Measurement and Analysis of Radiation Levels from Base Transceiver Station in Sambas

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Abstract
The development of telecommunications in Indonesia until now has experienced a very significant increase and has become a significant need in communication. Many people use communication tools daily, causing many providers to set up Base Transceiver Stations (BTS) to reach their users to remote areas. BTS has a transmit power that can reach the destination area, but most people still do not know the level of radiation emitted and the health effects on the body. Therefore the International Commission for Non-Ionizing Radiation Protection (ICNIRP) has set a threshold level of safe radiation for the human body. Sambas is one of the cities in West Kalimantan which is the target for the development of BTS establishments by operators. This makes the surrounding community feel afraid of the health caused by radiation from the BTS. So it is necessary to do some research, socialize, measuring, and evaluate the level of radiation emitted from BTS, especially in residential areas. The research was conducted through several stages, including; data collection, data collection methods on variations in distance from BTS, results of radiation level measurements, and comparisons to the safe threshold value for radiation intensity that has been set by ICNIRP. The measurement results from 20 BTS in Sambas show that the radiation level from the BTS measured is still far from the safe radiation threshold that has been set by ICNIRP.

Keywords: Base Transceiver Stations; Radiation Level; ICNIRP; Telecommunication; Sambas.

1- Introduction

The field of telecommunications currently has an essential role in developing and progressing a nation's culture. Especially during the pandemic, every human being is trying to narrow the space and time boundaries to get information, communicate anywhere, anytime, and with anyone in the form of voice, data, images, and videos. In communicating, we can use a communication tool such as a cellphone that almost owned by everyone.

Communicating using mobile phones requires the help of signals emitted from BTS (Base Transceiver Station) for the data exchange process. The establishment of BTS has simultaneously been regulated by the Ministry of Communication and Informatics and a Regulation of the Minister of Public Works and Public Housing which requires operators to use towers simultaneously in order to be more efficient and maintain the aesthetics of the environment and urban planning itself [1], [2]. The establishment of BTS is currently overgrowing due to the increasing public need for telecommunication networks. However, this is inseparable from the health facts that arise due to Radiofrequency (RF).

Communities in the Sambas feel that the sentence of telecommunication towers has an impact on health, safety, and social equity. Health impacts related to radiation emission from electromagnetic fields from transmitters in telecommunication towers have people's concerns about the impacts they experience, such as fertility problems, sleep problems, dizziness, and nausea. In addition, the people who live around the BTS feel afraid that the BTS tower may collapse and hit the surrounding settlements.

Previous research on the clustering effects of electromagnetic field radiation generated by GSM signals has been carried out [3], and concluded that continuous exposure to radiation in high-intensity values causes severe effects on human health. Evaluation of the effect of radiation on the human body by considering the distance to the BTS [4], concluded that radiation exposure could be reduced by a greater distance from the radiation source. The limit of exposure to radiation emission

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distribution in the middle of Mossoro City is 10 MHz to 8 GHz wideband with interpolation technique [5]. Research conducted by Agostinho L and Marco A [6], stated that the most substantial radiation exposure was received from 0 meters to 182 meters. So, therefore, the supervision and legal requirements in the development of BTS construction are needed. The antenna used must meet the standards set by ICNIRP so that the negative impact of radiation can be avoided [7]. In May 2011, the International Agency for Research on Cancer (IARC) evaluated the cancer risk from RF radiation providing evidence of the risk of gliomas and acoustic neuromas in humans [8].

Given the problems that arise in the community, it is necessary to research BTS in Sambas to measure and identify the level of radiation generated by BTS. This measurement is needed to provide information to the public about radiation that is around their residence. Measurement of radiation generated from the BTS tower is expected to have a value below the threshold set in ICNIRP. ICNIRP [9], state that there is a difference between the standard magnitude of radiofrequency radiation exposure between the general public living in a public environment and field workers whose daily lives are more often in an environment with a high intensity of radiofrequency or Occupational [10]. According to the ICNIRP General Public, radiation exposure standards for the range 1 - 10.W.m-2 are safe for the public.

