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Analysis of Electromagnetic Field Radiation From Synchronisation Signal Block (SSB) in 5G systems

Keze Li*, Michael S.Mollel*, Olaoluwa Popoola*, Yusuf Sambo*, and Muhammad Ali Imran*
*James Watt School of Engineering, University of Glasgow
23577611@student.gla.ac.uk
{michael.mollel,olaoluwa.popoola,yusuf.sambo,muhammad.imran}@glasgow.ac.uk

***Abstract*—The unprecedented data demand from new use cases such as extended virtual reality and holograms requires the development of new mobile generation architectures. The fifth generation and beyond (5G-Beyond) wireless technology aims to address this need by increasing the number of base stations per unit area and utilizing high-frequency bands such as millimetre and terahertz waves. The 5G-Beyond promises to deliver high data rates, network reliability, and low latency. However, this comes at the cost of increased electromagnetic field exposure (EMF) in a given area. Although there is no evidence that links EMF from mobile communication systems to health hazards, more research has to be carried out to better understand the interaction between EMF and the human body and keep an eye on the EMF level. This article presents the results of a study on the EMF power density caused by the control signals, especially synchronisation signal block (SSB), which are transmitted periodically from a 5G mobile communication antenna. In addition, from the findings, it can be observed that the level of EMF exposure caused by the SSB is within the international guidelines yet more research has to be done to mitigate the unnecessary SSB transmission to reduce even further the level of EMF and minimize energy consumption. In general, the results show that the highest power density values were observed at the closest distances and corresponding angles to the antenna, yet EMF exposure levels are still below the limit. The study findings can inform the development of guidelines and regulations for safe exposure to electromagnetic radiation from 5G technology and other sources.**

***Index Terms*—EMF exposure, Synchronization Signal Block (SSB), 5G, SSB Burst**

I. Introduction

The rapid growth of mobile communication technology has led to an increasing demand for high-speed and reliable wireless communication networks. The 5G-Beyond technology relies on synchronization signal blocks (SSBs) to provide high-quality communication between base stations and user devices [1]. This type of signal is an essential element of the 5G New Radio (NR) specification, which is transmitted periodically by the 5G base station that enables mobile devices to synchronise with the base station and establish a communication link. The SSB comprises a powerful signal that allows mobile devices to identify the transmission frequency and timing of the base station [2], [3]. It is a crucial component of 5G communication and is utilised at multiple phases of the communication process, including initial access, handover, and network slicing. To ensure reliable and efficient communication, SSBs are transmitted using beamforming and beam-sweeping techniques to increase the coverage and capacity of the network. However, this periodically transmitted signal (SSB) raises concerns regarding potential health hazards associated with electromagnetic fields (EMFs) from 5G antennas [4]. Although there is no direct connection between exposure to electromagnetic fields from mobile communication systems and health hazards, the world health organization (WHO) has called for more research to better understand the interaction between EMF and the human body [5].

To achieve better coverage, capacity, signal quality, and energy efficiency of the network, 5G relies on beamforming and beamsweeping to target the signal in a given direction and to find the best beam direction that provides the highest signal quality and reliability. Beamforming enables the 5G base station to transmit a high-power signal in a particular direction towards a mobile device while minimising the power transmitted in all other directions [1]. However, the raising power also raises concerns about the potential health hazards associated with electromagnetic field (EMF) exposure. The use of multiple antennas and high-power signals may result in increased power density levels in specific directions, which may result in increased exposure levels for those who live or work near a 5G base station. Instead of directing a signal towards a specific direction or target, beamsweeping allows the 5G base station to scan the surrounding area by swiftly transitioning between multiple beam angles. The beamsweeping technique offers numerous benefits for 5G communication [6]. It allows the base station to monitor the movement of mobile devices and adjust the beam direction accordingly, thereby expanding the coverage area and facilitating mobility. Rapid changes in beam direction may result in higher power densities in certain directions, which may increase exposure levels for individuals residing or working in close proximity to a 5G base station.

The purpose of this study is to investigate the electromagnetic field power density caused by SSB from a 5G mobile antenna. Specifically, the study intended to measure the power density levels in different directions and at varying distances from the antenna in order to assess the potential exposure levels for individuals residing or working in close proximity to a 5G base station. The findings of this study are crucial for policymakers, regulators, and individuals who are concerned about the potential adverse health effects of 5G antenna EMF exposure. By providing a comprehensive analysis of the power density levels generated by the SSB, this study can contribute to a greater understanding of the potential health hazards associated with exposure to 5G electromagnetic fields (EMFs).

