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Marlene H. Dortch
Office of the Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

August 14, 2015

Re: Reply Comments of U.S. Electrodynamics, Inc. in Gen. Dkt. No. 12-354

Dear Ms. Dortch:

US Electrodynamics, Inc. ("USEI") hereby submits its Reply to the industry Comments in response to the Federal Communications Commission's ("FCC's") Second Further Notice of Proposed Rulemaking in Gen. Dkt. 12-354, dated April 21, 2015, as it pertains to the protection of incumbent Fixed Satellite Service ("FSS") in this band. *See In* Re Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, *Report and Order and Second Further Notice of Proposed* Rulemaking, FCC 15-47 (rel. April 21, 2015).

In general, USEI supports the Comments of the Satellite Industry Association ("SIA"), and commends them for their appreciation for public interest in the protection of incumbent FSS earth stations. However, USEI wishes to add some additional perspective on the SIA statements about ITU modeling as it pertains to Mission Critical Services and wishes to add further detail as to what must be included--as an absolute minimum—in any interference modeling criteria to establish adequate protection for "Mission Critical" and "Life and Safety" specific satellite communications for which there are no service alternatives.

Part I

USEI, an aerospace and communications company founded in 1985 upon the encouragement of the Dr. Paul G Kaminski (who served as Director of the DoD Stealth Program and also as a member, and twice as Chairman of The Defense Science Board) based on America's ever growing needs for vulnerability/survivability research and development of radar evasion and RF camouflage design and construction for flying, sailing and rolling DoD applications: aircraft, ships and ground troops.

Over the last 46 years, USEI has had a remarkable evolution while leaving in its path important successes with the development and use of its first principles physics and quasi Quantum Electrodynamics ("QED") mathematical techniques to predict propagation.

This expertise comes by work over many years with U S Government communications and research programs, both classified and unclassified with results very pertinent to our discussions here.

USEI counts its span of propagation expertise development over 46 years from multiple perspectives, two most pertinent ones being very distinct: 1) methods of Boltzmann transport theory as related to its equivalent counterpart in radiative transfer theory (propagation and scattering) based on astrophysics work of Nobel Laureate Subrahmanyan Chandrasekhar, and 2) Quantum mechanical Lagrangian variational methods where propagation probabilities are determined through amplitude summations of "all possible paths" that follow successive solutions of Euler-Lagrange equations using creative mathematical techniques in some similarity as developed for QED (Quantum ElectroDynamics) by Nobel Laureate Richard Feynman. These methods were required for precision in critical mission design and in the present case of high relief terrain require intense attention to calculation methodology.

First, USEI has significant test time proving that FCC Appendix D methodology to protect FSS operations is, as stated by SIA, insufficient, -- likely because there is no adequate basis for microclimate analysis to justify this methodology. We note this because, in particular, the FCC chose the approximated coordinates for the Brewster Satellite Earth Station as an example, using 49N 120W. One thousand+ hours of calibrated precision test time and thousands more hours of qualitative survey testing have been conducted near and far around the Brewster Satellite Earth Station and with just a 20 milliWatt and 1 Watt EIRP 3.65GHz radiator from a 16 dB standard gain horn aimed variably from 0 to -10 degrees elevation and variably in azimuth 60 degrees north and south of Brewster while 150 to 200 kilometers away over rugged terrain of 4 mountain ranges [some at 4200 feet elevation, 3000 feet above test source (1700 feet ASL) and receiver at Brewster (1200 feet ASL)] a full motion 11 meter antenna was receiving while pointing variably from 70 to 180 degrees in azimuth directions and from 5 to 10 degrees in elevation. Very dramatic results were found supporting USEI quasi QED analysis and showing that ITU analysis is insufficient even at worst case setting is wholly insufficient to do interference predictions in microclimate zones, something that ITU propagation experts admitted, experts at Canada ITU Member State who are making plans to work with USEI to improve ITU capabilities. The combined time duration and signal level magnitude measurements show 'worst case ITU methodology' interference prediction to be in error at a minimum of 30dB to 65dB. Surprisingly aircraft scatter by itself as seen in Doppler examination of all recorded data was a substantial part of this interference. We have documented some of these results with FCC Wireless group. Time variability of interference was dramatic and often correlated with particular temperatures, wind directions and atmospheric moisture and precipitation content and mapping. USEI's quasi QED analysis shows how these likelihoods of interference are reasonably predicted and the data collected proves that analysis. USEI data for a single low power radiator at a distance of 150 kilometers and over rugged high mountain ranges as well was received at power levels sufficient to show that even one WiMax radiator would deliver interference to Brewster enough to degrade critical mission performance.

