INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH VOLUME 6, ISSUE 06, JUNE 2017 ISSN 2277-8616

Method Analysis For The Measurement Of Electromagnetic Field From LTE Base Stations

Fahad Faisal

Abstract: This paper is focused to analyze the proposed methods for in-situ measurements of electromagnetic fields transmitted by LTE base stations. One of the methods is based on measurements of physical broadcast channel (PBCH) using basic spectrum analyzer, whereas the other method is based on measurements of the reference signal (RS) using a decoder. Both alternatives are proposed to be used for extrapolation to the maximum electromagnetic field exposure level at full base station traffic load. The analysis is conducted with respect to instrument requirements, accuracy and time requirements. Different instrument settings of the spectrum analyzer and their impact on the measurement results is analyzed and discussed. Measurements using the spectrum analyzer method overestimate the electric field strength compared with the LTE decoder method in ≈ 70 % of all measurement cases in this work. All spectrum analyzer based measurements conducted in the main beam of an antenna at distances of less than 100 m were within ± 20% compared with the decoder results. Measurement results obtained in a reflective environment show that both methods are affected by fading, but significant deviations between the two methods indicate that the spectrum analyzer method is more sensitive to frequency selective fading.

Index Terms: 3GPP, EMF, IN-SITU, LTE, MIMO, PBCH, RMS.

◆

1 INTRODUCTION

Radio base station equipment use radio frequency (RF) electromagnetic waves for wireless communication with mobile terminals. A large number of studies have been conducted on electromagnetic fields (EMF) and possible health effects during the past 50 years, based on which national and international exposure guidelines and standards have been developed. For mobile communication frequencies, the International Commission on Non-Ionizing Radiation Protection (ICNIRP), provides basic restrictions in terms of specific absorption rate (SAR) [1]. Limits are given for both Localized and Whole-body averaged SAR to prevent from established adverse health effects associated with whole-body heat stress and excessive localized tissue heating. For practical exposure assessment purposes, ICNIRP also provides reference levels in terms of electric field strength (V/m), magnetic field strength (A/m) and power density (W/m2). Compliance with the reference levels assures compliance with the basic restrictions but field strength levels higher than the reference levels do not necessarily mean that the basic restrictions are exceeded.

2 LITERATURE REVIEW

To make sure that the EMF exposure associated with wireless products and services is below applicable limits, different standards have been developed. One of these standards, EN 50492 [2], specifies how to conduct in-situ measurements of RF exposure levels in the vicinity of base stations in operation. This standard contains specific information on how to conduct measurements for GSM and WCDMA base stations and currently this standard is being updated to also cover measurements for LTE (4G) base stations. In-situ measurement procedures can be used to verify that the EMF exposure level is below the applicable limit in areas to which the general public or workers have access. The measurement area can e.g. be an apartment, an office, or a roof-top terrace.

The procedure [3] for in-situ measurements is based on guidelines, requirements and recommendations from different International and European standards [2], [4], [5], [6], [7] and should be updated with guidance for LTE base station EMF exposure assessments based on the results of this work and the new version of EN 50492. When verifying compliance with exposure limits, the maximum exposure level is often of interest, i.e. the exposure level obtained when the base station is transmitting at maximum power (for maximum traffic). In order to determine the maximum exposure level, an extrapolation of the measurement value for a specific channel/signal transmitting at a constant and known output power level (regardless of traffic load) is required. Based on the ratio of the maximum output power of the base station and the known power level of the assessed channel/signal the maximum exposure level can be determined. EN 50492 describes extrapolation methodologies applicable to GSM and WCDMA. Similar methodologies for LTE have been proposed [8]. One method is based on the use of a dedicated LTE decoder, which is similar to the existing methods that are based on pilot signals [2] and another method is based on the use of a basic spectrum analyzer. The objective of this work is to analyze the two proposed methods for LTE exposure measurements in order to recommend a suitable procedure and to provide some guidance on how to determine the maximum exposure level from LTE base stations in operation. Secondly, the impact of spectrum analyzer settings for one of the methods is also analyzed.

