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RADIOFREQUENCY BASELINE ASSESSMENT OF A LARGE MINING CONCESSION ENCLAVE AND AFFECTED COMMUNITIES

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ABSTRACT

This study evaluated the existing RF levels within a gold mining concession before the planned installation of communication towers for a large-scale mining operation. Recorded power density levels ranged from 5.92 pWm^{-2} to 1.22 mWm^{-2}, which are lower than those reported in similar studies. The highest total exposure levels were observed at some proposed tower locations, suggesting a potential increase in RF exposure at these sites once the communication towers are installed. This underscores the need for regulatory bodies to consider pre-existing RF exposure levels during the permitting process. Notably, higher power density levels were recorded in nearby towns. The 900 MHz band exhibited the highest power density, contributing 50% of the total exposure, indicating a prevalent use of 2G GSM900 mobile technology in the study area. Conversely, the mine's designated communication frequency band recorded the lowest power density levels across all locations.

Keywords: Electromagnetic fields, radiofrequency radiation, baseline assessment, mining.

INTRODUCTION

Mining natural resources is one of the backbone activities of most countries' economies. Especially in Africa's natural resource-rich countries, mining activities sustain the country and bring in much-needed foreign currency. The vast job opportunities available in mining and the direct and indirect socio-economic impact on communities within and outside the mining enclave are enormous. The operation of a mine depends highly on good and reliable communication systems. It is an essential and critical asset of large and medium-scale mines. To this effect, telecommunication systems are one of the initial infrastructures the mining companies put in place in a new mine. This includes dedicated and exclusive communication channels for the mine's operations as well as connectivity for workers and public communication for mobile and landline communication. Mobile communication relies on antennas to transmit and receive signals carried by electromagnetic (emf) radiofrequency (RF) radiation (Giancoli, 2009). The antennas must be mounted on an elevation to ensure adequate signal connectivity. Levels of public exposure to RF fields from communication have been studied in Ghana. Using a spectrum analyzer and log periodic antenna (80 MHz to 3 GHz), Deatanyah *et al* (2020) determined the RF electric field levels from frequency modulation (FM), television (TV), and mobile base stations (MBS) transmitters in Ghana. The level produced ranged from 0.96 to 1220 mVm^{-1}. The levels from the MBS varied from 109 to 323 mVm^{-1}. They found FM frequencies a major source of RF public exposure in Ghana. However, they did not include 800 MHz and 2400MHz bands which are used in 4G applications. In another paper (Deatanyah, Amoako, Abavare and Menyeh, 2018a), they concentrated on RF levels at a radial distance of 61 to 254 m from mobile base stations in Ghana. They measured the electric field strength of RF fields of mobile base stations using a power sensor coupled to a log periodic antenna and connected to a spectrum analyzer. Their measured values had a maximum of 0.8950 mWm^{-2} and a minimum of 0.0717 mWm^{-2}. They found GSM900 applications to be the most prominent relative to UMTS2100 and GSM1800. By considering multiple RF sources, Deatanyah *et al*. (2018b) conducted wide-band (FM, TV and mobile base station) measurements at 200 public access places in Ghana using a spectrum analyzer to determine cumulative exposure. RF levels from FM maintained their dominance, followed by mobile base stations and TV. The maximum level measured was 0.19% of the ICNIRP reference level. The impact of mining operations on the RF exposure of the operational and catchment areas can be better evaluated if the exposure levels predating the commencement of the mining are known. The mining operation will not only affect the mining concession, but the influx of mine workers and associated direct and non-direct business into the towns within the catchment area will invariably raise communication needs, leading to potential increases in RF exposure from communication systems.

Data on the pre-existing (baseline) RF levels present at the concession (mining area) in its natural form, before the mine became operational, is a precursor to a proper and effective assessment of the impact the mining operations and related activities would have on the area. Despite the impressive number of studies on public exposure to RF radiation in Ghana, the subregion and Africa (Joyner, Wyk & Rowley, 2014), not much has been done on baseline assessment before the deployment of communication towers. This study helps to fill in the knowledge gap by determining preexisting empirical RF field levels prior to the full operationalization of a mine.

MATERIALS AND METHODS

Study Area

The gold mining concession in focus in this study was acquired by one of the large mining companies in Ghana. The concession is located near Sunyani in the Ahafo region of Ghana. The concession covers forests, farmlands and tick tree plantations. Towns, villages and hamlets fall within the mining lease area. The mining company intended to deploy five communication towers within the mining area. The proposed locations for deployment of the communications towers and communities nearby are depicted in Figure 1. The descriptions of the proposed tower locations are provided in Table 1 while that of the nearby towns are given in Table 2. Yamfo is the biggest town in terms of land size and population, followed by Techire, Adrobaa, and Afrisipakrom in that order. Locals are predominately farmers and traders. There were already existing communication towers in all four towns. Some towns have more than one communication tower depending on the size of the town. Because of the proximity of the townships to the proposed tower locations, the RF power density levels of these towns were also assessed.

