The Wideband Approach of 5G EMF Monitoring

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Abstract. The 5G mobile telephony has 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 the level of existing EMF in the environment. Consequently, this fact has initiated deep concerns of the public, who demanded overall investigation and monitoring of the inevitable 5G EMF exposure. In the last decade, the wireless sensors networks for EMF monitoring emerged as an innovative approach for effective analysis of EMF in the environment. The latest one is the Serbian EMF RATEL network, which offers a sophisticated approach of telecommunication service-based EMF monitoring. This network performs wideband monitoring, counting the EMF contribution of all active EMF sources in a predetermined frequency sub-band. In this paper, the preliminary EMF monitoring of 5G is presented, explaining technical details on the used Narda AMS 8061 sensor, the acquisition process, as well as the 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, in which is expected that will display intensive EMF radiation in living surrounding, regarding various telecommunication services.

Keywords: EMF monitoring · 5G technology · Wireless sensors network

1 Introduction

The latest generation of mobile telephony, named 5G, is rapidly being implemented throughout the world. Following the report of the Global mobile Suppliers Association (GSA), 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 pilots, planned and actual deployments*", concluding with April 2020 [1].

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Even though mobile operators recognize the benefits of 5G deployment, the strong controversy and an unprecedented negative public campaign has been following this technology. The negative campaign is insisting on potentially dangerous health effects of its high-frequency electromagnetic field (EMF), regardless the fact that recent scientific results demonstrate no evidence for such influence [2]. Therefore, it is foreseen that such unwanted shadowing can be one of the key factors for a slow and even delayed establishment of the 5G infrastructure [3]. The true reason lies in the introduction of new 5G base stations, as necessary EMF sources, that need to work in parallel with similar and already existing EMF sources from 2G/3G/4G technologies, raising uneasiness related to potentially exceeding admissible EMF limits [4].

It should be assumed that the public will always insist on lowering the power of the base stations and related EMF strength. Consequently, it would be reflected on dense installation of 5G base stations, as well as increased overall cost of 5G infrastructure. However, a compromise has to be made, highlighting the 5G EMF measurement and monitoring as a greatly important topic. It is to be expected that they have to act as a respectable and trustworthy mediator between public requirements for the safe EMF environment and a necessity of operators to effectively develop 5G infrastructure.

The organization of this paper is the following: Sect. 2 presents standardized approaches for 2G/3G/4G EMF measurement, as well as a proposal for 5G. Section 3 brings details on the EMF RATEL system concept and its 5G EMF monitoring, while Sect. 4 presents some initial results of 5G EMF monitoring by EMF RATEL. Finally, Sect. 5 concludes this paper.

2 Measurement of 5G EMF Level

Regarding the 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 [5] and EN 62232:2017 [6], 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 the frequency domain, and enabling the 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 the mobile network. The maximum EMF level is determined by measuring electric field level, as:

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

where n_{TRX} denotes the number of transmitters, and E_{BCCH} denotes the measured electric field from one BCCH only [5].

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:

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

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 $n_{P\text{-}CPICH} = 10$ [3, 5, 6].

Determination of the maximum EMF level, in the vicinity of the 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 the measurement equipment to the center frequency of LTE radio channel and then decoding the CRS signals in the code domain. After decoding the CRS, the maximum EMF level in a specific LTE cell sector is determined as [3]:

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

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 the CRS signal component P_{CRS} [3]. The n_{CRS} factor depends on the bandwidth of the LTE channel and it usually is: 300 for the 5 MHz channel, 600 for 10 MHz channel, or 1200 for 20 MHz channel [3].

2.1 Frequency Selective Approach for 5G EMF Measurement

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

There are attempts to develop a 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 [7]. Estimation of the maximum 5G EMF level is proposed as following [7]:

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

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 (this parameter depends on bandwidth B and subcarriers numerology μ); the F_{TDC} is a deterministic scaling factor representing the duty cycle of the signal, i.e., the fraction of the signal frame reserved for downlink transmission; E^{max}_{RE} 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 *Orthogonal Frequency Division Multiplexing* (OFDM) symbol in time domain [7].

