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April 9, 2004

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

Re: ET Docket No. 98-153, Ultra-Wideband Transmission Systems
Ex Parte Communication

Dear Ms. Dortch:

Motorola, Inc.,* pursuant to Section 1.1206(b)(1) of the Commission's Rules, electronically files this written *ex parte* communication in the above-referenced docket.

Attached is a technical response to the *ex parte* statements filed by the "Coalition of C-Band Constituents" on February 18 and March 5, 2004. Those submissions report on a simulation study that purports to show ultra-wideband (UWB) devices will cause harmful interference to fixed satellite earth stations receiving on C-band downlink frequencies.

The attached response shows the simulations misrepresented reality in significant respects:

- The simulations populate the area around an earth station with UWB emitters having randomly assigned locations, height, and environmental attenuation. The luck of the draw places a small number of emitters improbably hovering in the air in front of an earth station antenna, with no allowance for a building to contain them. *These few emitters account for nearly all of the interference reported.*

- The simulations overlook a second consequence of the fact that a UWB emitter close to the boresight of an earth station antenna must have a building around it: the building will partially block the earth station's view of the satellite, hindering reception far more than the UWB emitter does.

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* On November 14, 2003, Motorola acquired the assets of XtremeSpectrum, Inc.

- Assumptions of UWB emitter density are unrealistically high.

- The simulations assume all UWB emitters are all transmitting simultaneously 100% of the time -- a practical impossibility.

When we re-executed the simulations with these assumptions corrected to match physical reality, the reported harmful interference disappeared.

Please see the attached for details.

If there are any questions about this filing, please call me at the number above.

Respectfully submitted,

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Response to Coalition of C-Band Constituents

In their comments filed February 18, 2004, the C-band Coalition ("Coalition") claims that unlicensed UWB devices operating at FCC-authorized levels will cause harmful interference to C-band earth station receivers. Specifically:

> "The harm to C-band receivers by unlicensed UWB devices using the FCC's designated power levels is real, and the potential impact to C-band satellite services, especially television and radio transmission services, will be severe."[1]

These claims are based on a study conducted by Alion Science and Technology dated 11 February 2004, prepared for the Coalition and submitted into the public record. The Coalition's comments cite the study as the basis for their projections. They use the study's results to extrapolate for the much higher levels of UWB device deployment supposedly expected in the future and claim that this proves there will be harmful interference to C-band earth station receivers.

The real situation is much less severe than the Coalition claims. A careful examination of the Alion study shows the simulation methodology leads to unrealistic placement of a small portion of the UWB emitters high in the air, outside buildings, and close to the receive antenna main beam. This leads to a significantly exaggerated calculation of UWB signal power at the earth station antenna.

Subsequent sections of this document describe in detail the assumptions made in the Alion report. Later sections also report on additional simulations that not only reproduced the original Alion results, but also yielded additional results that include more realistic UWB device deployment and path loss assumptions. These new results show the Alion results led to highly exaggerated levels for predicted UWB aggregate signal power. Further extrapolations of those results are therefore unfounded. More realistic results now show that there is little chance of harmful interference to C-band earth station receivers from even widespread deployment of unlicensed UWB devices.

Coalition Claims about Extremely High UWB Device Densities are Unrealistic

Subsequent to their original filing, the Coalition filed a second document in which they claimed that the C-band interference situation would be even worse than originally stated.[2] This new claim was based on press statements that UWB technology would be used in consumer electronics devices. Based on this report, the Coalition now claims that UWB device densities will be much higher than anticipated and that device duty cycles will be "approaching 100 percent".

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[1] Comments filed by the Coalition of C-Band Constituents dated February 18, 2004.
[2] Comments filed by the Coalition of C-Band Constituents dated March 5, 2004.

These claims are unrealistic. Recent technical documents describing the performance of high-rate UWB devices and their capability to support dense deployments now provide a clearer view of how dense real-world deployments will really become.[3]

