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Increasing TX Power in Licensed Exempt Spectrum

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1 Introduction

This document proposes updates to certain FCC Part 15 rule sections to allow license-exempt devices to use higher power under certain conditions, without geographic limitation. The proposed changes will expand or strengthen the coverage areas of unlicensed wireless broadband service providers nationwide and promote efficient sharing of license-exempt spectrum, without causing additional interference to (1) in-band licensed users, (2) adjacent band licensed users, and (3) unlicensed users of low-power devices.

Specifically, Kiwi Networks, Inc. ("Kiwi") proposes that the FCC do the following

A) Amend Section 15.247 of the FCC's Rules to permit higher power transmission in the 902-928 MHz, 2400-2483.5 GHz, and 5.725-5.850 GHz bands;

B) Allow such higher power transmission in all geographic areas, as opposed to just rural areas;

C) define "maximum average interference power" or "MAIP" as:

MAIP *= Instantaneous Transmitter ("ITX")Power * TXduty cycle * HorizontalAntennaBeamwidth/360*

For purposes of this formula. InstantaneousTX Power= the amount of power entering the antenna at the antenna port

Note: Presently, Section 15.247 generally limits point-to-multipoint license-exempt transmissions in all markets at the antenna port to 1W at 100% duty cycle. Thus MAIP is presently set at 1W. Under Kiwi's formulation, MAIP would remain at 1W to maintain consistency with the current rule. However, higher Instantaneous TX power would be permitted so long as the MAIP (defined here as the product of Instantaneous TX power, the duty cycle and horizontal beamwidth) does not exceed the 1W limit.

Finally, in those extreme cases where interference could occur notwithstanding the above, Kiwi urges the FCC to encourage the use of cognitive radio technology in accordance with the recommendations below.

These proposals, if adopted, will benefit license-exempt service providers who are attempting to provide carrier grade wireless broadband services in all areas of the country, including those that have no alternative to incumbent cable modem or DSL providers, or have no broadband service at all. In turn, the availability of ubiquitous and competitive broadband communication services will benefit consumers, businesses, police/fire/emergency users, education and other segments of the economy that are becoming increasingly reliant on high-speed Internet access to deliver services to the public.

2 Proposal

2.1 General

For a number of years, Section 15.247(b)(1)-(4) has limited, point-to-multipoint license-exempt operations to an MAIP of 1 W and an EIRP of 4 watts (reflecting a maximum permitted antenna gain of 6 dBi). This limitation (adopted well before license-exempt spectrum became a viable broadband alternative) effectively limits license-exempt broadband providers to line-of-site, relatively short range deployments. This paints license-exempt WISPs into an economic corner – they must absorb additional infrastructure and service costs to compensate for limited coverage, but are prohibited from expanding their service areas and thereby spread those costs over a larger subscriber base.

Kiwi believes, however, that under certain conditions a license-exempt WISP's transmission power can be substantially increased while keeping general interference conditions constant. It should be noted that Section 15.247(b)(4)(ii) already permits higher EIRP for point to point license-exempt systems. In essence, Kiwi has used the underlying philosophy for that rule to devise a way for point-to-multipoint systems to enjoy the same benefits.

2.2 Conditions for Higher Power Transmissions

Kiwi Networks, Inc. proposes the following implementation principles:

1. Limit transmission power at the antenna port, not EIRP

2. Impose no limit on Instantaneous TX power under the following conditions:

    a. A limit is imposed on transmission duty cycle during higher power transmissions

    b. Define maximum contiguous channel activity (x msec) and interval statistics (for example: Poisson) during higher power transmission

3. Encourage use of directional antennas to increase performance of intended receivers and minimize interference to non-intended receivers

Higher power transmissions should be permitted so long as MAIP, as defined above, remains within the 1W limit.

2.3 Rationale

2.3.1 TX Power Limits vs. ERP

The average amount of interference generated by a radio signal is independent of the antenna radiation pattern, and is dictated by TX power injected into the antenna port That is, use of directional higher gain antennas does not change the overall amount of interference generated by the radio – it merely changes how different receivers within the antenna's range will be affected (i.e., receivers located in the path of the antenna's directional beam will receive a higher level of interference than they would have received if the antenna were omni-directional; by the same token, receivers outside the directional beam will receive no interference). As a result, the gain in signal strength from directional antennas can be used to increase range, building penetration, and/or system capacity, without increasing the overall interference injected into the RF environment.

