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Reply comments from Arthur D Little Inc.

In the matter of:

Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems

Docket 98-153

February 1999

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Secretary Secretary's name

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1 SUMMARY

Arthur D Little (ADL) is an engineering and consulting company based in Cambridge, MA, but with business worldwide.

We welcome the Commission's Notice of Inquiry (NOI) as an opportunity to discuss the technical and commercial issues in the use of ultrawideband (UWB) devices. The number and breadth of responses illustrates the interest which this subject can engender. The use of the radio spectrum is evolving, and the design of equipment able to make flexible use of different frequencies and waveforms will continue to advance. UWB short-range devices (SRDs) exemplify such advances, but introduce risks of incompatibility.

Many references have been made to useful applications of this technology, including those from M/A-COM, Endress & Hauser, Rosemount, TEM Innovations, GSSI, and others. Its ability to penetrate solid materials (not only walls and ground, but also plastic panels, bumpers, etc.) make it preferable to other methods. Such advantages offer a large market and profitable exploitation.

Considerable concern has been expressed in Comments by authorities and bodies with a proper concern for the integrity of existing communications and navigation systems, which depend for their operation on detection of very low level signals. Examples are GPS and unlicensed PCS. These concerns have been expressed in terms of the adequacy of existing rules and definitions to control emissions by these devices, and in terms of the unknown effects of their proliferation on a large scale.

Arthur D Little has experience in many aspects of the design and operation of these and other radio systems. These Reply Comments are additional to our Comment submitted Dec 7 1998.

We consider that individual devices of the kinds proposed could be dealt with under power spectral density limits, adapted minimally from existing Part 15 limits, with associated limits on instantaneous field strength or duty cycle, and with a relaxation associated with some or all restricted bands.

However the question of proliferation has not been addressed in any detail. Without this the largest economic opportunities can not be assessed. ADL considers that, in view of the potential value of the short-range applications here considered, explicit study is needed now to resolve the issue. We have begun this study, and have generated preliminary results using a numerical model of the propagation conditions for such devices. These results are reported below, together with some material repeated from our earlier submission, for the sake of clarity.

The study indicates that interference will only be an issue in close proximity to individual devices. Proliferation on the ground, even in extreme numbers, appears benign. We believe that the concerns expressed for the integrity of existing systems can be shown to be unfounded, and recommend that the Commission move to verify these findings in preparation for proposing a new rule making.

2 THE EFFECT OF PROLIFERATION OF WIDEBAND DEVICES

Proliferation of wideband (or ultrawideband) devices can be studied in the light of the emissions of individual devices, their distribution in space, and the propagation conditions surrounding them.

2.1 Individual devices

For individual devices we can calculate the effect of emissions at the level of existing general limits. We can define a minimum distance beyond which another system is unlikely to suffer interference, because the received power becomes less than the thermal noise power of the receiver. This distance is small, suggesting that individual devices will be benign, as experience suggests.

The emission levels equivalent to the provisions of 15.209 are:

Frequency (MHz)	EIRP (in 1MHz BW)
216-960MHz	12nW
Above 960MHz	75nW

Table 3: Emission Levels

The test bandwidth is stated as a minimum of 1MHz. A wideband transmitter which meets this limit will have spectral power density (nW/MHz) values equal to those shown in Table 3.

We can calculate the distance at which the level of power received falls below thermal noise in a receiver with an isotropic antenna (0dBi) and a noise figure of 6dB, and with the receiver at the peak of the emitter's beam. We measure receiver noise and interference over the same bandwidth. A conservative estimate of the maximum distance at which another device will see interference is shown in Table 4.

Since the majority of receiving equipments employ a degree of processing gain, these figures are probably conservative. They suggest that applications where the devices are separated normally by 10 metres or more, wideband applications above 5GHz will be reliably benign at these levels.

Frequency	Distance
500MHz	40 metres
960MHz	20 metres
1000MHz	50 metres
2.45GHz	20 metres
6.5GHz	10 metres

Table 4: Range for interference to fall below victim's thermal noise

2.2 What does proliferation mean? A distribution scenario

Examples of applications which would constitute a high degree of proliferation are provided by domestic intruder alarms and car collision warning aids. If successful commercially, these could be owned by a large proportion of the population and become integrated into its increasingly radio-aided lifestyle. This scenario is worth considering without prejudice. The value of the market for devices incorporating such sensors could be worth many billions of dollars.