This study aims to obtain radiation level data at 20 BTS in Sambas. Measurements were made using a Spectran HF V4 Spectrum Analyzer to measure the radiation level in watts per meter squared. Measurements were made at every 25m interval from the BTS with the maximum distance measured was 150m. The results of this study will be socialized to the surrounding community, especially those who live around BTS. Then a comparison of the measurement data will be carried out against the ICNIRP standard to determine the feasibility of radiation emission in the community.

2- Research Methodology

This research is descriptive and conducted in the Sambas area. Sambas was chosen because of the large number of public complaints regarding the impact of BTS establishment on health, safety, etc. The method used is the measurement of the actual value in the field. This method was chosen because it is easier and affordable to do when compared to the computational method. In addition, selective frequency measurement is better done directly because of the default frequency range setting.

The measured BTS is selected and investigated to see the radiation level (Power Density) produced by radiofrequency, especially on GSM 900 and GSM 1800 in units of watts per meter squared. Measurements were carried out using the Spectran HF V4 Spectrum Analyzer at every 25 m distance from the BTS guardrail. Measurements were carried out by directing the antenna of the measuring instrument slowly towards the direction of the radiofrequency source until the maximum power density value was obtained. Measurements are also carried out at the height of 1.5 m from the ground to minimize RF Radiation reflection from the ground. The measurement results obtained are then recorded, analyzed, and evaluated.

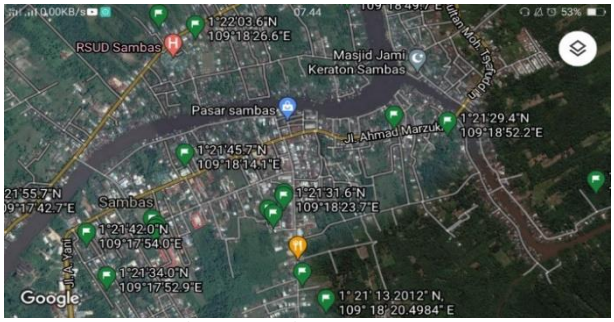

Fig. 1 Map of BTS Identification Locations in Sambas.

Figure 1 shows the distribution map of BTS sites in the Sambas. It can be seen that the towers scattered in the Sambas area are located in residential areas that need to be measured against the radiation generated.

2-1- Base Transceiver Station (BTS)

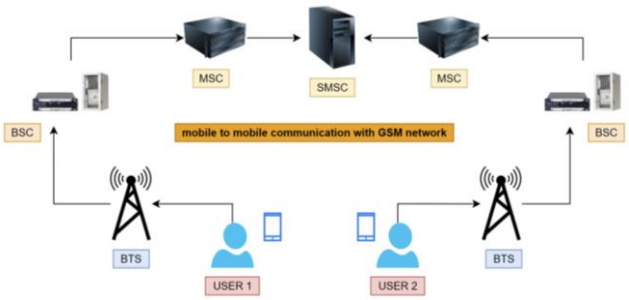

Fig. 2 Illustration of mobile phone network communication and BTS.

Base Transceiver Station is an essential part of the cellular telecommunications network that connects the network of a cellular telecommunications operator with its customers and is shown in Figure 3. BTS consists of three main parts, namely: Tower, Shelter, and Feeder. BTS shelter is a place to store telecommunications equipment. The BTS shelter serves as a device storage media that will be connected to a device center. There are various main and supporting components in the shelter, such as combiner, core module, power supply, fans, lights, and BTS shelter doors.

One beam range generated by a BTS can be called a Cell. Mobile communication is a modern communication that supports high mobility between users. It is then controlled

by a Base Station Controller (BSC) from several BTS, which is connected to a microwave or fiber-optic connection. Although the term BTS can be applied to any wireless communication standards, it is usually and generally associated with mobile communication technologies such as GSM and CDMA.

