NIPES Journal of Science and Technology Research 2(3) 2020 pp.386 - 396 pISSN-2682-5821, eISSN-2682-5821

NIPES

Journal of Science and Technology Research

Journal homepage: www.nipesjournals.org.ng

Investigating the Received Signal Strength and Electromagnetic Radiation from 2G, 3G and 4G Mobile Architectures

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Article Info

Received 21 January 2020
Revised 13 August 2020
Accepted 28 August 2020
Available online 31 August 2020

***Keywords*:**
Electromagnetic Radiation, Received Signal Strength Indicator, Power density, Base Transceiver Station, Redial Direction, Tenmars RF Meter, Second-generation (2G), Third-generation (3G), Fourth-generation (4G)

doi Crossref NIPES JOURNALS

https://doi.org/10.37933/nipes/2.3.2020.37

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Abstract

Most mobile phone service providers currently provide 2G, 3G, 4G and recently 5G services to their customers. The advancement of the Global System for Mobile Communication (GSM) from 2G to 4G, has improved numerous performance problems inherent in the communication channel of the network. Although, the motivation of this paper was to investigate two important factors that affect performance namely: Received Signal Strength Indicator (RSSI) and Electromagnetic Radiation (EMR) in different mobile architectures, it also ascertained the relationship that exists between these two metrics. The result showed that the second-generation (2G) network has a better-received signal strength as compared to the other generations, but it has a very high level of radiation. On the other hand, the third-generation (3G) technology seems to be in-between the 2G and 4G technology in terms of radiation and received signal strength. However, the fourth-generation (4G) technology has low radiation emission but very poor signal strength as compared to the others. Thus, this suggests that there is a significant relationship between the different generations' received signal strengths, electromagnetic radiation and distance.

1. Introduction

In the last two decades, there has been an unprecedented rise in the use of wireless communication technology. This technology has become an integral and significant part of our daily lives. The new and ever-evolving wireless technology has brought about new opportunities for utilising the available radio signals being used by GSM base transceiver stations [1]. One of such attractive opportunities that exist is that the GSM radio system relies on intelligent channels sharing and frequency reuse within a coverage area [2]. In other words, efficient frequency spectrum usage was realisable through technology like cognitive radio – this is a type of transceiver which can intelligently sense or detect unusable communication channels, and instantly allocate those channels to the unlicensed users without disturbing occupied channels [3].

It is noteworthy that if the number of channels per cell is small, the base station is very likely to be congested. However, the bid to resolve the problem of congestion, results in an increase in the number of channels. Although, since the bandwidths allocated for uplink and downlink transmission are fixed, this makes it very difficult to implement the aforementioned process. Also, the process of increasing the number of channels creates another problem. This is because frequencies used by one cell would have to be re-used in a neighbouring cell thus causing co-channel interference [4]. The higher the interference, the lower the channel capacity and vice-versa. Hence the problem of signal interference has equally resulted in poor quality of service and customer dissatisfaction.

Moreover, metrics such as packet loss, throughput, and delay in the GSM network, may be extremely bad and therefore affect its performance. Factors like the Received Signal Strength Indicator (RSSI) of the mobile station (MS), the electromagnetic radiation from the base station, and the distance for a successful handover, may be also responsible for increasing signal interference and hence signal degradation. These factors have a negative impact on the reception of good quality GSM signals in any area. This directly affects the user experience, customer patronage and sometimes attracts penalties from regulators. Therefore, the objective of a good channel management strategy is to ensure maximum channel capacity, while minimising interference [5].

Cellular networks nowadays are not only required to provide high-quality service for voice customers, but a large quantity of data transfer service as well. Such services may include: wireless internet, file transfer, multimedia, and other downloads [6]. Consequently, the performance of any network should be monitored and maintained strictly from time to time to ensure a high quality of service (QoS).