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 the proposal and experimental procedure from [7], the maximum EMF level, for a single RE is defined as:

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

where ${E_{RE}}^{PBCH-DMRS}$ 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 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 SSBs in a burst, allowing precise estimation of the maximum received EMF level for PBCH-DMRS, starting from the direct evaluation of ${E_{RE}}^{PBCH-DMRS}$), while the F_{beam} parameter takes into account the effect of a potential boost of the traffic beams with respect to the maximum level of EMF received from the pilot channel, due to the effect of beamforming produced by the usage of *Multi-User Multiple Input Multiple Output* (MU-MIMO) antennas [7].

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

2.2 Continuous Wideband Approach for 5G EMF Measurement

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

In that sense, the continuous EMF monitoring, used in EMF RATEL network [8, 9], can result in a better insight in EMF fluctuation, as shown in Fig. 1.

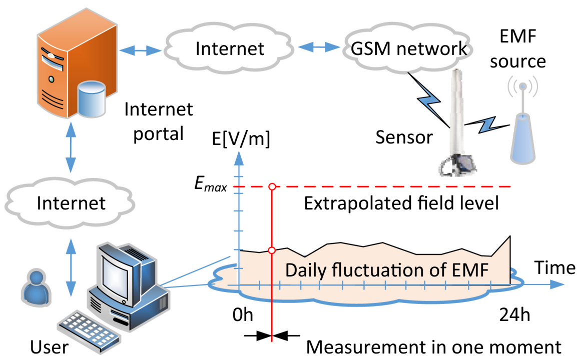

Fig. 1. The extrapolated field level versus continuous monitoring.

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

Such approach cannot distinguish frequencies and thus cannot offer field level per frequency, as the frequency selective measurement does. However, it can be advantageous through its high measurement speed, particularly when cumulative field level is required, as it is the case with investigation over location with unknown 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) [10], 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 the present level of EMF [8, 9].

3.1 The EMF RATEL Concept

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

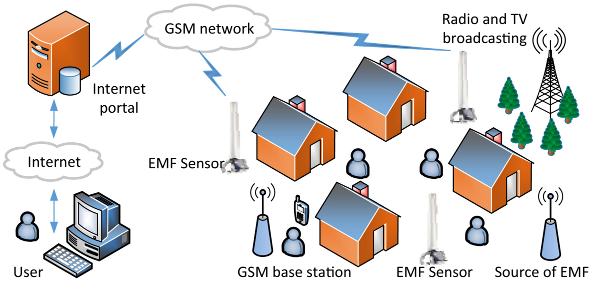

Fig. 2. The concept of EMF RATEL monitoring network.

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, forty-three sensors are active in major Serbian cities [9], 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 [11], 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.

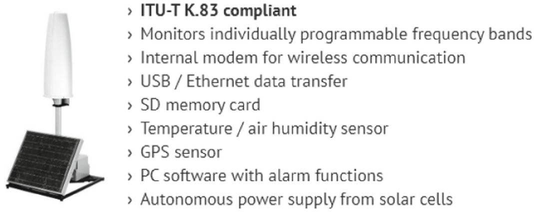

Fig. 3. Narda AMS 8061 monitoring sensor [11].

Narda AMS 8061 sensor covers a 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 [11]. 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 download (DL)
5	832 MHz–862 MHz	Mobile 4G upload (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	Wi-Fi
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	Wi-Fi

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

The intention was to make a comparison between the EMF level of 2G/3G/4G and 5G technologies, having in mind unreliable information from various social networks, which 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 the real EMF contribution of existing telecommunication services, while providing authorized measurement results and valid technical information for public debate on EMF levels in environment and their potential influence on health.

3.3 The AMS 8061 Data Transfer in EMF RATEL System

The implemented sensor AMS 8061 is equipped with GSM modem [11], allowing Internet access over the existing mobile telephony network. The sensor measurement results are wirelessly acquired and daily transferred to the centralized database of the EMF RATEL system [12], as depicted in Fig. 4.

