Investigation of Cellular Base Transmitter Station Power Radiation using Spectrum Analyzer

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***Abstract*— The development of information and communication technology has spurred the development of the world of telecommunications. The development of telecommunications can be seen from the number of cellular service users supported by technological infrastructure in the form of BTS (Base Transmission Station). But in its development, there are social problems in the form of resistance from the community around BTS, one of the things that people worry about is the danger of radiation from BTS. This could be due to a lack of socialization and knowledge from the community. This study aims to provide education as well as quantitative evidence regarding radiation from BTS in Bulakrejo which is compared with safety standards from International Commission on Non-Ionizing Radiation Protection (ICNIRP) and Ministry of Communication and Information Indonesia. The result of investigation shows that received Power Radiation in near Base Station is safe according to regulatory standard.**

Keywords—Cellular; Base Transmitter Station; Spectrum Analyzer

I. Introduction

Information technology and telecommunications have developed rapidly in Indonesia. The first generation (1G) cellular technology has entered Indonesia since 1985, followed by system upgrades in the mid 90's and the second generation (2G) with the highest phase of 2.75 G with Enhanced Data Rates for GSM Evolution (EDGE) standards with transfer speeds reaching 1 Mbps theoretically. In 2003-2004 the third generation (3G) was born with the highest phase of 3.75G or HSPA+ High Speed Packet Access. In theory, t3G can deliver download speeds of up to 168 Mbps and upload speeds of up to 22 Mbps. The fourth generation (4G) was implemented in Indonesia in 2015, with Long Term Evolution-Advance (LTE-A) technology offering download speeds of up to 100 Mbps and upload speeds of up to 50 Mbps.

Currently, communication with high mobility and speed of data transfer has become a primary need for most of the Indonesian population. Cellular service users in Indonesia reach 355 million subscribers (131% of the total population) [1]. Infrastructure development is an integral part of national development and the economic growth. During the construction of physical infrastructure such as roads, bridges and airports to form a nationally integrated connectivity, there are significant cost to reach rural area and country border due to its character as large and archipelago country. One of the infrastructures capable of overcoming these obstacles is the wireless/wireless telecommunications infrastructure. The Indonesian government see telecommunications and information technology infrastructure is one of the priority infrastructures and drives national economic growth [2]. Several studies, one of which is from shows that every 10% increase in telecommunication density will increase 1.3% of the country's GDP [3].

Telecommunications infrastructure in Indonesia currently includes: 401.64 thousand units of Base Transmission Station (BTS) (2018), fiber optic length of 348,442 km, has covered 514 cities and regencies throughout Indonesia, as well as 2 satellites with a capacity of 300 Gbps. Cellular telecommunications in Indonesia is implemented in several frequency bands, which include 800 MHz, 900 MHz, 1800 MHZ, 1900 MHz, 2100 MHz and 2300 MHz.

In accelerating the implementation of telecommunications infrastructure, the central government authorizes local governments to regulate telecommunications towers. The Sukoharjo Regency Government has issued Sukoharjo Regent Regulation Number 46 of 2018 concerning the Master Plan for Telecommunications Towers. The local state regulation regulates legal certainty for Telecommunication Operators, Tower Providers and Tower Managers in obtaining locations and building permits for telecommunications towers; determine the location of cellular telecommunications towers; as well as harmonizing cellular technical needs with the environment and adjusting to the Regional Spatial Plan. There are 156 coordinate points for telecommunications towers spread over 12 sub-districts in Sukoharjo district.

During operation of telecommunication tower, regulator, in this case Ministry of Communication and Information, regularly check the spectrum occupancy, transmission power and interference in the area. Several spectrum occupancy measurement has been conducted [4] [5]. Due to large spatial area of monitoring, spectrum monitoring is conducted in decentralized fashion distributed in several area, usually in the urban area. Dynamic spectrum monitoring methods can be solved using unmanned air vehicle (UAV) [6]. A new paradigm of shared spectrum using opportunistic method also known as cognitive radio is also becomes additional challenging for spectrum occupancy monitoring [7] .