In this case, the BTS is part of the base station subsystem (BSS) development for the management system. It may also have equipment for encrypting and decrypting communications, spectrum filtering devices (bandpass filters), and antennas as components of the BTS to facilitate BTS functionality. Typically, a BTS will have multiple transceivers (TRXs), allowing it to serve several different frequencies and different cell sectors in the BTS. A BTS controller controls a base station via the base station control (BCF) function. These BCFs are implemented as discrete units or even incorporated into TRX in compact BTS. The BCF provides the operation and maintenance of connections with the network management system and manages the operating conditions of each TRX. The increase in the use of networks connected to BTS will affect the intensity of the electric field around it [11].

2-2- RF Radiation Exposure Standard

The effect of RF radiation on humans is still under endless debate, but the results of studies that have been carried out state that RF emitted from cellular phones [12], including BTS, need to be considered because they have a thermal effect that affects human health [13]. Meanwhile, according to the consensus of the International Scientific Community, it is stated that the energy from BTS is improbable to cause health risks if they do not make direct contact.

Depending on the wattage required and the intended use, BTS can deliver a few watts of power or more. Base station antennas are generally about 20 cm to 30 cm long with a length of 1 meter mounted on a tower with a heig ht of 15 to 50 meters from the ground. The antenna can transmit radio frequency with a very narrow type and perpendicular direction.

RF radiation exposure can be categorized into radiation exposure for workers and the general public [14]. In worker exposure, the person exposed as a consequence of their work is fully aware of the dangers of such exposure and the worker's radiation protection treatment. The International Commission Non-ionizing Radiation Protection (ICNIRP) has set limits for exposure to RF radiation as shown in the following Table 1:

Table 1: Radiation Exposure for the General Public by ICNIRP [14].

Frequency Range	**E-Field Strength** (V/m^{-1})	**H-Field Strength** (A/m^{-1})	**B-Field** (μT)	**Equivalent Plane Wave Power Density** $S_{eq}(Wm^{-2})$
Up to 1 Hz	-	$3.2x10^4$	$4x10^4$	-
1 - 8 Hz	10,000	$3.2x10^4/f^2$	$4x10^4/f^2$	-
8 - 25 Hz	10,000	$4{,}000/f$	$5{,}000/f$	-
0.025 - 0.8 kHz	$250/f$	$4/f$	5/f	-
0.8 - 3 kHz	$250/f$	5	6.25	-
3 - 150 kHz	87	5	6.25	-
0.15 - 1 MHz	87	$0.73/f$	0.92/f	-
1 - 10 MHz	$87/f^{1/2}$	$0.73/f$	0.92/f	-
10 - 400 MHz	28	0.073	0.092	2
400 - 2,000 MHz	$1.375f^{1/2}$	$0.0037f^{1/2}$	$0.0046f^{1/2}$	$f/200$
2 - 300 GHz	61	0.16	0.20	10

2-3- Effect of Radiation Below Standard

The increasing use of communication using cellular phones impacts the development of BTS construction adjacent to homes, schools, hospitals, and densely populated areas. The development that continues to grow raises public concerns about the safety of the population from the radiation it causes.

ICNIRP has set standards for exposure to RF radiation from BTS to minimize health problems due to radiation exposure. Health problems due to exposure to RF radiation cannot be felt instantly [15]. However, the longer a person is exposed to RF radiation, the more dangerous that person's health. Suppose residential areas are too close to BTS or do not follow standards. In that case, it can cause health problems such as headaches [16], [17], brain tumors and cancer [1 8] , and fetal disorders in pregnant women due to imperfect formation of deoxyribonucleic acid (DNA) [19]. Another thing states that if the location of residential areas is following standards, it will minimize health problems due to exposure to RF radiation. A study on cancer stated that no cancer-causing cells were found, and DNA damage was caused by exposure to low RF

radiation levels [20].

