Before the Federal Communications Commission
Washington, D.C. 20554

Reply comment to ET Docket No 98-153 on UWB transmitters etc. from Saab Marine Electronics

Olle Edvardsson Januari 6 1999.

As a design engineer working with wireless communications and microwave level gauges I'm glad to get the opportunity to comment before the Commission on the very important notice of inquiry FCC 98-208. To my understanding the goal of the NOI is to maintain present protection and usability of our spectrum and even improve it in some corners of the specifications but also to remove restrictions which do not add protection today but mainly are obstacles for the technological development.

Some general remarks

The 60 answers to the NOI FCC 98-208 constitutes a very good survey of a wide range of aspects giving an important part of the background required for the proposed revision of the part 15 limits. It is obvious from the answers that the use of all kinds of wireless communications and wireless equipment will increase drastically and also that unintentional radiation from fast digital equipment (UHF and up) will increase likewise. One consequence of that is that it is important to formulate rules which maintains the usability of the spectrum and which simplifies the coexistence of different types of system with minimal mutual disturbance. Due to the growing number of units increased restrictions may be necessary in some details but in other cases the present rules can be modified without problems. Broadcasting TV and radio and the bands for mobile ground based and satellite phones are among the potential victim receivers covering a considerable part of the frequencies up to 2500 MHz. GPS obviously is another such possible victim which presently fortunately shares a restricted band.

Earlier FCC rules have stated different limitations for different kinds of equipment but in the world of increasing complexity and permanent change it seems more practical to formulate the rules around the victim receivers instead. As seen from the victim it should not be too important if the radiation is intentional or unintentional or if it is generated of a device labelled UWB, FMCW, XYZ or anything other. The important result is whether one radiator alone or the accumulated effect of a reasonable number of radiators can cause disturbances or not on various types of victim receivers. The big variety of different existing systems poses a special problem of interference in order to guarantee coexistence with preserved or in a practical sense preserved performance. Units operating under part 15 must not cause such disturbances especially not far away from the radiator (i.e. in your neighbours house or apartment). For the benefit of the users and the market it is also important to avoid regulations which mainly act as obstacles for utilising new technological possibilities without decreasing the noise level of the spectrum already limited by thermal noise. Since the present part 15 rules were formulated a big number of low or ultra low power devices have been possible to construct and there are also a lot of new measuring instruments which can actually determine the possible hazard of disturbance. With the right measuring method it should not be necessary to add extra constraints on the hardware like the prohibition of class B transmitters using attenuated oscillations. It seems like the best compromise between good protection of existing users and wide use of beneficial new applications is to formulate the rules around possible victims rather than various details in the transmitters or radiators operation under part 15. By this method the definition of "UWB" or other types of systems is not too important.

Rather than defined by various pulse parameters the following discussion will deal with unlicensed and fairly broadband systems which give a more or less noise-like radiation which by present or future part 15 rules do not disturb electronic units in the surroundings. The thermal noise is one reasonable base for an universal limit as any victim system must be able to operate under normal thermal noise. Obviously there are some systems using receivers cooled far below ambient temperature but they do not use antennas allowing radiation from the surroundings at normal temperature to enter. The present part 15 rules are partly in the same order of dignity as thermal noise but there are some remarkable differences especially far above 1 GHz.

A few subjects extracted from the answers to the NOI are:
Spectral power density should be the main limitation rather than the amplitude itself [said in most submitted papers]. To maintain continuity with present rules and to avoid potential problems at small distance from radiator to victim receiver a limitation on peak power should also be used. Present part 15 rules allows very high spectral densities within a narrow band (i.e. single frequencies below 0.5 mV/m) and that possibility can be maintained by limiting the test bandwidth (for instance to 30 kHz to 3 MHz). More wide band systems (W-CDMA etc) will require that the present 1 MHz limit is increased and 3 MHz is presently common on spectrum analyzers.

A limit related to the thermal noise will be good for adequate protection without introducing unnecessary limitation. [Xtreme Spectrum, Saab]. One important observation is that the thermal noise radiated from ground or buildings or receivable by an antenna is proportional to the square of the radiated frequency (Plancks law). Present rules with a frequency independent limit (0.5 mV/m above 960 MHz) thus are unnecessary low at high frequencies (a few GHz and up) but can also be too high at low frequencies like a few 100 MHz and down. Below 100 MHz various kinds of atmospheric noise and manmade noise can be stronger or much stronger than the thermal noise. The frequency dependence of the radiated thermal noise can easily be included by limit of the product of field strength and wavelength ("volts per wavelength") rather than the normal field strength.

