The Wideband Approach of 5G EMF Monitoring

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Abstract. The 5G mobile telephony become one of the worldwide most anticipated technology, which is followed by strong controversy regarding potentially dangerous health effects. This technology relies on electromagnetic field (EMF) emission from its network base stations, increasing existing EMF level in environment. Consequently, this fact initiated deep concerns of the public, demanding overall investigation and monitoring of inevitable 5G EMF exposure. In last decade, the wireless sensors networks for EMF monitoring emerges as an innovative approach for effective analysis of EMF in environment. The latest developed is the Serbian EMF RATEL network, which offers sophisticated approach of telecommunication service-based EMF monitoring. This network performs wideband monitoring, counting the EMF contribution of all active EMF sources in predetermined frequency sub-band. In this paper, the preliminary EMF monitoring of 5G is presented, explaining technical details on used Narda AMS 8061 sensor, acquisition process, as well as analysis and dissemination of the measurement results. The EMF RATEL is envisioned to be a support for the control and management of EMFs in upcoming smart-city ecosystems, for which is expected that will be followed by intensive EMF radiation in living/working surrounding, regarding various telecommunication services.

Keywords: EMF monitoring; 5G technology; wireless sensors network.

1 Introduction

The latest generation of mobile telephony, named 5G, rapidly implements through the world. Concluding with April 2020, the “73 operators in 41 countries have launched one or more 3GPP compliant 5G services, the 88 operators have announced that they have deployed the 5G technology in their networks, while 380 operators are investing in 5G networks, in the form of tests, trials, pilots, planned and actual deployments”, regarding report of Global mobile Suppliers Association (GSA) [1].

Even mobile operators recognize the benefits of 5G deployment, the strong controversy and an unprecedented negative public campaign follows this technology, insisting on potentially dangerous health effects of its high-frequency electromagnetic field (EMF). Thus, it is foreseen that such shadowing can be one of the key factors for the cost-effective establishment of the 5G infrastructure [2]. The reason is introduction of new 5G base stations, as necessary EMF sources that will work in parallel with similar and already existing sources from 2G/3G/4G technologies, which raises uneasiness on potentially exceeding the admissible EMF limits [3].

It should be assumed that the public will always insist on lowering the power of the base stations and related EMF strength. However, it will reflect with need for dense installation of base stations, as well as increased overall cost of 5G infrastructure. The compromise has to be made and therefore, the 5G EMF measurement and monitoring become greatly important topic. From those investigation it will be expected to acts as a respectable and trustworthy mediator between public requirements for the safe EMF environment and necessity of operators to effectively develop their 5G infrastructure.

2 Measurement of 5G EMF Level

Regarding existing base stations in 2G/3G/4G networks, the measurement of emitted EMF level is based on the measurement of a time independent channel and later maximum traffic estimation, as defined in standards EN 50492:2008/A1:2014 [4] and EN 62232:2017 [5], obtaining the worst-case situation and maximum radiated EMF.

Analyzing only one base station, the measurements are performed using frequency-selective equipment, allowing selective EMF measurements in frequency domain and enabling determination of the EMF level per frequency.

The determination of the maximal EMF level in the vicinity of the GSM base station (2G) is based on the *Broadcast Control Channel* (BCCH) signal, which is always broadcasted with constant and maximum power. The BCCH level can be determined after adjusting the measuring equipment to the appropriate GSM carrier frequency, on which this signal is transmitted, in a specific cell sector of mobile network. The maximum EMF level (usually is measured electric field level) is determined as:

$$E_{GSM\_BS}^{\max} = \sqrt{n_{TRX}}\, E_{BCCH}\ , \tag{1}$$

where n_{TRX} denotes the number of transmitters, and E_{BCCH} denotes measured electric field from one BCCH only.

Analogously, the determination of the maximum EMF level in the vicinity of the UMTS base station (3G) is based on the *Primary Code of the Common Pilot Channel* (P-CPICH) measurement. The measurement equipment has to be tuned to the appropriate UMTS radio channel center frequency, while decoding P-CPICH signals in the code domain. After decoding, the maximum EMF level can be determined by estimating the maximum traffic load carried by UMTS base station, according to:

$$E_{UMTS\_BS}^{\max} = \sqrt{n_{P-CPICH}}\, E_{P-CPICH}\ , \tag{2}$$

where $n_{P\text{-}CPICH}$ is the factor defining the ratio of the maximum possible UMTS transmitter power P_{MAX} to the power of *P-CPICH* signal component $P_{P\text{-}CPICH}$. Typically, it is assumed that $n_{P\text{-}CPICH} = 10$ [2], [4], [5].

