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TECHNICAL CONFIGURATION OF TV WHITE SPACE DEVICES: A CONCEPTUAL VIEW

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Abstract: As it is known, to eliminate interference, the frequency reuse approach is followed in digital TV (DTV) planning similar to cellular networks, avoiding the use of the same channel in two neighboring allotments. There are large areas where certain groups of TV channels are not deliberately used. They are called white spaces in TV spectrum (TVWS). Considering the great economical value of TV spectrum, it was proposed to use TVWSs for low-power wireless networking on non-interfering (secondary) basis with the licensed (primary) DTV service.

At the same time, restrictions imposed on white space devices (WSDs) to protect primary users should not devaluate spectrum for secondary use. The lack of knowledge about the locations of primary receivers, as well as the unreliable estimation of the aggregate interference impact caused by the large number of secondary devices accessing the spectrum are reported to be among the key challenges for the use of TVWSs.

In our view, parameters for the protection of primary system should be based on the determination of minimum separation distance, which by all means should be observed at a certain area. A required shadow margin, as well as a multi-user margin should be calculated for such a minimum safety range. To reuse spectrum efficiently, mobile/portable WSDs should support dynamic power control ability which has to play a key role in sensing and operate with the lower power??? when a TV signal is weak. Except for providing WSDs with a list of available channels, the geolocation database should contain recommended parameters for path loss calculations, as well as minimum distances which could be ensured for a certain inhabited locality.

Key words: TV white space; cognitive radio; white space device; spectrum sensing; geolocation database; opportunistic spectrum access; secondary use; aggregate interference; LTE over TVWS.

1. Digital TV, "white" spectrum, cognitive radio

As a result of the Regional Radiocommunication Conference (RRC06) being held in Geneva in June 2006, TV bands IV–V (470-862 MHz) were assigned to DVB-T usage and divided into 49 channels, each one 8 MHz wide. Region 1 was divided into geographical allotments and into the sets of frequency assignments for each of them. To eliminate interference, the frequency reuse approach is followed in DTV planning similar to a cellular network, avoiding the use of the same channel in two neighboring allotments [1]. So, there are always vast unused frequency bands between used TV channels. These areas are called "white spaces" in a television spectrum (TV white spaces, or TVWS: that is how they look like at a bandmap). DTV allocations are much larger than the size of cells in mobile communication, and as usual cover areas of several hundred square kilometers. Considering the economical value of TV spectrum due to perfect propagation characteristics and reasonable size of antennas, it was proposed to use these "white" frequency bands for low-power low-range wireless networking on non-interfering (secondary) basis with the licensed (primary) DTV transmissions.

The US Federal Communications Commission was a pioneer in developing the concept of using TVWS. In Europe these tasks are carried out by the CEPT Spectrum Management Group and the CEPT Spectrum Engineering Working Group (WGFM and WGSE). ETSI Reconfigurable Radio Systems Technical Committee is responsible for standardization efforts. Thus, increased spectral efficiency and great savings of spectrum after the transition to DTV makes a profit not only for broadcasting. Many services and applications could benefit from the secondary use of TVWS [2], for example:

- Wireless low power networks for hotspots and premises in TV bands, as an alternative to the highly congested industrial, scientific, and medical (ISM) band.
- Regional-area networking, especially suited to providing the Internet in areas with poor wireline infrastructure.
- 3G/4G networks extension over TVWS, complementing licensed spectrum usage: in particular, in femtocells to minimize interference to own macrocells.
- Short Range Devices, and others.

For the effective exploitation of TVWS it is necessary to develop mechanisms for determining TV channels which could be occupied by this or that secondary device and maximum effective isotropic radiated power (EIRP) allowed. This is the idea of so-

With no regard to it, the authors suggest a definition of their own: the near field is everywhere, where the measurements are performed. Although the boundary given by formula (1), in some sense, is in agreement with intuition locating the near field at distances of several ells from a source, with no regard to it, especially in the case of long-wave antennas or high gain antennas, it may be pretty several hundred of yards, far away of a source. Due to propagation phenomena, there may appear EMF of a structure and properties similar to those in the near field. It implies necessary caution during any EMF measurement and it has created an inspiration for the authors to define the boundary [2].

Concepts of widely applied solutions of EMF meters for both fields are presented in Fig.1.

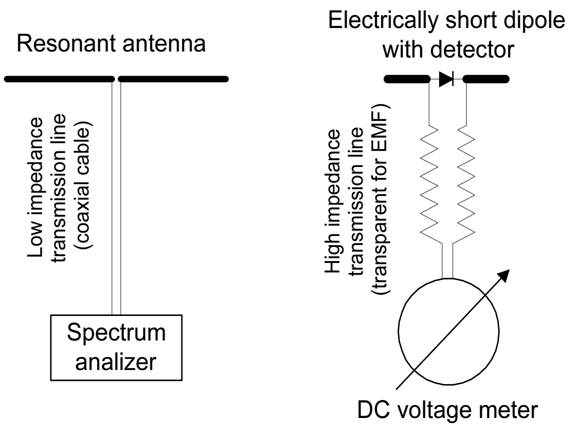

Fig. 1. EMF meter for the far field (left) and for the near field (right).