The restricted bands as a concept should be maintained but the exact formulations might be revised. [Multispectral Solutions Inc and others]. The possibility to use extremely low power for certain applications might make "intentional radiation" less harmful than present typical strength of "non intentional radiation". The restricted bands could have lower limits but applied for all kinds of radiation (intentional, unintentional etc.) and at a level relevant for the band in question. For instance the GPS bands obviously must have a much lower limit as a GPS receiver is very sensitive and uses an antenna covering whole the upper hemisphere. Already a disturbance of 0.05 mV/m (i.e. 20 dB below 0.5 mV/m) will generally degrade the performance of a GPS receiver assuming a suitable (or rather an unsuitable one!) spectrum. A typical mobile phone will have a similar sensitivity limit but over a more narrow band. The choice of restricted bands might need an update from time to time as the possible victim receivers change with the development.

The definition of UWB is discussed in a number of papers. [Thomas E McEwans, Time domain and others]. As a consequence of the more general formulation extended from present limits (or related to thermal noise) the definition of "UWB", "FMCW" and other types of system should not be too important. Later on other system principles might appear and it should be more practical to formulate "eternal" rules related to how efficient the scarce natural resource "spectrum" is used. Still a fairly well defined spectrum occupation or an extremely low power should be useful means to avoid restricted bands and to keep hypothetical future spectrum collisions under control especially far from the radiator.

Earlier experiences of present rules are referred to in some papers but are not really adequate for three reasons. First the order of dignity of the number of more or less intentional radiators will increase dramatically with the increasing use of wireless equipment. Second the use of higher frequencies will simplify radiation as units smaller than a quarter of a wavelength will be poor radiators or receivers. Frequencies of a few hundred MHz and up contained in a unit of handheld size will on the other hand radiate much easier with an antenna (more or less intentional) contained within the small unit. For the third the present rules are originally established for frequencies below 1 GHz while more adequate limits related to noise would be frequency dependent and probably proportional to the frequency squared and higher than the present limits at a few GHz and up.

The effect of several accumulated radiators is treated in many papers among the NOI answers. [Xtreme spectrum, Interval research, Time domain and others]. One important conclusion is that conditions on the ground are worse than up in the air and that the accumulated influence can be estimated which gives a sound foundation of the limits of spectral density. Another obvious conclusion from the calculations is that the main contribution comes from the radiators very close to the victim receiver. That should make air-planes secure under the assumption that all ground based units really are fulfilling adequate limits which gives acceptable disturbance already at ground level. The same calculations are also the base for the separation between different part 15 limits intended for domestic and industrial use. Peak power on the other hand is mainly limited by possible influence on non-linear effects in the victim receivers at a very close distance. By applying a limit like 1 mW it is highly unlikely that LNAs in the vicinity are saturated.

The limitation of peak to average should be substituted by a peak power limitation. If the peak power is fixed (such as 1 mW) then a bigger quotient than present 20 dB will decrease average power and spectral density and thus cause less harm than a unit fulfilling present 20 dB limit with the same peak power.

A few other remarks

Obviously the geographical density of the transmitters is important to judge the accumulated effect of the units. In the present part 15 rules this is made by different requirements for domestic and industrial use and this seems like a good principle for practical reasons. Some of the discussed applications might ultimately appear in dozens in each home which of course requires the spectral density as well as the peak power to be restricted accordingly to avoid too high accumulated effects. You do not have any control over units at your neighbour but still must have the right to use sensitive receivers of various kinds (some of which may not exist today). For industrial applications technical requirements might make it impossible to refrain from certain powers but it is also possible to apply certain restrictions as long as victim receivers outside of the premises of the user are not disturbed. A suitable warning label may be used to make the user aware of possible problems in very special cases (for instance the ground penetrating radars etc where high powers must be used to get reasonable performance). Another method presently applied is to restrict use of certain equipment to for instance closed metallic tanks.

