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October 4, 1999

Magalie Roman Salas
Office of the Secretary
Federal Communications Commission
445 12th Street, S.W.
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Washington, D.C. 20554

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ICL

Re: **Amendment of Part 15 of the Commission's Rules Regarding Spread Spectrum Devices Notice of Proposed Rulemaking ET Docket No. 99-231**

Dear Ms. Salas,

I am writing on behalf of ICL, a division of Fujitsu Ltd. to endorse the proposals set out in the above-referenced Notice of Proposed Rulemaking. ICL strongly supports the Commission's initiative to facilitate increased innovation and competition in the on-going development and use of broadband spread spectrum technologies at 2.4 GHz.

Our company and its customers benefit directly from advances in spread spectrum technology in the 2.4 GHz band. In particular we sell RF based handheld terminals that allow our customers to take advantage of higher speeds that complement the faster processors provided in our handheld computers.

Frequency hopping spread spectrum technologies are tailor-made for broadband applications. They are quite resistant to interference in this unlicensed communications band, which also is shared with such ISM devices as the ubiquitous microwave oven. They also consume very little power, which is a critical consideration for mobile devices. Overall, frequency hopping technologies provide excellent cost/performance value.

Adoption of the Commission's proposal will mean that frequency hopping systems can more fairly access the available frequencies in the 2.4 GHz band. They will also be able to deliver higher data rates, while being backward-compatible with the installed base of existing, more narrow-band systems. Higher data rates made possible by the Commission's proposal will enable our company and our customers to realize additional benefits, such as faster file

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A business of Fujitsu-ICL Systems Inc.

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transfers, speedier Internet access, and enhanced multi-media experiences. Moreover, frequency hopping systems that comply with the proposed rules will not result in additional interference to existing users of the 2.4 GHz band. This point is very important to us because of our own installed base in this band.

For all these reasons, we urge quick adoption of the Commission's proposal in this proceeding.

Respectfully,

Ron Omohundro
Senior Vice President/General Manager
ICL
11085 N. Torrey Pines Rd.
La Jolla, CA 92137

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In Matter of	)	
	)	
Amendment of Part 15 of the Commission's Rules	)	
Regarding Spread Spectrum Devices	)	ET Docket No. 99-231
Notice of Proposed Rulemaking	)	

COMMENTS

ICL, a division of Fujitsu Ltd. endorses the proposals set out in the above-referenced Notice of Proposed Rulemaking. ICL strongly supports the Commission's initiative to facilitate increased innovation and competition in the on-going development and use of broadband spread spectrum technologies at 2.4 GHz.

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For all these reasons, we urge quick adoption of the Commission's proposal in this proceeding.

Respectfully submitted,

ICL

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October 4, 1999

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MICRILOR, Inc.

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30 September, 1999

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Magalie R. Salas, Esq.
Secretary
Federal Communications Commission
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Re: ET Docket No. 99-231

Dear Ms. Salas:

MICRILOR, Inc., endorses the FCC proposals refining the rules for spread-spectrum operation under Part 15.247 to remove artificial constraints on Frequency Hopping systems and to eliminate mathematical anomalies in the present Processing Gain test for Direct Sequence systems.

MICRILOR is a developer of DSSS equipment. **We observe that the proposed FH rules should not result in increased harmful interference, relative to that from existing FH systems, for well-designed DS systems. The burden rests upon the DS system designer to ensure robustness by providing adequate processing gain.** MICRILOR further considers the existing FH rules to be overly restrictive. In military systems, where FH originated, FH channels (carrier frequencies) are normally spaced such that there is substantial overlap of instantaneous spectra for adjacent channels. The current FCC rules force FH systems to use non-overlapping channels, which is one extreme of operation. The FCC's proposed relaxation of the constraint on FH bandwidth should enable innovation to the benefit of consumers.

FCC rules for DSSS operation require a PG of at least 10. It is currently required to demonstrate this by a Direct Processing Gain Measurement (DPGM) test (15.247.e.1), or via the CW Jamming (CWJM) Margin test (15.247.e.2). On January 14, 1998, Micrilor filed a request for declaratory ruling regarding the use of fewer than ten chips per symbol N_c under Part 15.247. FCC/OET judged that disposition required a rule making; the issue is addressed in the above referenced NPRM.