In the far field case, an antenna (usually resonant, often directional) is connected to an indicator (microvoltmeter, spectrum analyzer) via a matched cable. There are several exceptions from the idea, especially while low frequency fields are of concern, for instance, a whip antenna or loop antenna for E-field measurement, however, it does not change radically the presented concept. In the case of the near field measurements, a small size antenna, loaded by a detector, is connected to an indicator via a transparent line which is “invisible” to a measured field and does not affect the field. Also here any modifications and solutions are possible and acceptable; however, one parameter must remind unchanged, i.e the sizes of the antenna.

The issue of the antennas size is well discussed in the literature [2]. We would like only to remind the two most important factors limiting the size:

* Contrary to the far field, where, with acceptable simplification, we may assume the presence of a TEM wave (although such a wave, in free propagation, does not exist); in the case of the near field this is a spherical wave of three spatial components and remarkable curvature. The curvature causes measurement of an averaged (at the antenna) field and leads to an error of the measurement which is a function of the antenna sizes, distance to a source and its type.

* A small antenna is characterized by its input reactance. The reactance is affected by couplings between the antenna and material media close to it. A role, played here by surrounding, is similar to the above.

We may add here that the both errors may be assumed as negligible at distances exceeding sizes of an applied antenna. In order to neglect an influence of the phenomena on the meters, available on the market, a probe is often covered by a dielectric material of an appropriate diameter.

The last question: what size of an antenna is here acceptable? There is no univocal answer to the question. The size is to be selected for specific requirements of the measurement. Sometimes it must be as small as possible, for instance in EMF measurements close to a printed board or a microchip. In the case of measurements related to environment protection, it may be larger. The enlargement of the antenna’s size may be sometimes necessary to get required sensitivity and to limit instability and other undesirable effects while working with maximal sensitivity.

3. Selected solutions

In order to present specificity of the near field measurements, the authors propose several solutions that illustrate practical applications of the theoretical considerations.

* Selective meters

One of the oldest designs of the authors were selective EMF meters designated mainly to EMF measurements in transmitting centers for labor protection purposes. They are presented in Fig. 2.

Fig. 2. A selective H-field meter (left) and E-field meter (right).

In the solutions, no transparent separation between the antenna and indicator exists. In the H-field meter, the inductance of electrostatically screened loop takes a part of the resonant circuit. The separate antennas are applied to specific frequency ranges. The circuit is loaded by a detector and an analog indicator. In the case of the E-field meter, a symmetric dipole antenna (behind the meter) is coupled with a resonant circuit, switched for specific frequency ranges. Both antennas allow a single spatial component of the field to be measured. However, a possibility to turn the antenna and turning the meter on the tripod makes it possible to measure three field components.

The construction of the meters is, in some sense, “panzer”. It well illustrates the problems the authors had with screening and limitation a role of the field penetration into the meter via other ways than the meters antenna. It is a place to call attention that the problem is still not satisfactorily solved in many meters available on the marked.

* Integrated wideband meters

Wideband meters are the alternative to the selective meters preferred by sanitary and inspection services.

As a rule, a frequency response of a wideband meter should be flat within a frequency range. In the case of the E-field meter, it requires loading the measuring antenna by a high resistance detector (amplifier) while in the case of the H-field meter, an increasing, with frequency, effective high of the antenna must be compensated by a low pass filter connected between the antenna and loading it detector (amplifier). Such an approach is widely applied to different types of meters and probes available on the market.

The authors’ proposals of the integrated E- and H-field meters are presented in Fig. 3.

Fig. 3. An integrated wideband E-field meter (left) and H-field meter (right).

In the E-field meter, its antenna is a part of screening, while in the H-field meter, a loop antenna is connected to the rear wall of the meter. Both of them are placed at a dielectric handle and are designated mainly for measurements at the power line frequency and its harmonics.

* Universal wideband EMF meter

A concept of a universal wideband EMF meter is similar to that shown in Fig.1. A measurement procedure, using such a meter, is shown in Fig. 4. The upper photo demonstrates measurements with a meter in which a probe is connected directly to an indicator while the lower one shows a solution in which both components are connected by a cable.

Fig. 4. EMF measurements using an universal EMF meter.

An arbitrary probe is connected to an indicator (monitor). The probe includes an appropriate antenna (dipole or loop), filters shaping the frequency response and a detector. Output voltage of the system, in majority of E-field probes, is connected to an output of the probe through a transparent line. Then the probe may be connected with the indicator by a screened cable or may be connected directly to the casing of the indicator. The probes are prepared for specific frequency ranges, for required sensitivity and with different directional patterns.