3- Result and Discussion

This study's measurement of BTS radiation levels was carried out at 20 BTS in Sambas. Radiation level measurements were carried out at intervals 25 meters from 0 to 150 meters. So, seven variations in distance describe the value of the radiation level emitted by BTS around residential areas. The measurements were carried out at two GSM frequencies, namely the 900 Mhz and 1800 Mhz frequencies. RF and EMF transmit power measurements were carried out using the Spectran HF V4 Spectrum Analyzer. The locations of 20 BTS in Sambas and the results of the measurement of transmit power at the GSM 900 frequency are shown in the following Table 2:

Table 2: Measurement results BTS radiation level at GSM 900 Mhz frequency.

BTS Number	BTS Location	Power Density ($W.m^{-2}$) measurement result in various distance (m)						
		0	25	50	75	100	125	150
1	Jl Kramat Dusun Lb Sari Rt 11 Rw 06 Desa Pendawan Kab Sambas.	0.0012	0.0041	0.0043	0.0057	0.0049	0.0035	0.0075
2	Kab Sambas Desa Pandawa.	0.0034	0.0032	0.0098	0.0016	0.0024	0.0074	0.0094
3	Jl. Tabrani, Lumbang, Kec. Sambas, Kabupaten Sambas, Kalimantan Barat 79462, Sambas.	0.0029	0.0030	0.0067	0.0039	0.0084	0.0056	0.0069
4	Jl Kramat Dusun Lb Sari Rt 11 Rw 06 Desa Pendawan, Sambas.	0.0014	0.0041	0.0061	0.0038	0.0041	0.0065	0.0079
5	Gapura Kec Sambas Kab Sambas.	0.0016	0.0042	0.0006	0.0051	0.0097	0.0053	0.0074
6	Jl. Dusun Sukaramai Rt013/Rw004, Kel. Dalam Kaum, Kec. Sambas, Kab. Sambas, Sambas.	0.0019	0.0029	0.0031	0.0047	0.0093	0.0033	0.0045
7	Jl. Pembangunan, Dn. Sukamantri Rt012/Rw003, Kel. Dalam Kaum, Kec. Sambas.	0.0030	0.0032	0.0022	0.0038	0.0059	0.0079	0.0071
8	Jl. Dagang Tim. Dalam Kaum Kecamtan Sambas Kabupaten Sambas.	0.0021	0.0031	0.0006	0.0036	0.0084	0.0011	0.0042
9	Jl. Gusti Hamzah, Kecamtan Sambas, Kabupaten Sambas.	0.0003	0.0039	0.0031	0.0026	0.0090	0.0031	0.0049
10	Jl. Pendidikan, Jagur, Kecamtan Sambas, Kabupaten Sambas.	0.0024	0.0044	0.0049	0.0017	0.0040	0.0057	0.0060
11	Jl. Sambas - Ledo, Dalam Kaum, Kecamtan Sambas, Kabupaten Sambas.	0.0020	0.0048	0.0084	0.0028	0.0057	0.0027	0.0048
12	Jl. Tabrani, Sunsung, Saing Rambi, Kecamtan Sambas, Kabupaten Sambas.	0.0026	0.0040	0.0061	0.0049	0.0062	0.0053	0.0028
13	Jl Raya Panji Anom	0.0006	0.0006	0.0058	0.0056	0.0069	0.0023	0.0071
14	Jl. Raya Ahmad Mardzuki Kacapuri Rt12/Rw06. Desa Sebayan. Kec. Sambas. Kab. Sambas. Kalimantan Barat	0.0032	0.0012	0.0053	0.0097	0.0046	0.0075	0.0056
15	Jl. Sukaramai Rt 03/ Rw 11. Desa Dalam Kaum. Kec. Sambas. Kab. Sambas.	0.0007	0.0016	0.0033	0.0015	0.0016	0.0059	0.0045
16	Jl. Raya Tabrani Sambas - Singkawang. Dusun Sunsung Rt 07/ Rw 03. Kel. Saing Rambi. Kec. Sambas.	0.0038	0.0032	0.0071	0.0025	0.0096	0.0019	0.0031
17	Jl Raya Sambas Semangau Kec Sambas.	0.0025	0.0039	0.0096	0.0071	0.0007	0.0032	0.0012
18	Jl. Sabas_Subah Dusun Sei Benuah Desa Lubuk Dagang Rt.15 Rw.07 Kec. Sambas Kab. Sambas	0.0030	0.0028	0.0014	0.0073	0.0075	0.0056	0.0075
19	Jl. Sungai Raya Dalam Ii_40. Sambas.	0.0033	0.0008	0.0039	0.0021	0.0098	0.0090	0.0027
20	Jl. Daya Nasional, Sambas.	0.0013	0.0067	0.0081	0.0052	0.0076	0.0049	0.0027