USEI analysis and extensive supporting field data shows that ITU propagation modeling is very poor for these low gain antenna 3.5 GHz band operations. In this regard USEI cannot support SIA's endorsement of ITU North American propagation modeling, at least not for mission critical services. Taking our analysis and data in hand to ITU Canada State member Hydro Quebec, USEI received acknowledgement from ITU propagation scientists that North American ITU data fields are not sufficient for supporting accurate analysis in North America. Data fields in Europe are supposedly much better. Additionally, it was agreed that for the mountainous microclimate regions surrounding Brewster, ITU modeling is not sufficient, and as described further down, USEI analysis and exhaustive field testing prove the same.

USEI cannot endorse SIA's 6% allowance increase of noise floor as the target objective for FSS protection – at least not at Brewster. In the first place, for purposes of rigorous analysis, interference does not in general present itself in a strict sense as noise, or even pseudo noise, certainly not from a quantifiable perspective of either randomness or (in some topological sense) of smooth continuous power density. As a practical matter there are many circumstances where it presents in a way as to effectively degrade service and cause harm similar to how noise does, and this likely is how SIA has determined that -12dB is the allowable limit. But for the lowest levels of interference the parameters of measure quantifying the potential for harm are quite variable, non-linear and difficult to analyze, and in general, interference is much more threatening Watt for Watt than noise. In this regard, some types of modulations are more or less threatening/vulnerable than others. In any regard, the matter will be debatable about how do you measure the units of interference signal in a way that for their equivalent units of noise they have the same effect of communications degradation.

For some of the most critical data service work USEI is doing, interference comes with something far worse than noise or pseudo noise, it comes with bias, bias because interference signals are fragments of non-random energy levels. The detail structures of interference fragments are formed in the rhythm of repetitive format and sequencing of data. Probability and aliasing science can show that the biasing potential of digital interference can be much more threatening than noise.

Communications operating at marginal receive power levels of very weak signals are most vulnerable to interference and its bias influences, and such are the nature of the types of service that USEI supports using specialized modulation systems such as ones tailored to time integration processing where critical data signals need extraction from far below the noise floor. Consider the hypothetical overseas transmission, not suitable for spread spectrum, but for the sake of survivability requires the very demanding 'camouflage and concealment, decoy and deception' (CCDD) technologies. Service must be so power uplink limited as to allow **no** detect-ability opportunity, and in such cases time integration is necessary where very short data streams may necessarily be continuously repeated many billions of times over various but relatively long intervals of time to guarantee successful message delivery while operating at extremely low power. Similarly, when dealing with maritime catastrophes where ship

board antennas have been damaged or must operate on side lobes because antenna pointing errors are not correctable, or signals are coming through violent storms very sporadically, time integration, or some alternately vulnerable modulations may be the only ways to get detailed critical information data necessary to support rescue. There are many scenarios of 'trouble needing urgent help' where 'ultra weak receive signal communications' need the support of the most massive antennas available in interference free environments like those at Brewster. In these cases, biasing interference is a much more severe penalty than increasing random noise, which itself has a costly penalty.

