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Ultra Wideband Wireless Solutions

Ms. Magalie Roman Salas
Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, DC 20554

February 2, 2002

RE: Ex Pate Presentation, ET Docket 98-153

Dear Ms. Salas:

Pulse-Link is focused exclusively on the development of Ultra Wideband technologies, and more precisely the definition and development of optimized wireless communications systems based on UWB. As such, we have followed the filings surrounding approval not only with an eye towards an optimistic ruling, but equally and perhaps more important to assess the data, findings and methods of companies making submissions so that we might continually evaluate, assess and refine our own approach towards the definition of optimized UWB technology.

We present specifics later herein, but in general we take exception with several of the observed testing methods and their resulting conclusions. Some groups are basing their positions relative to UWB approval and their filings on this matter based solely on those test results. Companies that have little or no experience in Ultra Wideband and which hold no noticeable Intellectual Property for that matter are presenting "findings" based on tests that have no apparent relevance in viable real world UWB operations. Fundamentally, these experiments employ methods that no company with an understanding of UWB and committed to providing reliable data communications or Quality of Service (QoS) through UWB would ever use.

There is significantly more to creating a reliable, robust Ultra Wideband Air Interface capable of reliably communicating data and providing QoS to multiple users than simply hooking up an antenna to a pulse generator and turning it on. Using a simple pulse generator to represent an UWB Air Interface would be the equivalent of someone saying they could use a sine wave generator to simulate a cell phone air interface. Obviously, a sine wave generator would not take into account such parameters as spreading, modulation, filtering, power control, Channelization, propagation and multi-path to name a few. We would not expect the cellular industry to accept any results derived in such a manner. Understandably then, it is hard for us to accept such methods when they are being systematically applied to "defining" UWB.

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I. Certain widely cited UWB tests are optimized to yield significant interference measurements. These testing methods have little basis in practical UWB communications application.

As a starting point, on September 26th, 2001, Qualcomm submitted a filing first alluding to the "findings" that UWB interferes with GPS, in particular relative to their planned gpsOne™ products and the potential impact to E-911 services. This was later expanded upon in their filings between January 11th and present, and generally cited in over a dozen filings made by them individually and jointly with others between September 2001 and the present. Several other companies, including Sprint, Verizon, Cingular, AT&T Wireless, Tendler Cellular and others have quoted from these very same reported "findings of interference" to form the basis of their suggestions about Ultra Wideband ruling parameters.

Review is warranted insomuch as this is being used to suggest real world operating parameters of a UWB Air Interface. We'll start with our analyses of Qualcomm's test setup and findings and proceed to others later. Though we certainly do not mean to imply or suggest it was intentional on Qualcomm's part, we might suggest that if someone wanted to build a GPS jammer to induce as much inter-modulation distortion as possible, Qualcomm's UWB test setup would be an ideal implementation. This may be understandable; Qualcomm is a great company, but not a UWB company, and may not possess relevant expertise when it comes to UWB. As a test setup for UWB, however, we will demonstrate that their assumptions and methods have little relevance to the implementation of UWB communications. Following are a few reasons why:

a. <u>No relevant UWB technology employed in testing.</u>

As mentioned earlier, one can no more expect to emulate a UWB Air Interface by hooking up an antenna to a pulse generator than you could emulate a cell phone by hooking up an antenna to a sine wave generator. But that is what has been modeled. In relevant testing, assumptions, and analysis that formed the basis of Qualcomm's findings, they did not perform any of their tests or analysis based on any defined or simulated UWB Air Interface. (*To be fair, Qualcomm has stated that they attempted to obtain UWB solutions from several vendors but were unsuccessful. Given the proprietary nature of our industries, however, it may be understandable why such proprietary solutions were not made available.)*