2.1 LTE Basics

The 3rd Generation Partnership Project (3GPP) was formed jointly by T1, ARIB, TTC, ETSI and TTA in December 4, 1998 [9]. The initial purpose of 3GPP was to provide technical reports and technical specifications for third generation mobile system based on evolved Global System for Mobile communication network which will be globally applicable [9]. Right now more than 50 companies and research institutes are participating in the largest joint standardization effort ever to specify the new world wide radio access and evolved core network technology, LTE [10]. LTE is targeted for VoIP and data rates up to 100 Mbit/s, and is specified in 3GPP Release 8. LTE consists of emission of signals at specific time frequency allocation [11], [12]. The frequency allocation

---

- *Fahad Faisal, E-mail: fahfa930@student.liu.se*

method used for LTE is dynamic. LTE signals are subject to time variations due to the random fluctuations of propagation medium and traffic variations. For downlink operation LTE utilizes Orthogonal Frequency Division Multiple Access (OFDMA) technique. The downlink operation of LTE is very efficient due to its flexible bandwidth (1.4 MHz up to 20 MHz). LTE supports both Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD) for operation. LTE also supports MIMO antenna configurations to increase the data rate.

2.2 Specifications of LTE

The most important specifications [13] for LTE are:

- High Data Rates: Downlink > 100 Mbps, Uplink > 50 Mbps.
- Spectrum Flexibility: Scalable bandwidths of 1.4, 3, 5.0, 10.0, 15.0 and 20.0 MHz with support for both TDD (Time Division Duplexing) and FDD (Frequency Division Duplexing) [14].
- Simplicity: Less signaling with auto configuration for eNodeB (Plug and Play).
- Supported antenna configurations: Downlink: 4x2, 2x2, 1x2, 1x1 , Uplink: 1x2, 1x1
- Mobility: Optimized for low speeds (<15 km/hr.), High performance at speed up to 120 km/hr.
- Coverage: Full performance up to 5 km, slight degradation after 5 to 30 km.

2.3 Radio interface description (downlink)

LTE radio-access architecture consists of a single node which is called eNodeB[1]. The eNodeB communicates with one or several mobile terminals (MTs). The experiment, we are supposed to do Fig. 1 shows the overall LTE radio protocol interface architecture for the downlink [15].

2.3.1 Downlink Transmission Technique

LTE utilizes Orthogonal Frequency Division Multiplex (OFDM) technique for the downlink channel. In LTE, the smallest modulation structure is a Resource

