Exposure Measurements of Modern Digital Broadband Radio Services

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***Short Abstract*—This paper describes methodologies for exact exposure measurements in the vicinity of modern digital broadband RF transmitters like DVB-T, DAB and UMTS stations. The measurement parameters for the spectrum analyser measurements are derived from the signal characteristics of the RF signals in frequency and time domain. Study designs of present measurement campaigns are also presented.**

Keywords - radiation protection, RF exposure, exposure measurements DVB-T, DAB, UMTS

I. Introduction

In the present debate about possible health risks of electromagnetic radiation, the location fixed RF transmitters like DVB-T, DAB and UMTS stations are still in the focus of the public discussion. Besides numerical field strength prediction techniques, especially exposure measurements have proven to be a practicable measure highly accepted in the public to show the compliance of transmitters with radiation protection guidelines and exposure limits.

Whereas GSM mobile phone base stations, analogue radio and TV transmitters are still operating for some years or decades with their exposure characteristics and field distribution widely studied [1-2], more and more digital broadband RF services like UMTS, DVB-T and DAB transmitters had come into operation during the last months.

These transmitters exhibit RF signal schemes completely different from narrowband, analogue RF services. Therefore, new measurement methodologies have to be developed to exactly capture all relevant components of the transmitted signal. Moreover, for time-variant signals like UMTS, techniques have to be developed to extrapolate the measured momentary value to the maximal operational state of the station, as is demanded in some exposure standards.

The correct measurement of modern digital broadband RF signals proves to be a challenge for the measurement personnel and the measurement apparatus and requires a deep understanding in the signal characteristics of the services as well as in the operational principles of modern RF measurement equipment. This is especially important due to the emotional driven exposure debate, where measurement errors may have disastrous consequences for the acceptance of these new communication services in the public.

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The paper starts with an analysis of the shapes of DVB-T, DAB and UMTS signals. From their characteristics in frequency and time domain demands for appropriate measurement equipment and actual measurement parameters are derived.

II. Signal Characteristics

A. DVB-T

For DVB-T, a multi-carrier modulation with COFDM (Coded Orthogonal Frequency Division Multiplexing) is used. The data stream is divided into several thousands of partial data streams. A very broad spectrum results with a bandwidth of 7.6 MHz in the UHF (470-862 MHz) and 6.6 MHz in the VHF (174-223 MHz) TV frequency range. Fig. 1 shows a real measured UHF DVB-T spectrum.

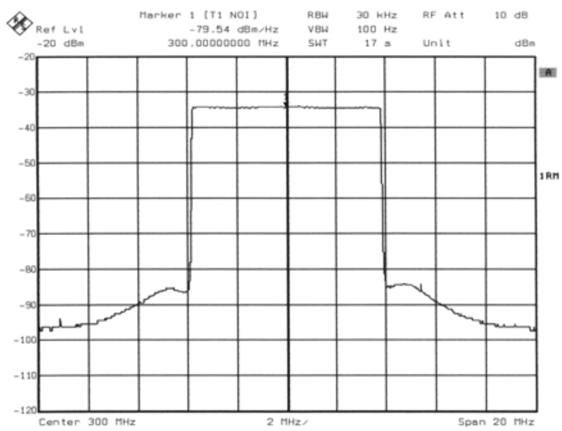

Figure 1. Spectrum of a DVB-T signal (UHF band)

In the time domain, the DVB-T signal exhibits a noise like character. Very typical for noise like signals is the large difference between short time maxima U_{Peak} and the RMS value U_{RMS} of the signal. This difference is described by the crest factor C [dB] as

$$C = 20 \cdot \log (U_{Peak}/U_{RMS}). \quad (1)$$

Crest factors at real DVB-T transmitters are in the range of 10 to 12 dB.

B. DAB

For DAB, the data stream is divided into about 1,500 different carriers. The modulation is COFDM as with DVB-T. For DAB, frequencies in the bands 174-230 MHz and 1452-1492 MHz are reserved. Presently in Germany primarily the band 223-230 MHz is used.

The DAB spectrum is very similar to DVB-T, but the signal bandwidth is only about 1.5 MHz. Fig. 2 shows a real measured DAB spectrum in VHF band.