According to Qualcomm's filing on January 11, 2002 page 6 section 3.1.2, their tests did not actually use an UWB transmitter. Instead, they used a simple off-the-shelf pulse generator module that generated a fixed Pulse Repetition Frequency (PRF) rate, with no power control, no envelope shaping, no filtering, no processing of any kind other than possibly a questionable implementation of dithering. *(The dithering used by Qualcomm, according to their March 8, 2001 filing in section 4.7.1, specifies "3-position Dithering". This is not random dithering and can still cause spectrum lines. The dithering offsets are not specified, nor are any other dithering parameters. As a result, it is impossible to extract meaningful information on how they were spreading their signal. As a further result, this makes it extremely difficult to extrapolate any meaningful conclusions.)*

b. <u>Errant use of fixed PRF</u>

If Qualcomm had used a UWB Air Interface such as the one that Pulse-Link has implemented, they would have found that fixed PRF's are not generally used in UWB communications. The reason is obvious; a fixed PRF in UWB can yield a significant probability of generating harmonics that create the types of interference we all want to avoid. We aren't aware of any leaders in UWB communications that would generally suggest using a fixed PRF, there certainly is no fundamental need to do so. Just as we use pulse shaping to evenly spread the spectrum of our pulses, we use pseudo-random spreading of our PRF's for the same reason.

The result of using a fixed PRF caused spurious harmonics, which are in no way representative of how a UWB Air Interface would be implemented. Once again, to be fair to Qualcomm perhaps they cannot be faulted, several other tests we will point to also employed a fixed PRF in their UWB testing. As a result, however, their results are skewed. The fact remains; this is a fundamental error in the testing methodology that optimized their test results towards demonstrating the worst possible interference outcomes and does not represent a real world implementation of a UWB Air Interface.

The more appropriate use of pseudo-random PRF's typical to most proposed UWB implementations is an easily adopted technique that minimizes spectral lines, provides the additional benefit of enhancing UWB data security and is a strategy for enhancing user QoS. Use of a pseudo-random PRF is one of the most simple and dramatically effective methods of reducing the potential for UWB interference with traditional RF.

When performing analyses of the spectrums generated from UWB transmissions, one must consider the following two factors:

- The spectral lines generated by the actual individual pulses (which can be controlled through pulse shaping).
- The spectral lines generated by the occurrence of a sequence of pulses (which can be controlled by the pseudo-randomness of the spacing).

The primary challenges of UWB in conjunction with GPS come not from the pulse shape, particularly where pulse shaping and filtering are employed, but from the PRF's themselves. Fixed PRF's construct a system that can potentially generate spectral lines at a multitude of frequencies, this is the very method that several studies have used.

Let us be clear, as an Ultra Wideband company dedicated to the development of an optimized UWB air interface capable of insuring desirable Quality of Service for multi-user, multi-application environments, we can find no supportable basis for using a fixed PRF – we won't do it. Our reasons for employing a pseudo-random PRF have everything to do with system optimization and reliable QoS. As a byproduct, this mitigates the significant problems inherent in using a fixed PRF. Simply, you wouldn't use a fixed PRF for several reasons – meaningful tests shouldn't be based on such an implementation because the results won't correspond to application.

Other tests that are based on a fixed PRF model include but may not be limited to:

- Stanford University and Department of Transportation: Report - *Potential Interference to GPS from UWB*
- University of Texas Advanced Research Laboratory: Final Report – *Data Collection Campaign for Measuring UWB/GPS Compatibility Effects*
- John Hopkins University Applied Physics Laboratory: Final Report – *UWB-GPS Compatibility Analyses Project*
- NTIA Report: *Assessment of Compatibility Between Ultrawideband Systems and Global Positioning System Receivers.*
- Qualcomm submission of March 05, 2001:

It should be noted that Time Domain also cites these examples in their filing of April 25, 2001. As noted by Time Domain, the Stanford, UT and NTIA reports acknowledge the decreased interference through what Time Domain refers to as "white noise-like" models – which are created through a pseudo-random rather than fixed PRF.

c. **<u>Specific use of fixed PRF multiples GUARANTEED to generate the worst possible interference in GPS band.</u>**

We note with interest that the gpsOne test implemented not just fixed PRF's, but fixed PRF's that are direct multiples of the GPS frequency at 1575 MHz. (Qualcomm filing January 11, 2002 Table 4). Use of those specific PRF's are a formula guaranteed to specifically generate interference into the GPS band. Pulse-Link and other UWB companies typically use pseudo-random spreading of the pulses over time. Some UWB companies have been known to add dithering on top of this. Obviously, the goal is to uniformly spread the RF power over the spectrum and minimize any possible inter-modulation from the pulses. This is common knowledge in the UWB community, but knowledge not implemented in these tests.

d. **<u>Unrealistically High Power Levels of test "UWB Pulses".</u>**

The power levels depicted in Qualcomm's January 11th, 2002 filing are over 1,000 times higher at the GPS frequencies than levels typically used by UWB companies to transmit data. This is a direct result of their use of fixed PRF's, which is compounded even more by their selection of fixed PRF's that are common multiples of the GPS frequency.