The paper is organized as follows. In section II, we provide the method to access the EMF power density level of SSBs. Section III presents the results of the measurements and the impact of various factors on the power density. Section IV gives a discussion of the results and finally, in section V, we conclude the paper and highlight the importance of measuring the power density of SSBs from 5G base stations.

II. Method

A. SSB and SS-RSRP

The term Synchronisation Signal Block refers to Synchronization/PBCH block because the synchronisation signal and PBCH channel are bundled into a single block that always travels together. There are two components of this S/PBCH:

- Synchronization Signal: PSS (Primary Synchronization Signal), SSS (Secondary Synchronization Signal)
- PBCH: PBCH DMRS and PBCH (Data)

which occupies 240 subcarriers and four contiguous OFDM symbols. Block patterns are shown in Figure 1. SSBs are sent in the first 5 ms of the frame in blocks called SSB bursts, with a customizable periodicity of 5 ms, 10 ms, 20 ms, 40 ms, 80 ms, or 160 ms. The 3rd Generation Partnership Project (3GPP) technical specification defines five different cases (i.e., A, B, C, D, E) for a total of eight possible configurations [7]. Figure 2 presents the spectrogram of those different cases, and also illustrates how beam sweeping is implemented for SSB transmission. In a single SSB burst, multiple SSBs are transmitted with a predetermined interval of which each SSB can be identified by a unique number known as the SSB index and transmitted via a specific beam directed in a particular direction. Multiple user equipment (UEs) are located randomly at various places around the base station. Each UE measures the signal strength of each SSB it detected. UE can identify the SSB index with the strongest signal strength based on measurement results. The received power is called SS-RSRP stands for Synchronization Signal Reference Signal Received Power, which is a key parameter used to evaluate the signal quality and coverage of the 5G system [8]. It is used to estimate the received signal intensity at the mobile device and is measured in decibel-milliwatts (dBm). The received power of SSB (P_{SSB}) is given as:

$$P_{SSB} = SS - RSRP \times \frac{N_{SSB} t_{symbol}}{T_P} \quad (1)$$

Where N_{SSB} is the number of symbols in one SSB, t_{symbol} is the symbol duration and T_P is the period of SSB burst transmission.

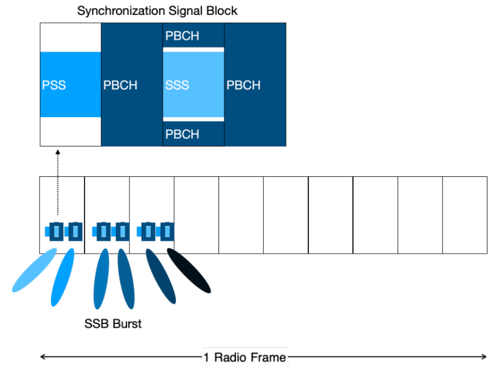


Fig. 1. Structure of SSB

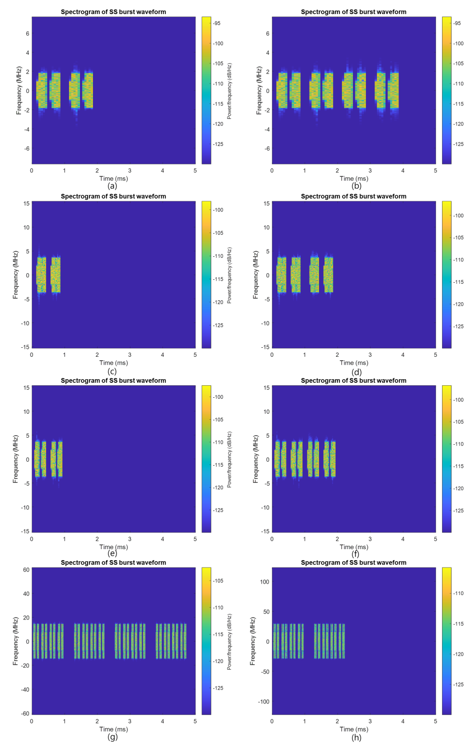


Fig. 2. Spectrogram of SS burst waveform

B. Near and Far Field

Near field and far field are regions encompassing a source of electromagnetic radiation, such as an antenna or transmitter, in electromagnetics. Due to so-called near-field conditions, antenna measurements are more challenging in close proximity. In the radiative near field, the relationships between the electric and magnetic fields are significantly more complex, and they should be evaluated separately [9]. Measuring the electric fields and applying the far field assumptions in this zone would frequently result in an overestimation of the exposure. This paper focuses primarily on the far-field region. Dimensions of the antenna and wavelength play a significant role in electromagnetic field propagation. Field distribution can be calculated theoretically using the parameter $L = 2D^2/\lambda$