The maximum EMF level determination in the vicinity of LTE base station (4G) is based on *Cell-specific Reference Signals* (CRS), which are always transmitted in subframes of Physical Downlink Control Channel (PDSCH), through one, two or four of LTE base station antenna ports. The CRS level can be determined by adjusting measurement equipment to the proper LTE radio channel center frequency and then decoding the CRS signals in the code domain. After CRS signals decoding, the maximum EMF level in a specific LTE cell sector is determined as:

$$E_{LTE\_BS}^{\max} = \sqrt{n_{CSR}} E_{CSR} , \tag{3}$$

where n_{CRS} is the factor that defines the ratio of the total radiated power by all active antenna ports P_{MAX} to the power of CRS signal component P_{CRS}. The n_{CRS} factor depends on the bandwidth of the LTE channel and usually is: 300 for the 5 MHz channel, 600 for 10 MHz channel or 1200 for 20 MHz channel [2].

2.1 Frequency Selective Approach for 5G EMF Measurement

The basic principle to firstly measure EMF level from a pilot signal, and to afterwards apply a proper extrapolation factor has been standardized for 2G/3G/4G technologies, but it is still under investigation for 5G technology.

There are attempts to develop methodology for 5G, which will be in-line with this basic principle, utilizing the extrapolation technique and introducing appropriate factors for taking into account a number of 5G features, such as Time Division Duplexing (TDD) and sweep beam in the measured level of the 5G signal [6].

Estimation of the maximum 5G EMF level is proposed by the product of three factors [6]:

$$E_{5G\_BS}^{\max} = \sqrt{N_{sc}(B,\mu) \cdot F_{TDC}} \cdot E_{RE}^{\max} , \tag{4}$$

where $N_{sc}(B,\mu)$ is the total number of subcarriers of 5G carrier, equal to twelve times the total number of *Resource Blocks NRB* (RBs) available for the signal, F_{TDC} is the deterministic scaling factor representing the duty cycle of the signal, i.e., the fraction of the signal frame reserved for downlink transmission, E_{RE}^{max} represents the maximum EMF level measured for a single *Resource Element* (RE), i.e. the smallest unit of the resource grid made up of one subcarrier in frequency domain and one OFDM symbol in time domain [6].

In order to harmonize 4G and 5G extrapolation methods, the proposed pilot channel for 5G is the *Physical Broadcast Channel* (PBCH) *Demodulation Reference Signal* (PBCH-DMRS). This signal is a part of Synchronization Signal/Physical Broadcast Channel (SSB), and its physical location is determined by the Physical Cell ID. According to suggestion [6], the maximum EMF level, for single RE, can be defined as:

$$E_{RE}^{\max} = E_{RE}^{PBCH-DMRS} \sqrt{\frac{F_{beam}}{R}} , \tag{5}$$

where $E_{RE}^{PBCH\text{-}DMRS}$ is the average received EMF level for PBCH-DMRS, for a single RE, R is defined as the ratio of the average detected power of all the SSBs in a burst to the power of the stronger SSB in the burst (this parameter accounts for the effect of the beam sweeping on the received EMF level of all the SSB in a burst, allowing precise estimation of maximum received EMF level for PBCH-DMRS, starting from the direct evaluation of $E_{RE}^{PBCH\text{-}DMRS}$, the F_{beam} parameter takes into account the effect of a potential boost of the traffic beams with respect to the maximum EMF level received from the pilot channel, due to the effect of beamforming produced by usage of Multi-User Multiple Input Multiple Output (MU-MIMO) antennas [6].

However, it can be seen that estimation of maximum 5G EMF, using frequency selective measurement, will be not an easy and straightforward task. Thus, it should be considered some other approaches, such as the continuous wideband measurement in dedicated 5G frequency sub-band.