We are not the first UWB company to suggest that Qualcomm is using unreasonably high power emission levels for their tests. Time Domain cites this in their April 15th, 2001 filing in referring to Qualcomm's March 05, 2001 submission, and Xtreme Spectrum cites this relative to the gpsOne tests. While Qualcomm may feel a supportable basis for the power they are using exists or that power is "only one variable" – clearly expert leaders in the development and definition of UWB technologies disagree

Perhaps more realistic is the following. Using Qualcomm's own numbers, we take a 150 pico-second pulse and inject the pulse at a power level of –41.5 dBm (< .1 micro watt) power level into a the gpsOne antenna port, we would be injecting a pulse with an instantaneous peak power in the time domain of –41.5 dBm for 150 ps. That same pulse measured in the frequency domain would be spread from DC to 7.5 GHz. To determine the power level present for that 150 ps across the spectrum divide the instantaneous –41dBm power level by 7.5 million for an effective instantaneous radiated power of less than 13 Femto watts or –100dBm radiated for 150 pico-seconds at any 1 MHz point between 1 MHz and 7.5 GHz. Now, using a pseudo-random spreading of the PRF we produce a relatively uniform spread of the spectral energy, take that –100dBm signal that lasts a total of 150 pico seconds and multiply it by the 17.5 MHz pseudo-random PRF rate and divide that value into one second for an average power level of -86 dBm - worst case.

The HL-9200 Pulse generator used by Qualcomm has the following parameters:

- A rise time of 35 pico seconds
- A fall time of 50 pico seconds
- A duration of 70 pico seconds

  (For a total pulse width of 155 pico seconds)

With the output of the pulse generator attenuated to –41.5 dBm - which is the power level specified by Part 15 - these are the power levels you would experience:

The PRF's used were:

- 1 MHz x 155ps = .0155 % emitting a total of -100 dBm Average Power
- 5 MHz x 155ps = .0775 % emitting a total of -92 dBm Average Power
- 15 MHz x 155ps = .2325 % emitting a total of -87 dBm Average Power
- 17.5 MHz x 155ps= .2712% emitting a total of -86 dBm Average Power

As you can see, using Qualcomm's numbers as a base, you can determine that UWB in this case is only transmitting no more than .2712 % of the time. This power level is well within proposed limits. It should be pointed out that this number was achieved without pulse shaping or filtering which could potentially reduce that number even further.

e. Use of fixed constant power levels.

Power is one of the most difficult parameters to quantify when it comes to UWB. Power in UWB is a dynamically changing quantity potentially from microsecond to microsecond depending on the application, data rate, data type, environment, transmission range, Quality of Service objectives, user Channelization, bandwidth allocation and more. UWB, by its very nature, tends to be sporadic and burst-like. Qualcomm has chosen to model UWB RF as a constant value – perhaps an understandable assumption based on how difficult it is to build a model with so many dynamically changing variables.

At Pulse-Link, we view and implement intentional dynamic power management as a specific strategy for optimizing and managing available bandwidth within a specified geographic communications area, managing near-far signal issues in point to multi-point configurations (particularly as devices become mobile), managing multipath, defining antenna spatial diversity and several other areas for optimizing UWB communications. Strategies for leveraging the benefits of direct, intentional dynamic power management form the basis for several of the patents our company has pending. Qualcomm's testing model, when it comes to representing UWB emissions at a constant value, is once again a flawed representation that does not represent real world implementations in a UWB air interface model.

A fixed power representation - as portrayed in Qualcomm's tests - will without question yield a "worst possible case" scenario in terms of measuring interference, but will not give you results based on anything that would represent a real world implementation.

The improper use of a fixed power, constant pulse repetition is also cited by Time Domain in their filing of October 27, 2000 on page 46 as one of the disagreements which they held with Sprint relative to Sprint's frequently cited joint tests with Time Domain and Telecordia of September 2000. These tests are further discussed later herein.

f. No consideration of Pulse-Shaping of transmitted UWB pulses.

