Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
OET Announces TAC Noise Floor Technical Inquiry	)	ET Docket No. 16-191
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To: The Commission

COMMENTS OF PERICLE COMMUNICATIONS COMPANY AND THE GOVERNMENT WIRELESS TECHNOLOGY & COMMUNICATIONS ASSOCIATION

Respectfully submitted,

PERICLE COMMUNICATIONS COMPANY

7222 Commerce Center Drive, Suite 180
Colorado Springs, CO 80919
(719) 548-1040
jacobsmeyer@pericle.com

GOVERNMENT WIRELESS TECHNOLOGY
& COMMUNICATIONS ASSOCIATION

By: Alan S. Tilles, Esquire

Its Attorney

Shulman Rogers Gandal Pordy & Ecker, P.A.
12505 Park Potomac Ave., Sixth Floor
Potomac, Maryland 20854
(301) 230-5200
atilles@shulmanrogers.com

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SUMMARY

The explosive growth of both intentional and unintentional radiators over the past 20 years raises important questions regarding the radio noise floor and its effect on reliable and efficient wireless communications. There are very few scientific surveys of radio noise relevant to this problem and our view is that the radio noise floor is not well understood, except in a few radio astronomy bands, and then only in the vicinity of the radio telescope. It is important to know whether the wireless industry is on the cusp of an exponential growth in radio noise that may severely handicap reliable and efficient use of the spectrum. If the U.S. can understand and quantify the rise in the noise floor, government and industry may be able to mitigate the problem before it gets out of hand. The proliferation of noisy LED lamps is a prime example of the potential for this problem to escalate quickly.

In these comments, Pericle Communications Company and the Government Wireless Technology and Communications Association share our experience with diagnosing and correcting real-world interference problems in public safety and commercial wireless bands. These examples should inform the FCC on the nature of the problem and practical solutions.

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Pericle Communications Company ("Pericle") and the Government Wireless Technology & Communications Association ("GWTCA"), hereby respectfully submit the following Comments in response to Public Notice issued by the Commission in the above-captioned proceeding.[1]

Pericle Communications Company ("Pericle") is a consulting engineering firm specializing in wireless communications. Founded in 1992, Pericle consults for the public safety, utility, personal wireless, transportation and broadcast industries. Through its client, the City and County of Denver, the company was deeply involved in the formulation of the 800 MHz rebanding plan adopted by the Commission in 2004. Pericle continues to help public safety agencies, utilities and cellular operators hunt down and resolve radio frequency interference.

The Government Wireless Technology & Communications Association ("GWTCA") is a newly-established non-profit trade association created to advocate on behalf of government and

[1] DA 16-676, Technological Advisory Council (TAC) Noise Floor Technical Inquiry, released June 15, 2016.

non-government users of wireless technology and communications in the public service industries, such as public transit.[2] GWTCA's membership includes government agencies, manufacturers, engineers and consultants working on a variety of issues impacting represented users. As transit users operating in the 800 MHz band have been deeply affected by interference, GWTCA has a significant interest in this proceeding.[3]

I. BACKGROUND

The TAC seeks a better understanding of changes to the spectrum noise floor over the past 20 years. Specifically, the TAC asked four questions (each with sub-questions) regarding the radio noise problem. We will attempt to answer these questions within the limits of our collective experience and offer some suggestions to resolving some of the most pressing noise issues. Because the term "noise" is used loosely, we wish to clarify that we are talking about man-made noise (sometimes called interference) rather than thermal noise or galactic noise.

II. QUESTIONS AND ANSWERS

1. *Is there a noise problem?*

Yes, there is a widespread noise problem that presents a significant obstacle to ubiquitous wireless voice and data communications.

a. *If so, what are the expected major sources of noise that are of concern?*

In Pericle's consulting practice, as well as GWTCA members, it has been found that there are many sources of radio frequency noise. Some of these sources are listed below in rough order of their impact to wireless services:

- <u>Bidirectional Amplifiers (BDAs)</u>. BDAs or *Booster Amplifiers* are used to provide coverage in hard-to-reach areas and are almost always limited to indoor use. A BDA can be fed

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[2] For more information, see www.gwtca.org.