Conversely, Section 15.247's current EIRP limitation may actually <u>worsen</u> interference conditions. Because the EIRP limit remains the same regardless of the directionalization (a.k.a. beamwidth) of the antenna, service providers who operate in the point-to-multipoint mode have no incentive to directionalize their operations (and operation under the more liberal power limitations for point-to-point service simply is not a viable economic alternative in many cases – point-to-multipoint is by far the superior means of delivering wide-area, carrier class wireless broadband service at the lowest possible cost). Changing the rule as proposed herein will provide license-exempt WISPs with an incentive to use more efficient antenna technologies in the point-to-multipoint mode, thus leading to decreased levels of interference without decreased quality of service to consumers.

Kiwi recognizes that increasing transmit power as proposed may increase interference levels in a limited number of cases, i.e., for those receivers that stand in the direct path of a WISP's directionalized transmissions. Hence, although the average level of interference in the RF environment does not increase, there will be some probability that antenna beams will be directed at some unintended receivers and hence increase those receivers' level of interference.

Kiwi believes, however, that the harmful impact of increasing interference to a smaller universe of receivers can be substantially mitigated by cognitive radio technology. It should be noted that Wi-Fi devices already implement a simple form of cognitive radio, i.e., a Wi-Fi receiver senses the environment and schedules transmissions based on acceptable interference conditions. Hence it is possible that even the performance of legacy Wi-Fi devices could be improved under Kiwi's proposal for reasons discussed in the next section.

2.3.2 Benefits of Cognitive Radio Technology

Cognitive radio technology benefits are greatest when reception conditions in the network vary. This is because the essence of cognitive operation is the radio's self-adjustment of its operating parameters based on location-specific and time-specific channel quality). The larger the variability in channel conditions, the more benefit cognitive radios will deliver.

Consider two environments, each containing the same number of non-cooperative radio systems communicating in a license-exempt band. Assume further that the absolute interference level for both environments is identical, though one has much higher interference variability than the other (or, put another way, the distribution of interference among receivers in the latter market is far more uniform).

Cognitive techniques can provide very limited benefits in the system where interference conditions are fairly constant. However, where interference levels have a high degree of variability, the system can use cognitive techniques to identify transmission opportunities when channel conditions are highly favorable.

While interference variability provides the optimal environment for cognitive radio technology, there remains the question of whether overall system performance under Kiwi's proposal (higher power transmissions limited by duty cycle, directionalization and cognitive techniques) would be superior to that of a system operating under the existing Part 15 limitations.

System performance does increase because of what is commonly known as multi-user diversity. If a particular radio experiences interference, it defers the transmit opportunity to another radio with superior channel conditions, and transmits only when channel conditions become more favorable for itself. In limited cases, if interference is both pronounced and constant, there may not be any opportunity for transmission under current Part 15 specifications

An important distinction between Kiwi's proposal and the NPRM is that Kiwi believes services providers should use cognitive techniques to help themselves combat interference, as opposed to focusing on minimizing harmful effects to others.

3 License Exempt Spectrum User Benefits

If the proposals contained in this document are adopted, users will experience an increase in capacity, a dramatic reduction in interference, improved range, building penetration and coverage. This section will quantify the benefits based on simulation results.

3.1 Increased Capacity

According to Shannon **Therom** the capacity of a system is given by:

$$Capacity = BW \cdot \log_2(1 + C/(I + N))$$

where BW is channel bandwidth, C is signal strength or power, and (I+N) are interference and noise, respectively. For example, if power (C) is increased by 20dB, the capacity can be increased by approximately 4.5X.

Appendix A presents a simulation model that illustrates the capacity benefits of Kiwi's proposal. The model examines performance of single radio that is receiving transmissions from (M + 1) sources. Only one of these transmissions is assumed to be the desired signal, and the other M transmissions are assumed to be undesired signals or interference. MAIP is assumed to be constant, while Instantaneous TX power is allowed to fluctuate based on duty cycle, and antenna beamwidth, per the relationship established by the equation given in Section 2.2.