In a possible scenario a national population of 100 million people live in 50 million dwellings and offices, with 50 million cars, distributed between large and small cities and towns over an area of 200,000 square miles. In this population there may be 1 billion sensors of this kind. The highest concentration of devices might be in a city of 10 million, with 10% of these devices within an area of 1100 square miles.

The sensors emit a maximum spectral power density of 75nW/MHz. Their operating cycles and beam patterns will vary with the application, but we will consider a worst case scenario in which they are all working simultaneously.

To build up a picture of the threat posed by these devices we need to consider many different scenarios.

The urban environment is built up, with devices operating in buildings or in the street.

The rural environment is relatively sparse, but without the obstructions of the urban setting.

Roads represent a particular case where many devices may operate, and in a non-random orientation.

Special cases such as large shopping malls, sports stadia etc. should also be considered.

Such scenarios could be used to discuss objectively what their effect would be on mobile phones, GPS and other classes of service. In our study to date we have considered what we believe to be the worst case; that of a large city, with respect to remote platforms such as aircraft, and local radio users in the street.

2.3 Propagation conditions

We have constructed a simple model which allows interfering field strengths and signal levels to be estimated for different levels of proliferation up to extreme examples in an urban environment. The model does not attempt to calculate phase delays or fading effects important to communications systems, but addresses the gross power attenuations to be expected in propagation through a built environment.

Experience with cellular communications and with solids-penetrating radar sensors has given us substantial knowledge of the effects of such materials, and of multiple scattering. We have used this experience to build a simple but effective model to investigate the issue of proliferation.

We want to calculate the field strengths which might be experienced by victim receivers in a number of locations, such as:

1. Inside a building;
2. On top of a tall building at 100m;
3. In a busy street;
4. In a park;
5. In an aircraft at 500 - 10,000m.

Many of the difficulties which might arise from such proliferation are seen as involving either airborne systems or cellular communications, and in this preliminary discussion we have given priority to items 3 and 5.

3 FIELD STRENGTH ESTIMATES IN THE URBAN ENVIRONMENT

Our preliminary results are based on devices operating over a wide (~2GHz) band centred at 6.5GHz, with EIRP of 75nW/MHz.

3.1 An aircraft flying over a city

With respect to systems on board an aircraft, the major threat may come from flying over such a city, at any altitude.

We will consider a city of 10 million inhabitants, with 100 million short range devices, all operating simultaneously, within an area of 2800 square kilometres (with a radius of 30km).

We assume that the devices emit an average of 75nW/MHz EIRP in the horizontal plane but have sidelobes decreasing to zero in the vertical direction with a reasonable beam profile approximating a $\cos^2$ function.

20 million devices on vehicles (parking, collision warning, blind-spot aids, etc.) operate in the open, and are distributed with a maximum density of 1 per $10m^2$ in the street. The streets occupy

20% of the area of the city. We apply a density varying from a peak of 20,000 devices per square kilometre near the city centre to a value reduced by 1/4 at the periphery.

Looking down on the street at a height h and an angle η from the vertical, signals traverse a number of buildings. The model uses a building separation equal on average to the building height, near the city centre, and estimates the number of buildings traversed, limited by diffraction effects and the reducing average height of buildings near the periphery.

Building materials absorb radio frequency energy at a rate depending on the frequency, the materials and the geometry. At a few GHz, building materials absorb at rates of tens to the lower hundreds of dB per metre penetrated. For devices in the street we approximate this effect by considering the shadowing effect plus absorption. If buildings are on average as high as the street width, the shadowing can be approximated by a multiplier of (1-tanη) up to 45°. For η>45°, we introduce a fixed loss of 10dB per building traversed by the propagating signal. In fact this loss is made up of several components, but taking an average over many devices and locations, a single conservative loss parameter will provide a useful first indication of the effects.