The frequency bands of interest which were assessed and their applications (NCA, 2017; NCA, 2020; NCA, 2021) are shown in Table 3. Apart from the 400 MHz band, applications of the other frequency bands are for public use and are not limited to mining operations. The applications are basically the Global System for Mobile Communication (GSM), Long Term Evolution (LTE) and Universal Mobile Telecommunications System (UMTS).

Table 1: Proposed Locations of Communication Towers

Location	Map Code	Elevation (m)	Vegetation/Area Description
Proposed Tower 1	EM	328	Crop Farm
Proposed Tower 2	YHR	335	Dense crop farm with cocoa plants
Proposed Tower 3	RDS	342	Newly cleared land for farming
Proposed Tower 4	WRF	373	Dense teak tree plantation
Proposed Tower 5	PTS	322	Mine site offices

Table 2: Towns in the Catchment Areas of Newmont's Proposed Towers Locations where measurements were taken.

Town Name	Location	Latitude	Longitude	Elevation (m)
Adrobaa	Close to Tower 4	7.26110	-2.13446	354 - 376
Afrisipakrom	Close to Towers 1 & 5	7.25458	-2.20366	290 - 314
Terchire	Close to Tower 5	7.22853	-2.17691	304 - 327
Yamfo	Close to Tower 2	7.22012	-2.23951	301 - 333

Table 3: Frequency Band Usage. (NCA, 2021; NCA, 2020; NCA, 2017)

Frequency Band (MHz)	Mobile Communication Technology
400 MHz	
800 MHz	4G LTE800
900 MHz	2G GSM900 and 3G UMTS900
1800 MHz	2G GSM1800
2100 MHz	3G
2400 MHz	4G

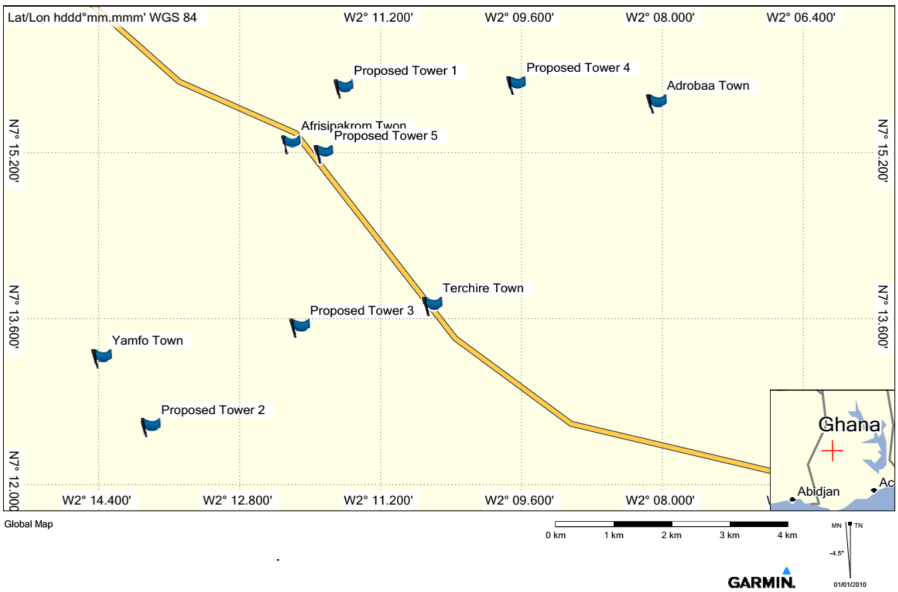

Figure 1: Towns and Proposed Tower Locations (Source: Gamin BaseCamp)

MATERIALS

Electric field strength measurements were carried out using an Anritsu Spectrum Master MS2720T with serial number 1508082 and a frequency range of 9 kHz to 43 GHz. It was connected to a handheld Transformational Security log-periodic antenna TS-6021 with serial number 00302 and a frequency range of 80 MHz to 3 GHz with an RF cable as shown in Figure 2. A Gamin global positioning system (GPS) device was used to take GPS coordinates of the measurement location. The use of a spectrum analyzer provides more adequate results (Naciu *et al*., 2023) and allows the examination of individual frequencies deducted.

Figure 2: Instrumentation for Electric Field Strength Measurements.

Method

The measurement methodology used complies with the Electronic Communications Committee recommendation ECC (2007) and International Electrotechnical Commission IEC 62232 (2004) protocols. Measurement points, spaced between 50 m to 500 m apart, were randomly selected. The measurement points were selected to the area under study and be representative of the study area. The selection of the measurement points or spots were also guided by the availability of occupancy and potential occupancy.