Figure 1 presents simulation results for the scenario where no cognitive techniques are deployed. Note that the existing Part 15 scenario is depicted in the lower left hand edge of the graph: 100% duty cycle, no additional gain (also, in the following illustrations 0 gain condition depicts an omni directional antenna, and as gain is increased, narrower beamwidth is assumed).

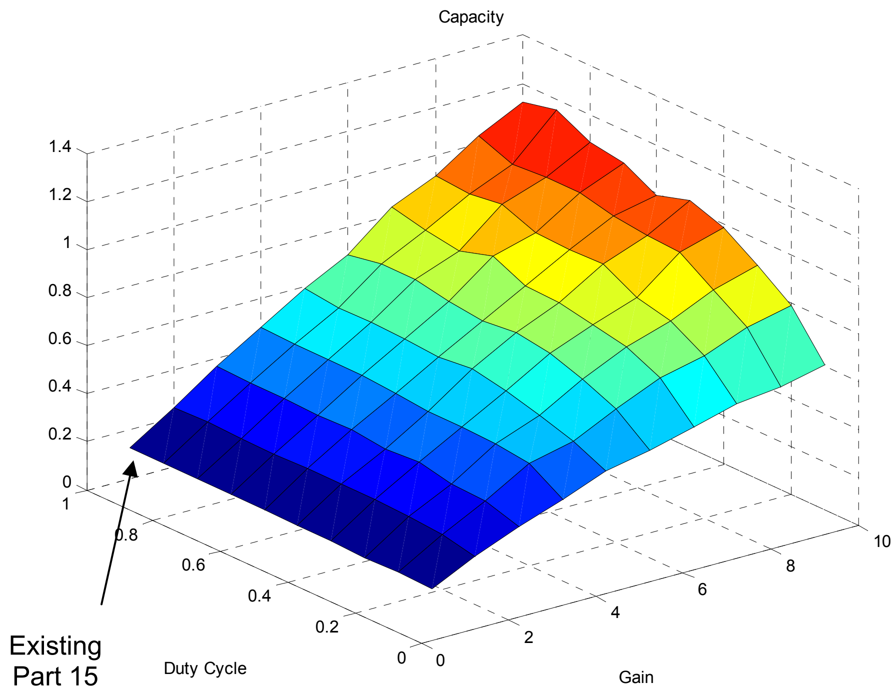

Figure 1: Capacity as function of antenna gain and TX duty cycle without cognitive functionality

As shown above, increase in gain naturally leads to increase in capacity. More interestingly, however, decreasing duty cycle does not have a material impact on system capacity, which is reduced by only half when duty cycle is reduced from 100% to 20%. Even at 20% duty cycle, system capacity is superior to the existing Part 15 case.

Figure 2 examines the case where cognitive capabilities are added to the network. Generally, the overall capacity numbers are 2x the existing Part 15 case.