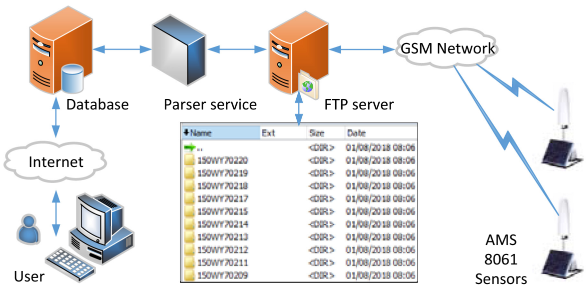

Fig. 4. The AMS 8061 data transfer in the EMF RATEL system [12].

Narda AMS 8061 sensor communicates with the 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 files [11, 12] and transferred with some other data to the FTP personal folder of the sensor [12].

In order to obtain usable data, those ".D61" files are processed with dedicated parser function [12], extracting valuable data from all records and saving them into database. Those data are published and freely offered to interested users.

4 The Initial Results of 5G EMF Monitoring by EMF RATEL

The first 5G testing 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, at the distance of 60 m, performing the monitoring of the electric field strength, as shown in Fig. 5.

The EMF RATEL system is intended to transparently and timely inform the Serbian public on daily EMF levels, using a dedicated Internet portal [9]. The measurement data are illustrated by time-line graphs, offering detailed information on EMF fluctuation.

Moreover, several user-friendly features have been implemented in the Internet portal, allowing users to analyze the measurement results per telecommunication service, in the selected time period.

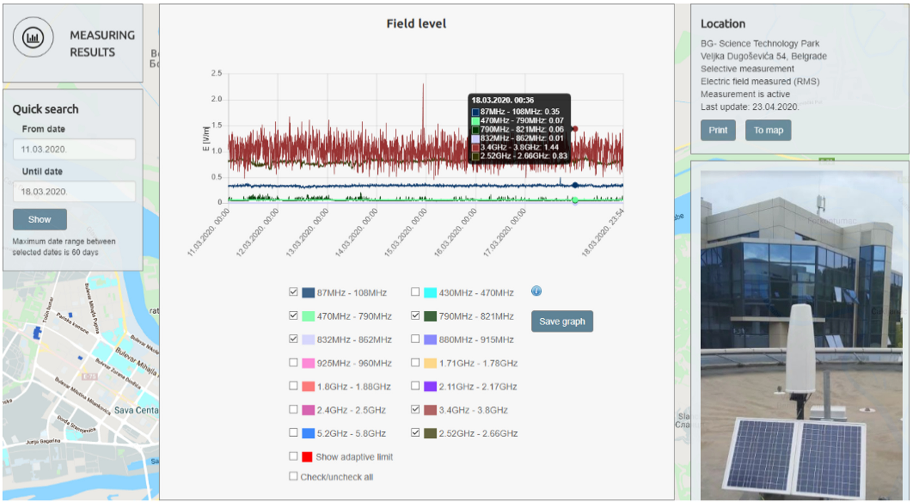

Fig. 5. Dissemination of the service-based EMF RATEL monitoring results.

Regarding handy work, users can select/deselect specific service and can compare its EMF levels with field limits for each service, prescribed by the Serbian legislation for the general population [13], as shown in Fig. 6.

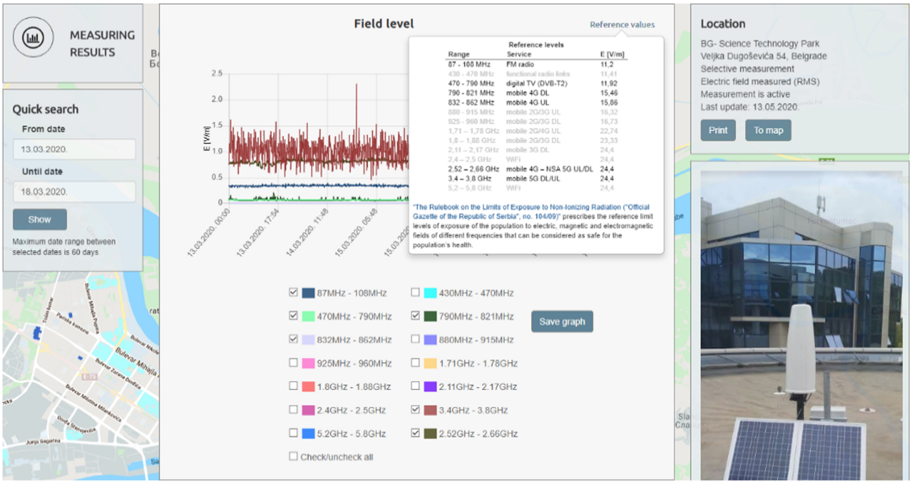

Fig. 6. The Serbian prescribed reference values per service for the general population.