Measurements were made at and within the vicinity of the proposed locations for deployment of five communication towers and within four towns found within the concession of the mine and sited close to the planned locations for the communications towers. Figure 3 depicts the measurement locations. The number of measurements taken at and within the vicinity of each proposed location for the communication tower and the nearby towns are provided in Table 4. Measurements were made over seven days.

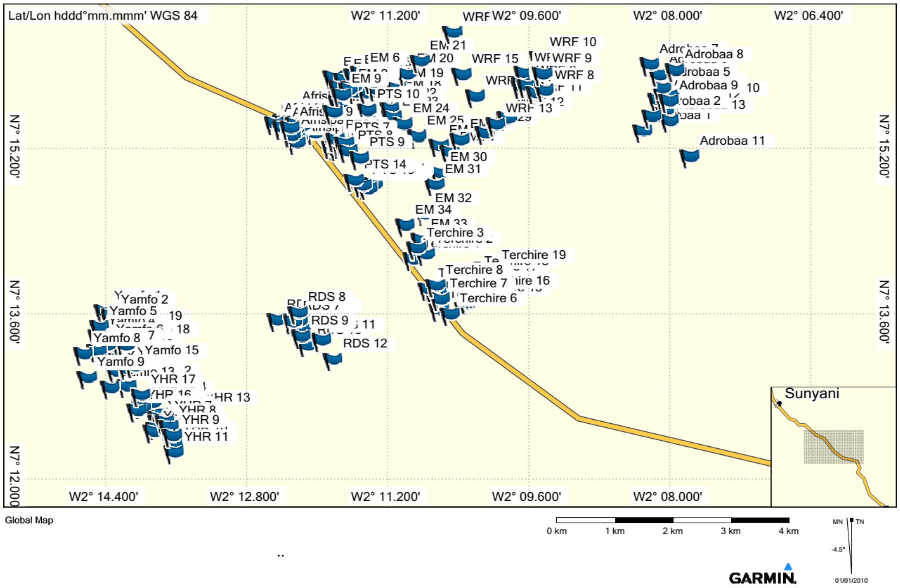

Figure 3: Map showing measurement points (Source: Gamin BaseCamp)

Broadband measurements over the frequency range from 300 MHz to 500 MHz and 750 MHz to 2.5 GHz. Maximum hold setting was used to measure the highest electric field over a six-minute interval. Measurement was made between the hours of 8 am to 6 pm. Description of measurement location, elevation, and GPS coordinates were recorded on a datasheet. By the use of sweep measurements method at the heights 1.0 m, 1.5 m and 2.0 m, the average height of both adults and children was considered.

Table 4: Number of Measurements taken at and in the vicinity

Location	Number of Measurements
Proposed Tower 1	34
Proposed Tower 2	17
Proposed Tower 3	12
Proposed Tower 4	18
Proposed Tower 5	14
Adrobaa	14
Afrisipakrom	14
Terchire	19
Yamfo	19
Total measurements	161

Data processing

The spectrum analyzer measures the incident electric field strength, V_o in dBµV. The losses attributed to the RF cable (A_c) and the antenna (K) were corrected using Equation 1 (Deatanyah et al., 2020). The RF cable loss term (A_c) corrects for the losses attributed to the transmission of electromagnetic waves detected through the 1 m RF cable connecting the antenna to the input port of the spectrum analyzer. The antenna factor term (K) is a calibration factor associated with the antenna used for the detection. The dimensional analysis of Equation 1 can be analysed using logarithms.

$$E_{dB}\left[dB\mu Vm^{-1}\right]=V_o\left[dB\mu V\right]+K\left[dBm^{-1}\right]+A_c\left[dB\right] \quad \textbf{eqn 1}$$

Equation 2 was employed in converting the electric field from the units of dBµ Vm^{-1} to Vm^{-1}. The resultant electric field at a measurement point E_r was evaluated vectorially using Equation 3 with E_i as the electric field strength for the n frequency band (Linhares, 2017; Kurnaz and Aygun, 2020; Naciu et al., 2023).

$$E_i\left[Vm^{-1}\right]=10^{\left(\frac{E_{dB}-120}{20}\right)} \quad \textbf{eqn 2}$$

$$E_r=\left(\sum_{i=1}^{n} E_i^2\right)^{\frac{1}{2}} \quad \textbf{eqn 3}$$

The power density levels were derived from the electric field strength using equation 4 with 377 Ω as the impedance of free space (Mohril et al., 2016). This is because the measurements were taken in the Fraunhofer region of the antenna, also known as the far field, where the electromagnetic waves are plane in nature. In the Fraunhofer region, the power density can be estimated from the measured electric field strength using equation 4. The average power density S_{av} representing a location was evaluated using Equation 5, where S_i is the power density of a detected frequency/signal.