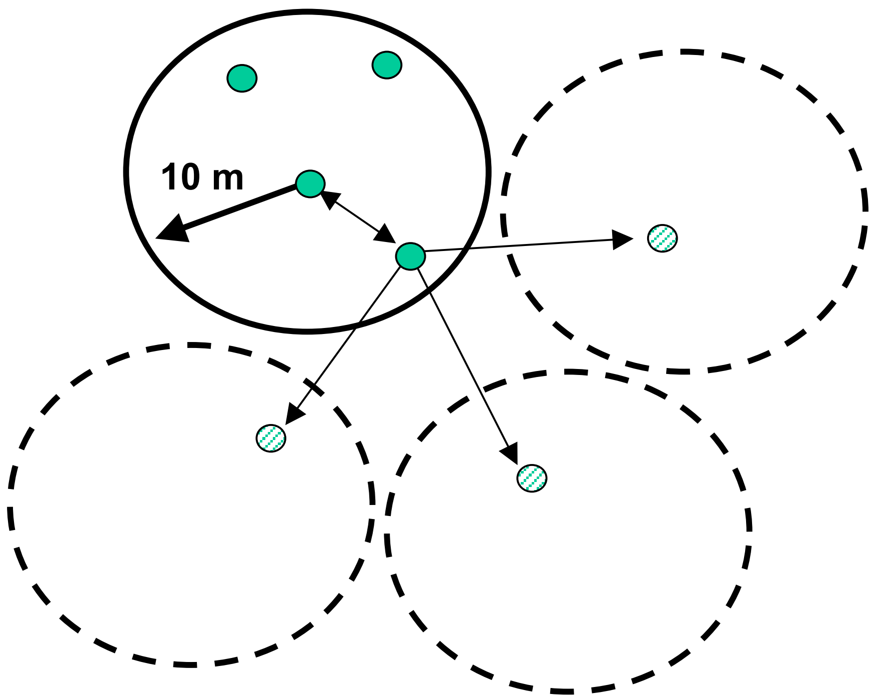

Figure 1: Operation of UWB wireless devices in "high density" deployments results in self-interference that fundamentally limits how many devices can be operating in a given location simultaneously. All devices within one wireless network (small solid nodes in the figure) use time division multiplexing to share the channel – meaning that only one device per wireless network can be actively transmitting at a time. Performance requirements limit "adjacent" wireless networks (dashed circles and cross-hatched nodes in the figure) from being closer than about twice the operating range of the first network.

Devices operating in the same network share the "channel" using time division multiplexing – only one device can be active. Other nearby operating networks are limited to be no closer than about twice the range between the two communicating devices (about 10 meters). This means that each independent "network" can have only one active transmitter, and that "adjacent networks" must be separated by about 20 meters. The implied bound on active UWB device density is therefore about one active

[3] Recent technical IEEE documents submitted as part of on-going UWB standardization work indicate that neighboring UWB wireless networks will have limited ability to operate in the same general area. Each network will have a range of up to about 10 meters, but dense deployments with multiple adjacent networks will require about twice that distance of separation for the UWB networks to continue functioning well. Otherwise devices will likely shift to other frequency channels (not overlapping C-band) or will use time division multiplexing (reduced duty cycles) to share a common frequency channel. See recent IEEE documents co-authored by engineers at Intel: IEEE document 802.15-04/0122-04 dated March 2004 and also IEEE document 802.15-04/0469-00.

device in a circle of 20 meters radius, or somewhat less than 1000 devices per km^2. This number is in rough agreement with previous figures estimated by the NTIA, where analyses assumed 200-1000 active devices per km^2 for high densities, and a very high density was estimated at 10,000 devices per km^2. These figures are now supported by the technical analysis that shows UWB devices at higher densities than about 1000 full-power active devices per km^2 are highly unlikely because performance will be degraded.

In reality, however, there will never be maximal density UWB device deployments over wide regions. Moreover, device duty cycles will be much lower than "approaching 100 percent," as claimed by the Coalition. The typical computer peripheral (e.g. a mouse) or wireless-enabled PDA is actually transmitting data only a few percent of the time. Designers must limit the duty cycles of all handheld wireless CE devices to maximize battery life. Worst-case real-world deployments of UWB devices will likely be close to the NTIA estimates of 200 active devices per km^2 and duty cycles for most applications will rarely exceed a few percent. The Coalition's fears of millions or billions of UWB devices in small areas (a few km^2), all operating at nearly 100 percent duty cycle, simply have no basis.

Why the Levels of UWB Signal Power Predicted in the Alion Study are Wrong

The simulation methodology used for the Alion study relies on random placement of UWB emitters and also randomly assigns path loss coefficients for each emitter. The result of this methodology is to deploy *most* of the UWB devices in somewhat realistic conditions – and these emitters do *not* lead to harmful interference:

- The random placement of UWB devices in the simulation leads to a great many devices that are widely dispersed and for which path loss modeling is realistic: these are the devices that realistically model emitters "in homes, office parks and vehicles".
- Those devices placed near the ground and with path loss assumptions representing realistic deployment situations ($1/R^3$ for foliage, $1/R^4$ for buildings, etc., as assumed by the Coalition) *do not* result in high levels of UWB signal power at the receiver.
- Those devices placed above the ground (i.e. "in buildings") and assumed to have non-line-of-sight path losses (e.g. $1/R^3$ or $1/R^4$likewise *do not* result in high levels of UWB signal power at the receiver.
- Even assumptions of much higher densities, in these realistic situations, would result in aggregate signal levels still far below those required to cause any adverse effects in C-band receivers.