In the model an additional 80 million devices are in buildings (intruder alarms, lighting controls, safety perimeters, stud finders, etc.) and will be approximated by introducing a fixed dielectric loss due to the building for η<45°, then increasing as the number of buildings traversed.

We consider two cases: one where the receiver is vertically polarised; that is, omnidirectional in azimuth with a null vertically down as sinη; in the other the receiver is horizontally polarised, with a maximum lobe vertically downwards, decreasing to zero on the horizon as cosη. (Some studies have performed a scalar aggregation of Poynting vector magnitudes over a hemisphere, which can not be justified; the receiver characteristics must be considered.)

The model suggests that for both cases, most power is received from a circular area on the ground whose radius is about twice the altitude of the aircraft. The first-order effects of shadowing and dielectric loss can be demonstrated.

For the aircraft, the ratio of power received from these devices to thermal noise is shown in Figure 1 as a function of altitude, for the vertically polarised case. It varies slowly from –8dB to –6dB between 500m and 5km altitude, falling again above that height.

3.2 Radio users at street level

For the user of other devices in the street, we also include the effect of the channeling of device concentrations along the street. The model suggests that at these high densities noise may be degraded by up to 6dB compared with thermal. This is as a result of the immediate proximity of up to 25 devices within 15 metres of the victim, not due to devices hidden behind vehicles or buildings.

This result suggests strongly that any problems of interference which may arise in this case will be at the level of the individual device, when the victim is placed in the direct field of view of the emitting device, not as a result of massive proliferation over an area.

Undesirable though any degradation is, this effect is minor when compared with the known effects of poor propagation for phones due to buildings, tunnels etc.

4 PRELIMINARY ASSESSMENT OF THE THREAT

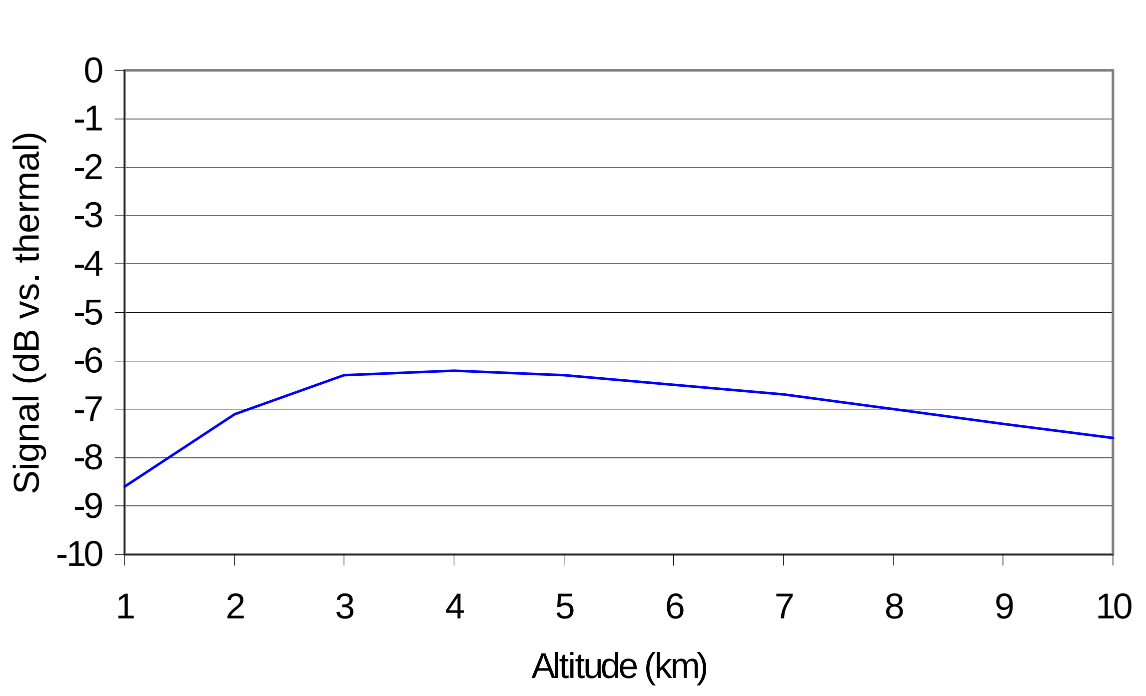
We have used this model to describe an extreme case of proliferation.