$$S\left[Wm^{-2}\right]=\frac{E^2}{377} \quad \textbf{eqn 4}$$

$$S_{av}=\frac{1}{m}\sum_{1}^{m} S_i \quad \textbf{eqn 5}$$

Equation 6 was used to calculate the total exposure ratios (TER) of a measurement point (ICNIRP, 2020) where E_i average power density for a frequency detected and E_{ref} is the reference level of the International Commission on Non-ionizing Radiation Protection (ICNIRP) for that frequency. The TER is a compliance assessment which evaluates the cumulative exposure (ratio of measured field to its frequency related limit) for all frequencies detected at a measurement point relative to the frequency exposure limits. Microsoft Excel was used as a tool to assist in the processing and analysis of the data. A calculated expanded uncertainty (Table 5) of 14.14% was applied.

$$TER=\sum_{f>100\,MHz}^{300\,GHz}\left(\frac{E_i}{E_{ref}}\right)^2<1 \quad \textbf{eqn 6}$$

Table 5: Evaluation of Uncertainty

Uncertainty sources	Uncertainty Type	Estimate (%)	Probability Distribution	Divisor	Standard Uncertainty (%)
Spectrum Analyser					
Resolution Bandwidth (1 Hz to 3 MHz)	B	10.0	Normal	2.00	5.00
Amplitude accuracy	B	5.92	Rectangular	2.00	2.96
Device-Under-Test					
Antenna calibration factors	B	5.95	Normal	2.00	2.98
Cable correction factor	B	1.45	Rectangular	1.73	0.84
Measurement Repeatability	A	0.10	Normal	2.00	0.05
Mismatch (Analyser and Antenna)	B	3.64	U-shape	1.41	2.58
Measurement Uncertainty					
Combined uncertainty (%)			Coverage factor		7.07
Expanded Uncertainty (95 %)			2		14.14

RESULTS AND DISCUSSIONS

The following emergent themes were identified from the analysis: RF power density levels and Total exposure.

RF power density levels

The average power density levels of the frequency bands calculated for the five proposed locations for deploying communication towers are provided in Figure 4. Proposed locations for towers 4 and 5 recorded the higher levels of RF, with the 900 MHz band producing the highest average power density value of 3.83E-06 Wm^{-2} for location 5 in terms of the proposed locations for the towers. Location 3 provided the lowest power density levels. Apart from location 5, the 400 MHz band recorded the lowest power density at all locations.

Figure 5 shows the average power densities of the towns closest to the proposed tower locations. The 900 and 2100 MHz bands dominate the power density levels. Similar to the proposed tower locations, the 400 MHz band remains in the lowest power density levels. Again, the highest average power density of the towns was recorded in the 900 MHz band with a value of 9.69E-06 Wm_{-2} for Afrisipakrom town.

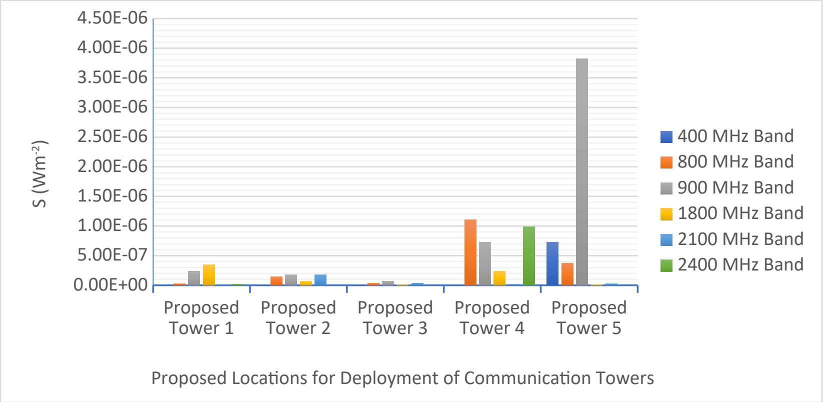

Figure 4: Average Power Density within the vicinity of proposed locations for installation communication towers showing existing higher RF field levels at Tower 4 and 5 relative to proposed Towers 1, 2 and 3.