Over many years Government measurement teams have spent weeks at a time doing full 360 degree noise floor measurements at Brewster to determine at what level of noise floor and interference disruption its operations can be maintained. USEI studies have included discussions with these particular projects to determine what the real impact of interference increases of any type would be. Brewster's isolation from population centers and its inherently clean noise floor was a primary reason for it being chosen as America's first COMSAT Satellite Earth Station 50 years ago.

Very sensitive and mission critical services have established their home at Brewster and take maximum advantage of this low noise environment, designing their needs and methods around what they say is America's lowest noise environment. We recognize that Stations built closer to large cities and used for basic telephone services, for example, may not have the same service and RF interference free environmental needs as Brewster.

In regard to SIA's statement regarding link budget margins, it is true that margins for weather and such, as important as they are, have had to be reduced to the very minimum to achieve the ever increasing bandwidth needs. In all areas of critical mission performance, such as during anxious moments of challenging periods for air traffic control, real time live combat support,.... and with new technologies such as the needed critical mission higher video resolutions it becomes increasingly hard to perform the FSS tasks of maintaining five 9s critical services. FEC must be adaptable in ways different than they were designed for, emphasizing support level minimum threshold data rates as well as threshold S/N. Freeze frame and lost lock can be difficult to recover from with the necessary heavily secure encryption of today. A signal that is hardened to either detection or to unauthorized decoding is difficult to recover re lock on.

SIA should not generalize all earth stations to their given G/T at a fixed 5 degree look angle. Again USEI has test results at Brewster showing interference from max range into 3 antennas simultaneously, antennas pointing at 5, 8 and 10 degrees elevation, all at different azimuth angles as well, and expects that this is more usual than not.

Regarding aggregate protection enforcement, USEI has experience that often small entrepreneurial services, like CBSD, are undermanned, not responsive to phone calls or even customer calls as

documented on the Internet complaints. This is a huge problem when critical life, safety and national security matters are at stake. We share SIA's concerns.

USEI also supports SIA's suggestion that on aggregate systems there must be fixed location controls/restraints in place so that rogue operating customers are not able to take their systems mobile or relocate. USEI has strong concerns as people would likely be motivated to take systems to higher elevation or near LOS locations where commercial Internet services are not available.

USEI has tested mountain radiations from beyond protection zone range at 190 kilometers and found that even a single tiny 20 milliWatt radiator is capable of causing service disruption. Geo location on all end user devices are absolutely necessary for not just this reason, but general matter interference as well, especially as it is possible that radiations even beyond exclusion zones can be a threat and needs identification if that threat materializes.

SIA has not recognized the interference potential from aircraft scatter. In its field testing, USEI encountered the equivalent of 10 hours per year of test interference caused by Doppler scatter of our small test signal bouncing off aircraft where the USEI test transmitted signal is translated into the interfered with receiver at higher or lower frequency by a small fraction variable offset. USEI shared some of this data with the FCC Wireless group in the 2014 March-April time frame. The largest magnitude Doppler test interference on record endured 15 minutes. Aircraft scatter has the potential to approach near line of sight interference and moves across wide angles of opportunity, hitting all antennas at the station one after the other, some days making aircraft the majority source of our plot recorded test interference.

Aggregate WiMax like systems with their proposed 3000 deployed units within the USEI protection zone would likely cause approximately 5-10,000 aircraft scattering interference incidents per day with total accumulated time risk outage potential of 2-3 hours per day. As unbelievable as these numbers seem, USEI data proves it is very real and is could definitely be by far one of the most pervasive of all interference matters. Considering aircraft scattered Doppler interference, it is possible and even likely, as it is being studied, that WiMax systems 150 kilometers behind (North of) the satellite station are an even greater risk do to aircraft backscatter of WiMax energy from aircraft in front (South of) the station than the WiMax systems 150 kilometers in front (South) of the satellite station putting the station at risk (from that direction) of aircraft to do forward aircraft scatter for which we have data.