Pulse envelope shaping allows shaping of the spectrum where the UWB pulse will be emitted. We hold issued and pending patents to accommodate this, as do other UWB companies. This is a common and understood strategy for mitigating potential interference issues – although we grant that part of the issues of the current approval process embody disagreement on where and to what extent these should be implemented. Repeated filings from UWB proponents have suggested the accommodation of this strategy in testing. Yet this technique continually fails to be utilized in tests that form the basis for suggestions to regulate UWB emissions.

Regardless, not once in the referenced filings did we see the use of pulse-shaping strategies to minimize emissions anywhere in the spectrum. It is commonly known and accepted that pulse shaping, in some implementations combined with filtering, can be used to notch areas of the spectrum to minimize RF emissions at specific frequency ranges. This technique can be easily used to create notches in the spectrum for additional protection of GPS frequencies.

g. <u>Use of shielded Qualcomm gpsOne™ units themselves created a fundamentally flawed baseline for any accountable test results.</u>

The gpsOne does not represent a credible baseline by which reference standards can be established. There are no detailed published technical specifications for gpsOne. It is in fact a product still in development. There do not appear to be baselines established for the performance of gpsOne™ except those performance standards that Qualcomm themselves have set.

Although under R&D for over three years, the gpsOne technology is not yet deployed or operational anywhere in the United States, and it cannot be overlooked that there is the possibility that Qualcomm's implementation of gpsOne™ is flawed and not yet market ready.   It could easily be possible that a system of this complexity, and still basically a product in development, could contain as of yet unknown flaws in hardware or software that would cause unpredictable results. Potentially faulty DSP algorithms, incorrect floating-point routines, poor shielding, excessive noise in a Low Noise Amp (LNA), manufacturing defects and more could all cause erroneous readings. To base a recommendation on tests against an unproven product still in development is not prudent.

Not to be flippant, but wouldn't it be nice to test a potential competitive product against a baseline that you control and set yourself? This is in essence what has been done - and by a Company with whom several expert UWB companies have had cited fundamental disagreements on methodology. Unfortunately, those same tests are being cited as the basis for several companies' positions when making various recommendations effecting UWB technology.   The inference is that the gpsOne system should be used as a standard benchmark by which the performance of the interaction of UWB and GPS technology are measured.

With no credible reference baseline, how does one quantify any measurements taken? This alone should be enough to discount the contents of the whole filing in regard to gpsOne™.

The filing states, "The two phones were isolated from each other using shielded boxes". The reason for the isolation boxes is presumably to establish a "Reference phone" and "Test phone" and eliminate "external factors". Placing both phones into shielded boxes removes the test units from their natural operating environment and places them into a sterile environment - devoid of the real world natural noise where UWB signals co-exist.

The creation of such an environment undermines the conclusions of the report. By isolating the phones from the natural noise floor, these tests established a false baseline from which the UWB measurements were derived. UWB exists in the noise floor. It resides and interleaves itself into the natural background of the noise floor. The noise floor itself is a quantifiable, measurable medium with it's own energy level. Take away or minimize the energy in the noise floor and you take away UWB's natural cover - so to speak.

We could go so far as to suggest that possibly part of the reason for the use of shielded boxes would be to mitigate potential interference that would have otherwise been created between the two test gpsOne™ units themselves, UWB or not. Based on published descriptions of the gpsOne system, our understanding is that these units integrate the phone and GPS receiver into the same chipset. Specifically; the on board digital and RF circuitry for the cellular phone circuitry has been engineered to minimize interference with the onboard GPS circuitry. Due to the extremely low signal levels at the GPS receiver input, the GPS receiver would not be able to function reliably without such engineering. Interaction between the integrated circuitry would be highly synchronized and tightly controlled to minimize the potential mutual interference. This becomes possible when they are integrated as one unit. Removing integration yields probable performance degradation of the GPS receiver, potentially to total failure. It can be assumed, therefore, that a likely benefit of using the two isolation boxes was mitigation of the interaction and potential interference between the gpsOne™ units themselves. While fundamentally reasonable, shielding to "Eliminate *other* variables" may have additionally flawed the desired benchmark.

In summation, using unproven gpsOne technology to infer UWB suitability relative to GPS services is flawed. The GPS system was initially designed for the military and to be tolerant to significant amounts of interference and even jamming. The GPS system is fairly robust in that there are often more satellites available than the minimum required for a solution and the system uses spread spectrum to minimize interference even further. Other GPS / UWB studies cited herein, even with the errant use of a fixed PRF, do not document the level of interference cited in tests of the gpsOne™ devices.