Micrilor re-asserts that the CWJM test fails to be a useful test for N_c<10 because of documented statistical anomalies, and recommends that the alternate Gaussian Noise (GN) Test be used <u>exclusively</u> in that limit. Because of its simplicity, it is recommended that the GN test be an alternative for all N_c. It is further recommended that the noise bandwidth used for the GN test be more than 25% and less than 50% of the signal bandwidth.

Retaining the CWJM test as an alternative for N_c<10 would enable continued exploitation of the statistical anomaly, cloaked by specious mathematical arguments; if this is allowed, then there is

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no point in instituting the GN test. Systems with reasonably large N_c yield consistent values of PG when subjected to DPGM, CWJM and GN tests. Entirely non-spread modulations, such as simple DPSK signaling, can pass the CWJM test. The CWJM test is simply not useful for $N_c<10$. The cost of keeping the CWJM test as an option for $N_c<10$, besides erroneous certification of non-spread-spectrum systems under Part 15.247, will be increased burden upon the Government for scrutiny of arguments presented to rationalize the CWJM test results. The OET staff will be placed in the difficult position of judging complex and potentially highly controversial mathematical "proofs" instead of simply verifying the single straightforward measurement of the GN test.

The worst-case jamming of a DSSS system occurs for center-band CW interference. The CWJM test requires measurements over the passband to average out spectral anomalies. Similarly, the GN test noise bandwidth should be more than 25% of the signal bandwidth to ensure averaging over spectral anomalies. This enables the GN test to be effected via a single measurement rather than the frequency-stepped measurement required for the CWJM test. A further constraint on the bandwidth of the noise should be that it be no wider than 50% of the signal bandwidth so that processing gain cannot be ascribed to simple filter rejection of out-of-band noise. With these simple constraints on the noise spectrum it is unnecessary to specify details of filters used in the GN test. It is both simple to use and unambiguous in its results.

MICRILOR engineers routinely perform both CWJM and GN tests on our DS equipment with consistent PG values obtained. The main difference between these tests is that a GN test takes about 5 minutes, while a CWJM test requires about 90 minutes due to the repeated CW measurements over the passband.

Appendices to this letter provide 1) considerations for the GN test, 2) a review of the CWJM statistical anomaly for small N_c, 3) discussion of drawbacks if the CWJM is kept as an option for $N_c<10$, and 4) suggested wording of paragraphs under Part 15.247.

Sincerely,

J H Cafarella

John H. Cafarella
President

Appendix 1: Gaussian Noise Test

The GN test was suggested as a means for "fixing" the CWJM test for $N_c<10$. It still relies on the well-accepted Jamming-Margin Equation, but it removes statistical inconsistency by using Gaussian noise instead of CW interference. It results in the following perspective regarding the four terms of the Jamming-Margin Equation:

a) The Gaussian-noise formulas for symbol probability of error now apply exactly for computing $(S/N)_o$, independent of N_c;

b) M_j is the interference-to-signal power ratio at the input of the correlator or matched filter; this is unambiguous, and independent of detailed spectral shapes, as long as the noise spectrum is contained in a bandwidth reasonably smaller than the signal's noise-equivalent bandwidth (See below);

c) G_p is defined unambiguously, on a symbol basis, as the ratio of the signal-to-interference power ratio at output of the correlator or matched filter to the signal-to-interference power ratio at the input (clearly required for consistency with the DPGM test).

d) L_{sys} exactly as before.

Thus, by adopting the GN test the only parameter remaining subject to any manipulation is L_{sys}, which is restricted in the current FCC rules to 2 dB, and should continue to be so restricted in the future. Note that L_{sys} is a function of various implementation choices that manufacturers make in trying to approach theoretically ideal performance. In particular, L_{sys} has no special relationship to the test procedure, whether DPGM, CWJM or GN.