[3] *See*, for example, *Ann Arbor Transportation Authority*, DA 14-1436, released October 2, 2014.

either over-the-air or directly from a base station radio or repeater. Cellular operators rarely use over-the-air BDAs because of the potential for harmful interference, but public safety agencies use over-the-air feeds extensively. Also, many municipalities require BDAs in public buildings to ensure reliable indoor radio coverage for firefighters.

While the FCC recently updated its booster amplifier rules to address the potential for harmful interference,[4] many problems remain. Most problems are caused by poor installation practices. For example, installers rarely adjust the gain downward on the uplink path, and in urban areas an FCC-compliant amplified noise floor at the BDA output will still exceed the thermal noise floor at the public safety radio repeater site. When many BDAs are employed in a downtown area, the rise in the noise floor is cumulative. In short, the repeater site is desensitized by the many BDA uplinks in the city. There are many cases of cascaded BDAs where the downstream amplifier is overdriven, causing high levels of broadband noise (which are now *non-compliant* with FCC emission rules).

- LED Lamps. LED lamps cause weak or strong broadband interference depending on make and model. Harmful LED lamp interference has been measured at several 800 MHz cell sites. The solution in most cases is to replace the lamp with a different brand that does not cause harmful interference. It is not clear that offending LED lamps meet Part 15 rules for unintentional emissions or not, because it is difficult to measure radiated emissions accurately in the field versus a chamber or range. The bottom line is that the interference is strong enough to affect a 700/800 MHz cellular base station, which in one case in which Pericle was involved was 162 feet away from the lamps.

- Large Display Signs (including LED, but not always LED). Two examples are the Fashion Show Mall on the Las Vegas Strip and several gambling casinos in Black Hawk, CO.

[4] *See*, for example, *Report and Order*, WT Docket No. 10-4, FCC 13-21, released Feb. 20, 2013.

The culprits here are the switching DC power supplies powering the LED lamps. Because these signs have large metal backings, they act as a reflector and focus the interfering power in one direction. At 800 MHz, harmful interference has been measured to cell sites within 100 feet of display signs while at VHF, harmful interference was measured as far as 900 feet from display signs.

- License-Free WiFi Radios & BDAs. There have been several cases of WiFi Access Points ("APs") causing interference in the 2.3 GHz WCS band where AT&T Mobility operates. Apparently, the radios were manufactured for use in the UK, but somehow ended up in the U.S. In one case, when the Wireless Internet Service Provider ("WISP") was notified that the system was operating illegally, the WISP immediately reprogrammed the AP to operate in the 2.4-2.4835 GHz license-free band. Whether the unit was imported legally or not, it was not an isolated case. Although the 2.3 GHz AP might not be considered a "noise" source, it does illustrate a serious interference problem and perhaps shortfalls in enforcement of import restrictions. There are also many cases of 2.4 GHz BDAs installed improperly or not adequately shielded, causing interference as far away as 849 MHz.

- Passive Intermodulation ("PIM"). Passive intermodulation is a non-linear mixing of two or more radio carriers in a passive device to create new frequencies. Common PIM products are 2A-B or 3A-2B where A and B on the original carrier frequencies. Devices that cause PIM include corroded joints, dissimilar metals, gaps in metal fabrication, metal fasteners and sharp edges or corners. Passive intermodulation is a problem caused primarily by poor installation practice or poor choice of materials. In many cases, materials on the rooftop in front of the base station panel antenna cause PIM. PIM can also occur in the antenna itself, but cellular operators are careful to purchase only PIM-tested antennas. Seemingly preventable, PIM is nevertheless a major cause of harmful interference at cellular base stations and LMR repeater sites.

- Leaking Connectors on Overhead Cable TV Transmission Lines. Leaking cable TV lines are a common source of interference to cellular base stations and other wireless services. Often the cable operator is equipped to measure aviation band interference (108-136 MHz) but not interference in other bands.