II. Devices used for UWB testing purposes have not been used as suggested by the leading companies that are innovating UWB technologies.

Repeated instances exist in which the companies innovating and holding significant intellectual property in the development of UWB applications have made recommendations or clarifications which are summarily ignored in testing methodologies. To be sure, UWB companies have responded to point out testing deficiencies and solutions for mitigating observed results.

In several instances, UWB testing has been done with little to no adherence to the device manufacturer's suggested use of the technology. To be sure, the report and filings process has at times been evolutionary in nature with positive benefit. Unfortunately, in many other cases flawed initial tests have been cited repeatedly over the course of almost a year.

As reported in the NTIA report 01-383 on Ultra Wideband, dated January 2001 Chapter 8 section 8.2.1 the Institute for Telecommunications Science (ITS) reporting. *" ITS is making no claims that the UWB devices works as intended or described. In most cases, ITS did not functionally test the UWB devices performance in any way and consequently ITS is unaware of whether a specific UWB device achieves any of its intended claimed functional performance objectives".* Despite this, the NTIA findings are often cited in recommendations for setting limits on UWB.

In its filing of November 15, 2001, and on several other occasions, Sprint cites joint testing with Time Domain Corporation in September 2000 as validating its position, and further cites Time Domain as supporting that these tests represented an "excellent theoretical analyses". At least in the November 15 filing Sprint does go on to say that, "(Time Domain has now disavowed joint testing, and Telecordia modeling results)". These same tests, however, are cited regularly in Sprint's filings from October 2000 forward, frequently without mention of Time Domain's disavowal.

In fact, in Time Domain's filing of October 27, 2000 on page 45, paragraph 2, Time Domain did represent the tests as an "excellent theoretical analyses", but then immediately continued with further explanation that real world tests differed dramatically from the model's predictions. The disavowal was not later, it was contiguous. Further, Time Domain goes on in this same filing from pages 46 through 48 to clarify where there were disagreements on several points of methodology and implementation.

III. Suggestions:

The Stanford University and Department of Transportation report - *Potential Interference to GPS from UWB*, which forms much the basis for recommendations of UWB above 6 GHz, are flawed in their use of a fixed PRF and other areas as cited by Time Domain in their April 25, 2001 filing. Similar reports including those from Qualcomm and the PCS industry, as noted herein, are flawed for similar reasons. These form the basis for various recommendations limiting UWB to above 2GHz.

What we have seen in the commercial sector as a result of all of this is an informal "coalition" of groups collectively recommending setting emission limits above 6Ghz, regardless of technical merit or individual "member" support, with even Motorola suggesting a "compromise" at 5GHz that seems to have nothing more at its technical foundation than being a nice "numerical average" between the DOD suggestion at 4.2GHz and the "coalition" suggestion of 6GHz. Not to make light of competitive concerns or those that have been truly lost in the confusion of "factual findings", but this is taking on overtones of a joke.

While we strongly support the DOD and national security interests, we haven't seen a filing detailing the technical nature and merit of their concerns that can be responded to, (*we do appreciate and respect, however, that this may be due to security interests*). Certainly, the DOD has not been regulating its own use of UWB to exist above 4.2Ghz for almost two decades. Several other countries (*i.e., Russia and China*) have studied the technology for decades and are fully aware of how to implement it. The generation of nano-second and sub-nanosecond Pulses are not unique to UWB devices (*i.e. computers, fiber optic*). Pulse-Link has been unable to identify any basis in sound methodology for limiting UWB to above 4.2GHz.

Making some accommodation for GPS around 1.6GHz (*and PCS allocations around 1.8GHz to 1.9GHz*), we propose the following.

Emission Masks: There have been several emission proposals put forth. The "Emission Masks" as proposed by both the NTIA and the DOD are not acceptable. They do not appear to be the result of testing methodologies that are representative of the emissions expected from real world UWB device operated with a UWB Air Interface. These proposals appear to be a "play it safe politically" response to tests that have been repeatedly cited as flawed and that have been appropriately addressed with mitigating solutions by companies with UWB expertise at their foundation.