USEI supports AT&T's suggestion that industry be assigned to work together for what standards are necessary to be fair and effective at implementing measures supporting spectrum sharing in the 3.65GHz band. It must always be important to protect the rights of 'first in time authority' (FITA) by mandating that if a correctly licensed 'second in time authority' (SITA) GAA or PAA causes interference,

it is incumbent on the SITA to cease emissions until it resolves the source of the interference problems caused to the FITA.

Part II

To offer up some substance, we briefly discuss these analyses as proven with thousands of hours working at USEI's 150 kilometer test range over 4 mountain ranges of severe terrain. USEI recognizes that quantum theory is the backbone of its analysis and that this is somewhat unique for the FCC. But, a photon **is** a Bose quantum particle and any terrain is a type of grating and all weather provides mechanisms of 'individually undetectable' momentum transfers, all reasons to demand that quantum probability amplitudes 'from everywhere' (as relates to 'all possible paths') need to be summed and then squared to determine probability densities. With this statement U S Electrodynamics argues that propagation analysis good enough to protect the neighborhood of shared spectrum is every bit as much of a first principles physics problem as it is an engineering one.

Weather dynamics insist that time variability of RF interference be exposed in any model. This means that over mountainous regions of severe terrain that microclimate must be studied for its effect of RF curvature during all types of scalar (temperature, humidity, air pressure,...) and vector (wind direction and speed, adiabatic terrain relief caused precipitation inducing updrafting rates causing RF line lensing....) weather, and that in non severe very low terrain relief environments the RF curvature effects caused by strong 4-dimensional (x,y,z,t) gradients of all weather parameters during changing weather systems are anticipated.

Probability distributions of all possible weather and in all its time dynamics and variability must be developed. Then the appropriate RF propagation models should be applied. Then the convolution integrals of these weather distributions with RF modeled propagation probabilities produce RF interference vulnerability/threat likelihood, rendering the data survivability.

In very non line of sight (VNLOS) propagation it is unreasonable to apply FSS antenna discrimination angles as a means of mitigating RF interference. All manners of scattering, reflections and the like are, during VNLOS propagation, finding very wide angle alternate paths to the earth stations, and as measured, quite strongly, especially so with the low gain antennas used in the 3.5 GHz band.

USEI was presented with ITU "worst case" predictions of interference from 3000 1 Watt EIRP hypothetical radiators at full and coherent power at distances from 100 to 150 kilometers and over 4 mountain ranges. All ITU predictions for this 3000 radiators system were consistently more than 30 dB below what was actually measured from a single 1 Watt EIRP radiator at Brewster . This could be construed as 65 dB of error in ITU analysis when assigning a value of 35 dB to the difference in the number of radiators used in test (only 1) compared with the 3000 used in ITU analysis. These

measurements were performed by USEI over thousands of hours of field study work done at the Brewster Satellite Earth Station from summer of 2013 until summer of 2014. USEI took this data and USEI analysis to Canada ITU Member Hydro Quebec in Montreal to discuss with their propagation experts. They had seen similar results themselves with their own field testing supporting their RF system protecting their 30 national dams of HydroQuebec (HQ). USEI had given in writing results of its QED analysis 3 years earlier to argue against the ITU predictions. It is documented that USEI reported in 2011 that USEI's QED analysis predicted that the interference from a single carrier would be 40 dB higher than what the ITU "worst Case" analysis had predicted for a much larger system. Measurements were performed validating QED analysis 3 years later.

It seems that 3.5GHz band operations come with legions of low gain radiating antenna systems that would flood the environment with ubiquitous interference especially in high relief areas. This is the big difference from the recent days of single point to point high gain terrestrial relay antennas. In scenarios of new 3.5GHz technology, 'low gain' is much more threatening than high gain as our testing shows and needs a quantum amplitude all paths summation approach.