- Electrical Transformers. Electrical transformers can deteriorate over time in the sense that they start creating interference when no interference was present before. Like many made-made noise sources, interference is strongest at lower frequencies, but sometimes transformer interference can be measured at cell sites and repeater sites in the 800 MHz band. Most utilities have a procedure in place for replacing noisy transformers and the problem is usually corrected quickly once it is found.

- GPS and Cell Phone Jammers. These devices are illegal in the U.S., but their use is still widespread.

b. *What services are being most impacted by a rising spectrum noise floor?*

Within the expertise of Pericle and GWTCA, land mobile radio (VHF, UHF, 700/800 MHz), cellular radio (all bands but especially 700/800 MHz), Positive Train Control (217-222 MHz) and GPS (1575.42 MHz) are most affected. However, outside of our practices clearly AM broadcast, FM broadcast and aviation (108-136 MHz) are also affected.

c. *If incidental radiators are a concern, what sorts of government, industry, and civil society efforts might be appropriate to ameliorate the noise they produce?*

There should be a multi-pronged approach to both the incidental and intentional radiator problem: (1) Voluntary adoption of industry standards to limit emissions from LED and other lighting systems; (2) Better FCC enforcement of Part 15 rules as they relate to devices like LED lamps; (3) Drastic improvements to National Fire Protective Association ("NFPA") and International Building Code ("IBC") standards for Radio Enhancement Systems (i.e., BDAs) to address better design and installation practices and qualifications of designers and installers; and (4) Better enforcement of import and sale rules to prevent sale of incompatible WiFi and cordless phone (e.g., DECT) radios in the U.S.

2. *Where does the problem exist?*

a. *Spectrally*

i. *What frequency bands are of the most interest?*

The upper VHF band (150-174 MHz) is especially susceptible to unintentional radiators because noise from computers, electrical transformers and motors are greatest at the lower radio frequencies. The 217-222 MHz band, used for Positive Train Control (PTC), is also susceptible, in part due to the high voltage lines and transformers at train stations. The 700 and 800 MHz bands are also prone to interference due to the vast number of devices in these bands but also due to widespread over-the-air BDA use.

b. *Spatially*

i. *Indoors vs outdoors?*

The noise problem is primarily an outdoor problem because the greatest impact to wireless services occurs when the interference is present at the base station or repeater site. Also, base station antennas are usually located above clutter, so they have line-of-sight to many interference sources. However, individual subscribers are also affected and are often affected indoors. The problem is insidious; the user has no way of knowing the dropped call is interference and will usually attribute it to weak signal. Further, the subscriber device is poorly instrumented to measure and report local interference. Examples of indoor interference sources (noise-like) include fluorescent light ballasts, LED lamps, cable TV set top boxes, and a variety of consumer electronics devices. Co-channel interference from WiFi sources also occurs often, although this might not fall into the "noise" category.

ii. *Cities vs rural settings?*

Urban settings are more susceptible to radio noise for obvious reasons.

iii. *How close in proximity to incidental radiators or other noise sources?*

Minimum harmful distances vary widely depending on the type of interference source, height above clutter, amplitude of the interference and the number of interferers in a particular area. Harmful interference at cell sites from tens of feet to several hundred feet has been found. Occasionally there is broadband noise at distances of several miles, but these sources are usually malfunctioning intentional radiators with directional antennas.

iv. *How can natural propagation effects be accounted for in a noise study?*

It is not clear what is being asked here. There are over-the-horizon propagation effects that might raise the noise floor. Most of these effects occur at frequencies below 100 MHz, but ducting and tropospheric scatter can occur in the 700/800 MHz bands, especially over water or the desert.

c. *Temporally*

i. *Night versus day?*

Most noise-like interference in the bands of greatest interest occurs during the day simply because the devices that cause interference are in use during that time. LED lamps might be a notable exception.

ii. *Seasonally?*

It is unclear that there is a seasonal variation to the types of man-made noise discussed in this proceeding.