In contrast, the simulation randomly assigns a small proportion of the UWB emitters to *unrealistic* positions and path loss coefficients. These few unrepresentative emitters dominate the aggregate UWB signal power at the C-band receiver and lead to predictions of interference:

- The random placement of UWB devices in the simulation results in a small number of UWB devices (less than a few percent) that are assumed to be high in the air (up to 100 m above the ground) and for which only free-space path loss is assumed. UWB devices cannot hover alone in mid-air. Yet for these few devices, the simulation makes no allowances for the additional attenuation of UWB emissions that would be produced by walls, furniture, ceilings, etc, of homes and office buildings.
- This tiny fraction of the modeled UWB devices is responsible for the vast majority of the interference power seen by the C-band receiver in the simulations.
- If this small set of the simulated UWB devices is disregarded, the levels of aggregate UWB signal power at the C-band receiver drop significantly – to levels far below those required to cause interference as measured and reported in the Alion study.
- At higher extrapolated densities, the same effects occur. Realistically modeled devices cause no interference, but those placed high in the air near the main antenna beam, with only free-space losses, lead to the appearance of unrealistically high levels of UWB interference power.
- The clear result: conclusions by the Coalition that C-band receivers would experience severe interference are incorrect.

Deployment of UWB devices, operating according to FCC rules, in homes and buildings, and even handheld devices near the ground in vehicles, will not lead to harmful interference for C-band earth station receivers.

Review of Alion Study Simulation Details

As part of the study, simulations were developed to predict the level of interference power that would be received by a satellite receiver with a wide deployment of UWB devices in all directions for a radius of 5000 meters. The simulations used a baseline of 1000 UWB emitters randomly placed over this area and then calculated individual path losses for each device to the receiver – each UWB emitter being randomly assigned a path loss coefficient based on its range from the C-band receiver. The simulation then summed the interference power of all emitters to derive a total interference power. The level of interference power varied depending on the assumptions about the distribution of the emitters over the area (uniform, normal about the receiver or inverse-normal). The received power levels were –94.4 dBm for the normal distribution (higher density near the receiver), -104.5 dBm for the uniform distribution, and –115.5 dBm for the inverse-normal distribution (higher density at the edges of the circular area). The simulation placed the 1000 emitters randomly and also assumed various path loss values ranging from $1/R^2$ to $1/R^4$, depending on the emitter range to the receiver (for example, at range of 0-1000 m, emitters had 90% chance of $1/R^2$ losses and 5% chance each of $1/R^3$ or $1/R^4$ losses). The model also included an antenna gain pattern for the receive antenna that used a maximum of +20 dBi gain for a 6 degree wide beam and fell off to –10 dBi at large angles off axis from the beam (>48 degrees).

In addition to distributing the emitters randomly over the circular area, the simulation also assumed that each device was uniformly distributed between 0 and 100 meters in height off the ground. *No additional allowance for path losses was made for the buildings that would have been present to contain these UWB emitters high up in the air.*

Specific Concerns with the Alion Study

Based on our analysis of the Alion study and a recreation of the simulations, we conclude that the concerns stated by the Coalition are based on unrealistic predictions of UWB signal power. A number of the specific assumptions are unrealistic and lead to a significant over-estimation of the amount of interference that would occur due to aggregations of unlicensed UWB devices. Specifically:

- For the simulations, UWB devices were randomly placed as high as 100 meters in the air, even close in to the site of the earth station receiver satellite dish.
- Propagation loss assumptions for the simulations are unrealistic: UWB devices placed high in the air, close to the receiver antenna (in fact, at the edge of or close to the antenna main beam) were often assumed to have simply free-space path loss – there were no allowances for obstructions and blockage due to the buildings that must have contained the devices.
- Other UWB devices at various heights above the ground are assumed to have free-space ($1/R^2$) propagation losses to distance of up to *5000 meters*. This can occur only in open terrain such as desert, where UWB deployment will be low or zero.
- Although it may be appropriate to model very close, outdoor (<3 meters in height above ground) UWB emitters as having only $1/R^2$ losses, this cannot realistically occur for UWB emitters on the ground at great distances (thousands of meters) or for devices places high in the air (3-100 meters in height above ground). Not surprisingly, those elevated devices assigned the $1/R^2$ path loss coefficient completely dominate the resulting aggregate UWB signal power level.
- Furthermore, assumptions about duty cycle of devices (especially those in close proximity to each other) are not included. The study discusses this effect at one point, showing the duty cycle < 100% will lead to correspondingly lower aggregate UWB signal power, but the effect is never included in extrapolations to high device densities.
- The simulation model is a statistical model and by its very nature will require a large number of simulation runs to get "average" values for UWB signal levels. It is not clear from the report if multiple simulations were performed to produce the reported UWB signal power levels. This effect would be particularly important when it is seen that the aggregate UWB signal power levels depend almost entirely on the few UWB emitters that are high in the air close to the antenna main beam and that are assigned a $1/R^2$ propagation loss coefficient.
- The Alion study considered several UWB emitter distribution patterns. One of these assumed a two-dimensional "normal" distribution about the C-band earth station receiver (again with vertical distributions up to 100 m in the air). This type of distribution thus resulted in much higher UWB signal levels because most of

the UWB emitters were closer to the C-band receiver. Clearly it is unreasonable to expect this type of distribution in the real world - it assumes that thousands of UWB emitters will be clustered around the satellite receiver antenna. The results for the "normal" emitter distribution are not therefore considered any further.

When more realistic assumptions are made about these factors-- device placement, building penetration losses, etc. -- additional simulations reveal that there would be no harmful interference to the earth station receiver.

Discussion of Re-created Alion Simulation Results

In order to further understand the results produced by the simulations, we reproduced the simulation and were able to achieve the same predicted levels of aggregate interference power when the same assumptions were applied to the UWB emitters.

Plots of simulation results illustrating the above conclusions are shown below. In Figure 2 we show the distribution of the power levels of the received UWB signals. The signal power distribution clearly has three "clusters" and matches the results shown in the original Alion Study. The different clusters correspond to those devices assigned $1/R^2$, $1/R^3$ or $1/R^4$ path loss coefficients. Clearly the devices with the $1/R^2$ path loss are much stronger interferers (by 40-80 dB) than the other devices having more realistic path loss values, even though the simulation allows devices assigned $1/R^2$ losses to range out to 5000 meters from the C-band receiver.

In Figure 3, we see a plot of the cumulative total UWB signal power computed as a function of the number of UWB emitters included in the sum. The dashed blue curve near the top shows that when the total power is summed starting with the strongest signals, the total power converges to its final value after only a small number of devices are summed: the total value is completely determined by a small number of the largest contributors. The solid red curve shows the cumulative sum starting with the weakest signals. This curve clearly shows the contributions of the different "clusters" of signals - those with the $1/R^4$ path loss coefficients contribute only a small amount to the total aggregate signal power. Those emitters with $1/R^3$ losses contribute more, but the levels are still low. The final groups of emitters (those with $1/R^2$ assumed losses) dominate the aggregate power level.

Figures 4 and 5 show the positions of the 10 UWB emitters with the strongest signal power at the C-band receiver for a typical simulation run. All of the emitters with the top 10 signal power levels are greater than 10 meters in the air, are very close to the antenna main beam and were assigned a $1/R^2$ path loss coefficient by the simulation. These strongest few emitters dominate the aggregate UWB signal power in all of the simulation runs – bearing out the intuition that the few emitters with the strongest power (those in the +20 dBi gain area of the antenna pattern) dominate the aggregate power. As we will see below, when this small number of UWB emitters with unrealistic placement and propagation is removed from the aggregate effect, there is no interference to the C-band receiver.