A number of additional features can be found on EMF RATEL Internet portal [9], 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 [14], as shown in Fig. 7, which is the central hub where data of the public interest are gathered, from all Serbian public institutions.

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 AMS 8061 sensor performed EMF monitoring of the 5G EMF strength, every six minutes, as defined by SRPS EN 50413:2010/A1:2014 standard [15], during the fifth month period: from November 1th, 2019 till March 19th 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 download (DL)	2.24	0.07	15.46
5	832 MHz–862 MHz	Mobile 4G upload (UL)	0.08	0.01	15.86

(*continued*)

Table 2. (*continued*)

No	Frequency sub-band	Telecommunication service	E [V/m]		
			Max	Average	Limit
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	Wi-Fi	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	Wi-Fi	0.72	0.45	24.40

The table presents maximal detected values per service, as well as, more importantly, the average electric field value, which reveals that the mobile telephony services dominate the “BG – Science-Technological Park” location, as presented in Fig. 8.

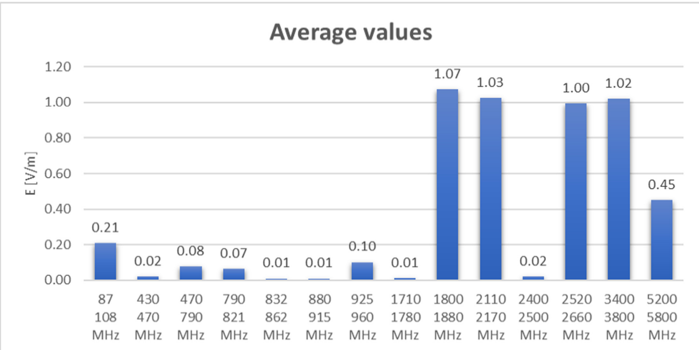

Fig. 8. Average field values for location “BG – Science technological park”.

It can be seen that the electric field level of 5G technology is very similar to levels for 2G/3G/4G. Even those values are acquired in testing period it can be presumed that levels will be the same during the 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 from the prescribed and allowed Serbian reference levels [13], depicted in Fig. 9.

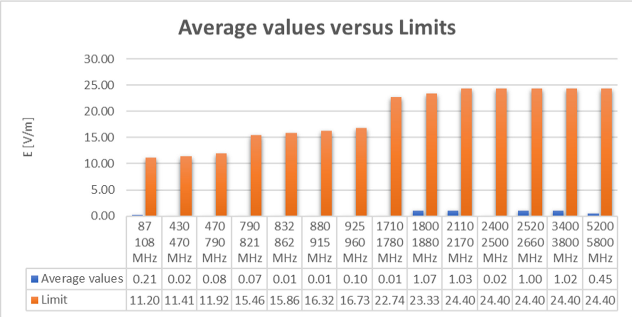

Fig. 9. Averaged field values versus Serbian prescribed reference levels (limit) [13].

It should be emphasized that the Serbian EMF legislation is based on internationally accepted "Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)", announced by the *International Commission on Non-Ionizing Radiation Protection* (ICNIRP) in 1998 [16], whose reference levels are additionally reduced by 2.5 times for use in the Republic of Serbia.

Having in mind this fact, the "BG – Science-Technological Park" location, where 5G technology was tested, can be considered as a location with a 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 has been followed by unprecedented, negative campaign, insisting on irregular levels and unsafe health effects of its high-frequency EMF.

Accordingly, the appropriate methodologies for 5G EMF measurements are being developed, in order to clarify doubts on existing 5G EMF levels. 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 a different approach, the continuous wideband EMF monitoring per telecommunication services, summing the EMF contribution of all sources per frequency sub-bands. Such service-based approach can be used for 5G, as well as 2G/3G/4G, providing comparison among their EMF levels.