The Gaussian noise test requires only non-critical laboratory components and standard test equipment, similar that used for the CWJM test. The GN test is easier to carry out than the CWJM test because it is performed as a single measurement, rather then being stepped in frequency across the passband as required for the CWJM test. This is so because the Gaussian noise can have a bandwidth covering a moderate fraction of the signal bandwidth to average out spectral anomalies. Because of its simplicity and statistical suitability, the GN test should be an option for all values of N_c. Several simple conditions should be enforced upon the GN test to ensure validity:

1) The noise bandwidth should be more than 25% of the signal bandwidth to ensure averaging over spectral anomalies (spikes and dips due to specific spreading codes);

2) The bandwidth of the noise should be no more than 50% of the signal bandwidth so that processing gain cannot be ascribed to simple filter rejection of out-of-band noise; and

3) Amplifiers passing the noise should have saturation levels 10-dB higher than the RMS noise power to ensure that reasonable Gaussian tails are maintained in the measurements.

With these conditions none of the components require precise specification, and the signal bandwidth specification is also non-critical; i.e., either 3-dB bandwidth or Noise-Equivalent Bandwidth (NEB) is adequate for nominal specification.

Specifying the Noise Bandwidth

The second of the above conditions requires further discussion, since some manufacturers have advocated that the GN test be carried out using noise which is spectrally flat over the signal null-to-null bandwidth. It is well known that the worst-case CW interference for a DSSS system is a center-band tone (when performance is averaged over all possible spreading codes). PG increases as the CW interference frequency departs from center band. The CWJM test is stepped over the passband to avoid spurious spikes in the response, but because of FCC rules only moderate increase in PG occurs as a result.

In a similar manner, the GN test should be based upon interference concentrated at center band to avoid over estimating PG. Widening the noise spectrum provides averaging against the spurious spectral spikes; this is similar to stepping the CW frequency in the CWJM test. However, such noise power as would fall outside the main spectral lobe of the signal can easily be removed by filtering and need not be "processed" away. This fact is well understood by designers of military systems. The following shows that the Gaussian interference should be limited to occupy only the flatter part of the signal spectrum, e.g., 50% of the signal bandwidth.

To quantify the over-estimation of PG, we calculate the PG of a system using an 11-bit spreading code, such as the Barker code of the 1-/2-Mbps 802.11 DSSS standard. To avoid confusion, we consider an ideal system transmitting an unfiltered PSK spectrum with chip duration T_c, and employing the corresponding optimum processor for the AWGN case; this is familiar as a touchstone. The noise is Gaussian in its amplitude statistics, has a rectangular spectrum of noise bandwidth B_N, and a spectral density of P_J/B_N. The input SNR is P_S/P_J. The output SNR is

$$\frac{P_S N_C}{\frac{P_J}{B_N}\int_{-B_N/2}^{B_N/2} \sin c^2(fT_C)\,df}.$$

Figure 1 shows the measured processing gain vs. $B=B_N T_C$ for this idealized case. B=2 corresponds to a measurement using noise whose flat spectrum spans the null-to-null signal bandwidth. This would attribute to the original 802.11 DSSS standard a processing gain of 13.8 dB instead of the 10.4 dB generally accepted as the processing gain (without L_{sys}) for that standard.

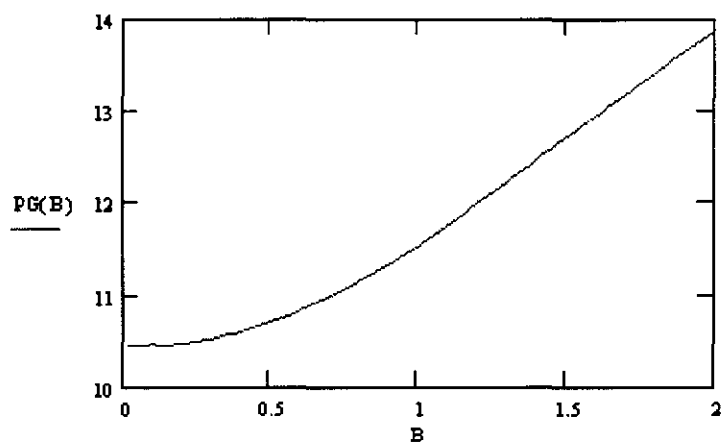

Figure 1 – Processing Gain vs. $B=B_N T_C$.