The presence of transparent lines, separating a probe and a device (operator`s hand) may be seen in Fig. 4. The transparent lines are immersed inside of tubes made of dielectric material. The solution may make some problems, especially at the lowest frequencies, due to their charging with static charges.

* Directional pattern

In the above presented selective and wideband meters, a single antenna (dipole or loop) was applied. As a result, such a meter allows measurement of a single spatial EMF component. Such a solution has several advantages, for instance, it allows a source of radiation to be found. There may be a problem related to (It may be of concern in) quantifying measurements as a source of radiation is often unknown *a priori*. Although the solution allows the resultant field to be found by the way of separate EMF components measurement and the result to be calculated, however, such a procedure is troublesome and may lead to mistakes. Thus, by inspecting the services, for quantifying purposes, omnidirectional probes are preferred. The examples of such probes, proposed and completed by the authors are shown in Fig. 5.

Fig. 5. Spherical E-field (above) and H-field probe (below).

* Low frequency H-field sensor

In the H-field probe, shown in Fig. 5, the loops are placed coaxially. Such a solution is possible in probes for higher frequencies. For lower frequencies and required sensitivity, it would require multiturn loops of quite large diameter and weight. In order to limit sizes and the weight, a solution with ferrite rods was proposed. However, it the case, a coaxial placement of the three loops is impossible and they have to be placed at a distance on three mutually perpendicular axes as shown in Fig.6. The loops are loaded by amplifiers of shaped frequency response and then to an indicator that allows separate H-field components measurement or resultant H-field.

It may be noticed that the E-field probe, shown in Fig, 5, because of construction problems, has three separate sensors placed mutually skewed in three walls of the prism.

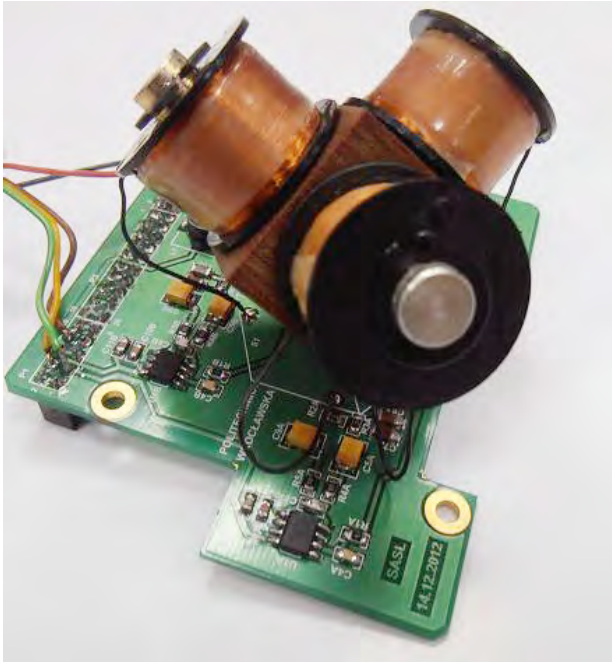

Fig. 6. An example of LF H-field probe.

4. Conclusion

As it could be seen from the presentation, both in the far field EMF measurements, and in the near field ones, a device that “pick-ups” the field is an antenna. Apart from large directional antennas, these are dipoles for E-field measurements and loops for H-field measurements. The main difference is in the sizes of the antennas. In the case of the near field, they should be as small as possible. The sizes here are usually a compromise between the sizes limitation and required sensitivity of the device.

As a result of more complex measuring procedures, in the near field measurements, there are more complex devices necessary for the measurements. Some specific solutions proposed by the authors illustrate attempts to the measurements optimization and increase in their accuracy.

Apart from the technical problems, there exists a specific problem concerning measuring teams. Far field measurements made for the purposes of propagation studies, EMC investigations, etc. are performed by the people experts in electromagnetics. Quantifying the measurements for evaluation of the hazard in terms of labor or for general public protection purposes are often performed by the people educated in biology, chemistry, and nonionizing radiation, etc. It often results in faults and mistakes. The best illustration of them are, for instance, presented in "scientific" papers or symposia presentations results of indoor EMF measurements using log-periodic, or similar directional antennas, E-field measurements with the use of commercially available meters with loop antennas (correct in the far field case), etc.

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РОЗВИТОК МЕТРОЛОГІЇ ЕЛЕКТРОМАГНІТНОГО ПОЛЯ В ЗОНІ ІНДУКЦІЇ

Павел Бєнковські, Віталій Нічога, Губерт Тшаска

У статті обговорено проблеми, пов'язані з вимірюванням електромагнітного поля в зоні індукції з метою охорони праці та захисту довкілля порівняно з вимірюваннями у дальній зоні.

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