Scientific Research Publishing

Detection, 2022, 9, 1-11
https://www.scirp.org/journal/detection
ISSN Online: 2331-2084
ISSN Print: 2331-2076

The Measurement and Evaluation of the Electromagnetic Environment from 5G Base Station

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How to cite this paper: Huang, W.W., Hu, Y.N., Zhu, J.J., Cen, Z.N. and Bao, J.L. (2022) The Measurement and Evaluation of the Electromagnetic Environment from 5G Base Station. *Detection*, **9**, 1-11.
https://doi.org/10.4236/detection.2022.91001

Received: December 6, 2021
Accepted: January 27, 2022
Published: January 30, 2022

Abstract

In order to evaluate the electromagnetic environment of 5G base station, measurement and evaluation of the electromagnetic environment are studied. The 12 measuring points are chosen on the roof, inside and outside of the building, which has a 5G base station on the top. The electric field intensity, magnetic field intensity, and power density have been measured. The measurement methods include background measurement and work measurement. Background measurement is the measurement of environmental electromagnetic field (EMF) before the installation of 5G base station while the working measurement is the measurement after the installation of 5G base station. The evaluation methods include *t*-test for qualitative evaluation and electromagnetic gain for quantitative evaluation. The results show that the electromagnetic environment after the installation of 5G base station in most places is different from that in the background. And the environmental electromagnetic fields in certain parts are lower than those in the background. The conclusions are as follows: 1) The electromagnetic environment of 5G base station is far lower than the control limit of the national standard and conforms to the national standard; 2) The electromagnetic environment of 5G base station has little impact on the electromagnetic environment; 3) It is not sufficient to assume that 5G is harmful to health without the results of the epidemiological investigation; 4) Before the construction of 5G base station, do background EMF detection, which can provide support for future evaluation.

Keywords

5G Base Station, Electromagnetic Environment, Health, Biological Effects

1. Introduction

The 5th generation mobile network (5G) is a new generation communication system developed for the needs of mobile communication after 2020. Its application field has gone beyond the function of mobile phones and will be widely used in many fields, bringing changes to the activity mode of human society in the future. In recent years, China's 5G communication technology has made great progress. Under the support of the national major project "new generation broadband wireless mobile communication network", many key technologies have been broken through [1]. A group of Chinese enterprises, such as Huawei and ZTE, have obtained a large number of 5G patents [2]. One of the core technologies of 5G is MIMO (Multiple-Input Multiple-Output) technology [3] and Ultra-dense network (UDN) [4]. The arrangement of high-density antenna can greatly improve spectral efficiency and reliability, and greatly increase the system capacity. However, with the rapid development of computer technology and electronic technology, the integration of circuits has been greatly improved, so that the performance and life of electronic systems are easily affected by various electromagnetic energy around them, which seriously affects and interferes with the normal operation of electronic systems. Whether the electromagnetic field released by 5G base stations will drastically change the electromagnetic environment and whether it will affect human health has caused widespread concern. Some viewpoints believe that Radio Frequency Electromagnetic Field (RF-EMF) has effects on health, and biological effects still occur below the regulatory limit [5]. Does 5G communication technology have any impact on the electromagnetic environment? What is the impact? Will it affect human health? These questions need to be answered with scientific knowledge and f data. 5G is an electromagnetic source that has emerged and has been commercially constructed in recent years. Measuring the electromagnetic environment before and after large-scale construction is the basis for evaluating its effect on the environment.

A qualitative evaluation method of electromagnetic environment by *t*-test and gain quantitative evaluation method are studied. Through the detection of the surrounding electromagnetic environment before and after the construction of a 5G base station, the impact of 5G communication on the electromagnetic environment and the relationship with human health are analyzed and evaluated.

2. Objects and Methods

2.1. Object

In a building with eight floors, two 5G base stations are installed at both ends of the roof, respectively. The base stations work at a frequency of 2.6 GHz.

2.2. Measuring Instrument

According to the Environmental Protection Standard *monitoring method for electromagnetic radiation environment of mobile communication base station*

(HJ972—2018) and the deviation analysis [6], a wide-band non-selective radiometer with isotropic response is used [7]. The electromagnetic radiation analyzer (Beijing Sen-Fu Technology Co., LTD., SEM-600) and the passband of probe (Beijing Sen-Fu Technology Co., LTD., RF-03), whose passband is 100 kHz - 3.5 GHz, is selected.