2.2 Continues Wideband Approach for 5G EMF Measurement

Even extrapolation approach is widely accepted and standardized, it should be pointed that it can result with the overestimated EMF levels. In many situations, the base station radiates with lower power then the maximum one and therefore, the present EMF is typically lower than the maximum, considered with extrapolation.

In that sense, the continuous EMF monitoring, used in EMF RATEL network [7], [8], can result with better insight in EMF fluctuation, as shown in Fig. 1.

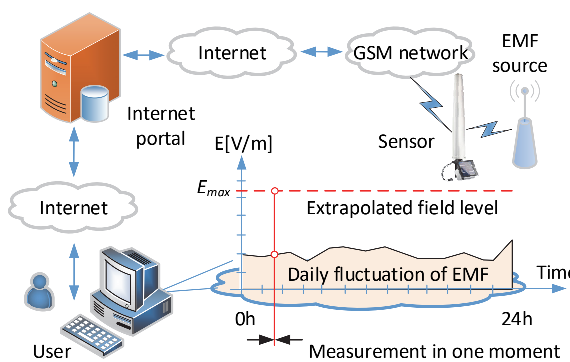

Fig. 1. The extrapolated filed level versus continuous monitoring.

The continuous monitoring can be performed over a frequency sub-band, in a way that counts EMF contribution of all active sources. Such approach is known as wideband measurement/monitoring and results with cumulative field value, regardless to individual contribution of any source.

Such approach cannot distinguish frequencies and thus cannot offer field level per frequency, as the frequency selective measurement. However, it can be advantageous, since it's measurement speed, particularly when cumulative field level is required, as it is the case with EMF investigation over location with unknow EMF sources.

3 The EMF RATEL monitoring of 5G EMF

The EMF RATEL was launched in 2017, by Serbian Regulatory Agency for Electronic Communications and Postal Services (RATEL) [9], as an innovative approach for long-term EMF monitoring. This network is established on spatially distributed wireless monitoring sensors, performing EMF observation over the Republic of Serbia, in order to timely inform the Serbian public on present level of EMF [7], [8].

3.1 The EMF RATEL Concept

This network uses autonomous EMF monitoring sensors, installed in zones of special interest or zones of the high sensitivity, which are joined in a unified wireless sensors network, as shown in Fig. 2.

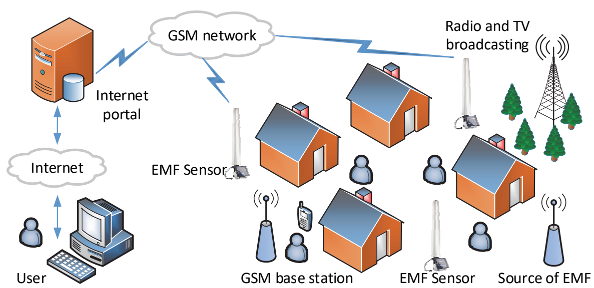

Fig. 2. The concept of EMF RATEL monitoring network.

Those sensors acquire measurement results of daily EMF levels, sending them over the existing mobile telephony network to the centralized database of the EMF RATEL Internet portal. Currently, the forty-three sensors are active in major Serbian cities [8], while the goal is to reach one hundred installed sensors till 2021.

3.2 The Service-based Wideband EMF Monitoring

The EMF RATEL network uses Narda AMS 8061 monitoring sensor [10], for modern EMF monitoring per telecommunication service, i.e. wideband monitoring in service frequency sub-band, known as the service-based monitoring.

The sensor hardware and main features are presented in Fig. 3.

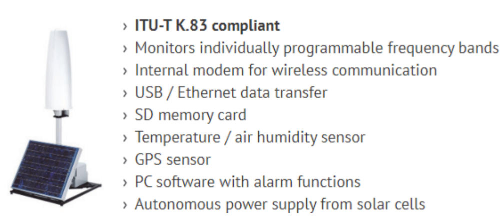

Fig. 3. The Narda AMS 8061 monitoring sensor [10].

The Narda AMS 8061 sensor covers wide frequency range from 100 kHz – 6 GHz, supporting separate and simultaneous monitoring in up to twenty programmable frequency sub-bands, in this main range [10]. Currently, the EMF RATEL is programed to perform service-based monitoring in frequency sub-bands presented in Table 1.