Pulse-Link suggests approval of the original limits as proposed by the FCC in their original NPRM of May 2000. These emission levels when coupled with a UWB Air Interface, are more than adequate to address even the most conservative concerns. Most of the controversy has centered on potential interference to systems below 2 GHz. Pulse-Link suggests at most a temporary restriction on "Intentional" UWB emissions below 2 GHz, with the understanding that additional testing and evaluation be completed and that after one year from the date of ruling an amendment would be issued based on reliable demonstration of appropriate emissions below 2 GHz.

On the issue of restrictions on Peer-to-Peer or battery operation of UWB devices: Pulse-Link sees no need for such an artificial restriction. The issues should appropriately center on emissions, not the nature or applications under which emissions take place. Limiting applications on anything other than the basis of emissions is nothing more than a cover for limiting competition between businesses. As a compromise, however, we would not be adverse to stipulating that access points be fixed and AC powered. That would restrict UWB devices to operations within the transmission range of the access point.

IV. Perspectives and Conclusions:

It is a fact of physics that users of RF spectrum must be tolerant of all users of spectrum below them. This is due to the unavoidable reality of harmonics that are generated as a natural by-product of generating an RF carrier. These harmonics are typically suppressed, but still manifest themselves at higher frequencies and tend to blend into the noise floor at higher frequencies. This is a well-understood effect and is taken into account by the FCC when setting emission limits. The UWB community is only asking for the same consideration that all other spectrum users have in this respect. The same rules of physics do apply to UWB.

Much has been stated about UWB's potential interference of GPS. If a case were going to be made for potential interference of UWB with GPS, it would be helpful and insightful to compare this interference to other potential interferers with GPS as well.

To be sure, with 50 years of evolution of the Part 15 rules plenty of comparative data exists. Not even the NTIA's testing of UWB early last year went so far as to test and report on such comparative issues. Since GPS resides so high in the spectrum it is at the mercy of all RF emitters below it. This is known and accepted. Part 15 devices of all types, be they PC's, PDA's, Televisions, Microwave ovens, hairdryers, light bulbs, any other of billions of electronic devices and even cellular phones that we use every day also impact GPS – at times greater than even UWB implementations as crude as those used in cited tests.

The Cellular industry also radiates out-of-band harmonic interference into GPS spectrum. This is known, and forms part of the basis for their regulatory approval requirements as Part 15 intentional emitters. We seek approval to be accommodated under the same parameters, yet the cellular industry would place significantly greater restrictions on our technology than they do on their own.

The only difference, lest we lose perspective, is that those devices are "Unintentional" in their emissions and UWB is "Intentional". Because UWB is intentional, however, it can be modulated, modified and regulated, and such considerations should form the basis of the approval process. Unfortunately, it cannot be questioned that certain proposals - such as limiting UWB signals used for communications to spectrum above 6 GHz and "tests" constructed with no basis in what might ever actually be conceivably built as a UWB communication system - seem little more than attempts to limit the commercial capacity of UWB so that it will not pose a conceivable competitive threat with the technologies of those very companies making such suggestions.

Every electronic device on the face of this planet emits RF noise into the RF spectrum. It is an irrefutable fact. These billions of devices have yet to significantly raise the noise floor. It appears many of the filers on this issue want to imply that somehow the laws of Physics are different for UWB. The question becomes, is this about sound technology or business competition? The answer needs to be sound technology and we urge a clear separation between what is technology and what is clearly a case of companies trying to protect their turf.

And what is that turf? To quote, "The demand for spectrum is simply outstripping supply," FCC Chairman William E. Kennard told the CTIA Wireless 2000 convention in New Orleans in February. "Spectrum is the lifeblood of [the wireless] business. Without it, [the] business can't grow."

The UWB technology of companies such as ours offers part of a solution. It is a solution we support to see developed in incremental steps, so long as those steps present viable opportunity based on technical reality and appropriately conservative review and agreement. Thank you.

Sincerely,

Bruce W. Watkins
President and Chief Operating Officer

Cc: Chairman Michael Powell
Commissioner Kathleen Q. Abernathy
Commissioner Michael J. Copps
Commissioner Kevin J. Martin
Bruce Franca, Acting Chief, OET
Julius Knapp, Deputy Chief, OET
Rebecca Dorch, Deputy Chief, OET
Dr. Michael Marcus, Associate Chief of Technology, OET
Lisa Gaisford, Chief of Staff, OET
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