2.3. Arrangement of Measuring Points

Twelve measuring points were set up in the building, one of which was the no.1 mark on the east of the building. Measuring point 2 is the mark 2 on the roof. Measuring point 3 is the mark 3 at the roof entrance. The measuring point 4 is the mark 4 on the west of the roof, and all the measuring points are within 5m around 5G communication equipment. Measuring point 5 is the eighth-floor landing; the measuring point 6 is the corridor on the eighth floor; measuring point 7 is the entrance of the office on the seventh floor. The measuring point 8 is the aisle window on the seventh floor; measuring point 9 is the seventh-floor staircase; the measuring point 10 is the entrance of the office on the third floor. The measuring point 11 is the corridor on the third floor; measuring point 12 is the parking lot on the first floor.

2.4. Method of Measurement

2.4.1. Background Measurement

Before the installation of 5G base station, the points are measured, including electric field intensity (V/m), magnetic field intensity (A/m) and power density ($\mu W/cm^2$).

2.4.2. Working Measurement

After the installation of 5G base station, the base station is in working state, and the points are measured with three parameters.

2.4.3. Measuring Time

Each measuring point should read 5 times, each reading time should not be less than 15 seconds, and read the maximum value of the stable state. If the fluctuate is large, the measurement time should be appropriately extended.

2.5. Data Processing and Analysis

2.5.1. Data Statistics

Calculate the mean and standard deviation of each measurement point according to the 5 readings.

2.5.2. *t*-Test

Firstly, qualitative analysis is conducted on the results of each measurement point to analyze whether the environmental electromagnetic field has been improved after the installation of 5G base station. *t*-test method was used to compare the difference in environmental EMF before and after the installation of 5G base station at each measurement point. The homogeneity test was carried out

by SPSS software. According to the results, two T values with homogeneous variance and uneven variance were selected. The significant level was $\alpha = 0.05$. If $P > 0.05$, there is no difference between the mean of background and the mean of working. On the contrary, they are different.

2.5.3. Gain

The quantitative analysis is conducted on the results of each measurement point to analyze how much the environmental electromagnetic field is increased or decreased after the installation of 5G base station.

1) For electric and magnetic fields:

$$G = 20\log\frac{A_w}{A_b} \tag{1}$$

2) For power density:

$$G = 10\log\frac{W_w}{W_b} \tag{2}$$

where, A_b is the average value of background electric field intensity or magnetic field intensity; A_w is the average value of working electric field intensity or magnetic field intensity; W_b is the average value of background power density, and W_w is the average value of working power density.

2.6. Standard of Comparison

The national standard of China *Control Limit of Electromagnetic Environment* (GB 8702-2014) [8] is used. The frequency band is 30 MHz - 3 GHz, the control limit of electric field intensity is 12 V/m, the control limit of magnetic field intensity is 0.032 A/m and the control limit of power density is 40 μW/cm^2.

3. Results

3.1. Measurement

Figure 1 shows the results of environmental EMF before and after the installation of 5G base station of the building (*P ≤ 0.05, **P ≤ 0.01). Table 1 shows that the electric field intensity was distributed in the range of 0.5 - 5 V/m, the range of the magnetic field intensity was 1.4 - 11.1 mA /m, and the range of the power density was 0.08 - 5 μW /cm^2. The electromagnetic fields of background and working environment meet the control limit of national standard of China GB 8702-2014.

3.2. *t*-Test

Table 2 is the P-value of the *t*-test for the comparison of the working EMF and the background EMF at each measuring point in the building. When $P > 0.05$, mark "#". (Indicates that there is no significant difference in the corresponding measurement parameters of the measuring); without "#" mark, it indicates significant difference. The results show that there is no change in the electric field

intensity of the roof (Point 2 and 3). There is no change in the magnetic field intensity at several locations in the building (Points 1, 4, 6, 7 and 12). The power density of individual locations in the building has not changed, and the electromagnetic field of the environment of other measuring points in the building is different from the background data (Points 2, 3, 4).