3. ***Is there quantitative evidence of the overall increase in the total integrated noise floor across various segments of the radio frequency spectrum?***

Yes, this is readily apparent to those working in the field, but scientific studies may be lacking. One must recognize that the interference problem is only partially one of a rise in the broadband noise floor. Interference is rarely white noise. Instead, it has structure with strong amplitude variations in frequency and time. A study that pre-supposes time-invariant white noise, even within the confines of a particular frequency band, will fail to address the real problem.

a. *At what levels does the noise floor cause harmful interference for particular radio services?*

The short answer is at any level that increases the thermal noise floor in the receiver. Typical subscriber radio receivers used in land mobile radio and cellular radio have noise figures of roughly 6 dB, but the base stations and repeater sites use tower-mounted amplifiers and the composite noise figure can be as low as 2 dB. Thus, of greatest interest are noise sources that raise the noise floor above kT plus 2 dB, or -174 + 2 = -172 dBm/Hz. As a practical matter, cellular operators typically add several dB to this threshold before triggering an alarm as there is often an irreducible noise floor at urban sites.

b. What RF environment data from the past 20 years is available, showing the contribution of the major sources of noise?

Very few studies exist. There are many studies of spectrum *occupancy*, but this is not the same as a noise floor survey. Unless the band is unoccupied, it is very difficult to separate legitimate signals from interference, especially for an outside observer. The cellular operator is in a better position to separate users from interference, but in Pericle's experience, the base station radio is not instrumented well for this task.

c. Please provide references to scholarly articles or other sources of spectrum noise measurements.

[1] M. Hoyhtya et al., "Spectrum occupancy measurements: A survey and use of interference maps," *IEEE Communications Surveys and Tutorials*, 2016.

[2] Silicon Flatirons Conference, "Radio spectrum pollution: Facing the challenge of a threatened resource," Reading List, November 14, 2013.

[3] D. Roberson, "Illinois Institute of Technology Spectrum Observatory," WSRD Workshop #5, March 31, 2014.

[4] mass, "Autonomous Interference Monitoring System, Phase 2," Final Report, March 2007.

4. *How should a noise study be performed?*

The following comments are necessarily general in nature. Pericle is happy to contribute to the development of a detailed radio noise survey test plan at the appropriate time.

a. *What should be the focus of the noise study?*

Such a study should focus on bands where popular wireless services operate so the greatest benefit is realized by the largest group of users.

b. *How should it be paid for?*

To date, one of the huge problems for private wireless licensees, particularly public safety agencies, has been the need to spend vast amounts of money to locate and mitigate interference from other parties. Yet there is no methodology presently to recover these costs. Thus, to the extent that studies can be performed which results in rules that minimize interference, and thus minimize interference to public safety, the public benefit is to all. Given the sheer amount of money that can be saved vs. the small amount of money that such a study would cost, this would seem to be a valid use of public funding.

c. *What methods should be used?*

There is significant literature on methods to conduct radio noise surveys. Once the objectives of the survey are known, appropriate methods will be more obvious to those skilled in the art. It will be difficult to isolate noise in occupied bands and unoccupied bands are few and far between.

d. *How should noise be measured?*

i. *What is the optimal instrumentation that should be used?*

A spectrum analyzer is the logical instrument for this task, but dynamic range and noise figure are challenges. A low noise amplifier and low-loss bandpass filter are essential. There are many companies in the business of selling instruments and software for this type of survey.

ii. *What are the measurement parameters for the instrumentation used?*

This depends on the objectives of the survey.

iii. *At what spatial and temporal scales should noise be measured?*

For the data to be useful, one must capture it over time periods corresponding to significant variations in noise level. Because these are man-made sources, a period of at least two weeks makes sense because it captures the diurnal variation as well as the work-week versus weekend variation. Spatial scales are tougher to capture. In our experience, most interference is localized, so measurements from a single tower site in a city, for example, will result in too small a sample size to be reliable. On the other hand, if the objective is to measure subscriber interference, measurements at lower elevations in the clutter are relevant.