Appendix 2: Statistical Anomaly for Small N_c

It has been common practice to estimate BER performance of direct-sequence spread-spectrum systems using standard (Gaussian-noise) probability of error formulas. While it is well known that the distribution of post-processed interference in a DSSS system is not identically Gaussian, traditional (military) DSSS systems employed very large N_c, and in this regime the difference between the actual distribution and Gaussian is of little consequence. Only since DSSS systems entered the commercial world has emphasis on higher data rates motivated the use of extremely small spreading factors.

For center-band CW interference the post-processing distribution in quadrature correlator channels is actually Binomial. The key difference between the Binomial and Gaussian distributions is that the Binomial distribution does not possess the characteristic tails of the Gaussian unless N_c is large. As a result, for any DSSS system experiencing signal plus CW interference alone, there will be a threshold in S/I ratio at which the probability of error drops abruptly to zero. This is in contrast to the case of signal in Gaussian noise, for which the probability of error decreases exponentially, but not abruptly, as a function of S/N. For few chips per symbol this abrupt drop to zero probability of error actually happens at a much lower S/I than would be predicted using Gaussian-noise formulas. This is very important because the FCC allows manufacturers to compute processing gain using the CWJM test the formula

$$G_p = (S/N)_0 + M_j + L_{sys}$$

where G_p is the processing gain, $(S/N)_o$ is the output SNR required at threshold error rate, M_j is the threshold Interference/Signal ratio, and L_{sys} is the system implementation loss.

The FCC, recognizing that claiming an artificially high L_{sys} inflates the value of G_p, limited the allowable L_{sys} to 2 dB. Unfortunately, there remains a larger opportunity for inflating the apparent G_p if manufacturers are allowed to employ $N_c<10$ while basing a value of $(S/N)_o$ upon Gaussian statistics.

We consider baseband bi-phase signaling in the presence of a constant-level interferer to demonstrate the anomaly encountered when using small N_c. It corresponds to coherent PSK with a CW interferer very near the signal carrier. Figure 2 compares the probability of error for Gaussian and Binomial post-processed distributions for N_c=8,16 and 32.

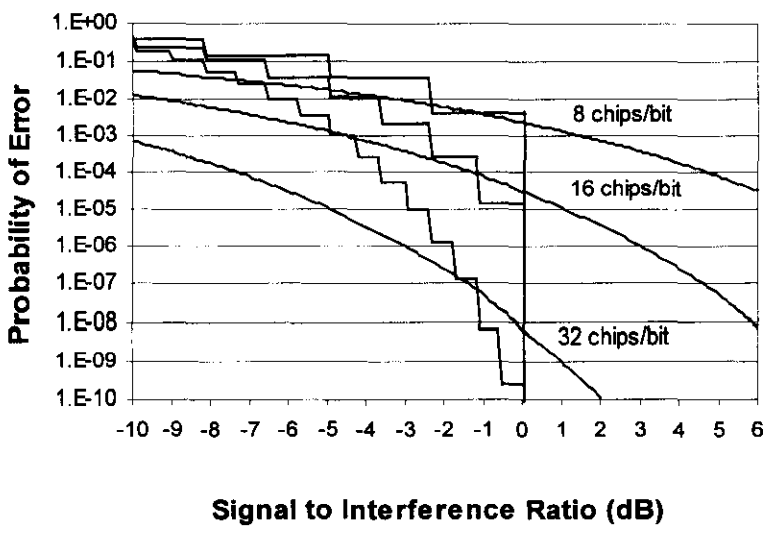

Figure 2 – Gaussian and Binomial Cases Compared.