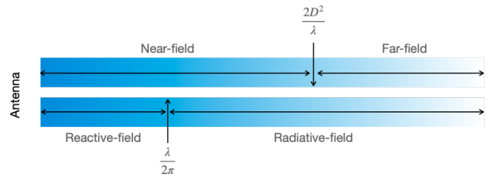


Fig. 3. Far field and near field of the antenna

as in Figure 3, where D refers to the dimensions of the antenna, λ is the wavelength, and L represents the transitory field range [10]. For instance, a $1m$ tall antenna emitting electromagnetic radiation at $3.5GHz$ is 23.6 meters. Thus, distances less than this value are governed by near-field regions, whereas distances greater than this value are governed by far-field regions. In the near-field, the electric and magnetic field strengths are not perpendicular to one another, making it challenging to relate them to a propagating electromagnetic wave. In the far field, it is sufficient to measure only the electric or magnetic field intensity and calculate the EMF power density using formulas :

$$S_{ab} = EH = \frac{E^2}{Z_0} = \frac{E^2}{377} \tag{2}$$

The equations describe the relationship between the far-field electric component E, the far-field magnetic component H, and the power density P_d, where Z_0 indicates the characteristic impedance [4].

C. Power Density and SS-RSRP

Power density refers to the amount of power per unit area of a surface. In EMF, power density quantifies the intensity of electromagnetic radiation at a particular location. Typically, it is expressed in watts per square metre (Wm^{-2}). The power density P_D at a distant point from the transmitter with an antenna gain of G_t is the power density from an isotropic antenna multiplied by the radar antenna gain, which is given as:

$$P_D = \frac{P_t G_t}{4\pi R^2} \tag{3}$$

where P_t is the transmit power and R is the distance between the receiver and transmitter, which is based on free space path loss [11].

Power density is utilised to measure SSB because it quantifies the signal intensity at various distances from the antenna. The 5G base station periodically transmits an SSB signal that enables mobile devices to synchronise with the base station and establish a communication link. As the distance from the antenna increases, the SSB signal's power density decreases due to the inverse square law of propagation. By measuring the power density at various distances from the antenna, it is possible to estimate the potential exposure levels for those who live or work in close proximity to a 5G base station. Thus the power density can be get from:

$$P_{D-SSB} = \frac{4\pi}{\lambda^2 G_r}\left(\sum P_{SSB}\right) \tag{4}$$

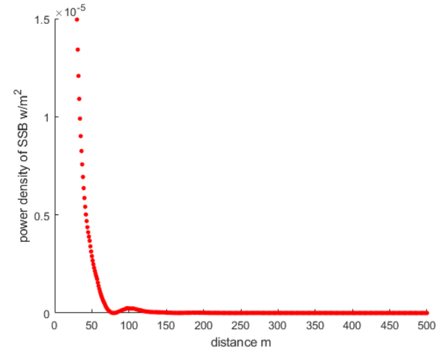


Fig. 4. Power density from the transmitting antenna with distances of all SSBs

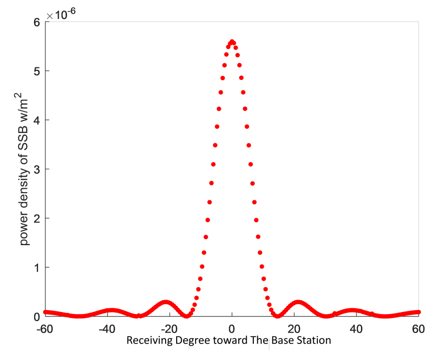


Fig. 5. Power density from the transmitting antenna with degrees of a single SSB

It is essential to measure the power density of SSB in order to assess the potential health risks associated with exposure to electromagnetic fields (EMFs) from 5G antennas. There are established guidelines for safe levels of EMF exposure based on power density, and measuring the power density of SSB allows policymakers and regulators to assess compliance with these guidelines [12].