There have been many complaints by staff and students concerning the quality of mobile reception in Benson Idahosa University. This University is one of the leading private Universities in Nigeria [7], and as such complaints especially from staff and students within and around the vicinity of the campus led to this research. There were several reports of ‘no service’ and dropped calls. Hence, the GSM Base transceiver station (BTS) located within the Ugbor campus environment of Benson Idahosa University was investigated to determine, if a significant relationship exists between the received signal strength, electromagnetic radiation level and distance. This study measured the received signal strength (in dBm), the electromagnetic radiation levels (in mW/m^2), and also the corresponding distances from the existing GSM base station (in metres). The results for the various generations 2G, 3G and 4G were compared.

The need to improve the quality of service by telecommunication operators has become more and more imperative. Hence, this study looked at the causes of poor mobile reception, out of which two factors were chosen and investigated.

[8] indicates that there are some factors that negatively affect the reception of mobile signals. These are:

i. Distance from the Tower or BTS
ii. Physical Obstructions
iii. Building Structures
iv. Interference
v. Network Issues e.g. tower load, and
vi. Network Congestion.

From the listed causes mentioned above, this study zeroed-in on two factors namely: distance from the tower, and interference. It is observed that BTS has a pre-set coverage area over which a signal can be broadcasted. This coverage is most often limited to the hardware that was used on the base station, the output power, the mobile station location in relation to terrain and the frequency being used to broadcast. [8] further posits that a critical factor for mobile network efficiency is the distance from the base station as this would affect the quality of service for customers. For instance, customers within the cell area need optimal service quality and to ensure this the BS may limit its signal strength to accommodate the majority of its customers, while ignoring customers at the edge of the network. The author further states that a typical cell range maybe 30, 60 or 160km, so that only users within that range would be able to connect to the base station. Therefore, if anyone is at the outer footprint of the coverage area, such a person would likely experience an unreliable level of service resulting from call dropouts and slow data speeds [8].

Another factor looked at by [9] was interference. The author pointed out that base station lowers output power when they are experiencing interference and as such leads to poor service. The interfering signals from other sources and also the signals emitted by these base stations are measured based on their strengths which can be expressed in different units. There are four units of measurement used to represent RF signal strength in wireless communication. These are: mW (Milliwatts), dBm (“dB”- milliwatts), RSSI (Received Signal Strength Indicator), and a percentage measurement [9]. Signal Strength also known as Received Signal Strength Indicator (RSSI) is the measurement of the power present in the mobile station. To put it in a different way, it is the power level being received by a mobile station after deduction of all possible losses and maybe used in link budget calculation [10]. The Received Signal Strength of a mobile Subscriber from the base station determines the quality of reception [5]. It is used to describe the total signal power received in milliwatts, and its value is usually expressed in dBm (logarithmic scale). Typical values ranges between -100dBm for low signal level to -60dBm for a very strong signal level [11]. RSSI represents the relationship between a transmission and received power [12].

Signal strength values are defined by a few different measurements values and they vary depending on the mobile generation under review [13]. These measurement values are as follows:

a) RSSI – Received Signal Strength (2G and 3G [UMTS, CDMS and EV-DO])
b) RSRP – Reference Signal Received Power (4G LTE)

However, to measure signal quality the following measurement values are used. They are:

c) RSRQ – Reference Signal Received Quality (4G LTE)
d) RSCP – Received Signal Code Power (4G LTE)
e) SINR – Signal to interference plus Noise Ratio (4G LTE)
f) EC/NO – Energy to Interference Ratio (3G [UMTS, CDMS and EV-DO])

The network generation determines which measurement value should be implemented. For the purpose of this study, RSSI values were used for all the generations so as to have one common/consistent measuring unit to compare each generation.It should be noted that for 2G and 3G, RSSI values can be obtained directly. However, the RSSI value for 4G is derived from its quality measurement values as shown in Equation 1. Thus, the RSSI values for 4G are an approximation of the true values, with the RSSI values shown in Table 3. For the second-generation (2G) network, signal strength is defined by only one value, that is RSSI and it is a negative value. The closer to 0 the value is, the better or stronger the signal. These received signal strength indicator values and signal strength description are shown in Table 1.