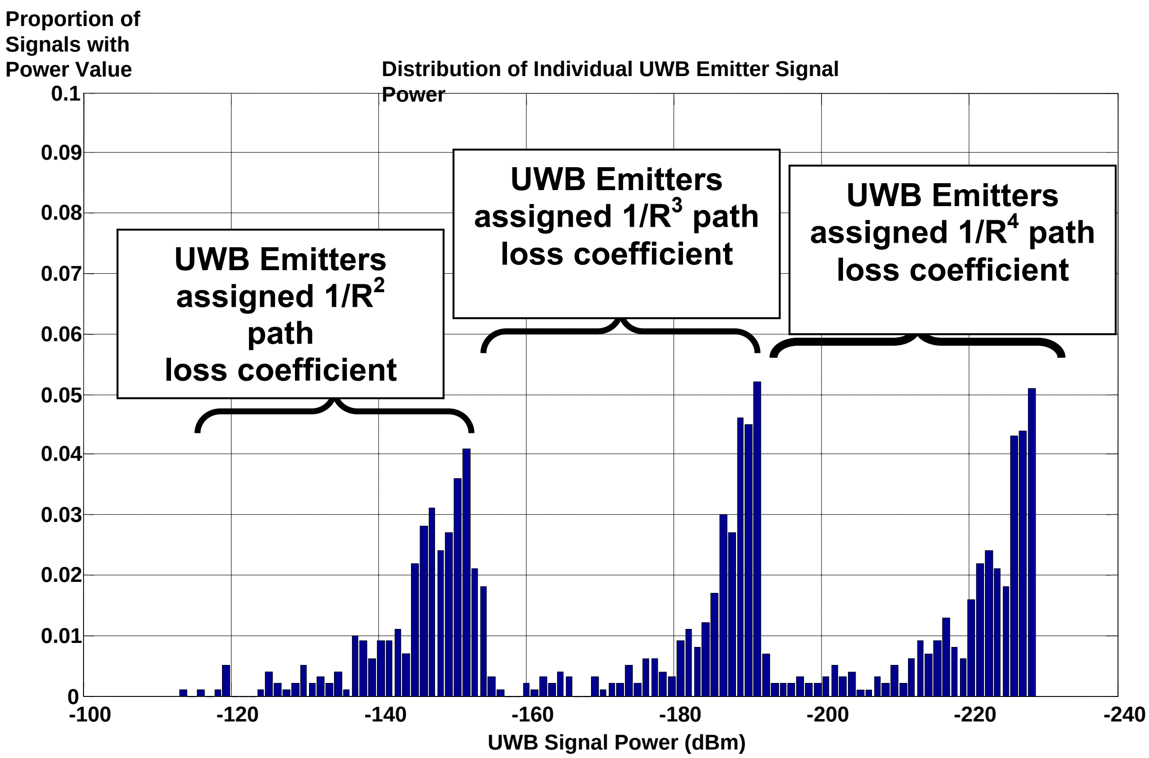

Figure 2: Distribution of the UWB received signal power in a re-done simulation showing similar clustering as in the Alion report. The clusters are due to the randomly assigned path loss coefficients (the clusters correspond to the groups of emitters with $1/R^2$, $1/R^3$ and $1/R^4$ path loss). Note that the few left-most points in the distribution dominate the total received UWB power (the sum of all the signals – see below). The vast majority (>98%) of the UWB signals contribute almost nothing to the total aggregate received power since they are between 20 and 100 dB weaker than the few strongest signals (the few left most points in the distribution). For example, it would take *one million signals* with power of –180 dBm to equal *a single* UWB signal with received power level of –120 dBm. Clearly, the small number of strong received signals will dominate the sum of the aggregate power.