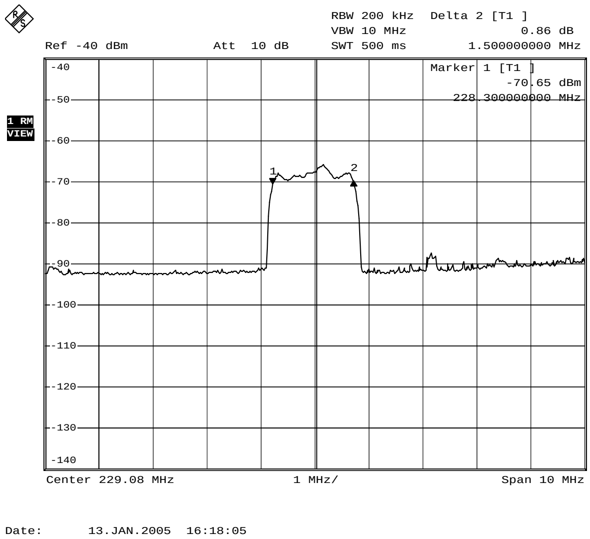

Figure 2. Spectrum of a DAB signal in VHF band

In time domain the DAB signal is also noise like with a crest factor of about 10 dB.

C. UMTS

UMTS uses a multiple access technique, where several users as well as the signalization is separated by different spreading codes (WCDMA - Wideband Code Division Multiple Access). By multiplication with the spreading code, the data signal is spread in the spectrum.

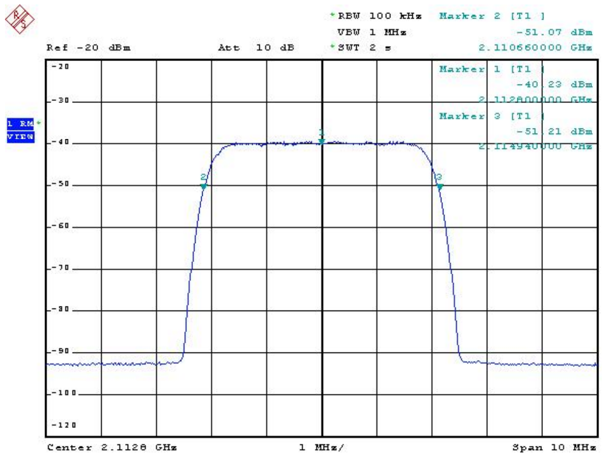

Figure 3. Spectrum of a UMTS signal

Fig. 3 shows a real measured UMTS signal in frequency domain. The 10 dB bandwidth is about 4.3 MHz, in the literature 4.6 MHz is often stated. In time domain UMTS signals are also noise like with typical crest factors in the region of 8 to 10 dB. In contrast to DVB-T and DAB, the crest factor at UMTS is not constant in time, but varies with the traffic of the station. The downlink frequency range for UMTS is 2110-2170 MHz.

Due to the power control of UMTS, the radiated power of a station is dependent on the transmitted data volume and the connection quality to the UMTS terminal. The minimal transmit power results from the permanent signalling. Presently, the stations are adjusted in that way, that 15 to 20 % of the maximal power is used by the signalling. The remaining is available in principle for the data channels, whereas a real UMTS station does not allow for transmit power more than 50 to 75 % of the maximal power.

Due to the power control a spectral measurement gives only the present exposure value, because the operational state of the station during the exposure measurement is not known.

III. CONSEQUENCES FOR THE MEASUREMENT TECHNIQUES

The investigations, reported about in this paper, deal with suited measurement techniques for the determination of the public exposure to modern digital broadband radio services. The public focus areas to be investigated exclude the “safety distance” and are located several tenth to several hundreds of meters away from the station. The available field strengths are as low, that broad band field probes can not be used due to their lack in sensitivity. Therefore, spectrum analysers or measurement receivers with appropriate receive antennas have to be used. As a method for the determination of the maximal exposure in a defined volume, the so called “sweeping method” is recommended. Here, the volume is scanned with a hand driven antenna with continuously polarization and direction changes to pick up the signal maximum. During the scan, the spectrum analyser runs in the “Max hold” mode to fix the maximum signal during the sweep.

The measurement parameters of the analyser, first of all resolution bandwidth and detector type, are important for the correctness of the measurement result. They have to be chosen in accordance to the measured signal. Here, many investigations with synthetically as well as real life signals had been carried out. The key results are described in the following.

A. DVB-T and DAB

For the exposure measurements it is of utmost importance, that the RMS power has to be determined instead of the short term maximal power. This is due to the thermal model of RF power reaction in the human body, which underlies the exposure limit concept.

A measurement of the peak power of the DVB-T signal overestimates the real exposure in the order of the crest factor. Therefore, for correct measurements the RMS detector of the analyser has to be used. Depending on the analyser type the sweep time has to be chosen large enough, because the RMS detector needs a lot of samples per frequency step to perform a real RMS computation. As an example, for measurements with modern Rohde & Schwarz analysers (e.g. ESPI-3) minimal sweep times of 100 ms are necessary. With the resulting 10 sweeps per second, also the “sweeping method” for volume maximum detection can be used with satisfactory accuracy.