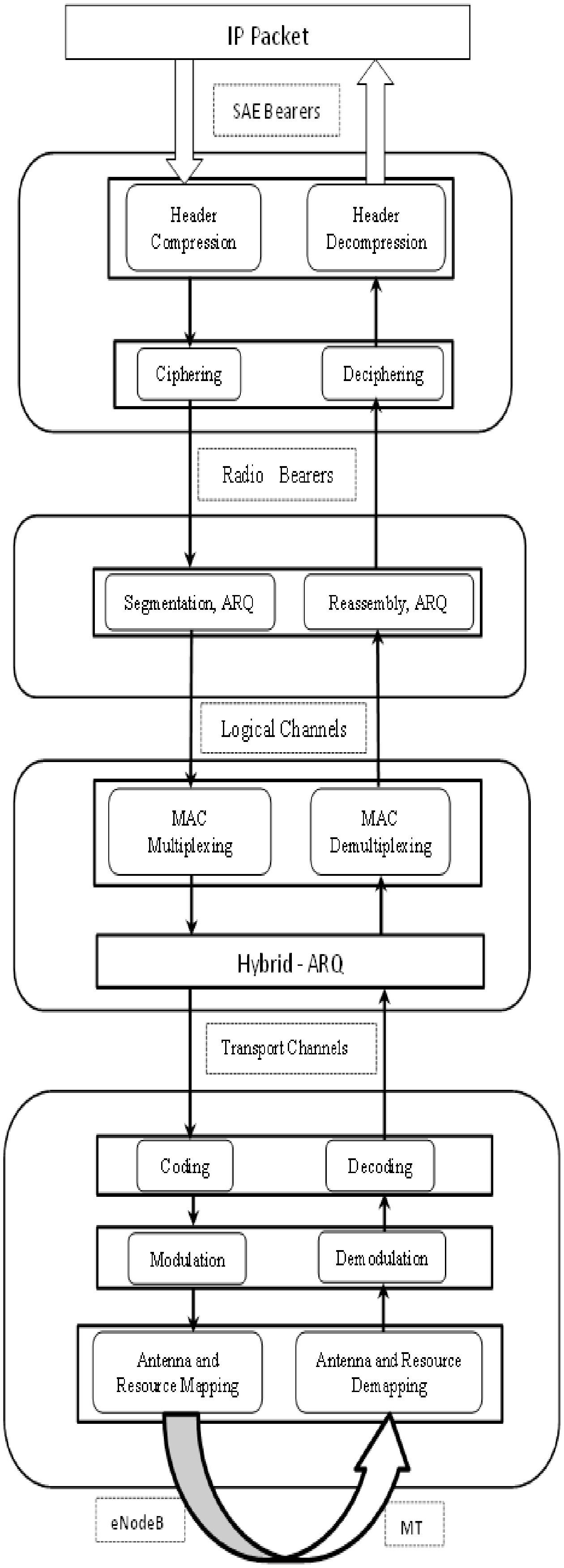

Fig. 1. *LTE radio protocol interface architecture (Downlink) [15]*

Element (RE). A resource element is one 15 kHz sub-carrier[2] occupied by one OFDM symbol. The downlink subcarriers are grouped into resource blocks, where each resource block consists of 12 consecutive sub-carriers by 7 OFDM symbols (assuming normal cyclic prefix). Each resource block, thus corresponds to 84 resource elements [15] as shown in Fig. 2.

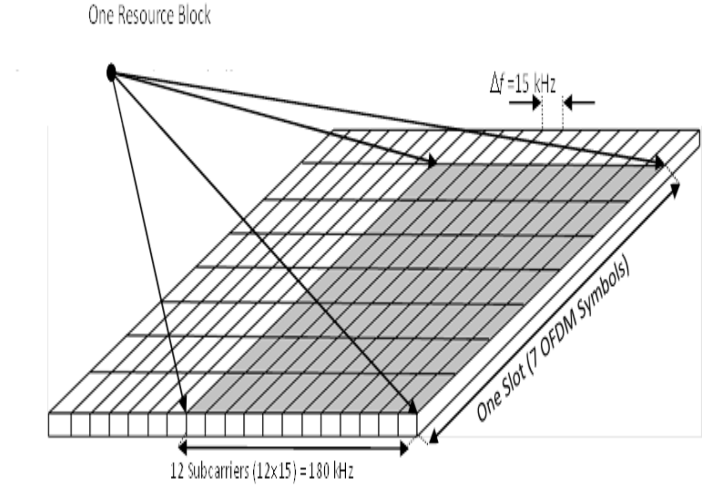

***Fig. 2.** Resource Block in Time-Frequency Domain (Downlink)*

2.4 Downlink Reference Signal

Downlink reference signals are used by the MT for downlink channel estimation to enable coherent detection and are inserted in the OFDM (time/frequency) grid. There are three types of reference signals for LTE downlink [15]. They are:

a) Cell-specific Reference Signals (CRS)
b) Multicast Broadcast over Single Frequency Network (MBSFN)
c) UE-Specific reference signals

Cell-specific Reference Signals (CRS):

Cell specific reference signals are used for channel estimation and span over the entire downlink cell bandwidth. It enables the mobile terminal to determine the phase reference for the demodulation of downlink control channel [15]. The cell specific reference signal pattern for a single transmit antenna in OFDM is shown in Fig. 3 [12].