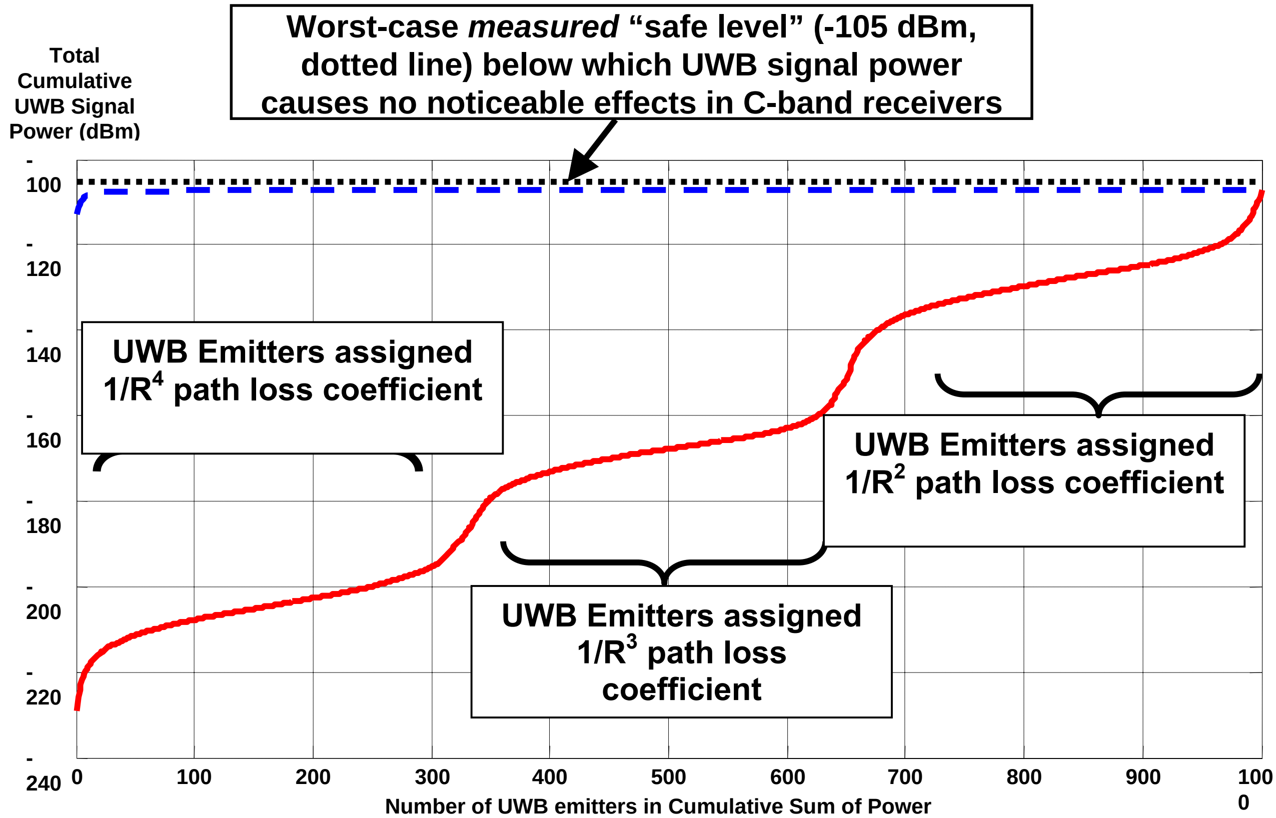

Figure 3: Total aggregate received UWB power using the assumptions of the Alion study. Here we also see cumulative total power values as more UWB emitters are added from left to right, 1 to 1000 emitters. The dashed blue curve shows the cumulative total power as the emitters are added from strongest to weakest. The solid red curve shows the cumulative total received power as the emitters are added from weakest to strongest. Note that the "clusters" of devices with different path loss coefficients lead to inflection points in the red cumulative curve. The total power due to the "$1/R^4$" emitters is around –200 dBm. When the "$1/R^3$" emitters are added, the total power is about –160 dBm. The total received power without the strongest few received signals is about 10-20 dB lower than the total with all 1000 emitters.