Table 1. The EMF RATEL monitored frequency sub-bands.

No.	Frequency sub-band	Telecommunication service
1.	87 MHz – 108 MHz	FM radio
2.	430 MHz – 470 MHz	Functional radio links
3.	470 MHz – 790 MHz	Digital TV (DVB-T2)
4.	790 MHz – 821 MHz	Mobile 4G DL
5.	832 MHz – 862 MHz	Mobile 4G UL
6.	880 MHz – 915 MHz	Mobile 2G/3G UL
7.	925 MHz – 960 MHz	Mobile 2G/3G DL
8.	1710 MHz – 1780 MHz	Mobile 2G/4G UL
9.	1800 MHz – 1880 MHz	Mobile 2G/3G DL
10.	2110 MHz – 2170 MHz	Mobile 3G DL
11.	2400 MHz – 2500 MHz	WiFi
12.	2520 MHz – 2660 MHz	Mobile 4G – NSA 5G UL/DL
13.	3400 MHz – 3800 MHz	Mobile 5G DL/UL
14.	5200 MHz – 5800 MHz	WiFi

Those sub-bands are defined by RATEL, concerning existing spectral allocation in the Republic of Serbia. In order to support testing activates on pilot 5G network, the RATEL has allocated frequency sub-band from 3400 MHz to 3800 MHz to 5G.

Furthermore, in order to fully exploit Narda AMS 8061 sensor ability, the frequency sub-bands for 2G/3G/4G technologies have been covered, as well as sub-bands for FM radio, digital TV and WiFi technology.

Also, the intention was to make comparison between EMF level of 2G/3G/4G and 5G technologies, having in mind that unreliable information from various social networks propagate that 5G EMF level will be drastically higher. Thus, the EMF RATEL feature of the service-based EMF monitoring has been used to help and clarify doubts on EMF contribution of existing telecommunication services, while providing authorized measurement results and valid technical information for public debate on EMF levels and their potential influence on health.

3.3 The AMS 8061 Data Transfer in EMF RATEL System

The implemented AMS 8061 sensor is equipped with GSM modem [10], which allows Internet connection over existing mobile telephony network. The sensor measurement results are wirelessly acquired and daily transferred to the centralized database of EMF RATEL system[11], as depicted in Fig. 4.

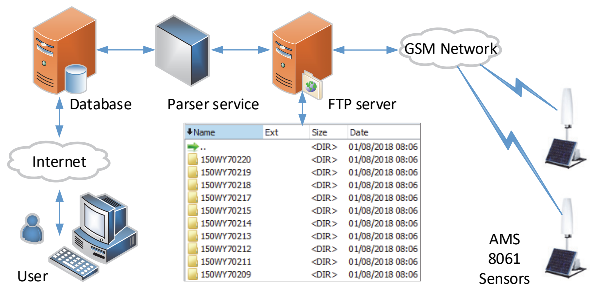

Fig. 4. The AMS 8061 data transfer in EMF RATEL system [11].

The Narda AMS 8061 sensor communicate with dedicated FTP server, which performs as a centralized data storage hub for all EMF RATEL monitoring sensors. The measurement results are packed into specially formatted ".D61" binary file [10], [11] and transferred with some other data to the FTP personal folder of sensor [11].

In order to obtain readable data, the transferred ".D61" is processed with dedicated parser function [11], extracting data from all records and saving them into appropriate database. Those data are published and freely offered to interested users.

4 The EMF RATEL monitoring of 5G EMF

The first testing 5G base station was installed on Science technological park building, in Belgrade, the capitol city of the Republic of Serbia. Therefore, the AMS 8061 sensor was installed in vicinity of this 5G base station, where it performed monitoring of the electric field strength, as shown in Fig. 5.

Fig. 5. Dissemination of the service-based EMF RATEL monitoring results.

The EMF RATEL system is intended to transparently and timely inform the public on present EMF levels, using dedicated Internet portal [8], where measurements data are illustrated by time-line graphs, offering the detailed information on EMF fluctuation. Moreover, several user-friendly features have been implemented in Internet portal, allowing users to analyze the measurement results per telecommunication service, in selected time period. Regarding handy work, the users can select/deselect specific service and can see the filed limits for each service, prescribed by the Serbian legislation for the general population [12], as shown in Fig. 6.