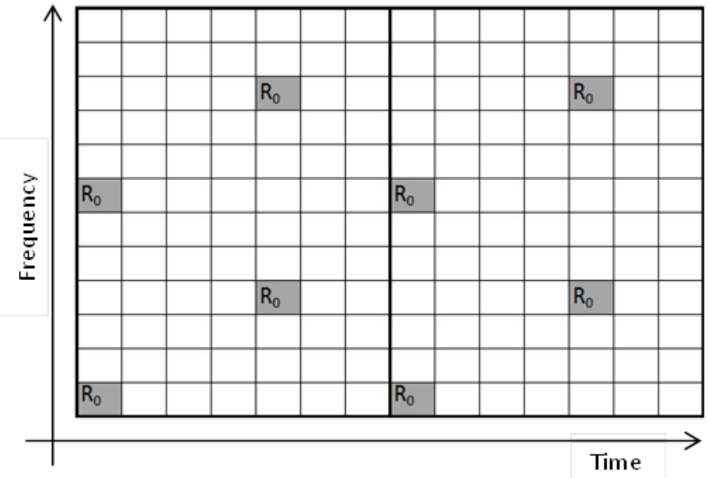

***Fig. 3.** Cell specific reference signal pattern for single antenna port [12]*

For a single transmit antenna, a single cell-specific unicast reference signal is inserted into the time-frequency grid. The reference symbols are inserted within the first and third last OFDM symbol of each slot with one reference symbol at every sixth subcarrier in frequency domain [17]. Each resource block (RB) contains four reference symbols.

3 ONGOING STANDARDIZATION

In the current draft of the EN 50492 standard for in-situ RF exposure measurements; both a dedicated LTE decoder based method and a method based on the use of a basic spectrum analyzer can be used for the assessment of the maximum theoretical RF exposure level from an LTE base station.

3.1. Maximum exposure assessment method using dedicated LTE decoder

Using this method, the reference signal (RS) E-Field from the antenna(s) is measured and extrapolated to the maximum traffic case value with an extrapolation factor. Equipment: Dedicated LTE equipment or LTE analyzers (in our case Rohde & Schwarz FHS-4 handheld analyzer with LTE option) and suitable probe (in our case Rohde & Schwarz tri-axial isotropic antenna, TS EMF-B1) which cover the LTE frequency band. Procedure: To estimate the worst-case value or the maximal exposure level (Emax,DEC) [18] of the LTE signal at each measurement location, equation (1) shall be used:

$$E_{\max,DEC} = \sqrt{\frac{\eta_{RS}}{BF}} \times E_{RS} \qquad \textbf{(1)}$$

Where,
E_{RS}=Total E-Field Value for the Reference Signal (V/m)
η_{RS}= Total number of occupied subcarriers
BF= Boosting Factor

If we consider the E-Field from all antennas to be uncorrelated, then the total E-Field for a (N × M) MIMO case is-

$$E_{RS} = \sqrt{\sum_{k=1}^{N} E_{ant-k}^{\ 2}} \qquad \textbf{(2)}$$

3.2. Determining the total number of subcarriers

All subcarriers are not used for LTE transmission. The central subcarrier is not transmitted and approximately 10% of the total subcarriers at the channel edge are used as guard carriers [16]. Different channel bandwidth and the corresponding number of occupied subcarriers are shown in Table 2 [14].

TABLE 1.
TOTAL NUMBER OF OCCUPIED SUBCARRIER FOR DIFFERENT CHANNEL BANDWIDTH

Channel Bandwidth, $BW_{CHANNEL}$ (MHz)	Total number of occupied sub-carriers
1.4	72
3	180
5	300
10	600
15	900
20	1200

4. ASSESSMENTS TO DETERMINE THE INFLUENCE OF DIFFERENT SPECTRUM ANALYZER SETTINGS FOR PBCH MEASUREMENTS

The influence on the results when measuring the electric field strength of the PBCH using different sweep time or span is analyzed below in Sections 4.1 and 4.2.

4.1. Influence of Sweep Time

The sweep time plays a vital role for the assessment result. Exact sweep time is needed for RMS detector to obtain the integration time close to the symbol duration for each pixel. The sweep time is calculated by multiplying number of display points with symbol duration (66.7 µs). The spectrum analyzer used in the test had 631 display points, which corresponds to (66.7 µs× 631) ≈ 43 ms. For a spectrum analyzer with higher or lower display points should be calculated accordingly. To study the influence, laboratory measurements of the PBCH were performed with different sweep time starting from 20 µs up to 20 s including the exact sweep time proposed in ongoing standardization (43 ms for our case). The result is shown in Fig. 4.