iv. *Is directionality an important measurement?*

It depends on the objectives of the noise survey. If it is focused on the impact of interference at a particular location such as a cell site, then it makes sense to use the directional sector antenna at the cell site. Attempts to measure subscriber received interference should normally use omnidirectional antennas, but even in this case, MIMO antenna arrays at the subscriber device would lead to some directionality considerations.

v. *Is there an optimal height above ground for measurements?*

This is an important detail. For example, in July of 2016, Pericle mitigated a stubborn interference problem that was affecting a City of Aurora, Colorado 800 MHz repeater site used for public safety communications. The interference was obvious when measured from the receive antenna on the tower, but was too weak to be seen from the ground, even with directional antennas. Direction finding from several tall buildings was necessary before the source was identified. Ironically, the offending emitter was a BDA with excessive uplink gain installed to comply with the City's public safety Radio Enhancement System ordinance. The proper height above ground for measurements should match the particular service/band being investigated. If the band is cellular, one must match the height to the existing sector antennas.

e. *What measurement accuracy is needed?*

Off-the-shelf test equipment will be limited to accuracies on the order of +/- 1.5 dB and this accuracy should be adequate.

i. *What are the statistical requirements for sufficient data? Would these requirements vary based on spectrum, spatial and temporal factors?*

These requirements would vary based on spectrum, spatial and temporal factors, but well-established parameter estimation techniques should be used.

ii. *Can measurements from uncalibrated, or minimally calibrated, devices be combined?*

This is an interesting opportunity that should be investigated further. If errors are unbiased, then we know variance (error) can be reduced by combining measurements. Cellular base stations and controllers already capture a significant amount of data, at least during the precommissioning phase. After that, it is typical that the operator's equipment cannot differentiate between interference and user activity. Sometimes user activity (especially because it is not power controlled by the site) is a problem even before commissioning. Perhaps the greater potential is from subscriber devices but we are not sure the devices are instrumented well for measuring noise or interference of any kind.

iii. *Is it possible to "crowd source" a noise study?*

An interesting possibility. While the desirability of such an approach seems appealing from an inclusiveness standpoint as well as a financial standpoint, it would seem that there would be too many opportunities for improperly (unintentionally or otherwise) created data to enter the study. The study is far too important to impart such risks. A crowd source study that eliminates direct human involvement and instead uses the subscriber radio as the test instrument has potential. At present it is not clear that the subscriber device is instrumented adequately to accurately collect this information.

f. *Would receiver noise measurements commonly logged by certain users (e.g. radioastronomers, cellular, broadcast auxiliary licensees) be available and useful for noise floor studies?*

Yes, they could be available, but wireless carriers are generally very protective of what they consider proprietary information. It does not hurt to ask.

g. *How much data must be collected to reach a conclusion?*

Depends on the objectives of the study and spectral, spatial and temporal factors.

h. *How can noise be distinguished from signals?*

This is a tough one. There are signal processing techniques that can be used to isolate noise from signals occupying the same spectrum, but many limitations apply.

i. *Can noise be characterized and its source identified?*

In many cases, yes. Pericle does this at over one hundred cell sites and repeater sites each year. The firm's engineers and technicians are expert at identifying and classifying common sources of interference from their spectral signature.

ii. *Is there a threshold level, below which measurements should be ignored?*

In general, yes, but licensees will have different opinions on this point. The threshold should of course be matched in some way to the accuracy and sensitivity of the instrument, but also to the sensitivity of typical receivers. One rule of thumb is to treat interference as negligible if it causes no more than 1 dB rise in the thermal noise floor of the receiver. This results in a measurement threshold of 6 dB below the thermal noise floor of the receiver ($10\log_{10}(1.25) \cong 1$ dB).

WHEREFORE, the premises considered, it is respectfully requested that the Commission act in accordance with the Comments submitted herein.

Respectfully submitted,

PERICLE COMMUNICATIONS COMPANY

By: Jay M. Jacobsmeyer, P.E., President
Pericle Communications Company
7222 Commerce Center Drive, Suite 180
Colorado Springs, CO 80919
(719) 548-1040
jacobsmeyer@pericle.com

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