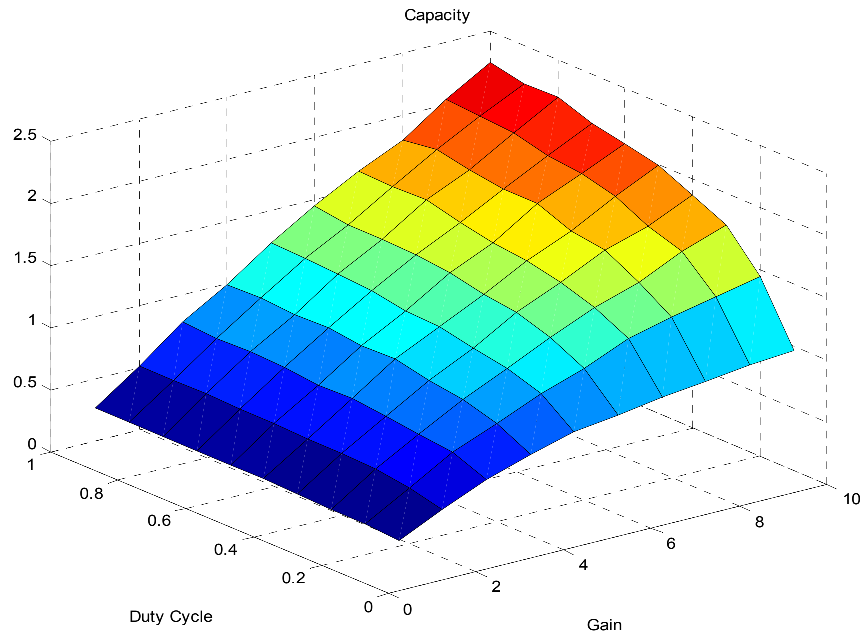

Figure 2: Capacity as function of antenna gain and TX duty cycle with cognitive functionality

3.2 Interference Reduction

For the same network model depicted in Appendix A hereto, we next examine outage probability experienced by each radio. Figure 3 illustrates outage probability for each radio as a function of antenna gain and TX duty-cycle (where the Instantaneous TX power level is inversely proportional to TX duty-cycle). No cognitive ability is assumed.

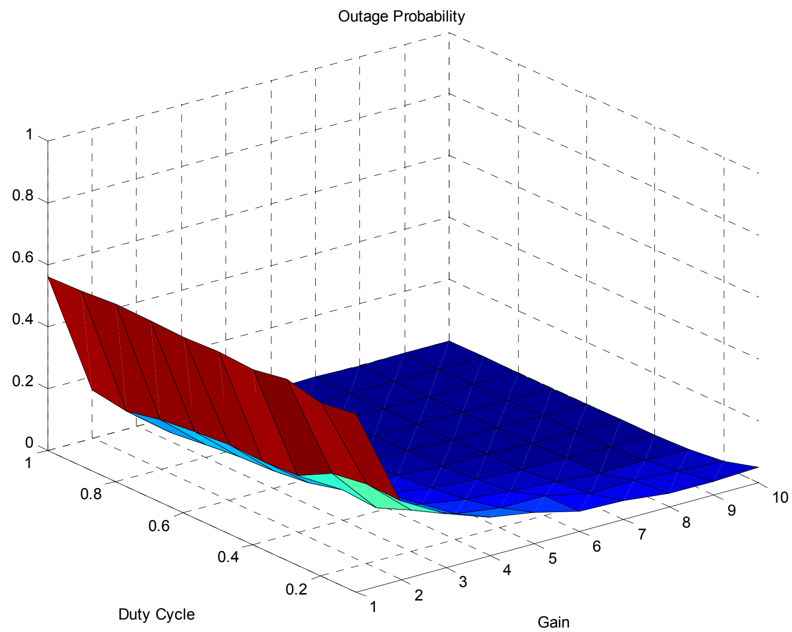

Figure 3: Interference related outage probability without cognitive functionality

Figure 4 illustrates the same scenario, but with cognitive capability. In both cases, with or without cognitive capability, increasing antenna gain and reducing TX duty-cycle while increasing Instantaneous TX power reduces the outage probability. As expected, cognitive capabilities lead to much lower outage probability.