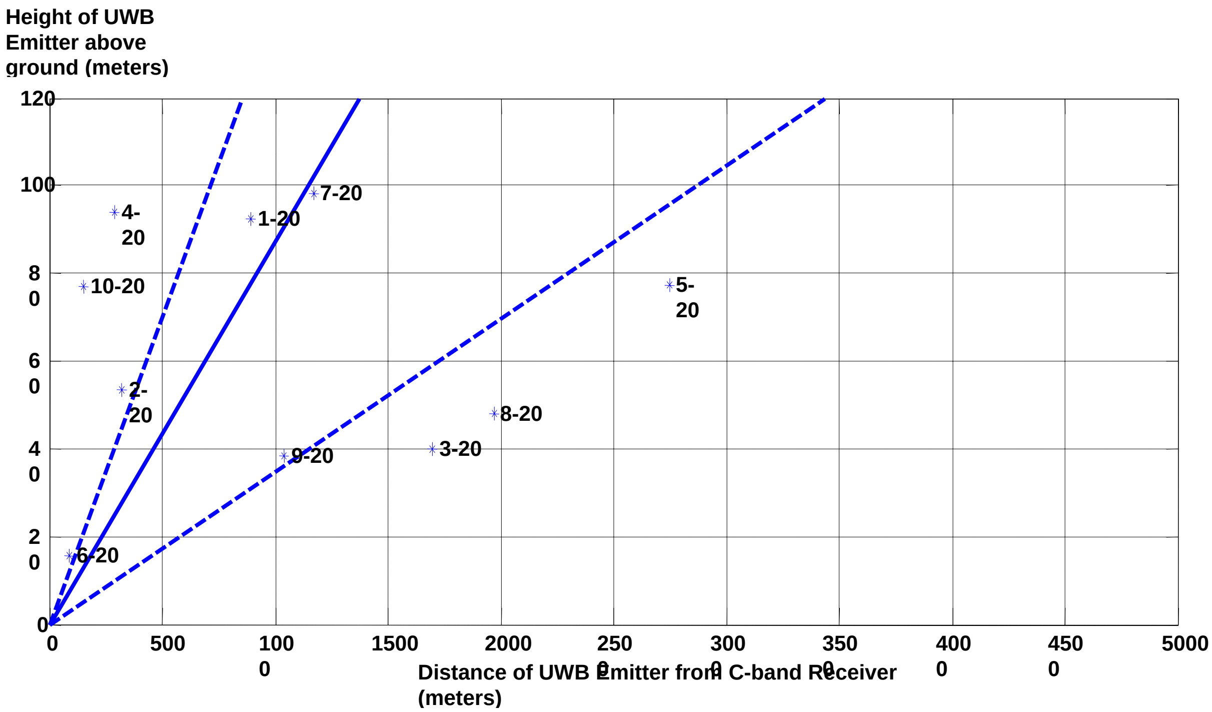

Figure 4: "Side view" of antenna beam showing the vertical placement of the 10 UWB emitters producing the largest received power levels. Note that all of them are >10 meters in the air. The 10 UWB emitters with the strongest received power are numbered 1-10, strongest to weakest in the figure. These correspond to the 10 left-most bars in the distribution plot shown in Figure 2 above. The antenna pattern shown appears distorted due to different horizontal and vertical scaling. The beam pattern axis (solid line) is elevated 5 degrees above horizontal and the beam width (dashed lines) at maximum gain (+20 dBi) is 6 degrees wide. Any UWB emitters placed in the main beam by the random simulation are assigned a maximum antenna gain of +20 dBi). Also shown next to each emitter position is the path loss coefficient assigned to that emitter – here we see that all of the top 10 contributors to the aggregate power were assigned a value of "20" (corresponding to $1/R^2$ losses) even though the ranges were as far as several thousand meters and all would have had to be inside buildings based on their heights.

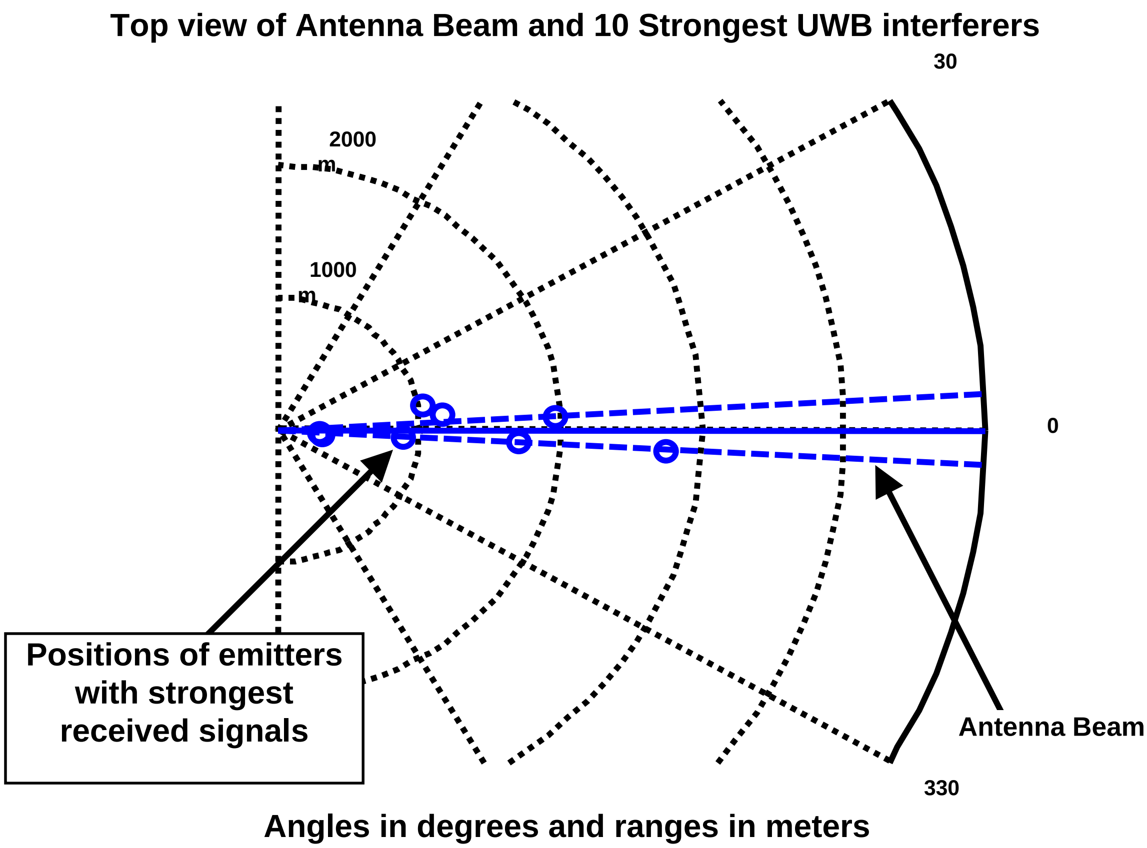

Figure 5: "Top view" of antenna beam showing the placement of the 10 UWB emitters with the largest received power in the x-y plane around the receive antenna (located at (0,0)). Note that the antenna beam pattern is also shown for reference. The 10 UWB emitters with the strongest received power are clear all very close to the main beam of the antenna. The other 990 UWB emitters are uniformly distributed in a circle of radius 5000 meters and are not shown here.