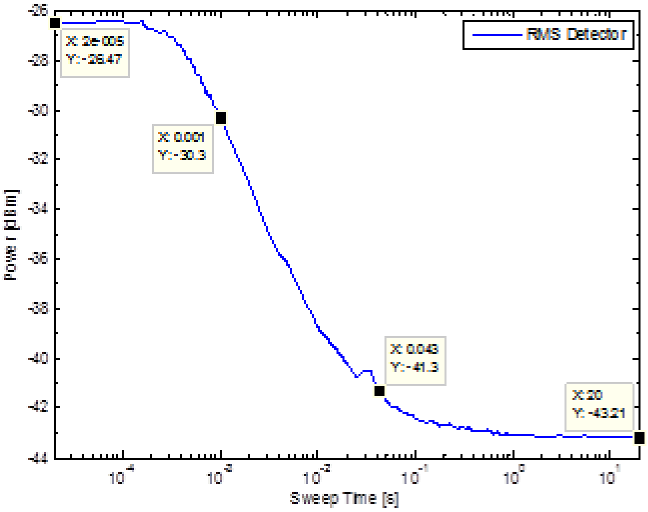

Fig.4. *Sweep Time vs Power using max-hold for 20s*

From the figure above it is evident that selecting an appropriate sweep time is essential for the accuracy of the results. The reason for the high values with the shortest sweep time is that, when using the max-hold function together with an extremely short sweep time; the rms detector will work as a peak detector as it has very few samples to integrate over. The results are in agreement with [19]. In this analysis, the deviation between the largest sweep time and exact sweep time according to ongoing standardization is very low (2 dB). The reason for this was that the traffic load was 100% with data and control channel having the same power. It can be expected that corresponding measurements for a real site with lower traffic load would result in larger differences between the results for correct sweep time and the largest sweep time. The difference between the shortest sweep time and exact sweep time according to ongoing standardization is high (15 dB). The reason for this was most likely due to the configuration of the LTE signal generator and this large difference is not expected in a real scenario. An OFDM signal has a peak-to-average ratio of approximately 10 dB, when peak-to-average reduction methods are not used. This indicates that the laboratory generated LTE signal in this test was not fully realistic, but on the other hand this assessment was conducted in order to show the importance of correct a sweep time setting in general. For RMS detector measurements, the averaging time depends on the ratio of Sweep Time and Number of Display point (SWT/Display Point) resulting in slower measurements for longer sweep time. As PBCH is send only over the second slot (first subframe) of a whole frame, noise like samples where the PBCH is not transmitted will be included in the integration for longer SWTs. As a result, the PBCH value will be underestimated for longer sweep times.

4.2. Influence of SPAN

Span basically defines the frequency range of interest, where the measurement will be performed. In Fig. 5, laboratory measurements of power with respect to various span settings are presented. According to ongoing standardization, the measurement should be performed in time domain (Zero Span) mode. The highest deviation obtained was 0.75 dB indicating that span has very little influence on the result and it is near to the measurement uncertainty of the instrument. But it is preferred to perform the measurement in time domain (zero span). In zero span mode the spectrum analyzer will be working as an oscilloscope, where different amplitude levels will be detected with respect to time. Thus if duration of the signal is known, the desired value can be obtained from the measurement.

5.1. Sweep Time Analysis with Proposed Method

A test with different sweep times for PBCH measurement was also performed. The main reason behind the test was to confirm the recommended settings in ongoing standardization. Some random sweep times were selected; starting from very short time (200 µs) upto a very large sweep time (20 s). The deviation summary for different sweep times is given in Table 2.

