WIDE BANDWIDTH MEASUREMENTS ON NON IONIZING RADIATION: THEIR ERRORS VERSUS THE MOBILE PHONE SYSTEM OPERATING LEVEL.

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Abstract. *It was well demonstrated by high scale measurement campaigns that only the 20% of the total electromagnetic radiation to what citizens are exposed comes from mobile phone systems (Base stations and mobile phones). Overall, the average exposure levels for a big city are below 5V/m, while approximately 1 mV/m is required by a mobile phone to operate normally.*

Broadband measurement instruments are frequently used because of their simplicity and economical price but it's important to take into account that their sensitivity is around 1V/m, what makes very difficult to identify which is the real contribution of the mobile phone system to the resultant field in a measurement point. Nevertheless the most important error source in non-ionizing radiation measurements is the electromagnetic noise level outside the band of interest. Simple noise power integration at frequencies below the AM broadcasting system plus noise power integration at frequencies above the mobile phone bands will result in measured values of one magnitude order higher than the real radiated field from the mobile phone systems.

This work presents the level of the above mentioned errors, proposes an alternative to mitigate them and shows how the current discussion for the exposure guidelines is related to a proper non-ionizing radiation measurement procedure.

Key words: *broadband, measurement, mobile, errors.*

1. Introduction

Measuring non-ionizing radiation (NIR) in the radio frequency (RF) spectrum is not a new problem.

From the beginning, two method or techniques were performed, depending on the signal or service under study. The most popular, simpler and cheaper is the wideband measurement method; and the other technique, more expensive and complex, is the narrowband measurement, which is implemented with a Spectrum Analyzer (or a similar narrowband detector) and a set of calibrated antennas [1].

Until the early 80's, the main services in the RF spectrum were the AM and FM Broadcasting systems, Over-the-air TV stations, some radio links, military communications systems and RADAR, but in all the cases the amount of these systems was little. It was the fast deployment of Mobile Telephones Systems (MTS) what renewed the interest for measuring RF fields and their exposure limits.

Nowadays, the controversy about RF and Microwave fields' exposure effects on humans even persists. Therefore, there are different exposure guidelines with a high disparity on their limits.

Many countries have adopted the World Health Organization recommended limits [2], which are based on thermal effects, while others have based their standards on non-thermal mechanisms [3] or the precautionary principle. But for both cases, if we consider the exposure limits for mobile phone frequencies (in general between 850MHz and 2000MHz), the values are several times higher than the necessary operative RF Electric field for MTS, that is close to 1mV/m.

This work shows the importance of choosing an appropriate measurement method to perform a correct characterization of the NIR level of any MTS.

2. Materials and Methods

2.1. Measuring Methods

For a typical city, whether big or small, the RF spectrum (see Fig. 1) is mainly occupied by other well known services as: AM and FM broadcasting systems, over-the-air analogue and digital TV, aerial, maritime and terrestrials radio communication in V/UHF bands, microwaves data-links, trunked radio systems, Wi-Fi, Wi-Max and 2G, 3G and 4G MTS (including radio bases plus "the mobile phone").

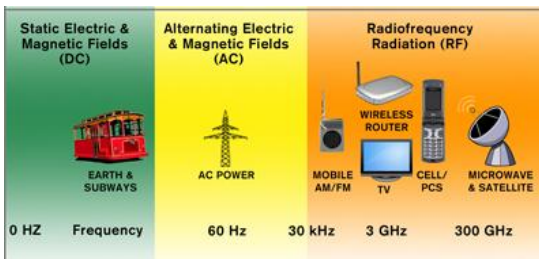

Fig. 1 Radiofrequency Spectrum (source emfrf.com)

For the purpose of verifying the public (or occupational) exposure level to RF fields in a simple and fast way, isotropic broadband detectors were developed (see Fig. 2). This classical meter probes consist of triaxial very short antennas (dipoles or loops) connected to a fast diode detector, like a Schottky.

Fig. 2 Typical broadband RF (Electric or Magnetic) Field survey meter (source L3)

These survey meters display a scalar value of the in-situ Field, whether Electric or Magnetic, or Power density, which can be compared with the exposure limit values. In fact, that value is the result (in Root Mean Square) of adding all RF Fields contributions *over the whole probe's bandwidth* at the point of measurement. Therefore, in this case it's impossible to determine the contribution of each signal. These instruments are simple, cheap and user-friendly, but on the other hand the level of measurement uncertainty is high [4].

Certainly, if there was only one source to characterize and its intensity was well above the radio noise, the measurement uncertainty could be considered acceptable (close to 3dB). But this is not the most common case; usually the measurement at any point is affected by many RF signals, plus the noise over the bandwidth. For these survey meters the common error sources are: non-linear responses, anisotropies, square error due to multiple frequency signals, modulation errors, thermal drift errors, and induced currents over the high impedance line that connects the probe to the field monitor.