This paper presents the preliminary EMF monitoring results of testing 5G technology in Serbia, exploiting the capability of EMF RATEL system. The early measurements, acquired during the period of five-month-long 5G testing, demonstrate that 5G EMF levels are very similar to the existing 2G/3G/4G EMF levels.

All these levels are far below the Serbian prescribed reference levels. Also, it can be seen that, for some telecommunication services, the acquired EMF levels are twenty and more times lower than the prescribed field limit. However, additional monitoring campaigns are required in future, particularly after the 5G is fully deployed and in the real cases where several base stations cover the same cell.

The service-based EMF monitoring of EMF RATEL intends to improve the quality of human life in approaching modern EMF environment, particularly for developing regions, where social awareness on EMF and environment could be additionally increased. Such approach of EMF monitoring offers daily EMF observation and better knowledge on EMF spatial distribution, as well as demanding feature to timely inform the public on existing EMF levels and their influence on health.

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

References

1. Global mobile Suppliers Association (GSA) – April 2020 Report. https://www.ratel.rs/uploads/documents/empire_plugin/GSA5G.pdf. Accessed 20 May 2020
2. Final Opinion on Potential Health Effects of Exposure to Electromagnetic Fields (EMF) – Scientific Committee on Emerging and Newly Identified Health Risks (SCENIRH) (2015). https://ec.europa.eu/health/scientific_committees/emerging/docs/scenihr_o_041.pdf. Accessed 20 May 2020
3. Pawlak, R., Krawiec, P., Żurek, J.: On measuring electromagnetic fields in 5G technology. IEEE Access **7**, 29826–29835 (2019). https://doi.org/10.1109/ACCESS.2019.2902481
4. International Commission on Non-Ionizing Radiation Protection (ICNIRP). Guidelines for Limiting Exposure to Electromagnetic Fields (100 kHz to 300 GHz), Health Physics, vol. 118, no. 5, pp. 483–524, May 2020. https://doi.org/10.1097/HP.0000000000001210.
5. Basic standard for the in-situ measurement of electromagnetic field strength related to human exposure in the vicinity of base stations, EN 50492:2008/A1:2014 (2014)
6. Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure, EN 62232:2017 (2017)
7. Franci, D., et al.: Experimental procedure for fifth generation (5G) electromagnetic field (EMF) measurement and maximum power extrapolation for human exposure assessment. Environments **7**, 22 (2020). https://doi.org/10.3390/environments7030022
8. Djuric, N., Kavecan, N., Mitic, M., Radosavljevic, N., Boric, A.: The concept review of the EMF RATEL monitoring system. In: 22nd International Microwave and Radar Conference – MIKON 2018, 15–17 May 2018, Poznań, Poland, pp. 1–3 (2018)
9. EMF RATEL Internet portal. https://emf.ratel.rs. Accessed 20 May 2020
10. Regulatory Agency for Electronic Communications and Postal Services (RATEL). https://www.ratel.rs/en/. Accessed 20 May 2020
11. User's Manual Narda AMB-8061 Area Monitor Selective (2015). https://www.narda-sts.us/pdf_files/AMS8061EN-71006-1.22.pdf. Accessed 20 May 2020
12. Djuric, N., Kavecan, N., Kljajic, D., Mijatovic, G., Djuric, S.: Data acquisition in Narda's wireless stations based EMF RATEL. In: International Conference on Sensing and Instrumentation in IoT Era – ISSI 2019, 29–30 August 2019, Lisbon, Portugal, pp. 1–6 (2019)

13. The rulebook on the limits of exposure to non-ionizing radiation, Official gazette of the Republic of Serbia, no. 104/09. https://www.sepa.gov.rs/download/strano/pravilnik5.pdf. Accessed 20 May 2020
14. The Serbian Open Data Portal. https://data.gov.rs/sr/. Accessed 20 May 2020
15. Basic standard on measurement and calculation procedures for human exposure to electric, magnetic and electromagnetic fields (0 Hz–300 GHz), SRPS EN 50413:2010/A1:2014 (2014)
16. Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz), International Commission on Non-Ionizing Radiation Protection - ICNIRP (1998). https://www.icnirp.org/cms/upload/publications/ICNIRPemfgdl.pdf. Accessed 20 May 2020