III. Measurements and Results

In Figure 4 and Table 1, SSB signals are assumed to be transmitted from the 5G base stations with 120 degrees within a cell at $3.5GHz$ (Case B). Eight SSBs are beamformed toward eight different directions labelled from 1 to 8. The direction of each SSB is from -45 degrees to 60 degrees from the base station and the receiving point is 0 degrees away from 30 metres to 500 metres. The periodicity of SSB transmission is assumed to be $20ms$, which specifies the default periodicity throughout the initial cell search or inactive mode. The symbol duration for the subcarrier spacing of $30kHz$ is $33.3\mu s$. Figure 4 shows that the power density decreases sharply with a distance up to 75 metres and it slows down in the following ranges. The strongest power density is received at the closest test point. At a distance of 30 m from the base station's vertical axis the EMF power density value created by the mobile transmitting antenna at a height of 1.5 m above the ground is 15 $\mu W/m^2$, which

TABLE I
RESULTS OF ADAPTIVE THRESHOLDS.

Distance(m)	SSB1	SSB2	SSB3	SSB4	SSB5	SSB6	SBB7	SSB8	Power Density W/m^2
30	-75.0125	-145.1561	-81.2466	-52.1186	-81.2444	-136.3758	-74.9683	-70.0219	1.4953×10^{-5}
100	-93.0274	-145.4267	-99.3242	-70.2054	-99.2151	-136.2562	-92.6581	-87.8882	2.3264×10^{-7}
200	-105.9707	-145.2659	-112.3379	-83.2563	-112.1529	-136.4153	-104.2339	-100.4736	1.1573×10^{-8}
500	-120.2397	-141.0014	-127.3988	-100.4558	-126.9456	-133.9965	-109.0087	-119.3449	2.4887×10^{-10}

TABLE II
SIMULATION PARAMETERS

Parameter	Value
SSB Pattern	Case A, B,C, D,E
Frequency Band	2 and 3.5 Ghz (FR1) 30GHz (FR2)
Bandwidth	10,25,100,200 MHz
Beamsweeping Angle	-60 to 60 degree
Base Station Transmit Power	5 dBm, 10 dBm, 40 dBm
SSB Transmission Period	{5,10,20,40,80,160} ms

is well below the restriction level for electromagnetic field exposure 10 Wm^{-2} provided by International Commission on Non-Ionizing Radiation Protection (ICNIRP). However, the restriction indicates the overall power density of all resources but this report only evaluates the power density produced of only SSB signals by a single base station. The table presents detailed results of SS-RSRP from all SSBs and the power density level at different distances. The strongest received power occurs in the corresponding direction.

Figure 5 presents the results of measurements at 100 m far with different angles from a single SSB. The simulation carried out from -60 degrees to 60 degrees around the transmitting base station revealed that a much higher power density will be received at the transmitting direction due to beamforming. The EMF power density value around the transmitting antenna from a single SSB does not exceed 6 $\mu W/m^2$.

The distribution of the EMF power density produced by the mobile directional antenna with different transmitting periods is presented in Figure 6. The results are taken at 50 m far and the periods is changing from 5 ms to 160 ms. Higher periodicity leads to lower EMF power density level that can be observed with the highest power density level occurring at a 5 ms period. While in reality, busy areas always require a high demand for communication resources calling for short SSB periods which will result in high EMF power density levels.

All above simulations are taken at FR1, Figure 7a and 7b show EMF power density level produced by SSB signals both at FR1 and FR2 with 6 different cases (case A to case E, 8 situations). Case A to Case C are working at FR1 and Case D and Case E are working at FR2. All results revealed that the EMF power density from SSB signals from a single base station did not exceed the permissible level.