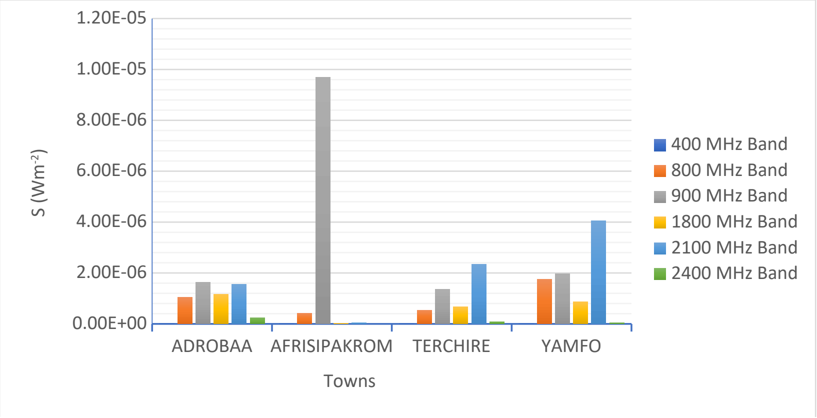

Figure 5: Average Power Density levels within towns nearest the proposed locations for the installation communications towers with Afrisipakrom recording significant RF field levels for the 900 MHz band.

Figure 6 combines all the frequency bands to provide the average power densities across the frequency bands for a location. The average power densities of the nearby towns exceed the levels for the proposed tower locations. However, the level for the proposed location for Tower 5 is comparable to that of Adrobaa and Terchire. For the proposed tower locations, the highest was location 5, followed by locations 4, 1, and 2 with proposed tower location 3 having the lowest power density levels.

Despite being one of the smallest towns, Afrisipakrom exhibited relatively high RF field levels (Figure 6), likely due to the higher transmission power of its communication antennas to serve nearby villages and settlements. In contrast, larger towns have multiple communication towers, allowing network operators to reduce transmission power while maintaining quality service.

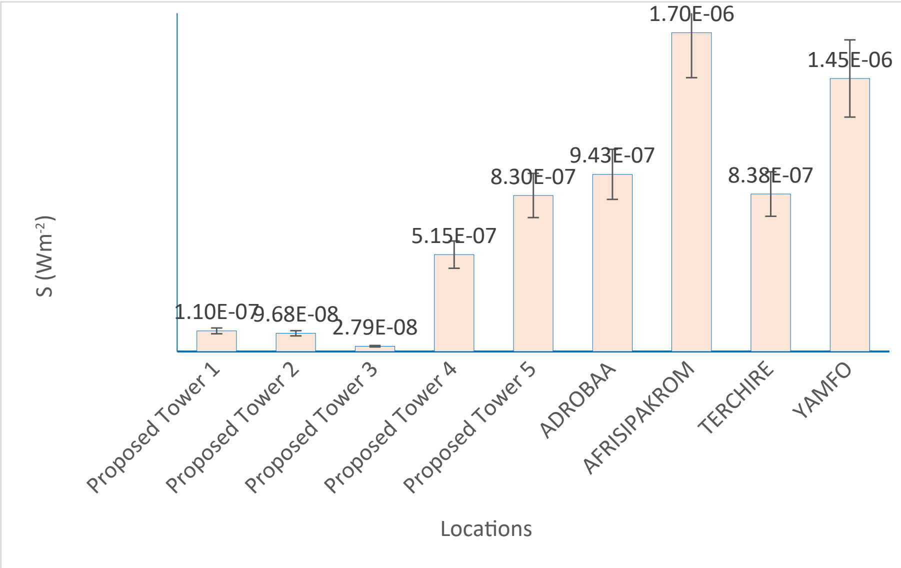

Figure 6: Average Power Density levels at the proposed locations for installation of communication towers and nearby towns showing the towns recording higher levels relative to the proposed tower locations.

As shown in Figure 6, the average power densities in the towns were higher than those at the proposed tower locations. This was expected, as the towns have existing communication towers, whereas the proposed sites do not, resulting in higher field levels within the townships. The relatively higher power density at proposed tower location 5 is due to its proximity to Afrisipakrom (Figure 1), which recorded the highest power density levels (Figure 6). However, the total exposure levels at proposed tower locations 4 and 8 exceeded those of all the towns except Afrisipakrom (Figure 9). Total exposure accounts for contributions from all detected frequencies across different frequency bands, weighted by their respective ICNIRP reference levels (Equation 6). These reference levels are frequency-dependent (ICNIRP, 2020). The fact that proposed tower locations 4 and 8 recorded higher total exposure levels despite the absence of communication towers is significant. It suggests the potential for elevated RF exposure once the towers are constructed and operational. Regulators should take these relatively high pre-existing field levels into account during the permitting process. The maximum and minimum power densities for a location, the corresponding frequency band, and the elevation of the measurement point or spot which produced the maximum and minimum power density levels are provided in Tables 6 and 7 respectively. The global positioning system (GPS) coordinates of the measurement spot where the maximum field was measured, and the elevation as well are also given. The 900 MHz band dominates the bands recording the maximum fields. A description of the measurement point is also provided. All the minimum power density levels were recorded in the 400 MHz band (Table 7). In comparing the elevations where maximum and minimum power density levels were measured, (Tables 6 and 7), it is observed that most of the maximum field levels recorded occurred at relatively higher elevations when compared to their respective elevations for the minimum field. All measured and evaluated RF field levels were below the ICNIRP reference levels (limits). At the proposed communication tower locations, the maximum recorded power density field was 5.1E-04 Wm^{-2} from the 900 MHz band at an elevation of 328 m in Afrisipakrom (Table 6), which is 0.25 % of the ICNIRP limit. Similarly, the maximum power density recorded in the four towns was within Afrisipakrom township. The value was 1.22E-03 Wm^{-2} from the 900 MHz frequency band at an elevation of 304 m (Table 5), representing 0.14 % of the corresponding ICNIRP limit.