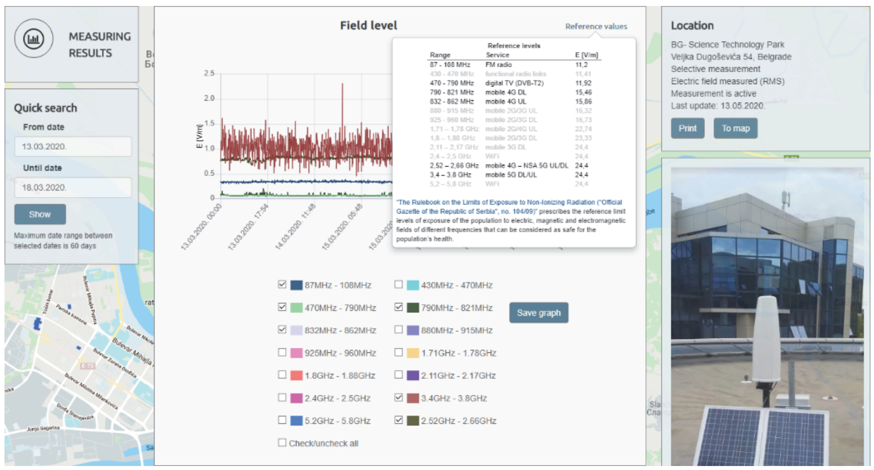

Fig. 6. The Serbian prescribed reference values per service for the general population.

A number of additional features can be found on EMF RATEL Internet portal [8], allowing users to work and analyze measurement results, along with saving and printing. Furthermore, the acquired measurement results are delivered for free use over the national Open Data Portal [13], which is the central hub where data of public interest are gathered, from all Serbian public institutions, as shown in Fig.7.

Fig. 7. Part of the Serbian Open Data Portal with results of EMF monitoring.

4.1 Analyses of Measurement Results from Service-based Monitoring

The used AMS 8061 sensor performed EMF monitoring of the 5G EMF strength, every six minutes, as defined by SRPS EN 50413:2010/A1:2014 standard [14], during period from November 1th, 2019 till March 19th of 2020, in which 5G network of the Serbian mobile operator Telenor was tested.

The simple analysis of the measurement results is presented in Table 2.

Table 2. Data analyses for EMF RATEL location "BG – Science technological park".

No.	Frequency sub-band	Telecommunication service	E [V/m]		
			Max	Average	Limit
1.	87 MHz – 108 MHz	FM radio	1.65	0.21	11.20
2.	430 MHz – 470 MHz	Functional radio links	0.61	0.02	11.41
3.	470 MHz – 790 MHz	Digital TV (DVB-T2)	1.45	0.08	11.92
4.	790 MHz – 821 MHz	Mobile 4G DL	2.24	0.07	15.46
5.	832 MHz – 862 MHz	Mobile 4G UL	0.08	0.01	15.86
6.	880 MHz – 915 MHz	Mobile 2G/3G UL	0.10	0.01	16.32
7.	925 MHz – 960 MHz	Mobile 2G/3G DL	0.18	0.10	16.73
8.	1710 MHz – 1780 MHz	Mobile 2G/4G UL	0.20	0.01	22.74
9.	1800 MHz – 1880 MHz	Mobile 2G/3G DL	4.93	1.07	23.33
10.	2110 MHz – 2170 MHz	Mobile 3G DL	2.00	1.03	24.40
11.	2400 MHz – 2500 MHz	WiFi	0.21	0.02	24.40
12.	2520 MHz – 2660 MHz	Mobile 4G – NSA 5G UL/DL	3.28	1.00	24.40
13.	3400 MHz – 3800 MHz	Mobile 5G DL/UL	4.48	1.02	24.40
14.	5200 MHz – 5800 MHz	WiFi	0.72	0.45	24.40

The table present maximal detected values per service, as well as more importantly, the average electric filed value, which reveal that on "BG – Science technological park" location, the mobile telephony services dominate, as presented in Fig. 8.