The resolution bandwidth has to be chosen in accordance to the signal bandwidth, that is 6.6 or 7.6 MHz for DVB-T VHF or UHF bands and 1.5 MHz for DAB. If these large bandwidths are not available at the analyser, the measurements can be performed with the highest bandwidth available. The results have then to be corrected with a factor, which takes into account the signal bandwidth and the used resolution bandwidth. In this case, however, a tendency towards an overestimation of the real exposure was found. Channel power measurements are possible too, but in practice time consuming, because every channel has to be measured in a separate run. An exemption represents the Selective Radiation Meter SRM-3000 by Narda, where in “Safety Evaluation” mode a channel power measurement across several DVB-T channels in one single run is possible.

In the investigations, the reproducibility had been studied in conjunction with the defined measurement parameters. To that purpose, 10 consecutive measurements were performed in several Line-of-Sight (LOS) and non-LOS scenarios at indoor and outdoor measurement sites. Reproducibility was found to be in the order of ±1 dB. Taking into account the uncertainties of the measurement equipment, an overall measurement accuracy of ±3 dB can be achieved (confidence interval 95 %).

B. UMTS

Basically, exposure measurements in the surrounding of UMTS stations can be performed with spectral measurement techniques in a similar manner as for DVB-T and DAB. Due to the noise like signal characteristic with high crest factor, the RMS detector remains compulsory. The resolution bandwidth has to be chosen to 5 MHz. For older types of spectrum analysers channel power measurements or a smaller bandwidth with afterwards correction can be used alternatively, although in practical measurements especially in scenarios without direct sight to the base station (NLOS) a trend for an erroneous assessment of the exposure has been found [4]. The statements concerning sweep time are the same as for DVB-T/DAB.

As mentioned before, the UMTS signal varies strongly in time because of the power control mechanisms at the base station. The relevant exposure regulations, in Germany the 26. BImSchV [5], demand for an exposure assessment at the maximal operational state of the radio station. Because in reality it is not practicable to set the UMTS station to be measured artificially in the maximal operational state during the time of the measurement, extrapolation techniques for the measured temporary values have to be used. These techniques, known for example from measurements around GSM base stations [7], base on the measurement of signalling channels emitted from the station with a time constant power. By multiplying the measured exposure from the signalling channels with a factor, relating the maximal possible power of the station to the power of the signalling channels, the exposure at the maximal operational state of the station can be determined.

Whereas for GSM base stations these extrapolation technique can be performed in an easy way with spectrum analysers, this method does not work with UMTS. The reason is, that in UMTS signalling and transport channels are not separated in frequency as in GSM, but in different codes. Therefore an extrapolation for UMTS, based on frequency domain measurements, becomes strongly erroneous: As a worst case the measurement personnel must assume, that during the measurement only signalling, but no traffic was present. Under the assumption, that 15 % of the station power is used for signalling (this percentage can vary from station to station!) one has to multiply the measured exposure by 100/15=6.67 in terms of power unites to get the maximal exposure (another multiplication by a factor 2 has to be done to account for the second frequency channel, which is applied to the Federal Network Agency (BNetzA) by most network operators. Assuming that the station was actually in 50 % load during the measurements due to traffic, the real exposure would have been overestimated by 5.2 dB! Another argument against spectral measurement is the fact, that some network operators presently operate a three sector station only with one base station and a power splitter. This kind of station can not be detected during an ordinary frequency selective measurement which would result in an underestimation of the exposure.

These problems can be overcome with another kind of measurement technique: Instead frequency selective spectrum analysers code selective devices must be used, which offer the possibility to separate signalling and traffic channels in code domain. Among the signalling channels especially one channel is very important for an exact exposure extrapolation: The so called Primary Common Pilot Channel (P-CPICH) is permanent on air with a presently constant and well known amplitude (mostly 10 % of the maximal station power). Insofar code selective equipment, measuring the UMTS signal, decoding it and separating the P-CPICH from the other channels would resolve the problem.