The Binomial case reflects a staircase behavior which is finer for larger N_c, and the probability of error drops abruptly to zero at S/I=0 dB for all N_c. This occurs because at S/I > 0dB the highest value the CW can sum to at the output of the correlator is smaller than the signal component out of the correlator. The correct data decision will always be made; an incorrect data decision requires that the component due to the CW must exceed that due to the signal. When the average power of the CW interferer is higher than that of the signal at the input, then at the output the CW may be larger or smaller than the signal. The largest output interference amplitude has probability 2^{-Nc}; and it is the first case to cross the boundary where an error will be generated as the CW level is increased.

The Gaussian approximation is good for typical operating points for systems using large N_c. However, as the number of chips per bit becomes small the Gaussian formula overestimates the required $(S/N)_o$, relative to that actually needed for the Binomial distribution, which in turn gives a greatly inflated PG value using the CWJM test.

We now consider the behavior of common DPSK signaling. Earlier correspondence provided to the FCC included detailed analysis of this case; however, the results can be obtained intuitively. When estimating whether the received signal has a differential phase of 0 or π, required for DPSK demodulation, the larger of two phasors dominates the decision. Thus, the probability of error for a DPSK system with CW interference is ½ when the interference is larger than the signal, and 0 when the interference is less than the signal. The DPSK probability-of-error curves for CW and for Gaussian interference are compared in Figure 3.

It is clear that a DPSK system requiring an error probability lower than about 10^{-5} will pass the CWJM test. The threshold is M_j=0dB, where the interference can no longer influence the demodulator decision. The claimed signal to noise ratio for 10^{-5} BER is $(S/N)_o$=10.4dB, computed using the Gaussian-noise formula. These would lead to a PG measurement of PG=$(S/N)_o$+ M_j=**10.4 dB**, without resort to an assumed L_{sys}. Thus, simple DPSK could be certified under Part 15.247 if the CWJM test were the criterion.

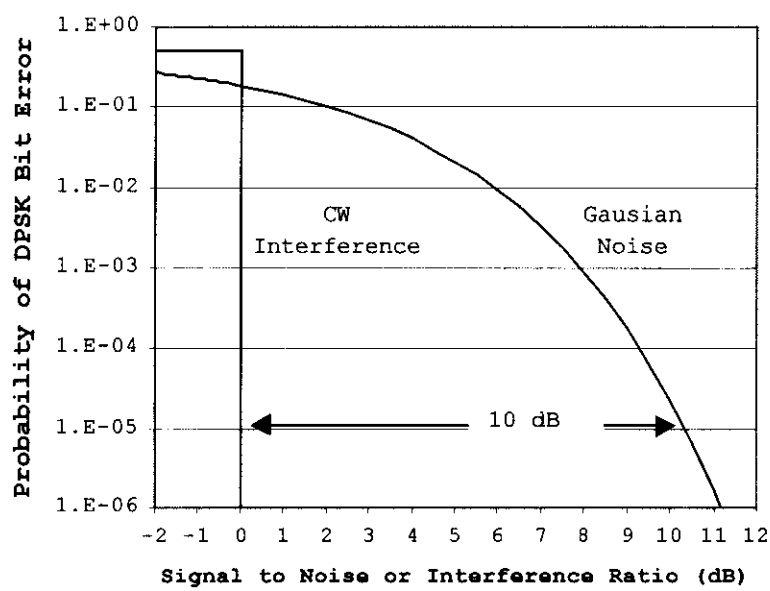

Figure 3 – DPSK with Gaussian and CW interference.

Appendix 3: Mathematical Justification of PG Using CWJM Test

Some manufacturers have suggested that they be allowed to use the CWJM test supported by a mathematical justification of the PG calculation via the Jamming-Margin Equation. If these manufacturers' equipment could not pass the GN test, then they certainly would prefer to use the CWJM test because of its statistical anomaly. **However, claims for "internal coding gain" or other mechanisms are specious; the reason such systems pass the CWJM test is that formulas based upon Gaussian statistics greatly overestimate the value of $(SNR)_0$ for $N_c<10$ with CW interference.** Appendix 2 shows that a DPSK system, which has no such coding gain, passes the CWJM test. While complicated modulations can be supported by complicated arguments, these will appear to pass the CWJM test, but only for the same statistical anomaly as does DPSK. This is why we recommend that the GN test be used exclusively for $N_c<10$.

