshold levels for each band, geographic region, or service. Waiting for noise survey results is not necessary.

We also suggest that the Commission consider what spectrum bands will unlicensed or licensed "opportunistic-type" cognitive-type radios (that can use spectrum

[2] Page 34 of SPTF Report

[3] Page 5 of SPTF Report

within the Interference Temperature restrictions) be allowed to utilize and with what restrictions.[4] In the near-term, we suggest that the FCC should immediately take action on the Secondary Markets proceeding so that there is a near-term economic incentive for cognitive radio development.

Respectfully submitted,

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[4] Page 63 of SPTF Report