Presently two types of measurement equipment are available on the market, which allows for an decoding of the UMTS signal and an extraction of the P-CPICH: Firstly spectrum analysers with a special WCDMA decoding software can be used (e.g. Rohde & Schwarz TS-EMF, i.e. spectrum analysers with decoding software RFEX, Narda SRM-3000). Secondly, separate devices, so called drive testers, can be used (e.g. Rohde & Schwarz Radio Network Analyser "TSMU"). The presented examples distinguish not only by WCDMA decoding, but also by providing a software especially adapted for exposure measurements concerning human safety in electromagnetic fields. Fig. 4 shows as an example the output of an UMTS measurement with Rohde & Schwarz RFEX software. “Scr. Code” stands for “Scrambling Code”, which distinguishes different UMTS base stations.

The devices TSMU, SRM-3000 and TS-EMF were tested extensively and found to give reproducible and accurate UMTS exposure measurement results [4]. TSMU and SRM-3000 offer in addition to a fast mode also a slow measurement mode, which has to be preferred to get the more accurate results. Slow mode requires very slow sweeping speed in the measurement volume, because otherwise the exposure was found to be underestimated and the spread in results between consecutive measurements increased.

Scr. Code	Frequency	Field strength	Power density
	MHz	V/m	µW/cm²
22	2112.8	0.145	5.58E-03
105	2112.8	0.0106	2.98E-05
375	2112.8	0.023	1.40E-04
175	2167.2	0.047	5.86E-04
Sum (RMS):		0.1545	V/m
Sum (Square):		0.0239	V/m
Max. Value:		0.1450	V/m

Figure 4. Example of a UMTS measurement output

The absolute sensitivity of the tested code selective measurement systems is in the area of -100 dBm (measured as P-CPICH level from a signal generator connected to the code analyser). Taking into account typical antenna factors and cable losses, field strengths in the range of the minimal necessary field strengths for UMTS coverage can be detected. When several UMTS signals are present at the same time, the dynamic decreases to typ. 20 dB, i.e. signals on the same carrier frequency, which are more than 20 dB below the strongest signal, cannot be detected.

The reproducibility of several consecutive measurements in different scenarios was measured to be ±1.8 dB. This value is somewhat worse than with frequency selective DVB-T or DAB measurements, which may be due to the code selective algorithm in the measurement apparatus. Taking into account the uncertainties of the measurement equipment, an overall measurement accuracy of ±3 dB can be achieved (confidence interval 95 %).

As measurement antennas for the UMTS downlink frequency range 2110-2170 MHz 3-axis isotropic antennas (as provided with the Rohde & Schwarz TS-EMF and Narda SRM-3000 devices) as well as logarithmic-periodical (log.-per.), dipole or horn antennas can be used. All these types were tested to user influence, i.e. the question was investigated, to which degree the person holding the antenna during the measurement influences the results in comparison to the "free space" case. As a result it was found, that log.-per. and horn antennas offer only minimal influence of about 0.1-0.2 dB compared to free space, whereas with dipole and isotropic antenna differences up to 2 dB, at direct contact of the person to antenna even more, have been measured. Taking also practicability considerations into account, log.-per. antennas should be preferred for UMTS exposure measurements with the sweeping method. In comparison to the 3-axis probes, log-per. antennas provide also an increase in decoding rate, because at the 3-axis probes the axes are switched sequentially, resulting in a 3 times longer measurement time compared to 1-axis antennas.

IV. FUTURE WORK

The investigations reported about in this paper are part of two studies for the German Federal Office for Radiation Protection. The development of suited measurement techniques serves as a base for a comprehensive measurement campaign. The study design is as follows:

Concerning DVB-T and DAB, an extensive measurement campaign at more than 200 measurement points is carried out presently in the surrounding of DVB-T transmitter locations in the Munich and Nuremberg area. By comparing the exposure results with measurements of analogue TV exposures, taken at identical measurement locations before, it is possible to detect changes in the exposure of the public due to the introduction of the DVB-T transmitters. Concerning DAB, the comparison is performed to the FM radio network.

Concerning UMTS, the field distribution around several typical Node B base station configurations will be measured to get a knowledge about the real public exposure situation in the vicinity of UMTS stations. An interesting point in the investigation is the additional measurement of GSM signals around stations, which transmit GSM and UMTS services simultaneously. In that way, differences between both exposure parts can be investigated. The UMTS measurements also cover long time measurements to study in influence of traffic in the UMTS network on the exposure situation.

The results of the measurement parts of both studies will be published in the future.

REFERENCES

[1] Chr. Bornkessel, M. Neikes and A. Schramm, “Elektromagnetische Felder in NRW - Untersuchung der Immissionen durch Mobilfunk-Basisstationen”, Study for the Ministry of Environment and Nature Conservation, Agriculture and Consumer Protection Nordrhein-Westfalia, Final Report, IMST GmbH, Kamp-Lintfort, 2002.