Table 6: Maximum Measured Field Levels and Frequency Band Usage

Location	Maximum Power Density (Wm^{-2})	Frequency Band (MHz)	GPS Coordinates of Measurement Point	Elevation of Measurement Point (m)	Description of location
Proposed Tower 1	4.13E-05	1800	-	366	Crop farm
Proposed Tower 2	6.53E-06	2100	-	336	Cocoa farm
Proposed Tower 3	1.08E-06	900	-	-	New road under construction
Proposed Tower 4	1.85E-04	900	-	352	Village in teak plantation
Proposed Tower 5	2.51E-04	900	-	328	Plant site
Adrobaa	5.58E-05	2100	7.26637, -2.13723	376	Town
Afrisipakrom	1.22E-03	900	7.25597, -2.20429	304	Town
Terchire	4.37E-05	900	7.22903, -2.17293	324	Near water tank
Yamfo	1.18E-04	2100	7.21778, -2.23466	321	Town

Table 7: Minimum Measured Field Levels and Frequency Band Usage

Location	Maximum Power Den sity (Wm^{-2})	Frequency Band (MHz)	GPS Coordinates of Measurement Point	Elevation of Measurement Point (m)	Description of location
Proposed Tower 1	1.22E-11	400	-	351	
Proposed Tower 2	1.45E-11	400	-	335	Proposed spot for tower 2
Proposed Tower 3	1.77E-11	400	-	-	New farm
Proposed Tower 4	8.16E-12	400	-	362	Village
Proposed Tower 5	2.26E-11	400	-	334	
Adrobaa	1.96E-11	400	7.26064, -2.13568	365	Basic School
Afrisipakrom	5.92E-12	400	7.25571, -2.20297	309	Main Sunyani Highway
Terchire	1.03E-11	400	7.22683, -2.17706	304	Sunyani highway (Fufu base)
Yamfo	1.00E-11	400	7.21976, -2.24433	301	Town

The average power density of the various frequency bands for all the measurements or locations is given in Figure 7. The 900 MHz band leads widely and is followed by the 2100 MHz band, and then the 800 MHz band. The 1800 MHz band comes after the 800 MHz band, with the 400 MHz band having the lowest power density average levels.

Figure 8 shows the percentage contribution of each band in terms of average power density levels. The 900 MHz band leads and the 400 MHz band trails in last place.