In general, engineers and NIR professionals choose a high bandwidth probe, i.e 100kHz-18GHz (see Fig. 3) to perform their measurements. This option is meant to cover all significant RF sources and the value displayed in the field monitor is directly compared with the corresponding exposure limit value.

It is true that there are probes with a more limited bandwidth, generally focused on certain services, i.e AM broadcasting, FM broadcasting or others, and in these cases the resulting measurement error decreases due to a smaller probe bandwidth.

The other well-known method is the narrowband measurement, that allows to obtain an Electric o Magnetic field value that exclusively corresponds to a selected service, broadcasting station or channel, or a certain narrow band selected by the professional.

This measurement technique can reduce the error of the method because the obtained value is exclusive for the tuned (narrowband selected) service with a low level of radio noise. But, in fact, only in few cases the obtained value can be compared with the exposure limit values, because in general, the public is exposed to a multiple RF emissions.

Fig. 3 Field Engineer with broadband instrument (source author)

The narrowband method is more complex for its implementation, and a good expertise on spectrum analyzer management and antenna deployment are required (see Fig. 4).

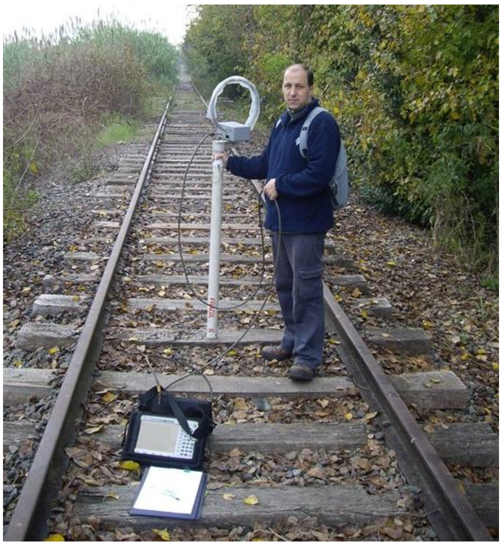

Fig. 4 Field Engineer with narrowband equipment (source author)

All the broadband measurements in the present work were performed with a Holaday HI-2200 (100kHz-5GHz) survey meter. The narrowband measurements were performed using an Anritsu 2721B spectrum analyzer with and Electro-metrics double ridge horn (1-18GHz) (see Fig 5).

Fig. 5 Measurement Instruments

2.2. Values: limits and mobile phone operation.

As mentioned before, there are two main biophysical arguments to elaborate the guidelines. This situation is well depicted in the limits disparity that appears for different entities or countries.

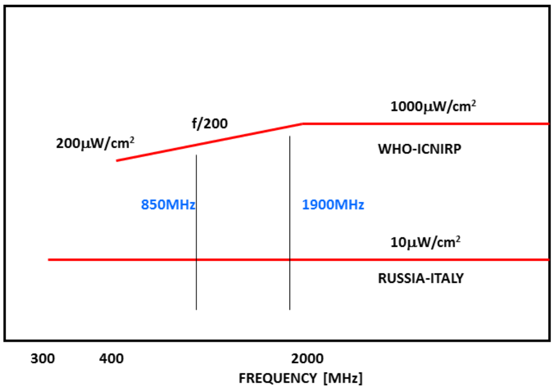

Fig. 6 Different guidelines in mobile phone spectrum (source author)

The Fig. 6 shows the limit values in terms of power density for a plane wave, the Electric Field can be calculated taken into account the air impedance of 377 ohms, with a resultant Field of 6V/m for the Russian and Italy cases and close to 40 V/m for the World Health Organization and International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines.

The typical field level required for the proper operation of mobile phones in current use depends on the technology generation and the condition of use, but it is accepted that the power level on the receiver may as low as -90dBm [5]. Each mobile phone has its own antenna. Therefore, in terms of the Electric Field intensity its value should be close to 1mV/m. As it will be shown later, this small field value, as the total radiation from MTS (mobile phones and base stations) is, at least, one magnitude order lower than the stricter exposure limit.

3. Results And Discussion

For a typical big city, the environmental power density radiated by the main RF services is distributed as shown in Fig. 7 [6]. This figure shows a narrowband Electric Field characterization, service by service, in a neighborhood in Buenos Aires City (11 million people). The presented Electric Field values are the result of all contributions over the spectrum for each service. For instance, the computed bandwidth for the AM broadcasting system is 530kHz-1750kHz, 88MHz-108Mhz for FM, and a 50MHz bandwidth for each MTS. Over-the-air TV services were excluded because in this case their contribution to the total field is much lower than the other broadcasting systems. Depending on the site where the measurement is performed, there can be great field variations due to the AM and FM broadcasting systems contributions, but the contribution of the MTS to the total field is approximately constant everywhere in the city and much lower than the other two.