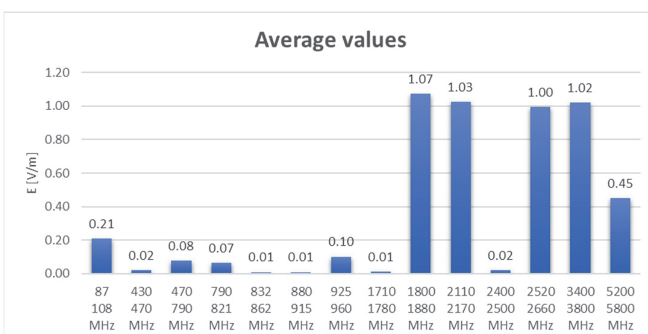

Fig. 8. Average field values for location "BG – Science technological park".

It can be seen that the electric field level of 5G technology is very similar to levels for 2G/3G/4G. Even those are values acquired in testing period, it can be presumed that levels will be the same during full utilization of 5G technology. However, the 5G is to be implemented in the Republic of Serbia during 2021, when additional service-based EMF monitoring campaign will be conducted, in order to obtain real-time EMF levels of fully functional 5G service.

When comparing obtained field levels, it can be noticed that they are far away of prescribed and allowed Serbian reference levels [12], as depicted in Fig. 9.

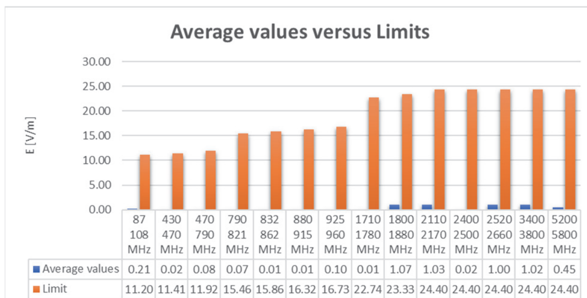

Fig. 9. Averaged field values versus Serbian prescribed reference levels (limit) [12].

It should be emphasize that the Serbian EMF legislation is based on internationally accepted ICNIRP “Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)”, announced in 1998 [15], which reference levels are additionally reduced 2.5 times for use in the Republic of Serbia.

Having this fact in mind, the “BG – Science technological park” location, where 5G technology was tested, can be considered as a location with low level of the high frequency electric field, produced by existing telecommunication services.

However, such conclusion has to be verified by further monitoring campaigns, particularly when 5G is fully deployed in the Republic of Serbia. For such activities, the EMF RATEL feature of service-based EMF monitoring is an excellent base for future comprehensive EMF investigation per telecommunication services.

5 Conclusion

The 5G technology, as natural evolution of mobile telephony, offers a number of features, which will radically improve the technical capability of Internet access and data transfer. However, the 5G technology has been followed by unprecedented, negative campaign in public, which insist on abnormal levels and dangerous health effects of its high-frequency EMF.

Accordingly, the appropriate methodologies for 5G EMF measurements develops, in order to clarify doubts on existing levels of 5G EMF. Several techniques have been proposed, where some of them are in-line with standardized EMF measurements for 2G/3G/4G technologies.

However, the Serbian EMF RATEL system offers continuous and wideband EMF monitoring approach, per telecommunication services, counting the EMF contribution of all sources per frequency sub-bands. Such service-based approach can be also utilized for 5G, as well as 2G/3G/4G technologies, providing simultaneous comparison between their EMF levels.

This paper presents the preliminary EMF monitoring results of 5G technology testing in Serbia, exploiting capability of the EMF RATEL AMS 8061 sensors. The early measurements, acquired during the testing period of five months, on location "BG – Science technological park", shows that 5G EMF levels are very similar to the existing 2G/3G/4G EMF levels.

Furthermore, all these levels are far below the Serbian prescribed reference levels. It can be seen that for some telecommunication services, the obtained EMF levels are twenty and more times lover than the limit. However, further monitoring campaigns are required in future, particularly after 5G technology is fully deployed in the Republic of Serbia.

The EMF RATEL service-based EMF monitoring is ready to welcome the 5G in the Republic of Serbia, helping with EMF contribution clarification of this and some other telecommunication services, while providing valid technical measurement data for public debate on EMF levels and their influence on health.

This system and such feature can serve as an appropriate mediator between normal requests of the general population for the EMF safe living and working environment and commercial mobile operators that require installation of additional EMF sources, in order to improve their telecommunication infrastructure.

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