Radiation power of transmission energy from BTS is concerned by regulator for safety measure due its risk to human health [8][9]. Both transmitter and receiver/mobile device must be checked by standardization agency to comply with regulation before being utilized by operator or consumer. However, during device operational, there could be device damage or leakage, which may violate regulatory compliance.

This paper present the radiation measurement caused by Cellular BTS in Sukoharjo regency. The method of measurement is conducted by surveying in the field and by measuring RF power using spectrum analyzer. The result of measurement is then compared with safety standard by World Health Organization (WHO) and ICNIRP. Structure of this paper is presented as follow. Section 2 explain the propagation model and radiation standard. Section 3 explain the methods and analysis used in the RF power field measurement. Section 34describe the result and Section 5 shows its conclusion and suggestion.

II. Radiation Model and Standard

Data analysis to process data from field studies, surveys to obtain results in the form of quantitative values of BTS radiation measured. These results were then compared with the WHO standard radiation and the Directorate General of Post and Telecommunication,

A. Propagation Model

In the wireless communication network architecture, at the transmitter/BTS there is a power supplied of P_t which is forwarded to the transmission line, where the transmission line provides an attenuation of L_f. Furthermore, the signal enters the sending antenna with a gain of G_{tx}. After passing through the antenna, the signal will enter the unguided media/air. In air propagation, the signal is attenuated by L_{prop}, so that the signal power reaching the receiver is an accumulation of P_t to L_{prop}, which is formulated as follows.

$$P_r = P_t - L_f + G_{tx} - L_{prop} \quad (1)$$

In the cellular wireless communication system, L_{prop} has been modeled empirically, including Okumura-hata [10][11] , Walfisch and Ikegami/COST 231 modeling [12][13].

1) Free space path loss model

The model is simplest model typically for unnobstructed line of sight (LOS). Received power signal is

$$P_r = P_t \left[\frac{\sqrt{G}\lambda}{4\pi d}\right]^2 \quad (2)$$

Power falls off proportionally to the ratio of wavelength λ over squared distance *d*. *G* is net antenna gain. However, this model is not accurate for general environment.

2) Okumura-Hata model

The formula for the pathloss of Okumura-Hata modeling is as follows:

$$L_{prop} = A + B \cdot \log(d) + C \quad (3)$$

where A, B, and C are factors that depend on the frequency and height of the antenna, namely:

$$A = 69.55 + 26.16 \cdot \log(f_c) - 13.82 \cdot \log(h_b) - a(h_m)$$

$$B = 44.9 - 6.55 \cdot \log(h_b)$$

with f_c in Mhz, and d in Km. while h_m and C depend on the classification of the area (urban, suburban, or rural). For urban areas:

- For urban area
  - Small and medium cities:
    - $a(h_m) = (1.1 \cdot \log(f_c) - 0.7)h_m - (1.56 \cdot \log(f_c) - 0.8)$
    - $C = 0$
  - Large cities (metropolitan):
    - $a(h_m) = 8.29(\log(1.54hm)^2 - 1.1$, for $f \leq 200$ MHz
    - $a(hm) = 3.2(\log(11.75h_m)^2 - 4.97$, for $f \leq 400$ MHz
    - $C = 0$
- For suburban area,

  $C = -2[\log(f_c/28)]2 - 5.4$
- For rural areas,

  $C = -4.78[\log(f_c)]2 + 18.33\log(f_c) - 40.98$

3) Walfisch dan Ikegami/COST 231

The COST 231 model is used in conditions where the distance between the BTS and the Mobile Station (MS) is close and or the MS antenna is short. The total pathloss for LOS (Line Of Sight) with this model is,

$$L_0 = 42.6 + 26 \cdot \log(d) + 20 \cdot \log(f_c)$$

where d 20 m, d in km and f_c in MHz.. For non LOS or there are obstacles, the pathloss is:

- $L_{prop} = L_0 + L_{rts} + L_{msd}$, for $L_{rts} + L_{msd} > 0$
- $L_{prop} = L_0$, for $L_{rts} + L_{msd} = 0$

where L_0 = free space loss L_{rts} = diffraction of building roofs with roads and scatter loss L_{msd} = multiscreen loss $L_0 = 32.4 + 20 \cdot \log(d) + 20 \cdot \log(f_c)$ dB

B. BTS Radiation Standard

1) ICNIRP Standard

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) is a non-profit international organization/institution that focuses on handling non-ionizing radiation protection. The institution is recognized by the World Health Organization (WHO). The organization together with experts/experts in other fields such as biology, epidemiology, chemistry, medicine, physics, etc. defines the risk of ionizing and non-ionizing exposure and provides standard guidance. ICNIRP issued a new document regarding exposure to electromagnetic waves [14] . In this document, the limits for exposure to electromagnetic waves range from 100 KHz to 300 GHz from Extremely Low Frequency (ELF) to Gamma ray. There are three parameters that are regulated, namely receiving power density, electric field strength, and magnetic field strength. It is explicitly written in the document that the acceptance meeting threshold for the general public is categorized as

1. Frequency 400 – 2000 MHz power density threshold of $\frac{f_M}{200}$ (W/m^2)
2. Frequencies 2 GHz – 300 GHz the power density threshold is 10 (W/m^2).

All base station/BTS transmitters of telecommunications operators in Indonesia 800 MHz, 900 MHz, 1800 MHZ, 1900 MHz, 2100 MHz and 2300 MHz are included in this frequency category. The ICNIRP document describes the Signal Absorption Rate (SAR) threshold for various frequencies for organs around the head & torso with an exposure time of more than 6 minutes. It is stated that the SAR threshold for the general public with a working frequency of 100 KHz – 6 GHs around the head & torso is 2 W/kg

2) Indonesian Ministry of Communications and Informatics Standard

Indonesia goverment through Ministry of Communications and Informations explains the technical aspects of exposure to electromagnetic waves and SAR [15]

In the base station, a threshold value for power density/power density exposure to EMF has also been set. The regulated frequencies for cellular telecommunications in Indonesia include: 450 MHz, 800 MHz, 900 MHz, 1800 MHz, 2100 MHz, and 2300 MHz. It is clear that the frequencies of 450 MHz, 800 MHz, 900 MHz, 1800 MHz (400 – 2000 MHz) use a threshold of f/200 W/m^2, while the frequencies of 2100 MHz and 2300 MHz have a threshold of 10 W/m^2.

f_M = 450 MHz then the threshold = 450 /200 = 2.25 W/m^2

f_M = 800 MHz then the threshold = 800 /200 = 4 W/m^2

f_M = 900 MHz then the threshold = 900 /200 = 4.5 W/m^2

f_M = 1800 MHz then the threshold = 1800 /200 = 9 W/m^2

f_M = 2100 MHz then the threshold = 10 W/m^2

f_M = 2300 MHz then the threshold = 10 W/m^2

It is explained in [15] that the SAR level limit for devices held by users/MS for the general public is 2 W/kg. This value means that body parts (head, neck) per 1 kilogram around the cellphone are recommended to receive electromagnetic waves exposure of no more than 2 W. The duration and intensity of exposure in this document are not regulated. The SAR value of the user/MS has been provided by the vendor that produces the user/HP device. Each manufacturer has a different SAR value, but it will not exceed the recommended threshold (2 W/kg). Several MS vendors/manufacturers have provided information regarding the SAR value for each of their products, following their website which can be accessed to check.

III. METHODS

RF power measurement is measured using two methods, first methods is by mathematical calculation using preliminary data of BTS antenna. The second one is by field measurement using spectrum analyzer. The distance between measurement system are 0, 25, and 50 meter from BTS ground.

A. Preliminary Calculation

Preliminary field data are used to determine radiation based on BTS data in the field. Table below shows the parameter that is gathered in field.