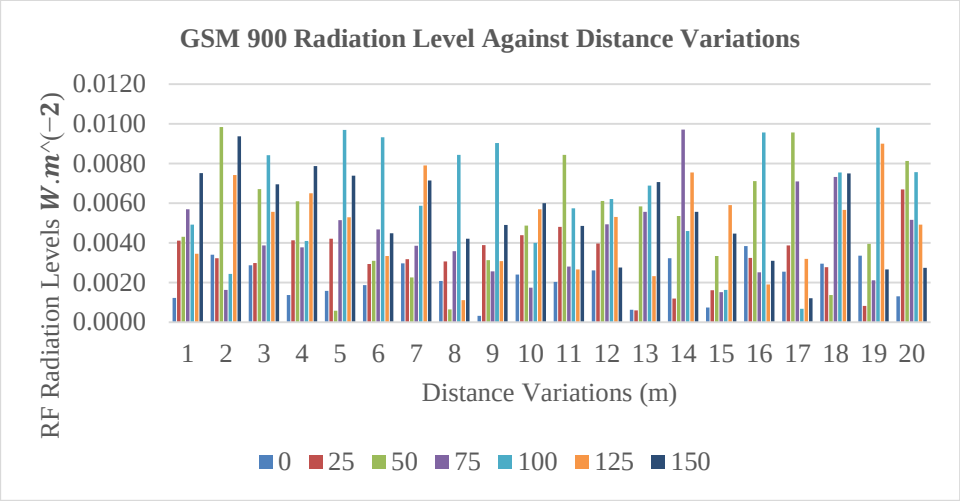

Fig. 3 GSM Radiation Level Frequency 900 to variations in measurement distance.

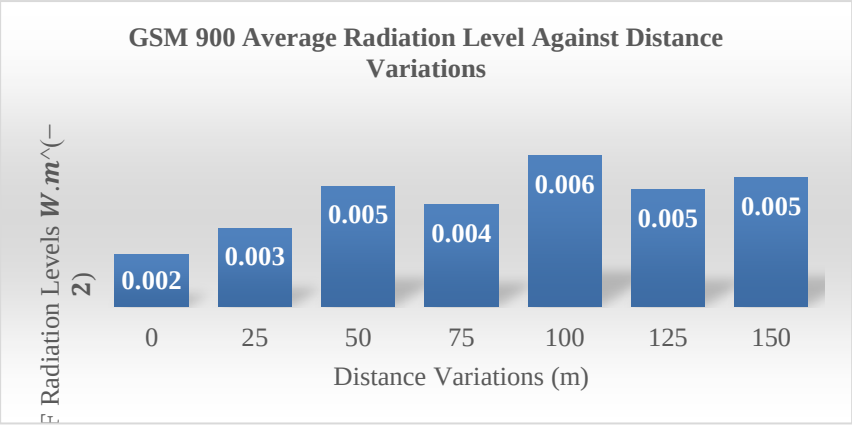

Fig. 4 The average radiation level of GSM 900 to the variation of the measurement distance.