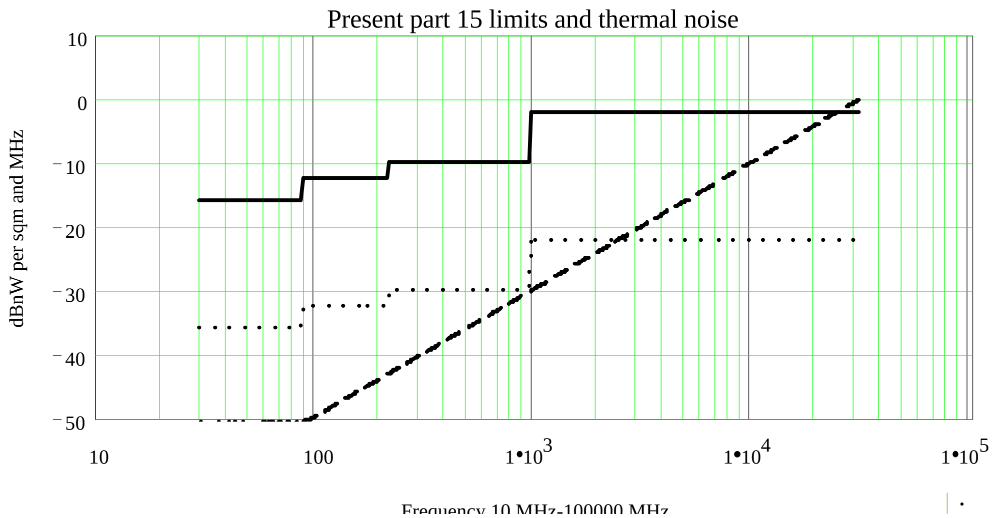
A general remark is that the radiation from any kind of system for information transmission, radar etc can be described as a number of frequencies sent out with various phase and amplitude. The number of frequencies can be small or very big (which is the case if the signal can be described as a pulse train or as a pseudo random noise). The same amplitudes creating a pulse will appear more like a noise at a considerable lower amplitude if the relative phases are different. The transmission path from transmitter to receiver (which can be located together with the transmitter (=radar) or at another place (=communication)) will change amplitude and phase in a random-like and time dependent way and the received signal generally will be quite different from the transmitted one. For the communication case the transmission is generally described using the term “delay-spread” which gives the timely expansion of the signal which basically is the same independent of the type of radiated signal. Indoor the delay-spread is in the order of 10-100 ns while it is in the order of one to several microseconds outdoor. The practical choice of equipment and detection principles may be different for different type of signals but the change of phase and amplitude under the transmission path will be the same for the same frequencies. The performance may be similar for different hardware solutions and so will the radiated spectrum. Bandwidth and average power are the key factors both for pulsed and frequency modulated systems. Given the same limitations (bandwidth, average power, propagation path etc) any hardware and working principle would give approximately the same possibilities for transmission capacity etc. Presently most multiple access systems (mobile phones etc) are rather narrowband with a high spectrum efficiency. Systems using ultra short pulses are very interesting for many applications but ultimately they are limited by the same laws of nature like for instance mobile phones. Some of the comments seems to have overlooked this limitations due to the low density of units for the time being [Thomas McEwan].

The present test method naturally takes possible antenna gain of the radiator into account by searching for the worst case radiation. The victim receiver is assumed to have low gain (in the order of 0 dBi) in the direction of the radiator under test which is a realistic assumption as a possible high gain antenna surely not is directed against an accumulation of disturbing units. As will be discussed later the thermal radiation from the ground will be a natural base of comparison.

Some estimations of present and proposed limits.

To consider which limits might be adequate the following estimates can be made. The surface of the ground will radiate $8\pi kT\Delta f/\lambda^2$ watt per square meter (Planck’s radiation for a “black body”). As an example at 1 GHz bandwidth and λ=0.03 m (10 GHz) the thermal noise is 111 nW per square meter at normal temperature (15°C). If the unit under test (at a distance of 3 m) was substituted by a solid wall this is what the system would measure with regard to the bandwidth (i.e. 111 pW at 1 MHz). The present part 15 limit above 960 MHz (0.5 mV/m 3 m away from the radiator) corresponds to 0.66 nW per square meter radiation density ($=E^2/Z_o$). With an assumed isotropic radiation the 0.66 nW at 3 m corresponds to 75 nW total power over the whole sphere which is an overestimate. The measuring bandwidth during a part 15 verification test is now 0-1 MHz which hypothetically would correspond to 660 nW per GHz in the case of a noise like signal due to short pulses or noise like CW-modulation. Seen as spectral density the present part 15 limits thus are 8 dB above the thermal noise which can be regarded as adequate with regard to noise factors, bandwidths, losses and practical margins. Another comparison is that the thermal radiation over 1 GHz from a typical industrial installation (>1000 sq m around a tank equipped with a radar level gauge) is a few 100 microwatts which probably is bigger than escaping power from any kind of such system.

The curve below gives the spectral density (in nW per sqm and MHz) over 0.03-30 GHz together with the present part 15 limits (15.109 and 15.209) which are 0.5 mV/m above 960 MHz.