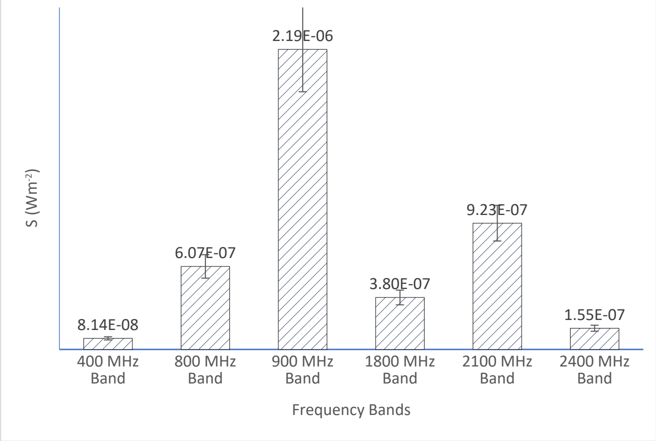

Figure 7: Average Power Density levels of the Frequency Ban

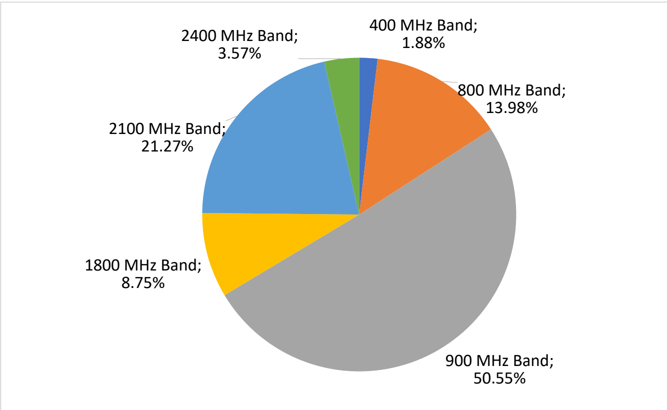

Figure 8: Average Power Density Percentage Contribution of the Frequency Bands

The 900 MHz band exhibited the highest power density levels among all frequency bands (Figures 4, 5, 7, and 8), indicating that it is the most widely used network technology and carries the highest communication traffic in the study area. This band is primarily allocated for 2G GSM900 and 3G UMTS900 communication technologies. Observations suggest that many people in the study area use basic mobile phones, commonly referred to in Ghana as "yam phones." These phones support voice calls and short text messaging, are relatively inexpensive, and are therefore widely accessible. Since they operate on the

2G GSM900 network, their prevalence may contribute to the elevated power density levels associated with higher usage. The next most utilized band is 2100 MHz (Figure 7), which supports 3G applications and typically requires more expensive smartphones. Following this, the 1800 MHz band ranks third in usage and traffic, as indicated by the RF power density levels (Figure 7). There is also significant 4G LTE800 usage in the study area, reflected by the substantial power density levels in the 800 MHz band (Figure 7). However, because 4G technology requires costly smartphones, it is less common among residents. The 800 MHz and 2400 MHz bands are both used for 4G services. The 400 MHz band recorded the lowest power density levels. This band is designated for local communication by the mining company operating in the area. At the time of the study, the company was conducting preparatory activities, including fieldwork, and had deployed local communication installations. However, measurement results indicated that RF exposure contributions from the mining company's 400 MHz communication system were the most minimal at all measurement locations (Figures 7 and 8).

Total Exposure

The total exposure for each measurement point (spot measurement) was evaluated. The average for a location is reported in Figure 9. All the total exposure quotients are below the ICNIRP recommended limit of one (1). This implies that at no measurement spot did the RF power density levels cumulatively of the individual frequencies detected from the six frequency bands exceed the recommended limit. Conspicuously, the exposure quotients of proposed tower locations 2 and 3 are the lowest with Afrisipakrom having the highest.

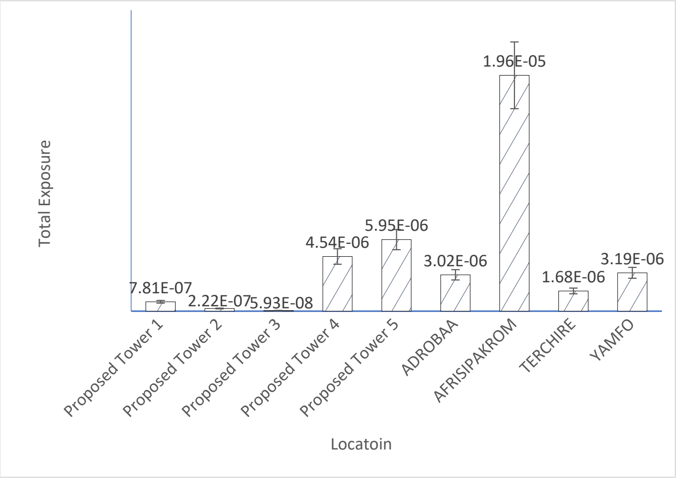

Figure 9: Total Exposure Ratio

A summary of the statistics of the resultant power densities (Equations 3 and 4) of each measurement point for all the locations are provided by Table 8. The resultant power densities, S_r, were evaluated from the resultant electric fields, E_r, using equation 4.

Table 8: Statistics summary of calculated resultant power density levels of spot measurements

.	Proposed Tower 1	Proposed Tower 2	Proposed Tower 3	Proposed Tower 4	Proposed Tower 5	Adrobaa	Afrisipakrom	Terchire	Yamfo
Mean	5.38E-06	1.25E-06	3.02E-07	2.06E-05	2.40E-05	9.27E-06	8.96E-05	1.06E-05	2.54E-05
Standard Error	2.45E-06	6.66E-07	1.21E-07	1.30E-05	1.78E-05	3.59E-06	8.68E-05	4.28E-06	7.56E-06
Median	1.23E-07	2.47E-07	8.31E-08	8.50E-07	2.01E-06	5.35E-06	7.07E-07	3.83E-06	1.34E-05
Mode	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Standard Deviation	1.43E-05	2.74E-06	4.03E-07	5.50E-05	6.66E-05	1.35E-05	3.25E-04	1.87E-05	3.29E-05
Sample Variance	2.04E-10	7.53E-12	1.62E-13	3.03E-09	4.43E-09	1.81E-10	1.06E-07	3.49E-10	1.08E-09
Kurtosis	12.65	8.06	0.73	12.24	12.85	8.27	14.00	11.71	4.79
Skewness	3.47	2.89	1.38	3.41	3.55	2.71	3.74	3.23	2.11
Range	6.84E-05	1.03E-05	1.17E-06	2.24E-04	2.52E-04	5.09E-05	1.22E-03	8.04E-05	1.30E-04
Minimum	1.64E-14	8.92E-10	1.40E-12	8.10E-10	1.11E-11	6.76E-07	1.99E-12	3.18E-14	4.05E-09
Maximum	6.84E-05	1.03E-05	1.17E-06	2.24E-04	2.52E-04	5.16E-05	1.22E-03	8.04E-05	1.30E-04