3.3. Gain

Table 3 shows the gain of environmental EMF and the gain of background EMF at each measuring point of the building. The "#" mark indicates that there is no difference between the measured parameters of this point and those of the background, and its gain is meaningless. The results show that the range of the gain

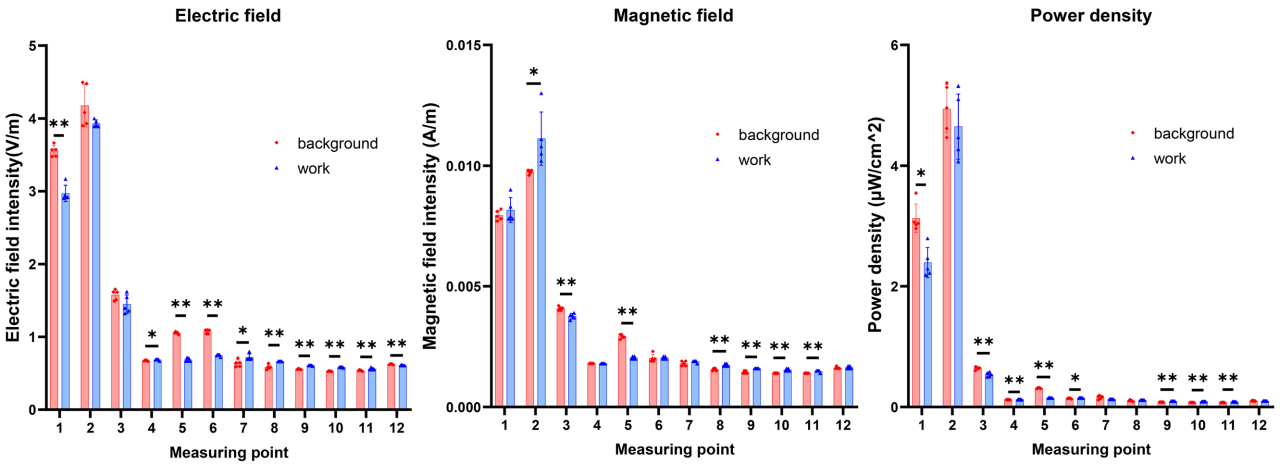

Figure 1. The measurement resorts of environment electromagnetic fields with 5G base station.

Table 1. The measurement resorts of environment electromagnetic fields with 5G base station.

Points	background			work		
	Electric field intensity (V/m)	Magnetic field intensity (A/m)	Power density (μW/cm^2)	Electric field intensity (V/m)	Magnetic field intensity (A/m)	Power density (μW/cm^2)
1	3.5522 ± 0.0779	0.0079 ± 0.0002	3.1272 ± 0.2372	2.9696 ± 0.1121	0.0082 ± 0.0005	2.3944 ± 0.2480
2	4.1764 ± 0.2905	0.0097 ± 0.0001	4.9420 ± 0.4004	3.9298 ± 0.0483	0.0111 ± 0.0011	4.6463 ± 0.5398
3	1.5769 ± 0.0727	0.0041 ± 0.0001	0.6425 ± 0.0249	1.4488 ± 0.1272	0.0038 ± 0.0001	0.5386 ± 0.0362
4	0.6721 ± 0.0072	0.0018 ± 0.0000	0.1201 ± 0.0011	0.686 ± 0.0100	0.0018 ± 0.0000	0.1255 ± 0.0030
5	1.0552 ± 0.0164	0.0029 ± 0.0001	0.3127 ± 0.0066	0.6865 ± 0.0236	0.0020 ± 0.0001	0.1503 ± 0.0034
6	1.0718 ± 0.0293	0.0020 ± 0.0002	0.1423 ± 0.0050	0.7461 ± 0.0143	0.0020 ± 0.0001	0.1503 ± 0.0034
7	0.6360 ± 0.0486	0.0018 ± 0.0001	0.1594 ± 0.0311	0.7192 ± 0.0434	0.0019 ± 0.0000	0.1299 ± 0.0005
8	0.5853 ± 0.0321	0.0016 ± 0.0001	0.1048 ± 0.0118	0.6631 ± 0.0027	0.0017 ± 0.0001	0.1153 ± 0.0026
9	0.5551 ± 0.0057	0.0014 ± 0.0001	0.0795 ± 0.0003	0.606 ± 0.0048	0.0016 ± 0.0000	0.0979 ± 0.0016
10	0.5272 ± 0.0038	0.0014 ± 0.0000	0.0738 ± 0.0008	0.5825 ± 0.0032	0.0015 ± 0.0001	0.0906 ± 0.0021
11	0.5376 ± 0.0080	0.0014 ± 0.0000	0.0742 ± 0.0013	0.562 ± 0.0130	0.0015 ± 0.0000	0.0866 ± 0.0034
12	0.6230 ± 0.0046	0.0016 ± 0.0000	0.1016 ± 0.0050	0.6092 ± 0.0058	0.0016 ± 0.0001	0.1012 ± 0.0020

Table 2. The *t*-test resorts of environment electromagnetic fields for 5G base station.