[2] Chr. Bornkessel and M. Schubert, “Entwicklung von Mess- und Berechnungsverfahren zur Ermittlung der Exposition der Bevölkerung durch elekrtromagnetische Felder in der Umgebung von Mobilfunk Basisstationen”, Study for the German Federal Office for Radiation Protection, Interim Report “Analyse der Immissioneverteilung”, IMST GmbH, Kamp-Lintfort, 2004.

[3] M. Schubert, Chr. Bornkessel and M. Wuschek, “Bestimmung der Exposition der Bevölkerung in der Umgebung von digitalen Rundfunk- und Fernsehsendern”, Study for the German Federal Office for Radiation Protection, Interim Report “Entwicklung und Beschreibung eines Verfahrens zur Expositionsabschätzung”, IMST GmbH, Kamp-Lintfort and EM-Institut GmbH, Regensburg, 2005.

[4] Chr. Bornkessel, M. Schubert and M. Wuschek, “Bestimmung der realen Feldverteilung von hochfrequenten elektromagnetischen Feldern in der Umgebung von UMTS-Sendeanlagen”, Study for the German Federal Office for Radiation Protection, Interim Report “Entwicklung geeigneter Verfahren”, IMST GmbH, Kamp-Lintfort and EM-Institut GmbH, Regensburg, 2005.

[5] Chr. Bornkessel, M. Schubert and M. Wuschek, “Bestimmung der realen Feldverteilung von hochfrequenten elektromagnetischen Feldern in der Umgebung von UMTS-Sendeanlagen”, Study for the German Federal Office for Radiation Protection, Interim Report “Entwicklung geeigneter Verfahren”, IMST GmbH, Kamp-Lintfort and EM-Institut GmbH, Regensburg, 2005.

[6] 26. BImSchV, Sechsundzwanzigste Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes (Verordnung über elektromagneti-sche Felder – 26. BImSchV), BGBl. Jg. 1996 Teil I Nr. 66, 20.12.1996.

[7] Messempfehlung für GSM-Basisstationen, Bundesamt für Umwelt, Wald und Landschaft (BUWAL) und Bundesamt für Metrologie und Akkreditierung (METAS), Bern, 2002.

Document Includes RF Exposure Info RF Exposure Info MPE.Â Prediction of MPE at a given distance 1. Limits The criteria listed in the following table shall be used to evaluate the environment impact of human exposure to radio frequency (RF) radiation as specified in 1.1307(b) Frequency range Electric field strength (MHz) Magnetic field strength (V/m) (A/m) Power density (mW/cm) Averaging time (minutes) (A) Limits for Occupational/Controlled. Exposures 0.3â€“3.0 614 1.63 *(100) 3.0â€“30 1842/f 4.89/f *(900/f2) 30â€“300 61.4 0.163 1.0 300â€“1500 f/300 1500â€“100,000 (B) Limits for General Population/Uncontrolled Exposure 0.3â€“1.34 614 1.63 *(100) 30 1.34â€“30 824/f. Exposure Measurements of Modern Digital Broadband Radio Services. D. Bornkessel, M. Wuschek. 2006. Short Abstractâ€"This paper describes methodologies for exact exposure measurements in the vicinity of modern digital broadband RF transmitters like DVB-T, DAB and UMTS stations. The measurementâ€¦ Expand. 4. Open Access. Save. Alert. Citizens Broadband Radio Service (CBRS) is a 150 MHz wide broadcast band of the 3.5 GHz band (3550 MHz to 3700 MHz) in the United States. In 2017, the US Federal Communications Commission (FCC) completed a process which began in 2012 to establish rules for commercial use of this band, while reserving parts of the band for the US Federal Government to limit interference with US Navy radar systems and aircraft communications. Exposures from devices held further away from the body such as wireless-enabled laptop computers, and transmitter masts in the community are very much lower than those from mobile phones and PHE considers that community or individual measures to reduce such exposures are unnecessary. See also the advice of the NPRB on reducing exposure to radio waves. Contents. Print this page. With 16 digitally implemented resolution bandwidths from 200 Hz to 1 MHz, the R&S FS300 can be optimally configured to perform narrowband measurements of the RF-fields generated by both GSM 900 and GSM 1800 base station antennas. Unfortunately, this instrument has no RMS detector (it has only positive peak detector), which is usually preferred when assessing the RF exposure originating on UMTS systems [1]Because the R&S FS300.Â (2006). Exposure measurements of modern digital broadband radio services. in Proc. GeMiC 2006 - German Microwave Conference. Karlsruhe. pp. 1-4.