Figure 3 and BTS 19 at 100 meters with a radiation level of 0.0098 W.m^{-2}. Then BTS 9 has the lowest radiation value of 0.0003 W.m^{-2} at 0 meters. Figure 4 shows the average radiation measurement at each distance variation. It can be seen that the lowest radiation frequency is at a distance of 0 meters with a value of 0.0002 W.m^{-2}. The highest average radiation value is at 100 meters which reaches 0.006 W.m^{-2}. The GSM 900 Mhz frequency has the advantage of covering a wider beam area. So that measurements at longer distances still produce higher transmit power.

Table 3 shows the results of measuring radiation levels at the GSM 1800 Mhz frequency against variations in the measurement distance. Figure 5 shows the results of the GSM frequency radiation level measurement at 1800 Mhz. BTS 16 has the highest radiation value of 0.007 W.m^{-2} at 100 m, while BTS 12 has the lowest radiation value of 0.0001 W.m^{-2} at 100 meters.

Table 3: Measurement results BTS radiation level at GSM 1800 Mhz frequency.

BTS Number	BTS Location	Power Density (W.m^{-2}) measurement result in various distance (m)						
		0	25	50	75	100	125	150
1	Jl Kramat Dusun Lb Sari Rt 11 Rw 06 Desa Pendawan Kab Sambas.	0.0021	0.0038	0.0011	0.0030	0.0013	0.0013	0.0044
2	Kab Sambas Desa Pandawa.	0.0062	0.0056	0.0038	0.0031	0.0022	0.0018	0.0026
3	Jl. Tabrani, Lumbang, Kec. Sambas, Kabupaten Sambas, Kalimantan Barat 79462, Sambas..	0.0036	0.0045	0.0034	0.0027	0.0047	0.0019	0.0023

4	Jl Kramat Dusun Lb Sari Rt 11 Rw 06 Desa Pendawan, Sambas.	0.0012	0.0011	0.0047	0.0047	0.0040	0.0005	0.0026
5	Gapura Kec Sambas Kab Sambas.	0.0048	0.0038	0.0044	0.0046	0.0002	0.0047	0.0022
6	Jl. Dusun Sukaramai Rt013/Rw004, Kel. Dalam Kaum, Kec. Sambas, Kab. Sambas, Sambas.	0.0021	0.0044	0.0029	0.0041	0.0016	0.0013	0.0015
7	Jl. Pembangunan, Dn. Sukamantri Rt012/Rw003, Kel. Dalam Kaum, Kec. Sambas.	0.0050	0.0055	0.0046	0.0037	0.0014	0.0012	0.0032
8	Jl. Dagang Tim. Dalam Kaum Kecamtan Sambas Kabupaten Sambas.	0.0047	0.0048	0.0039	0.0007	0.0035	0.0016	0.0032
9	Jl. Gusti Hamzah, Kecamtan Sambas, Kabupaten Sambas.	0.0038	0.0021	0.0049	0.0023	0.0041	0.0028	0.0046
10	Jl. Pendidikan, Jagur, Kecamtan Sambas, Kabupaten Sambas.	0.0016	0.0033	0.0043	0.0031	0.0017	0.0007	0.0013
11	Jl. Sambas - Ledo, Dalam Kaum, Kecamtan Sambas, Kabupaten Sambas.	0.0026	0.0015	0.0011	0.0042	0.0018	0.0006	0.0012
12	Jl. Tabrani, Sunsung, Saing Rambi, Kecamtan Sambas, Kabupaten Sambas.	0.0030	0.0012	0.0016	0.0015	0.0001	0.0013	0.0011
13	Jl Raya Panji Anom	0.0003	0.0013	0.0031	0.0031	0.0022	0.0017	0.0031
14	Jl. Raya Ahmad Mardzuki Kacapuri Rt12/Rw06. Desa Sebayan. Kec. Sambas. Kab. Sambas. Kalimantan Barat	0.0039	0.0060	0.0034	0.0013	0.0036	0.0027	0.0026
15	Jl. Sukaramai Rt 03/ Rw 11. Desa Dalam Kaum. Kec. Sambas. Kab. Sambas.	0.0044	0.0029	0.0050	0.0043	0.0023	0.0003	0.0026
16	Jl. Raya Tabrani Sambas - Singkawang. Dusun Sunsung Rt 07/ Rw 03. Kel. Saing Rambi. Kec. Sambas.	0.0010	0.0017	0.0021	0.0004	0.0070	0.0017	0.0031
17	Jl Raya Sambas Semangau Kec Sambas.	0.0023	0.0034	0.0036	0.0041	0.0034	0.0044	0.0030
18	Jl. Sabas_Subah Dusun Sei Benuah Desa Lubuk Dagang Rt.15 Rw.07 Kec. Sambas Kab. Sambas	0.0011	0.0039	0.0036	0.0045	0.0020	0.0031	0.0034
19	Jl. Sungai Raya Dalam Ii_40. Sambas.	0.0024	0.0033	0.0041	0.0017	0.0018	0.0031	0.0024
20	Jl. Daya Nasional, Sambas.	0.0050	0.0031	0.0026	0.0025	0.0023	0.0022	0.0048