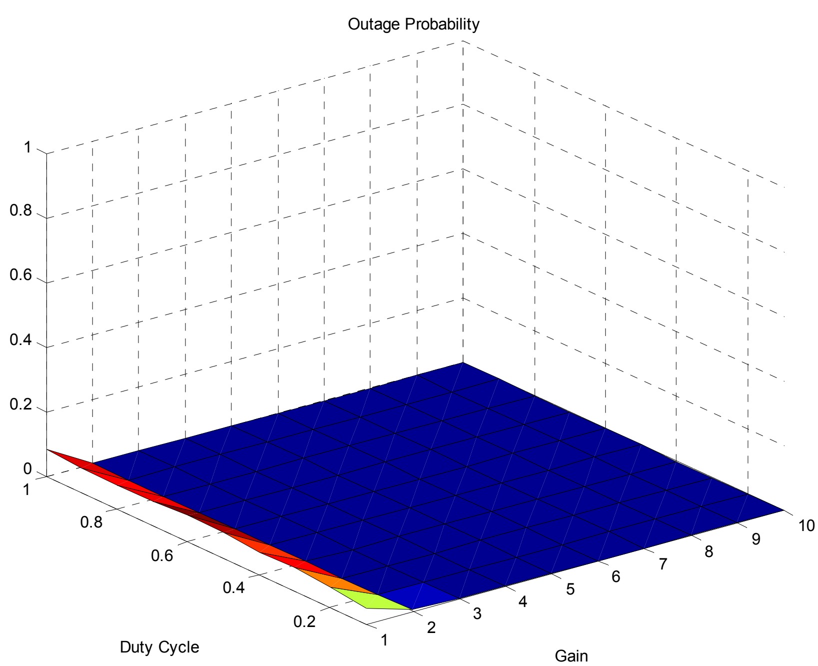

Figure 4: Interference related outage probability with cognitive functionality

3.3 Increase in Range and Coverage

Generally speaking, as discussed in previous section, allowing an increase in instantaneous power can esily increase the link budget by 20dB This will significantly improve coverage and help in building penetration. In that scenario, a significant percentage of license-exempt broadband deployments could use indoor CPE units, thus obviating the need for costly external CPE devices, dramatically reducing residential broadband costs, and helping proliferate broadband communications services across the U.S.

Figure 5 illustrates the benefits of instantaneous TX power increase at 2.4 GHz service in an urban environment: h_m = subscriber station's antenna height and h_b = base station's antenna height.

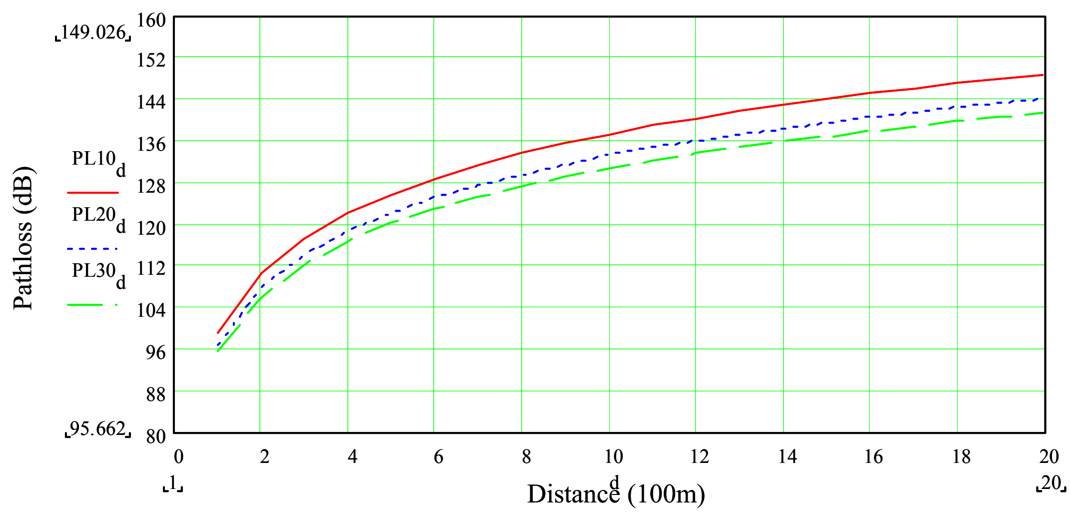

Figure 5: 2.4GHz path loss for h_b = 10, 20 and 30m, h_m = 5m, urban

Figure 6 illustrates the same scenarios for an suburban environment. There is no surprise to see that 12dB increase in ERP will approximately double coverage distance or quadruple the coverage area.