Measuring point	Electric field intensity	Magnetic field intensity	Power density
1	0.000	0.400#	0.001
2	0.098#	0.024	0.354#
3	0.087#	0.001	0.001
4	0.036	1.000#	0.005
5	0.000	0.000	0.000
6	0.000	0.803#	0.019
7	0.021	0.141#	0.068#
8	0.001	0.001	0.088#
9	0.000	0.000	0.000
10	0.000	0.000	0.000
11	0.007	0.004	0.000
12	0.003	0.545#	0.879#

Table 3. The gain resorts of environment EMF for 5G base station.

Measuring point	Electric field intensity (dB)	Magnetic field intensity (dB)	Power density (dB)
1	−1.56	0.24#	−1.16
2	−0.53#	1.15	−0.27#
3	−0.74#	−0.71	−0.77
4	0.18	0.00#	0.19
5	−3.73	−3.12	−3.18
6	−3.15	0.09#	0.24
7	1.07	0.38#	−0.89#
8	1.08	0.95	0.42#
9	0.76	0.92	0.90
10	0.87	0.83	0.89
11	0.38	0.48	0.67
12	−0.19	0.11#	−0.02#

is −4 - 1.15 dB, which indicates that when 5G base station works, the electromagnetic field in the environment does not increase more than 1.15 dB than that in the background, which is equivalent to no more than 14%. The electromagnetic field of the stairway entrance on the eighth floor is lower than that of the background (Point 5). The electric field intensity and power density of the corridor on the eighth floor and the parking lot on the first floor are lower than those in the background measurement. The roof is the installation location of 5G base station, and the electromagnetic field of its environment is also lower than that of the background.

This measurement is compared with the GB 8702-2014 limit. The gain of the background and the gain when the 5G base station is working are shown in Table 4. The environmental EMF within 5 meters around 5G equipment is 9 - 18 dB lower than the standard limit, which is equivalent to 1/3 - 1/8 lower than the standard limit (measuring points 1, 2, 3). The environmental EMF of other measuring points inside the building is 21 - 27 dB lower than the standard limit value, which is equivalent to 1/10 - 1/20 lower than the standard limit value. The values of all measuring points meet the standard control limit.

Table 4. The gain of environmental electromagnetic field of 5G base station compared with the standard limit.

Measuring point		Electric field intensity (dB)	Magnetic field intensity (dB)	Power density (dB)
Background	1	−10.57	−12.11	−11.07
	2	−9.17	−10.33	−9.08
	3	−17.63	−17.89	−17.94
	4	−25.03	−25.00	−25.23
	5	−21.12	−20.80	−21.07
	6	−20.98	−24.00	−24.49
	7	−25.51	−25.00	−24.00
	8	−26.24	−26.24	−25.82
	9	−26.70	−26.94	−27.01
	10	−27.14	−27.18	−27.34
	11	−26.97	−27.18	−27.32
	12	−25.69	−25.91	−25.95
Work	1	−12.13	−11.87	−12.23
	2	−9.70	−9.18	−9.35
	3	−18.36	−18.60	−18.71
	4	−24.86	−25.00	−25.04
	5	−24.85	−23.91	−24.25
	6	−24.13	−23.91	−24.25
	7	−24.45	−24.62	−24.88
	8	−25.15	−25.29	−25.40
	9	−25.93	−26.02	−26.11
	10	−26.28	−26.35	−26.45
	11	−26.59	−26.70	−26.64
	12	−25.89	−25.81	−25.97

4. Discussion

4.1. The Effects of 5G Base Station on Electromagnetic Environment

The transmitting power of 4G base station is 40 W, while that of 5G base station is 240 W. It seems that the emission power of 5G base stations has been increased several times, and the impact on the electromagnetic environment should also be increased several times. However, the results show that the environmental EMF of 5G base station does not increase much. In this survey, 1.08 dB was the most increased data in the building, which only increased by 13.3% in multiple (The electric field intensity at point 8). It can be considered that the impact of 5G base station on electromagnetic environment does not increase exponentially due to the increase of transmitting power, on the contrary, some positions decrease instead. The inhomogeneity of the distribution of the EMF, as well as the media characteristics of the air, is affecting the electromagnetic environment. We cannot simply understand the electromagnetic environment of 5G base station like this.