Table 1: RSSI values ranges for 2G

RSSI	SIGNAL STRENGTH	DESCRIPTION
>= -70 dBm	Excellent	Strong Signal with Maximum data Speed
-70 dBm to -85 dBm	Good	Strong signal with good data speeds
-86 dBm to -100 dBm	Fair	Fair but useful, fast and reliable data speed may be attained, but marginal data with drop-outs is possible
-101 dBm to -110 dBm	Poor	Performance will drop drastically
<-110 dBm	No signal	Disconnection

Source: [14]

For the third-generation (3G) signal strength the measurement values can be in any of the following values: RSSI, EC/IO and RSCP.

Note that the RSSI standard values for 2G and 3G are basically the same.

Table 2a: Shows RSSI values ranges for 3G

RSSI	SIGNAL STRENGTH
>= -70 dBm	Excellent
-70 dBm to -85 dBm	Good
-86 dBm to -100 dBm	Fair
-101 dBm to -110 dBm	Poor
<-110 dBm	No signal

Source: [13]

Table 2b: EC/IO values range for 3G

EC/IO	SIGNAL STRENGTH
0 to -6	Excellent
-7 to -10	Good
-11 to -20	Fair to Poor signal

Source: [13]

Table 2c: RSCP values range for 3G

RSCP	SIGNAL STRENGTH
-60 to 0	Excellent
-75 to -60	Good
-85 to -75	Fair
-95 to -85	Poor
-124 to -95	Very Poor

Source: [13]

For the fourth generation (4G) network, signal strength measurement values in RSSI are determined by a couple of other signal-related measurements. This must be known first before the received signal strength can be calculated [14]. The formula is given by:

RSSI = Wideband Power = Noise + Serving Cell Power + Interference Power (1)

The other signal strength measurement values that the 4G network can be presented in are RSSI, RSRP, RSRQ, SINR. Tables 3 shows the various measurement ranges for RSSI, RSRP, RSRQ and SINR. However, the Tenmars RF Meter (device) used for this study had everything calculated and presented in the RSSI values. This made it easier to get and record the values without any other calculation.

Table 3a: RSRP values ranges for 4G

RSRP	SIGNAL STRENGTH
>= -80 dBm	Excellent
-80 dBm to -90 dBm	Good
-90 dBm to -100 dBm	Fair to poor
<= -100 dBm	No Signal

Source: [14]

Table 3b: RSRQ values ranges for 4G

RSRQ	SIGNAL STRENGTH
>= -10 dB	Excellent
-10 dB to -15 dB	Good
-15 dB to -20 dB	Fair to poor
<= -20 dB	No Signal

Source: [14]

Table 3c: SINR values ranges for 4G

SINR	SIGNAL STRENGTH
>= 20 dB	Excellent
13 dB to 20 dB	Good
0 dB to 13 dB	Fair to poor
<= 0 dB	No Signal

Source: [14]

Table 3d: RSSI values ranges for 4G

RSSI	SIGNAL STRENGTH
>= -65 dBm	Excellent
-65 dBm to -75 dBm	Good
-75 dBm to -85 dBm	Fair to poor
-85 dBm to -95 dBm	Poor
<= -95 dBm	No Signal

Source: [14]

From the above Tables (1, 2, and 3) it can be seen that RSSI is present and common to all generations of the mobile technology. Hence this work used the RSSI values for all generation for its observation. This is to enable easy comparison of the signal strengths between generations.

For the radiation level the unit of measurement is milliwatt per square meter (mW/m^2). Although, there are other units which have be derived from this unit. Such units include Watt per square meter (W/m^2) or microwatt per square meter (µW/m^2). Due to the ease of taking measurement values from the device used, this work adopted the former (i.e. mW/m^2). However, the device could output the radiation values in either any of the above units.

Therefore, the objective of this paper is to investigate received signal strength (RSSI) and electromagnetic radiation (EMR) and to determine if there is any significant relationship between these two factors and the distance of the mobile station from the base station for the different architectures.

2. Methodology

This work used an App (called Cell Tower Info and Signal App) on a 4G Android mobile phone and a Tenmars RF 3-axis Field Strength Meter. The amount of received signal strength and electromagnetic radiation were measured at 10 meters from the feet of the base station and with repeated intervals of 10m to 100 meters' distance.