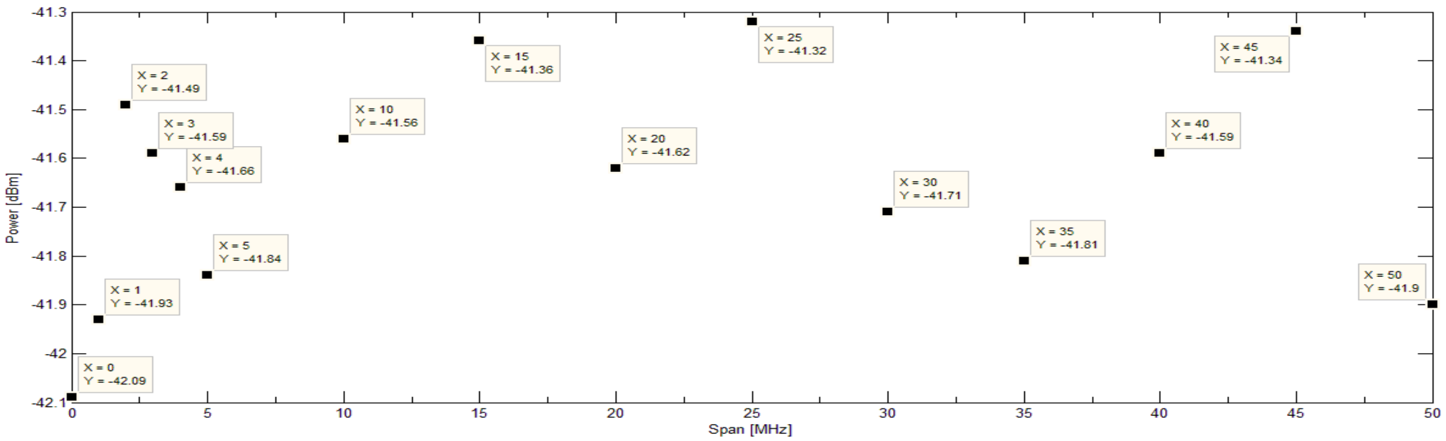

Fig. 5. *Span vs Power*

TABLE 2.
DIFFERENT SWEEP TIME ANALYSIS FOR PROPOSED ONGOING STANDARDIZATION

Sweep Time	RBW (MHz)	Emax,$_{\text{DEC}}$ (V/m)	Emax,$_{\text{SA}}$ (V/m)	Deviation
200 μs	1	1.18	3.54	200%
300 μs	1	1.18	3.77	219%
400 μs	1	1.18	3.75	218%
500 μs	1	1.18	3.59	204%
600 μs	1	1.18	3.4	188%
20 ms	1	1.18	1.9	61%
30 ms	1	1.18	1.8	53%
43 ms	1	1.18	1.68	44%
50 ms	1	1.18	1.79	52%
60 ms	1	1.18	1.77	50%
5 s	1	1.18	0.55	-53%
10 s	1	1.18	0.54	-54%
15 s	1	1.18	0.55	-53%
20 s	1	1.18	0.54	-54%

Table 2 shows that the use of an appropriate sweep time is important for rms detector measurements, where we found that using the exact sweep time proposed on ongoing standard will provide less deviations comparing with other sweep time in real site. When comparing the raw data with the results of section 5.1 where the measurements were performed in lab, it was found that the differences between exact sweep time (according to ongoing standardization) and largest sweep time for lab measurement and in-situ measurement are 1.91 dB and 9.90 dB respectively. The reason for this is that all the measurements performed in the lab were configured with 100% traffic, whereas the in-situ measurements were performed with a traffic load of 0-5 %. As a result the difference was larger for the in-situ measurement than for the laboratory measurement. For real LTE signals a peak-to-average ratio reduction method is often employed and the expected difference between the results for the shortest sweep time and the exact sweep time is around 8 dB. The difference between exact sweep time (according to ongoing standardization) and shortest sweep time for in-situ measurement is 6.37 dB, which is consistent with results obtained by Wout et al (Ghent University).