4.2. Health Impact

The effects of radiofrequency EMF (RF-EMF) on human health have long been debated. In 1996, the World Health Organization (WHO), in response to people's concern about the impact of electromagnetic field exposure on health, launched the International EMF Projects, which lasted for ten years, aiming to collect the latest research data of countries and International research institutions and evaluate the impact of electromagnetic field on human health [9]. In 2011, the International Agency for Research on Cancer (IARC, affiliated to WHO) considered RF-EMF a suspected human carcinogen and classified 2B [10]. The reason is based on the insufficient epidemiological survey data and the limited human and animal research evidence [11]. The epidemiological investigation is considered to be the most powerful evidence to evaluate electromagnetic health effects [12]. According to the published literature on the epidemiological investigation, most conclusions are negative about the health effect of RF-EMF [13]. Even the OR value of the positive results was 1.8 - 2.7, which was slightly less than the WHO's high-risk ratio (RR) of 5 and considered weakly correlated [14]. The current epidemiological investigation results show that it is insufficient to consider that the electromagnetic environment of mobile communication has harmful effects on human health. The 5G equipment has not greatly improved the existing electromagnetic environment and is at least one order of magnitude less than the control limit standard. Nor is it sufficient to assume, on the basis of a lack of epidemiological investigation, that 5G will have a health impact.

The debate on RF-EMF's impact on health has been going on for more than 30 years since the "Susan affair" in the 1980s, and then people have been concerned about this issue for more than 30 years. Governments and international organizations have spent a lot of scientific research funds on this issue. None of

these studies has produced clear harmful results. It can be considered that the current environmental electromagnetic level will not affect health. As a new mobile communication technology, 5G's environmental electromagnetic level has not been greatly improved, and the same conclusion can be drawn.

4.3. Effects on Biological Effects

Biological effects and health hazards are two different concepts. Biological effects are biological responses to electromagnetic fields, which can be harmful or beneficial. Health hazard is a kind of biological effect which has health consequences and damage to good health besides the compensation mechanism of the human body [14]. WHO evaluates electromagnetic health risk from five aspects: epidemiological investigation, human research, animal research, cell research and biophysical mechanism research [10] [12] [14]. These five aspects describe the effects of human groups, individuals, organisms as a whole and components at all levels. A large number of studies have shown that the biological effects of electromagnetism at the cellular and molecular level are more obvious, while the biological effects of the whole or population are weaker [13]. From the point of view of system theory, this phenomenon verifies the emergence of systems, that is, the system characteristics are not simply the addition of component characteristics. The organism is a complex system composed of many components. Its self-organization, self-learning and self-regulation have certain resistance to external EMF, that is, robustness [15].

Electromagnetic field is a physical factor. Electromagnetic biological effect is the joint reaction of organisms to this physical factor. The primary effect of this reaction is the first and key step to clarifying the biological effect. Currently, it is difficult to get the results of epidemiological investigation, so it is very important to study the primary effect [16]. The reactive oxygen species (ROS) are the important material basis of primary action. ROS can be used to explain the causality of electromagnetic biological effects in both physics and biology [17]. Real-time study of cells is the key technology to elucidate the primary effect of electromagnetic biological effects. Only by recording the biological response of cells under EMF in real-time can the results of the study be credible and reliable [18] [19].

5. Conclusions

From the electromagnetic environment detection and evaluation of 5G base station, the following conclusions can be drawn:

1) The electromagnetic environment of 5G base station is far lower than the control limit of the national standard and conforms to the national standard.

2) Compared with the background, the electromagnetic environment of 5G base station is not evenly distributed. Some electromagnetic levels are improved while others are reduced. The increased amount is only a few dB, which is equivalent to an increase of more than 10% compared with the background and has lit-

tle impact on the electromagnetic environment.

3) It is not sufficient to assume that 5G is a health hazard without epidemiological findings.

4) Before the construction of 5G base station, do background electromagnetic environment detection, which can provide support for future evaluation.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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