The Jamming-Margin Equation has a long history and is well-accepted. It has four well-defined terms: G_p, $(S/N)_o$, M_j and L_{sys}. No manufacturer should be allowed to make up an equation, or to introduce terms into the classical equation on an ad hoc basis. The original equation is derived from first principles, and is simple to understand. Any introduction of terms into this equation would not only lack consensus among communications engineers, and it would also place a large burden upon the FCC to determine whether each such modified equation is valid.

Designers of military spread-spectrum systems use the original equation and manage to find a way to account for all significant effects within one of the four terms. There should be no allowance for ad hoc modifications of the basic Jamming-Margin Equation, no matter how mathematically these are cloaked. If there were some "internal coding gain" mechanism, as offered by some manufacturers, then it should be reflected in one of these four terms. The PG calculation should not be a shell game.

Appendix 4: Suggested Wording

According to the recommendations herein, 15.247 paragraph (e), as well as paragraphs (1) and (2) under paragraph (e), would remain as in the current rules. Specifically, the proposed new wording for paragraph (e) would not be adopted. The new paragraph (3) under (e) would change from the FCC-proposed text as follows:

(3) For systems that employ a spreading rate less than 10 chips/symbol the ~~results of the CW jamming margin test described in paragraph (2) must be supported by a separate mathematical calculation of system processing gain. Alternatively,~~ processing gain ~~may~~ **must** be determined by using the jamming margin test procedure described in paragraph (2), except that the interfering signal used must be Gaussian noise **of bandwidth more than 25% and less than 50% of the signal (3-dB) bandwidth and centered on the signal center frequency. This Gaussian noise form of processing gain measurement may also be used for $N_c>10$.**

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roup, Inc.

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Re: **Amendment of Part 15 of the Commission's Rules**
Regarding Spread Spectrum Devices
Notice of Proposed Rulemaking
ET Docket No. 99-231

Dear Ms. Salas,

I am writing on behalf of Donovan Consulting Group, Inc. to endorse the proposals set out in the above-referenced Notice of Proposed Rulemaking. Donovan Consulting Group, Inc. strongly supports the Commission's initiative to facilitate increased innovation and competition in the on-going development and use of broadband spread spectrum technologies at 2.4 GHz. We feel that there is an uneven playing field for those vendors now hampered by the limited bandwidth capabilities imposed by the current rules.

Our company and its customers will benefit directly from future advances in spread spectrum technology in the 2.4 GHz band. We are in a unique position in our industry, as we do not sell any hardware. We are strictly a consulting and technical services organization that endeavors to suggest and implement the right wireless data solutions for our customers. Those solutions must include higher bandwidth frequency hopping technologies. Our customers must be given the opportunity to choose the appropriate technology for their applications based on the merits of a vendor's implementation of that technology. We feel it is a disservice for them to be forced to choose DS technology simply because frequency hopping systems are essentially crippled by the current rules structure.

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In addition, we believe that frequency hopping spread spectrum technologies are quite resistant to interference in this unlicensed communications band, which also is shared with such ISM devices as the ubiquitous microwave oven. We have successfully implemented them in environments that are highly susceptible to such interference. They also consume very little power, which is a critical consideration for the mobile devices that we, in particular, specialize in. Overall, we believe that frequency-hopping technologies provide excellent cost/performance value to our customers.

Adoption of the Commission's proposal will mean that frequency-hopping systems can more fairly access the available frequencies in the 2.4 GHz band. They will then be able to deliver the necessary higher data rates, while being backward compatible with the installed base of existing, more narrow-band systems. Higher data rates made possible by the Commission's proposal will enable our company and our customers to realize additional benefits, such as faster file transfers, speedier Internet access, and enhanced multi-media experiences. Moreover, frequency-hopping systems that comply with the proposed rules will not result in additional interference to existing users of the 2.4 GHz band. This point is very important to us because of our own installed base in this band.

For all these reasons, we urge quick adoption of the Commission's proposal in this proceeding.

Respectfully,

Mark W. Van Pelt

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