TABLE I. PRELIMINARY DATA OF BTS

Parameter	Value
Height of BTS	45 m
Transmitted frequency	900/1800/2100 MHz
Type, number and direction of antennas	Three sectoral antenna with direction 130, 240 and 330
Transmitter power	20 watt
Location	Bulakrejo, Sukoharjo Regency, Indonesia

Unfortunately, there is no data regarding antenna gain radiation pattern. We need to assume the worst scenario which yield highest possible total radiation in preliminary calculation. For simplification, we assume that antenna gain is isotropic and there is no multiple antenna interference between three antenna. It is assumed that area under BTS is so close that sectoral antenna gain is under 0 dBi and there is no interference with another two sectoral antenna. We assume of using free pathloss model of propagation, since it will yield highest power radiation possible compared to another model.

B. Measurement using Spectrum Analyzer

In this step, the RF power is measured using Spectrum Analyzer GSP 9300 with dipole antenna 3dBi. The center frequency of measurement are each 900, 1850 and 2140 Mhz, with bandwidth of 200MHz. To calculate radiation per surface area, we assume that dipole antenna surface area is 15.7 cm^2

Fig. 1. Display of Spectrum Analyzer for Measurement

Fig. 2. Field measurment of BTS Power Radiation

IV. RESULT AND DISCUSSION

The contribution of radiation per frequency data of calculation and measurement are shown in Table 2 and Fig. 3. It can be seen that the total radiation in calculation part is higher than in measurement part since we assumed the worst scenario in preliminary calculation

TABLE II. MEASUREMENT AND CALCULATION OF BTS POWER RADIATION

Frequency f_c	**Distance** *d*	**Radiation (Preliminary Calculation)** (uW/cm^2)	**Radiation (Measurement)** (uW/cm^2)
900MHz	0 meter	0.442632	0.041812
	25 meter	0.338238	0.15926
	50 meter	0.198084	0.12653
1850MHz	0 meter	0.104757	0.035051
	25 meter	0.0800505	0.076419
	50 meter	0.0468804	0.042044
2140MHz	0 meter	0.078289	0.054853
	25 meter	0.0598246	0.020184
	50 meter	0.0350354	0.025316

Table 3 shows the total radiation regarding to measurement distance. It is shown that the radiation power in measurement in close distance (0 meter) is less than in distance of 25 meter, it is because of low or negative antenna sectoral gain in the area that is closer to BTS.

TABLE III. MEASUREMENT AND CALCULATION IN BTS DISTANCE

Distance *d*	**Total Radiation (Preliminary Calculation)** (uW/cm^2)	**Total Radiation (Measurement)** (uW/cm^2)
0 meter	0.625678	0.131716
25 meter	0.4781131	0.255863
50 meter	0.2799998	0.19389

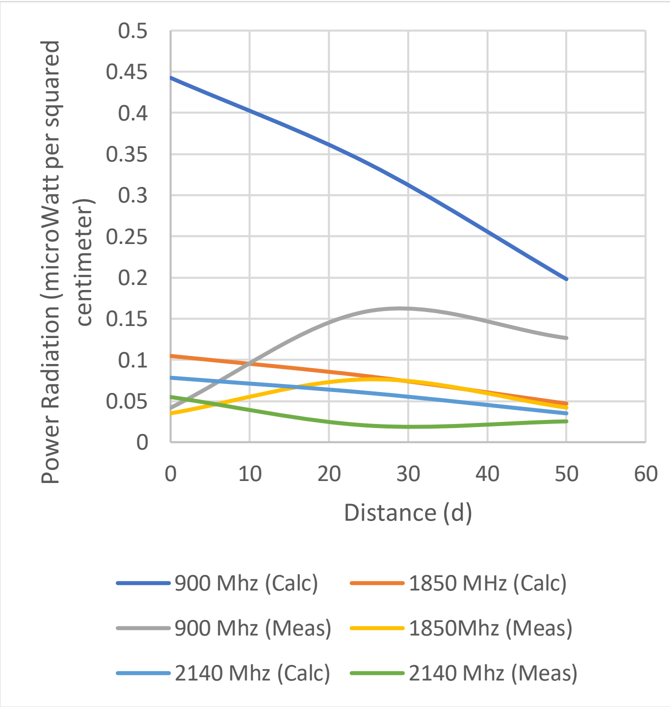

Fig. 3. Result of Power Radiation Calculated and Measurement

Compared with threshold standard from ICNIRP and Indonesia Government which are 4.5 W/m^2 or 450 uW/cm^2, both calculation and measurement are far less than required threshold by order of 100 times smaller. It can be concluded that area in the surround BTS is safe according to ICNIRP and Indonesia Government standard.