Part III

$$T = \int \frac{n(z)}{c} \sqrt{1 + (dz/dx)^2} dx$$

n is refractive index, c is vacuum speed of light, z is vertical elevation, x is down range horizontal trajectory, T is time duration of photon path journey.

Extremization of this equation can be considered a first step toward the most simple mathematical expression of Fermat's 'least time' principle, later to be generalized by d'Alembert, Lagrange and Hamilton, and as such is found to embody the full power of Newton's Laws and when taken together with Coulomb's Law and relativity it is suitable to derive Maxwell 's Equations .

RF propagation theory at first principles must solve the Euler-Lagrange equations for the minimization of this integral above and then assemble and sum path amplitudes using means similar to Richard

Feynman's methods of 'all possible paths' integrations yielding results predicting interference and at the same time keeping the full fundamentals of physics on the front lines. Maxwell's equations as historically developed are empirically based and not first principles though they are often used and spoken about as such, and certainly for primary path link budgets are good enough but not for much lower order magnitude interference signals that come mostly by way of NLOS quantum events. Fragmenting particular aspects of solution sets of Maxwell's equations (such as with wave equations) as done in diffraction theory is further distance from first principles. When your equations must carry the inverse R squared around, your analysis is classical, not good enough for NLOS interference analyses. Certainly purely classical analysis is not general. It is true that within the invariance of relativity that Maxwell's equations become theory. But still, it is not by itself theory for practical application with quantum analysis. There, Lagrangian mechanics are brought to bear on the problem, in which case Maxwell's equations are used incidentally only if necessary to specify energy terms in the Lagrangian density. But here in RF propagation there are no Maxwell Equation related energy terms and so the quantum summation of extremized all possible paths is the methodology necessary.

As many dimensions as there are weather parameter gradients can be put into the spatial variable(s) **z** and as many weather parameters defining n**(z)** as necessary to give complete account of all RF momentum transfer mechanisms can be input throughout an RF propagation. Also, these weather parameters and gradients can be found empirically with an inverse propagation analysis given feedback of measurements of data, using eigenfunction properties of Green's function methods to solve Boltzmann like integral equations as developed from work building on Subrahmanyan Chandrasekhar's 1930's work in scattering theory and further developed as matrix inversions as accomplished in Norman McCormick's Los Alamos work and his development with Ivan Kuscer of the means to determine neutron scattering coefficients.

At USEI we support mission critical real time combat, maritime service and distress response, FAA air traffic control for all of North America, relaying critical data and flight data correction for rocket launches from the oceans to White Sands and around the world, global emergency response, rescue and recovery.... and often at times when the maximum bandwidth needs of data throughput are too demanding to allow any bits wasted on strong FEC and often when urgent receive signals are very weak coming from distressed and crippled sources. High definition video in critical drone and rescue operations are always in greater need than what can be delivered, and often encryption matters make 'real time needs' data service recovery quite difficult after even short losses of signal throughput. There is no substitute and sometimes no margins for satellite service success and integrity in what we do. We are the last gas station on the highway to "Life and Safety", "Critical Services" and global security services.

Marlene H. Dortch
August 14, 2015

In Conclusion, there are no adequate simple scientific solutions. The solutions required by shared spectrum goals are difficult ones. Changing weather patterns, even one degree differences in wind directions over mountains cause very measurable changes in interference opportunity. ITU models can never predict that accurately for every case. QED can take propagation to the quantum level; it can make all the difference between initial analysis and excellent analysis, and USEI has the data to verify it and the support of the ITU propagation experts that it is correct.

Based on this, USEI believes that shareholder groups should continue to develop protection mechanisms, by taking them to specific environments, and that FCC FSS licensees should have the ability to interact with the SMS on a case-by-case basis to rapidly eliminate interference, even when the operation causing it is apparently consistent with the rules, and SAS should recognize unique facilities and differences of critical services and micro-environments.

Respectfully submitted,

_____/s/_____

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