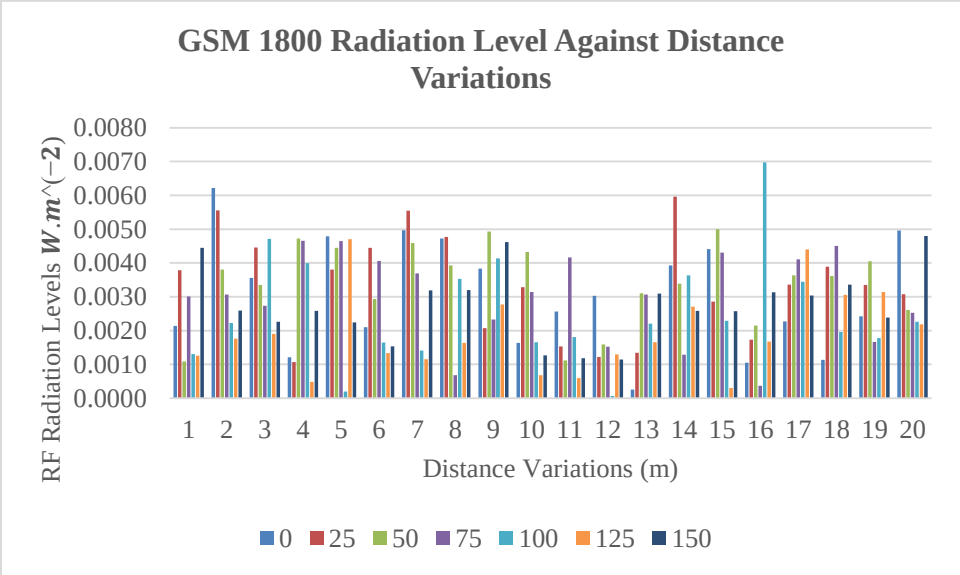

Fig. 5 GSM Radiation Level 1800 MHz Frequency against variations in measurement distance.