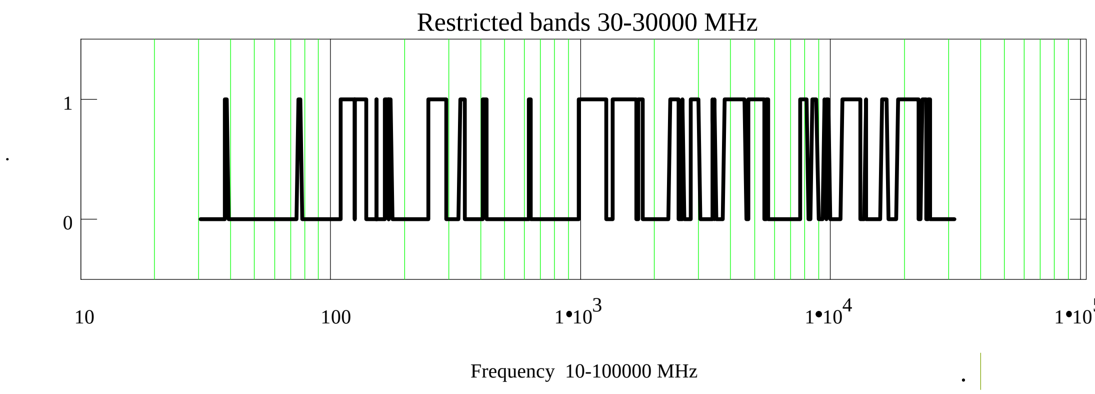


The horizontal frequency scale spans 10-100000 MHz but only 0.03-30 GHz are calculated. The solid line is the present part 15 limit (0.5 mV/m above 960 MHz etc) and the dashed inclined straight line is the thermal noise. The dotted line is 20 dB lower than the part 15 limit in case the victim receiver is 30 m away from the radiator (more typical in an industrial environment) rather than the 3 m as in the test situation. Around 1000 MHz (3 at the horizontal scale) the 30 m curve seems adequate for the practical use as the part 15 limit is similar to the thermal noise over 1 MHz. At lower frequencies the limit is over or far over the noise and well above 1000 MHz the limit is lover than the noise. A unit at 10 GHz (4 on the scale) could have a radiation 12 dB above the part 15 limit without being more visible above the noise than a unit just below 960 MHz. The diagram above suggests that the product of field strength (mV/m) and wavelength (m) should be used rather than field strength in order to reach a formulation independent of center frequency. Assuming the present 960 MHz value (0.2 mV/m at 3 m) can be considered as adequate (solid present experience!) the proposed limit should *be 0.064 mV per wavelength* for *all frequencies* (30 MHz to 30 GHz) at a bandwidth of 1 MHz. Other bandwidths (such as 30 kHz to 3 MHz) should be used as well but with accordingly adjusted limits to reflect spectral density:

Bandwidth	30 kHz	100 kHz	300 kHz	1 MHz	3 MHz
mV per λ	0.012 mV	0.02 mV	0.036 mV	0.064 mV	0.12 mV

Peak power limitation may be 1 mW without any 20 dB peak to average limit

The restricted bands can have a limit which 10-20 dB lower to get a margin which makes it impossible to get any disturbance. The diagram below gives an idea of the distribution of the restricted bands. Obviously only band limited UWB systems can avoid the restricted bands



but by sufficiently reduced power wide band operation could be feasible.

Summary

Present part 15 rules are not fully adequate and may disturb sensitive systems like GPS, mobile phones etc. in worst cases especially without restricted bands. In other cases current part 15 rules contain parts adding difficulties for new technology without adding further protection. The present rules can be replaced by more general rules based on spectral density and the margin to thermal noise. In this way the different rules for different radiators may be simplified and the formulation can be done more general and concentrated to the victim receivers. Especially no special rules for UWB systems should be required. The radiators under test should be measured in normal (or rather worst case normal settings) use without special settings like turning off the sweep or using the desensitization correction factor. The 20 dB limit on the peak to average ratio should be replaced by a peak power limitation which reduces spectral density. The measuring bandwidth should be as wide as existing instruments allows which presently is 3 MHz which is fairly adequate for various wideband systems including new W-CDMA telephone/data systems. Product of electric fieldstrength and wavelength should be used rather than only field strength to match thermal noise over a big frequency range as 0.1-100 GHz. The military EMC standard (MIL-STD-461C) has a similar frequency dependence for radiated emissions. Using a suggested limit like 64 μV per wavelength at 1 MHz BW seems to give a continuity (meaning preserved limit at 950 MHz) and by measuring over a range of bandwidths (like 0.03-3 MHz) and with accordingly adjusted limits the measurement will reflect spectral density rather than field strength.