For each position, data were recorded and the process was carried out also for two other (different) radial directions. Therefore, a total of three-directions with multiple points were taken and recorded. This process was repeated for 2G, 3G and 4G.

The graphs of electromagnetic radiation and received signal strength, were plotted against the various distances.

The result was analysed to determine the relationship that exists between the various parameters and to establish how significant the relationships are.

3. Results and Discussion

The results of the readings are shown as follows.

Table 4: EMR Values, RSSI values and the corresponding distances for the various architectures

		EMR (mW/m^2)			RSSI (dBm)		
Architectures	**Distance (M)**	**Direction 1**	**Direction 2**	**Direction 3**	**Direction 1**	**Direction 2**	**Direction 3**
2G	10	13.195	8.676	57.580	-63	-5	-51
	20	71.360	61.770	69.830	-71	-10	-51
	30	1.176	75.690	9.267	-57	-13	-51
	40	67.450	26.080	8.356	-59	-13	-53
	50	0.543	12.922	6.841	-73	-15	-55
	60	1.791	37.810	1.157	-67	-13	-51
	70	2.508	27.680	3.012	-57	-50	-57
	80	34.380	2.868	2.277	-57	-51	-55
	90	55.140	5.027	3.347	-59	-51	-51
	100	54.310	2.572	2.586	-75	-53	-53
3G	10	0.739	77.000	0.741	-65	-73	-71
	20	1.194	12.525	1.296	-73	-69	-73
	30	2.029	4.377	2.409	-77	-61	-61
	40	2.844	1.517	2.478	-81	-71	-59
	50	53.750	7.786	1.263	-67	-77	-73
	60	2.318	3.050	1.190	-61	-63	-77
	70	0.865	1.042	1.605	-71	-79	-81
	80	2.530	0.838	0.650	-61	-75	-81
	90	2.170	0.515	3.219	-71	-79	-75
	100	1.343	0.293	3.005	-69	-77	-73
4G	10	94.300	1.100	2.968	-74	-63	-76
	20	3.172	1.651	0.803	-79	-65	-79
	30	3.003	3.894	1.533	-65	-63	-78
	40	1.109	2.456	0.991	-64	-56	-81
	50	1.340	2.514	1.785	-63	-66	-79
	60	2.371	2.180	7.327	-76	-64	-78
	70	1.137	6.973	1.308	-72	-60	-76
	80	1.620	1.981	0.875	-67	-67	-72
	90	2.147	1.195	2.280	-77	-64	-75
	100	2.218	1.460	1.233	-83	-66	-69

The corresponding graphs showing the Mean electromagnetic radiation levels (Power density) and Received signal strength (dBm) versus Distance (meters) are shown in Figures 1a to 3c

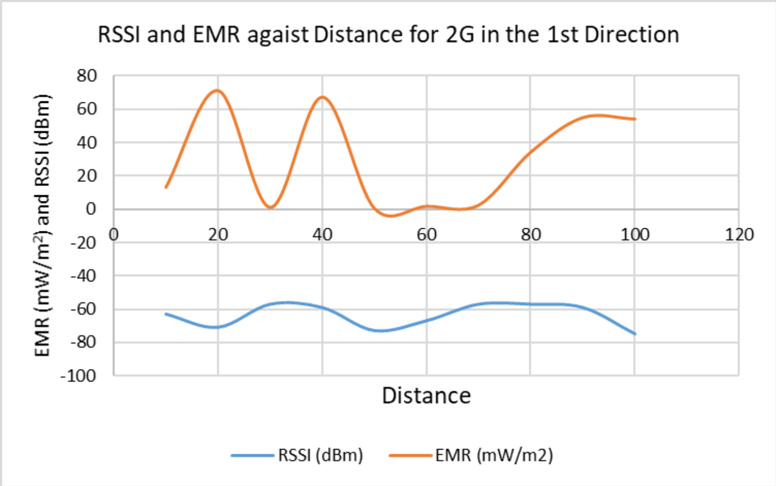

Figure 1a: EMR and RSSI against distance for ***2G*** network in the 1st direction