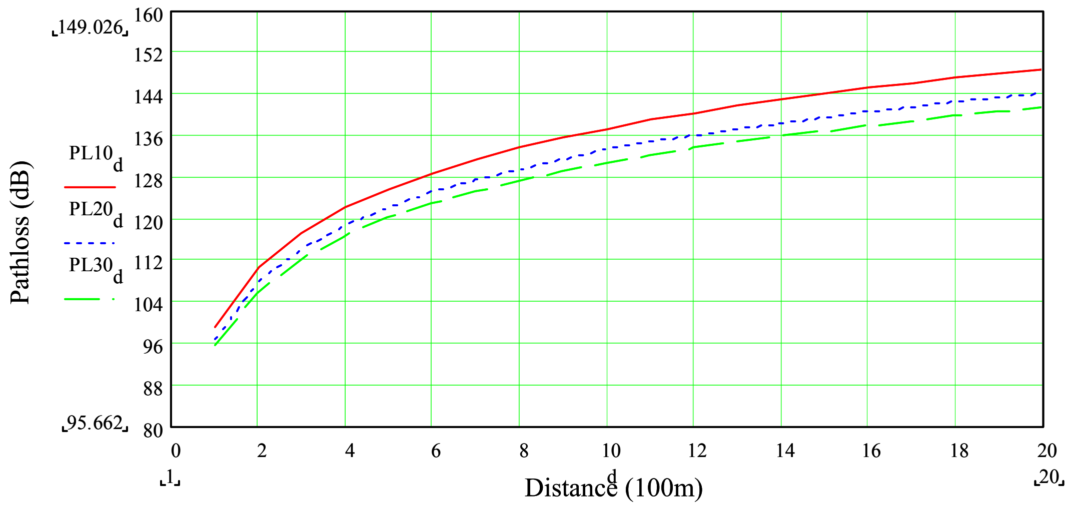

Figure 6: 2.4GHz path loss for h_b = 10, 20 and 30m, h_m = 5m, suburban

4 Summary

Kiwi proposes that the Commission can optimize the provision of wide-area point-to-multipoint license-exempt broadband service in *all* markets, without compromising the interference environment for other spectrum users. As discussed above, this can be accomplished by (1) redefining maximum average output interference power as a function of Instantaneous TX power, TX duty cycle and antenna beamwidth, 2) increasing allowable instantaneous transmission power (at the antenna port), but with corresponding reductions in transmission duty cycle and/or horizontal beamwidth, and 4) using cognitive radio techniques to greatly reduce outage probability. By implementing these guidelines, wireless broadband services can enjoy a 20dB increase in power delivery in the network without materially harming others.

5 Appendix A: Simplified model & simulation for signal and interference

Assume that the user receives transmissions from M + 1 sources. The strongest of these transmissions is assumed to be the desired signal, and the other M transmissions are assumed to be the interference. The values of the M+1 received transmissions are drawn from a lognormal distribution with a specified standard deviation.

Capacity calculations for the reference system [duty cycle = 1, omni antenna]

Let X[m] be these random values.

Then the signal S = max{X[m]} = X[mmax]

Interference I = sum X[m]   where the sum is over all m not equal to mmax

The capacity is given by:

$$C = \log_2(1 + SINR) \quad \text{where} \quad SINR = S/(N+I)$$

We compute the average capacity over many random drawings of X[m].

To "calibrate" the system we scale the signal and the interference so that the average SNR = S/N and INR = I/N equal some specified valued.

Capacity calculations for the system which uses antenna with gain, reduced duty cycle and multi-user diversity

Assume a duty cycle   0<D<1 and an antenna gain G.   Also assume that the antenna beam-width is approximately 360/G.

Pick binary random variables d[m] which is 1 with probability D and 0 with probability 1-D. Pick binary random variables g[m] which is 1 with probability 1/G and 0 with probability 1-1/G.

Then the signal and interference in this case will be given by

signal S = (1/D)*G*max{X[m]} = (1/D)*G*X[mmax]

interference I = (1/D)*sum d[m]*g[m]*X[m]

where the sum is over all m not equal to mmax

The factor of (1/D) represents the increase in power due in proportion to the decrease in the duty cycle.

The capacity is given by

C = D*log(1 + SINR) where SINR = S/(N+I)

We compute the average capacity over many random drawings of X[m], d[m], g[m].

To take into account the effect of potential multi-user diversity using cognitive functionality we proceed as follows: Assume that the users are divided into K groups. At each time we pick one user from each group, check their SINR, and transmit to the one which had the best SINR. In the simulation this is accomplished by generated K random values of C each time, and picking the largest one.

In addition to computing the average capacity it is useful to look at the outage probability, i.e. the probability that the capacity will be below a specified level. In the simulation the outage probability is evaluated by counting the number of cases where the random capacity was below a threshold, and dividing that value by the total number of cases.