To the extent that the model provides a fair approximation to reality, we find that any effect of these devices will be undetectable except in very close proximity.

This result would suggest that such devices, operating in high concentrations which coincide with a lossy propagation environment, may indeed be benign toward other users. This is contrary to the natural presumption that 100 million unlicensed emitters would represent a significant threat, and the conclusion needs to be validated.

This result has been obtained for devices operating in the 5-7GHz region. These devices would benefit from a relaxation of the restricted bands below 5.4GHz and above 7.2GHz. Other frequency ranges also require attention.

Figure 1: Interference vs altitude



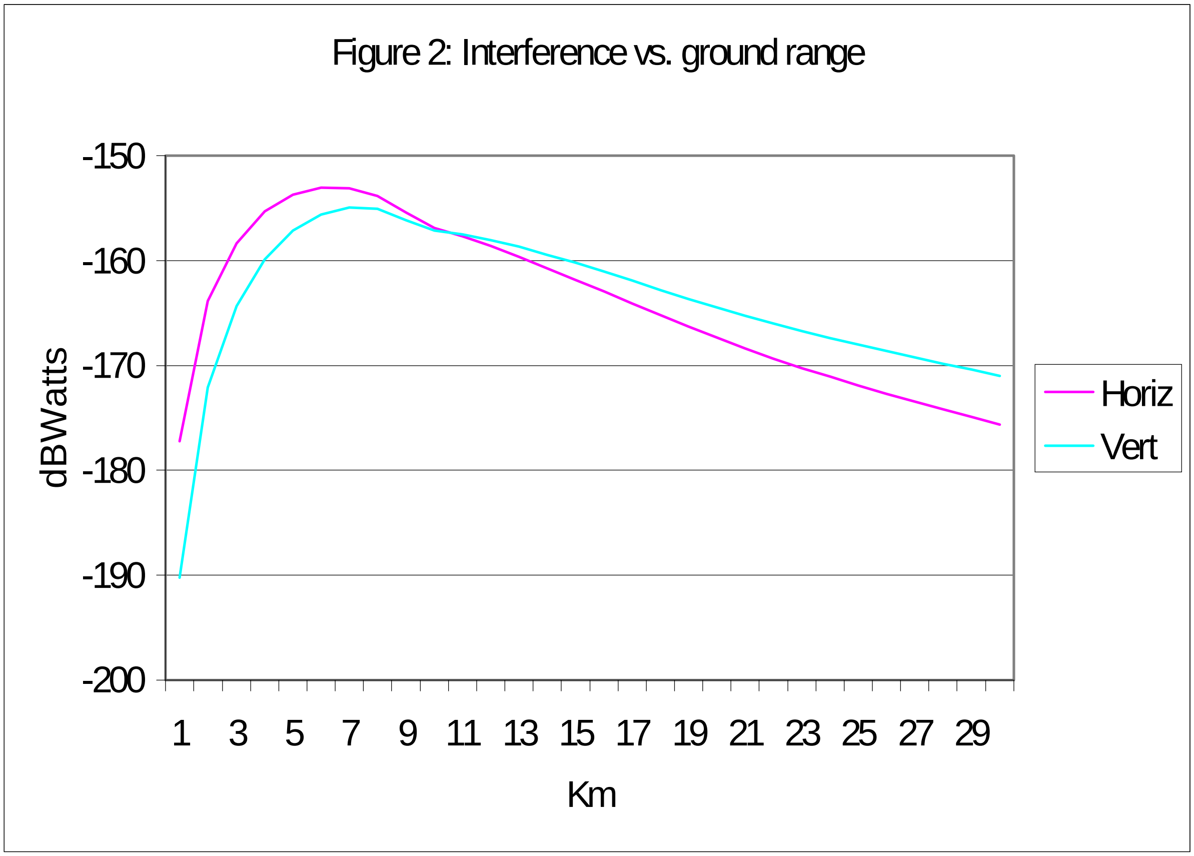


Figure 2: Interference vs. ground range
-150
-160
-170
-180
-190
-200
dBWatts
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Km
Horiz
Vert