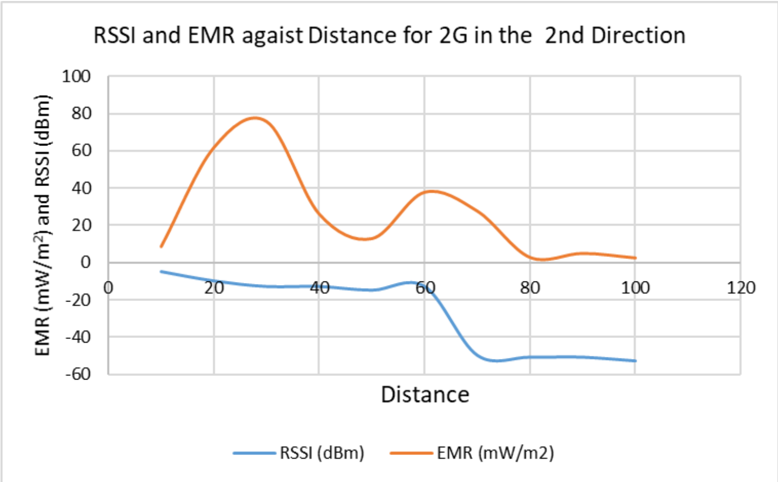

Figure 1b: EMR and RSSI against distance for ***2G*** network in the 2nd direction

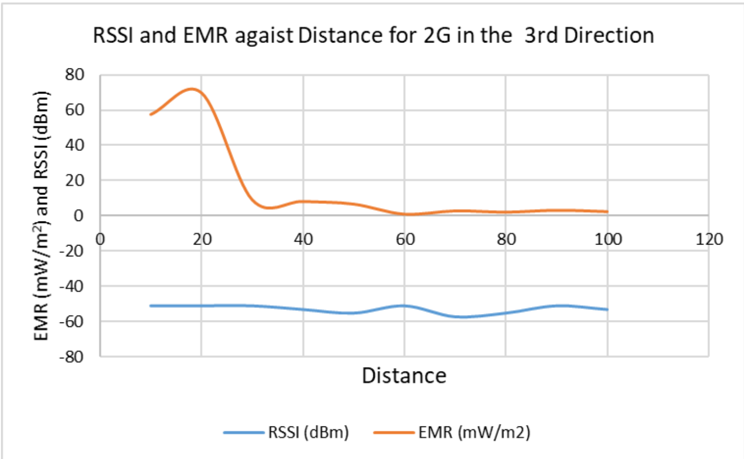

Figure 1c: EMR and RSSI against distance for ***2G*** network in the 3rd direction

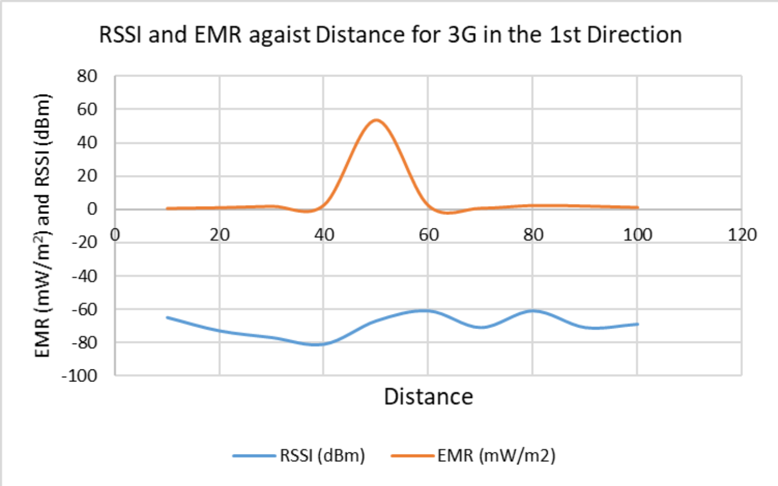

Figure 2a: EMR and RSSI against distance for ***3G*** network in the 1st direction