5 CONCLUSION

The decoder method was taken as the reference method throughout this work. This assumption was based on the fact that decoding the signal adds confidence in the results, since the user can be certain that the measured result is adherent to the considered base station antenna and not influenced by other sources. Here, only the contributions from the considered LTE antenna are included in the measurement result. The measurement of the PBCH, on the other hand, may be influenced by other nearby LTE sources. Also for the measurements in a reflective environment the decoder method was taken as the reference, since it was assumed that the spectrum analyzer method is more sensitive frequency selective fading. It is evident from table 2 that both methods were significantly affected by fading in general, but since the deviations between the two measurement methods were varying significantly between the measurement points this assumption was most likely correct. In [2] a maximum field strength search is recommended when conducting measurements in a reflective environment in order to avoid measurements in local minimas. In addition, spatial averaging should be used to reduce the impact of local minima or maxima.

REFERENCES

[1] ICNIRP, "Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)", Health Physics, vol. 74, no. 4, pp. 594–522, April 1998.

[2] CENELEC EN 50492:2008, "Basic standard for the in-situ measurement of electromagnetic field strength related to human exposure in the vicinity of base stations", European Committee for Electrotechnical Standardization (CENELEC) Std., November 2008.

[3] EAB-05:043776 Uen, "Ericsson procedure for in-situ measurements of RF exposure levels from radio base stations", April 2010.

[4] IEEE-SA Standards Board, "IEEE Recommended Practice for Measurements and Computations of Radio Frequency

Electromagnetic Fields With Respect to Human Exposure to Such Fields, 100 kHz–300 GHz", pp. i–126, January 2003. [Online]. Available: http://¬ieeexplore.ieee.org/¬servlet/¬opac?punumber=8351

[5] ECC/REC/(02)04, "Measuring Non-Ionising Electromagnetic Radiation (9 kHz – 300 GHz)", October 2003.

[6] CENELEC EN 50400, "Basic standard to demonstrate the compliance of fixed equipment for radio transmission (110 MHz - 40 GHz) intended for use in wireless telecommunication networks with the basic restrictions or the reference levels related to general public exposure to radiofrequency electromagnetic fields, when put into service", European Committee for Electrotechnical Standardization (CENELEC) Std., June 2006.

[7] 62232 IEC:2011, "Determinnation of RF Field Strength and SAR in the Vicinity of Radio Communication Base Stations for the Purpose of Evaluating Human Exposure", INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC) Std., Rev. 27, May 2011.

[8] W. Joseph and L. Verloock, "LTE measurement", Tech. Rep., December 2011.

[9] 3GPP PPA:1998, "Third Generation Partnership Project Agreement", December 1998.

[10] Ericsson: LZT123 8828 R2A, "LTE/SAE System Overview", Ericsson, Tech. Rep. LZT 123 8828, 2008.

[11] 3GPP TS36.201, "Long Term Evolution (LTE) physical layer General description", 3GPP Std. 9, Rev. v 9.1.0, March 2010.

[12] 3GPP TS 36.211, "Physical Channels and Modulation", 3GPP Std. 9, Rev. v9.1.0, March 2010.

[13] J. Zyren, "Overview of the 3GPP Long Term Evolution Physical Layer", no. 3GPPEVOLUTIONWP, p. 1, July 2007.

[14] ETSI TS 136 104 V10.5.0, "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception", Electronic, European Telecommunications Standards Institute Std. v10.5.0, Rev. 10, January 2012.

[15] E. Dahlman, S. Parkvall, J. Sköld, and P. Beming, "3G Evolution : HSPA and LTE for Mobile Broadband", 2nd ed. Elsevier Ltd, 2008.

[16] Telesystem Innovations Inc., "LTE in a Nutshell: The Physical Layer," pp. 10–11, May 2010.

[17] M. Baker, S. Sesia, and I. Toufik, "LTE – The UMTS Long Term Evolution From Theory to Practice", 2nd ed. John Wiley & Sons Ltd., 2011.

[18] Annex L: LTE measurements, to be included in next edition of EN 50492, latest draft sent to CENELEC TC106X, 2012.

[19] L. Verloock and W. Joseph, "LTE Meeting Paris", no. 1. IBBT-Ghent Wireless & Cable research group, October 2011, p. 3.