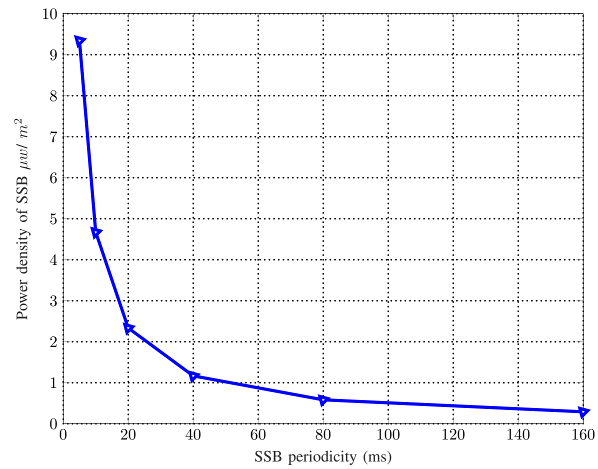
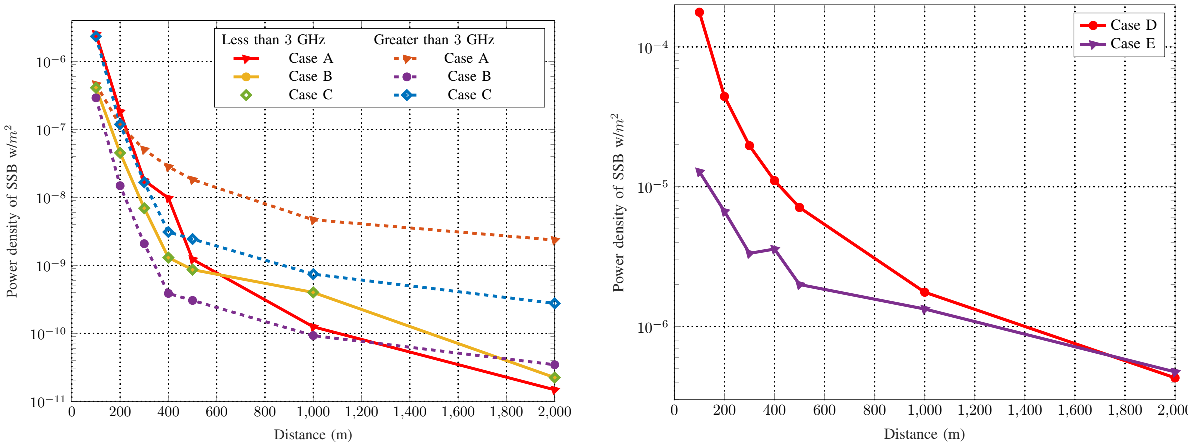


Fig. 6. Power density level of a single SSB from the transmitting antenna changing with periods

IV. DISCUSSION

The EMF power density value from SSB signals is related to many factors such as working frequency band, transmitting periods, receiving distances, angles and many other sources. In reality, the influence of environmental factors will lead to changes in many aspects, therefore, the situation described in this article is an experiment in an ideal state, and it is only used as a reference in actual use.

The results of this study indicate that exposure to the electromagnetic fields generated by the synchronisation signal block (SSB) from a 5G mobile communication antenna is unlikely to exceed the recommended limits. The findings are consistent with previous research on the power density of electromagnetic fields from mobile communication antennas. The study results also demonstrate the importance of adhering to the recommended exposure limits set by international guidelines and regulations. The limits for exposure to electromagnetic radiation are based on scientific research and are designed to protect public health. However, the study only considers the power density level radiated from a single base station, while in reality, individuals may be surrounded by multiple base stations with multiple transmitting antennas, which will result in an accumulated EMF power density. Moreover, the study only shows that the power density generated by SSB is under limitation, but other sources of electromagnetic radiation, such as other types of antennas or devices, may generate different levels of electromagnetic fields and may have different potential health effects. Therefore, the study



(a) FR 1 (b) FR 2

Fig. 7. Power Density level of 8 SSB transmission cases in FR1 and FR2

findings should be interpreted with caution when applied to other sources of electromagnetic radiation.

V. Conclusion

From analysis, the EMF power density level of SSB signals decreases according to the square dependence in free space, whereas in actuality, interference is most prevalent at great distances due to reflections from structures and relief roughness, causing the power density to decrease more frequently. The SSB transmitting periods and receiving angles also contribute a lot to this value.

The study findings suggest that exposure to the electromagnetic fields generated by the synchronisation signal block (SSB) from a 5G mobile communication antenna is unlikely to exceed the restrictions. The study also finds that the highest power density values are observed at the closest distances and angles to the antenna, but even these values are still well below the exposure limits. This study provides valuable information on the electromagnetic field power density caused by the SSB from a 5G mobile communication antenna. The study findings can inform the development of guidelines and regulations for safe exposure to electromagnetic radiation from 5G technology and other sources. Further research is needed to evaluate power density to electromagnetic radiation from various sources and to continue monitoring and updating the recommended exposure limits.

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