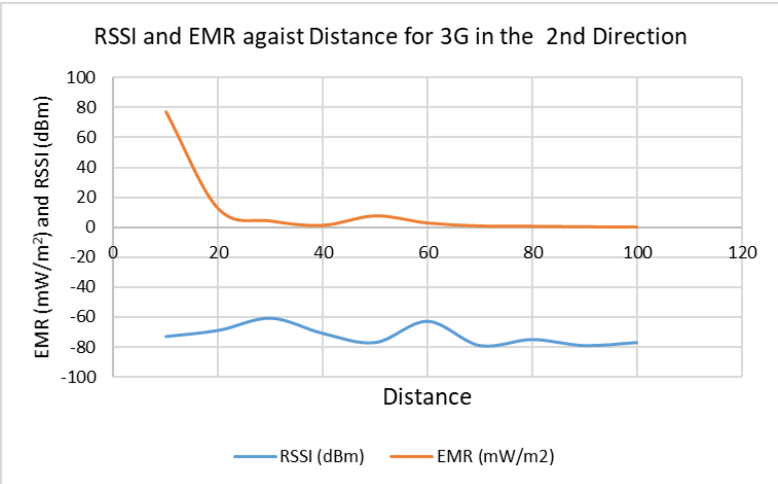

Figure 2b: EMR and RSSI against distance for ***3G*** network in the 2nd direction

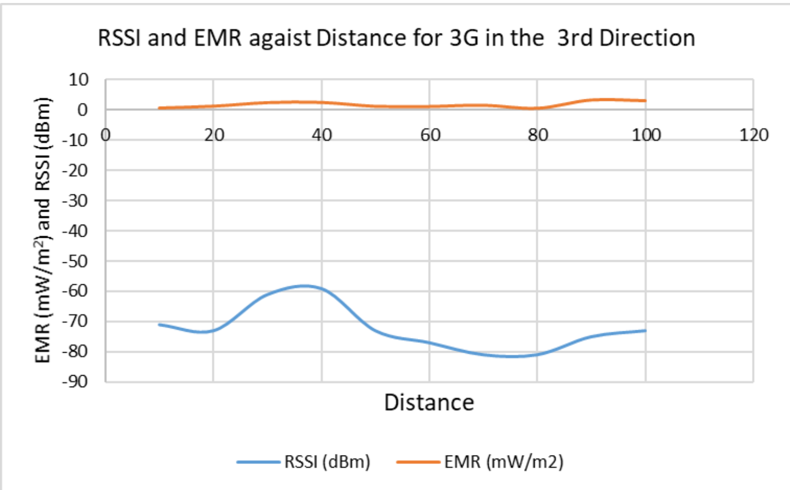

Figure 2c: EMR and RSSI against distance for ***3G*** network in the 3rd direction

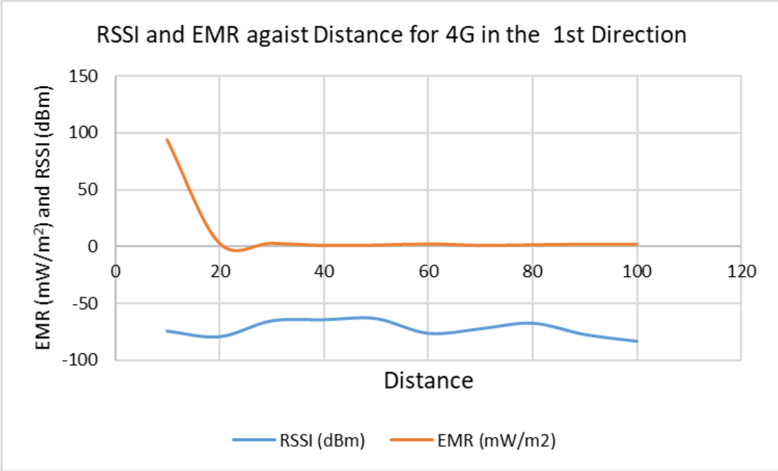

Figure 3a: EMR and RSSI against distance for ***4G*** network in the 1st direction