V. CONCLUSION

From the results of measurements and calculations during the study, it can be concluded, Quantitative measurements and calculations have been carried out at the BTS location in Bulakrejo

Measurements in three variants of places, namely at positions 0 meters, 25 meters and 50 meters, the results obtained by cellular signals are still far below the maximum threshold by ICNIRP and Indonesia Government with average of 100 times smaller. It can be concluded that area in the surround BTS is safe according to ICNIRP and Indonesia Government standard.

There may be possibility damage of physical BTS, which may resulting in misalign of antenna beam or increased transmitted power. It is suggested that telecommunication operator always check the BTS periodeically.

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REFERENCES

[1] Badan Pusat Statistik Indonesia, "Telecommunication Statistics in Indonesia 2020," BPS, 06300.2113, Sep. 2021.

[2] Perubahan Atas Peraturan Presiden Nomor 75 Tahun 2014 Tentang Percepatan Penyediaan Infrastruktur Prioritas.

[3] "Dampak ICT terhadap Pertumbuhan Ekonomi di Indonesia," MASTEL Living Enabler, 01-Dec-2015.

[4] M. Höyhtyä et al., "Spectrum Occupancy Measurements: A Survey and Use of Interference Maps," in IEEE Communications Surveys & Tutorials, vol. 18, no. 4, pp. 2386-2414, Fourthquarter 2016, doi: 10.1109/COMST.2016.2559525.

[5] Wellens, M., Mähönen, P. Lessons Learned from an Extensive Spectrum Occupancy Measurement Campaign and a Stochastic Duty Cycle Model. Mobile Netw Appl 15, 461–474 (2010). https://doi.org/10.1007/s11036-009-0199-9

[6] M. A. Jasim, H. Shakhatreh, N. Siasi, A. H. Sawalmeh, A. Aldalbahi and A. Al-Fuqaha, "A Survey on Spectrum Management for Unmanned Aerial Vehicles (UAVs)," in IEEE Access, vol. 10, pp. 11443-11499, 2022, doi: 10.1109/ACCESS.2021.3138048.

[7] Ian F. Akyildiz, Brandon F. Lo, Ravikumar Balakrishnan, Cooperative spectrum sensing in cognitive radio networks: A survey, Physical Communication, Volume 4, Issue 1, 2011.

[8] "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz," in IEEE Std C95.1, 1999 Edition , vol., no., pp.1-83, 16 April 1999, doi: 10.1109/IEEESTD.1999.89423.

[9] World Health Organization. (2002). Establishing a dialogue on risks from electromagnetic fields. World Health Organization. https://apps.who.int/iris/handle/10665/42543

[10] M. Hata, "Empirical formula for propagation loss in land mobile radio services," *IEEE Transactions on Vehicular Technology*, vol.29, no. 3, pp.317–325, Aug. 1980.

[11] Okumura Y., Ohmori E., T. Kawano, K. Fukuda, "Field strength and its variability in VHF and UHF landmobile service," Review of the Electrical Communication Laboratory, vol. 16, no. 9-10, 1968, pp. 825-873

[12] COST Action 231, "Digital mobile radio towards future generation systems, final report," tech. rep., European Communities, EUR 18957, 1999.

[13] COST 231, "Urban transmission loss models for mobile radio in the 900- and 1,800 MHz bands (Revision 2)," COST

[14] "Guidelines for Limiting Exposure to Electromagnetic Fields (100 kHz to 300 GHz)," *Health Physics*, vol.118, no. 5, pp.483–524, May 2020.

[15] K. K. dan I. R. I., Persyaratan Teknik Alat dan/atau Perangkat Telekomunikasi Low power Wide Area.