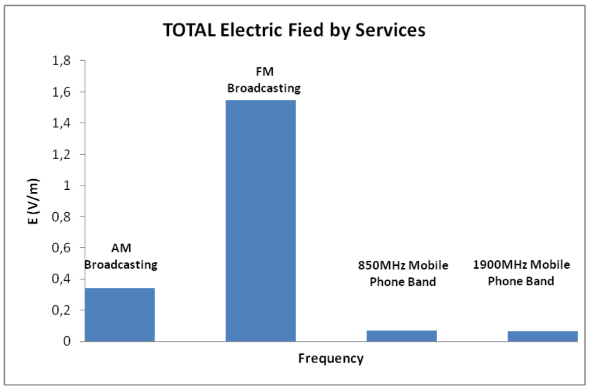

Fig. 7 Typical Electric Field Contribution by service in a big city.

Regarding human exposure, in a real situation, a person is not only exposed to the above mentioned signals but to the resultant of the RF signals plus RF continuous noise. This RF noise is a complex signal that comprises thermal noise, harmonics, inter-modulation phenomena and cosmic radiation among others.

For the present work, two noise spectrum bandwidths were chosen: the 100kHz-500kHz band, where switching systems harmonics, power lines glitches and residual LF and MF communications can be found, and the upper mobile telephony spectrum between 2GHz and 5GHz. The 5GHz cutoff frequency was selected in order to compare the results with those obtained measuring with a broadband probe whose upper cutoff frequency is 5GHz.

Figure 8 shows the integrated Electric Field noise magnitude which is around 0.1V/m. This value may seem small, but it's quite close to field level provided by the mobile telephony as shown in Fig. 7.

All of these values obtained by the narrowband measurement method must be compared to those obtained by the broadband method, which for this case are around 3.45V/m.

Logically, the Electric Field value obtained by the broadband method is higher than the sum of the individual services plus the noise in the selected spectrum bandwidth.

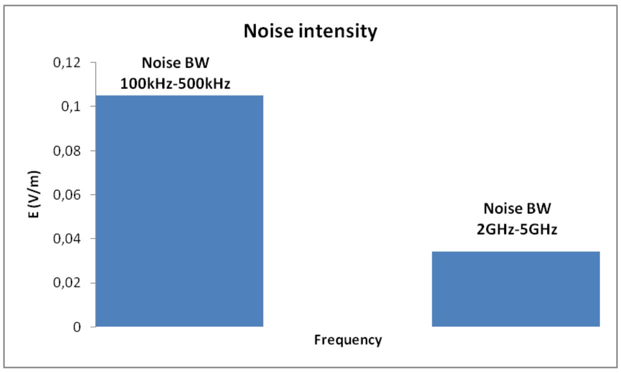

Fig. 8 Noise values for Low and High Frequency bands.

The broadband method computes all signals plus the noise over the total passband (in this case: 100kHz-5GHz).

The main interest of this paper is to analyze the real contribution of the MTS to the resultant Electric Field in a NIR measurement in comparison with the contribution of the rest of the services and the noise level, in order to make a proper evaluation of the measured values within the chosen exposure guidelines. It's clear to see that the Electric Field level of all MTS, which is 0,13V/m, is very similar to the contribution of the total noise measured in the two selected spectrums, which is 0,14V/m. It's well known that the noise level increases as you increase the bandwidth. For a band between 2GHz and 18GHz, the Electric Field measured value corresponding to the noise was 0,18V/m, clearly higher than that contributed by the MTS.

At this time, two particular situations should be pointed out: first, the integrated noise level is higher than the required by the MTS, and the higher the frequency of the broadband instrument (could be 18GHz or 40GHz, as typical) the broader the difference. Secondly, the concern of the population to follow stricter standards should be reconsidered, since even with the lowest limits like those of the Russian standard, Electric Field values contributed by MTS are, at least, 20 times lower.

While it is true that the standards discussion belongs to the bioelectromagnetics' field, the field measurements designed and performed by engineers should not have such an uncertainty that be high enough to mask the signal of interest.

4. Conclusions

As shown, the main source of NIR comes from the AM and FM broadcasting systems, which contribution to the resultant field is 10 times higher than that of the mobile telephony and has 24 hours continuous radiation, while MTS work under traffic demand.
In turn, the conventional measurement by the broadband method should be revised for the case of MTS characterization, since with low useful signal levels the magnitude of integrated noise in a very large bandwidth causes an unacceptable measurement error.

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