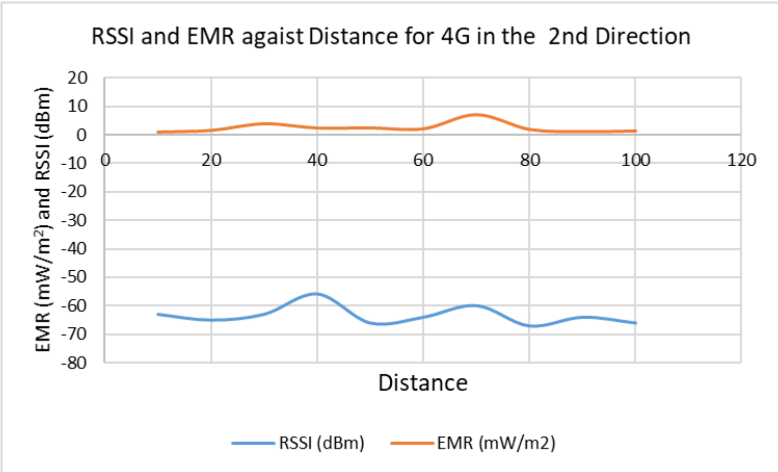

Figure 3b: EMR and RSSI against distance for ***4G*** network in the 2nd direction

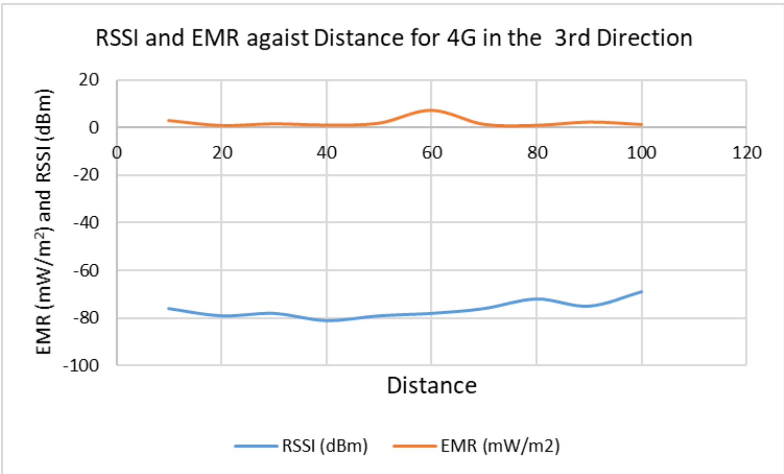

Figure 3c: EMR and RSSI against distance for ***4G*** network in the 3rd direction

As can be seen from Table 4, the electromagnetic radiation levels from the 2G technology are not stable and these fluctuate very highly from between 0.543 mW/m^2 to 71.360 mW/m^2 as compared to the RRSI values which vary from about -5 to -75 dBm. The Received Signal Strength Indicator values for radial directions 1, 2 and 3 show that the received signal is pretty good as it has a value of -5 which is close to the 0 dBm value. Table 4 also shows some very different characteristics for 3G as compared to the 2G architecture. This generation (that is, 3G generation) electromagnetic radiation levels was fairly stable as the fluctuation was not far apart with the peak level of 53.750 mW/m^2 and the minimum level of 0.293 mW/m^2. Here the radiation level was fairly constant as the distance increases. The RSSI was also constant and varied from -59 dBm to -81 dBm. This shows that the received signal by the user device was poor as compared to the 2G technology. Table 4, shows that the 4G technology had very constant and less fluctuating values for its electromagnetic radiation levels. It had its received signal strength values close to the -100 dBm level indicating that the signal received by the mobile terminal is weak.

4. Conclusion

In summary, the 2G has a better-received signal as compared to other generations but has a very high radiation level which can be harmful to the health of the general public. The 3G technology seems to be in-between the 2G and 4G technology in terms of radiation and received signal strength. The 4G technology has a low radiation emission, but a very poor signal strength. This study therefore recommends that more 4G base stations be built to replace existing 3G station as this would help reduce high electromagnetic radiation. Thus, this validates the author [15] findings "that penetration of radiation is reduced drastically if the distance of cell phone and/or cell phone towers from the human body can be maintained more".

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