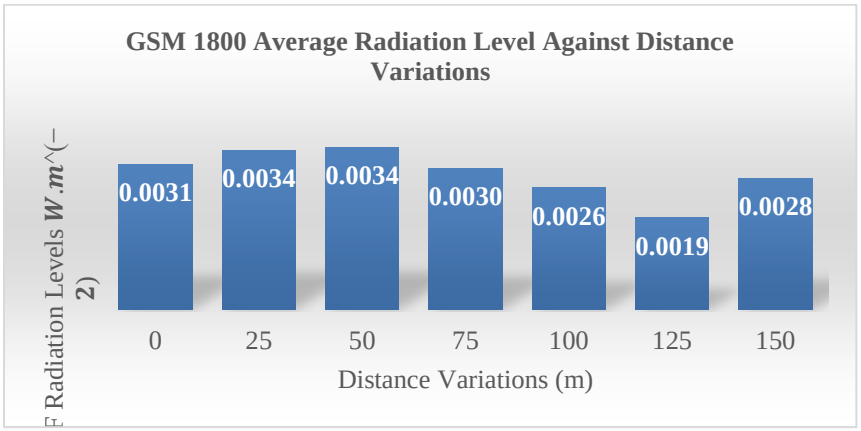

Fig. 6 The average radiation level of GSM 1800 to the variation of the measurement distance.

Figure 6 shows the average radiation measurement for each distance variation in the 1800 Mhz GSM frequency measurement. The measurements show that the transmit power of BTS has a relatively higher value at 0 meters to 75 meters because at the GSM 1800 Mhz frequency, the transmit power focuses more on the data capacity, which is distributed on the carrier frequency. So that the further the measurement distance, the value of BTS radiation decreases.

It can be seen that Figures 4 and Figure 6 have different measurement results caused by the characteristics of the GSM frequency itself and the measurement locations located in residential areas. The presence of obstacles such as buildings and other obstacles has affected the measurement results. However, in this study, measurements were made considering the time, the conditions of the measurement location, and the method of collecting data simultaneously [21], [22]. This step is done to determine the optimal measurement results and reduce the risk of measurement errors.

3-1- The Impact of BTS RF Radiation on Human Health

The negative impact of RF radiation on health is a significant issue developing in society. Health problems arise due to a lack of public knowledge about the RF emitted by BTS in residential areas supported by information from the public who do not know whether the RF from the BTS has a safe value for the human body. Ideally, the level of power density emitted by BTS is at 30m to 150m in densely populated residential areas and will experience a decrease in power at a distance of 200m [23]. According to a study conducted by Ayinmode B. and Idowu P. [24], there are reports that the effects of radiation can affect emotions, physical fatigue, skin problems, dizziness, nausea, headaches, and sleep disturbances. However, Kumar ruled out exposure to RF radiation as a cause of symptoms and health problems if the area has BTS transmit power which is still below the safe limit according to ICNIRP [25].

According to the ICNIRP General Public, radiation exposure standards for the range 1 - 10.W.m^{-2} are safe for the public. Based on the results of measurements that have been carried out at 20 BTS using distance variations, the radiation value in residential areas is still below the ICNIRP standard threshold. All BTS have transmitted power with different values but are still within safe limits for the surrounding population. Then the construction of the BTS tower has also been carried out with the Standard Operational Procedure (SOP) in terms of height, depth of grounding on the pole, and the materials used. So that the results of the BTS transmit power measurement in Sambas can be said to be safe for residents around the BTS and do not have severe problems in terms of health for humans and the security of the tower's location in residential areas.

4- Conclusions

Measurements on 20 BTS in Sambas have produced various RF radiation values. The measurement distance to the BTS significantly affects the results of the measurements. At the GSM frequency of 900 Mhz, the value of RF radiation has a higher value than the GSM frequency of 1800 Mhz because the frequency spectrum on GSM 900 Mhz is more substantial in transmitting power on frequency bands so that the transmission range is more expansive than GSM 1800 MHz. The measurement results have positively impacted residents in the BTS area who have been convinced that the radiation value is still within safe limits for humans. The establishment of a BTS

tower following the SOP is essential for the community to have a sense of security when living in the BTS tower area. Given the public's concerns about the health and safety conditions living in the BTS tower area, the radiation value measurement can be carried out periodically by both the provider and the relevant government agencies so as not to cause negative impacts on the community in the future.

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