Simulation Results for Aggregate UWB Signal Power	**Power due to all 1000 Emitters**	**Power in Top 10 Emitters (Near antenna beam)**	**Power in the Remaining 990 Emitters**
Alion Study (uniform distribution)	-104.5 dBm	Not Reported	Not Reported
Recreated simulation using same Alion parameters (top 10 emitters used $1/R^2$ path losses to ranges as far as 5000 meters) – Average of 100 runs	-105.0 dBm	-105.6 dBm	-114.3 dBm
Adjusted for realistic path loss coefficients with same 5 degree antenna angle	-131.7 dBm	-131.9 dBm	-145.0 dBm
Simulation using 10 degree antenna beam angle	-131.4 dBm	-131.5 dBm	-148.4 dBm
Adjusted to include 12 dB attenuation for emitters > 3 m in the air (5 degree antenna angle)	-136.6 dBm	-136.8 dBm	-149.7 dBm

Table 1: Aggregate UWB signal power levels based on re-created simulations and also revised simulations using more realistic path loss assumptions.

More Realistic Simulation Results

To provide a more realistic understanding what might occur in the situation simulated in the Alion study, we made several modifications to the model:

- We modeled more realistic path loss coefficients: we used three values of $1/R^3$, $1/R^{3.5}$ and $1/R^4$ in the same proportions assigned by the original Alion study for $1/R^2$, $1/R^3$, and $1/R^4$. Note from the results in Table 1 that this change alone resulted in 25-30 dB reductions in aggregate UWB signal power.
- For UWB emitters more than 3 meters in the air, we included an additional 12 dB of path loss to account for losses in the building wall. Note this does not account for the effects of the building itself on the performance of the satellite downlink. The presence of a building in the main beam of a satellite receiver would likely impact the system performance (by blocking the view of the satellite) more than the UWB emitter in the building.

- All of the modifications that we introduced to make the simulations more realistic resulted in MUCH lower interference levels (25-30 dB).
- The fact that most of the interference comes from only 10 or fewer interferers high in the air and close to the antenna main beam means that in realistic situations -- having no such unshielded UWB devices in buildings within 3 degrees of the beam axis -- the interference will be even lower still (the value in the right column – 10 to 15 dB even lower)
- Duty cycle effects: The Alion study showed that duty cycle will lead to corresponding reduction in the total aggregate UWB power at the receiver. This effects was shown clearly (20% duty cycle led to a 7 dB reduction in the aggregate power), yet this is not taken into account in their conclusions. Real world duty cycles of a few percent for most typical applications would lead to a even lower aggregate power levels.

It is important to note that the Alion study also reports the *measured* threshold levels for which the different C-band receiver began to show noticeable interference effects. In all of the cases, the onset of degradation seemed to occur at levels of between –105 dBm and -90 dBm of interference signal power. The revised simulation results above (after excluding the few emitters high in the air close, using free-space losses and close to the C-band antenna main beam) show that aggregate UWB signal power levels are between –150 and –130 dBm. Thus emitter densities could be as much as one hundred to ten thousand times higher than the simulated densities and still be below the threshold level for the onset of interference effects to the C-band receivers. Based on the revised simulation results above, it is clear that under realistic conditions the C-band earth station receivers are unlikely to experience severe or harmful interference from UWB emitters.

Conclusions

The Alion study started with unreasonable assumptions about device placement and propagation losses for UWB devices high in the air. This led to unrealistic predictions for aggregate UWB power levels for their simulations.

Based on the revised simulations with the more realistic path loss models, building blockage effects for devices high in the air (and near the antenna main beam), the inclusion of a realistic duty cycle (<10%) and realistic density projections, it is clear that no significant interference will result. The aggregate UWB signal power levels drop by 25-60 dB when more realistic assumptions are made in the simulations. This means that the predictions of severe interference into C-band satellite receivers are unwarranted and that the current FCC UWB limits will allow for safe operation of C-band receivers in realistic situations.