Since the resultant power density values at various locations were skewed (Table 8), and considering the kurtosis, the median values better represent the data than the mean values. All locations exhibited positively skewed resultant power density distributions, further indicating generally low recorded power density levels (Table 8). Among the locations, Afrisipakrom showed the greatest variation in relative power density values, while Proposed Tower Location 3 had the least variation (Table 7). This is further supported by their kurtosis values. All the proposed tower locations (except proposed tower location 3) had kurtosis values greater than 3 (Table 8), indicating that their distributions are more peaked and contain outliers. In a similar work by Deatanyah *et al*. (2020), they focused on RF levels within the vicinity of communication towers across the regions of Ghana, they used a spectrum analyzer and a directional antenna over the frequency bands of 900, 1800 and 2100 MHz. However, they focused on only locations with existing communication towers. They recorded an RF power density range of 0.0008 to 182 mWm^{-2}, far higher than the 0.00000854 to 1.22 mWm^{-2} range recorded in this current work for the 900, 1800, and 2100 MHz bands. In another similar study by Deatanyah *et al*. (2018b) on public exposure to multiple RF sources including TV, FM, GSM 900, GSM 1800 and UMTS 2100 they measured an electric field range of 1.09E+01 to 3.23E+02 Vm^{-1} (0.315 to 276 mWm^{-2}) from mobile communication base stations in Ghana, which also exceeds the levels recorded in this current work. Fuseini *et al*, (2023) measured RF power density at varying horizontal distances from a hundred 4G LTE 800 mobile base stations in the Western and Ashanti regions of Ghana using a spectrum analyzer. They recorded a range of 3.42E-08 to 1.52E-01 mWm^{-2}, exceeding the range of 2.83E-05 to 8.31E-02 mWm^{-2} recorded in the current work. Kumaz and Aygun (2020) conducted a study on RF electromagnetic fields in hospitals in the Samsum province of Turkey. They assessed the frequency range of 27 MHz to 3 GHz and discovered that LTE 800, GSM 900, GSM 1800, LTE 1800 and UMTS 2100 frequency bands contributed 40.4 % to RF-EMF fields. Comparatively, their contribution is lower than the results obtained in the current study, where the contribution from the four bands was 94.55 %. RF radiation affects the body basically by increasing temperature and changing the permeability of membranes. Apart from these two biological effects, RF exposure can also cause nerve stimulation (ICNIRP, 2020). There are many studies on effects of RF exposure, but the established health effect from RF exposure is related to an increase in body temperature above 1°C which can occur with applications such as RF heaters (WHO, 2006). However, the RF exposure levels to the public from communication towers, including levels recorded in this study, are not enough to cause such heating health effects as they are lower exposure limits.

CONCLUSION

The RF power density levels from the proposed locations for communication towers and the nearby towns were below the ICNIRP reference levels. The highest power density level was recorded in Afrisipakrom town, which was 0.14 % of the ICNIRP reference levels, demonstrating compliance with exposure limits. Compliant with exposure limits eliminates the potential for exposed persons experiencing biological effects of RF radiation. However, the proposed locations for Towers 4 and 5 recorded the highest total exposure, raising the potential for elevated exposure when the towers are deployed at those locations and the importance of continuous monitoring of exposure levels after installation. The 900 MHz band was the most used, pointing to a popular usage of 2G GSM900 mobile phones in the study area. The band contributing the least to RF radiation exposure was the 400 MHz band which consistently recorded the lowest power density levels at all locations. Comparatively, the RF levels recorded in this work are lower than those measured in similar works elsewhere in Ghana and in Turkey suggesting lower radiation exposure environment in terms of RF fields exposure. But unlike in this study which had some locations without communication towers, there were communication towers at all locations in the referenced Ghana and Turkey similar studies, thereby contributing to the lower levels recorded in the current study. Also, the study did not consider TV and FM frequencies which are predominately used by residents.

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DECLARATION OF COMPETING INTEREST

The authors declare no conflict of interest.

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