NIPES

Journal of Science and Technology Research

Journal homepage: www.nipesjournals.org.ng

Investigating the Health Hazards Associated with 5G Network: A Review

Udo, E. U.[a], Aru, O. E.[a], Okey, D. O.[b], Agwu, E. O.[c]

[a,c]Department of Electrical/Electronic Engineering, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.
[a]Department of Computer Engineering, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.
[b]Department of Systems Engineering and Automation, Universidade Federal de Lavras, Minas Gerais, Brazil

Article Information

Article history:
Received 17 January. 2022
Revised 07 February 2022
Accepted 12 February 2022
Available online 05 March 2022

Keywords:
Health hazard, Radio Frequency Emission, Mobile Technology, 5G Network

https://doi.org/10.37933/nipes/4.1.2022.6

https://nipesjournals.org.ng

Abstract

This paper is focused on the fifth generation of mobile technology (5G) and concerns over alleged health hazards and the concept behind this mobile technology. The deployment of the fifth-generation (5G) wireless communication services require the installation of 5G next- generation Node-B Base Station (gNBs) over the territory and the wide adoption of 5G User Equipment (UE). 5G should offer connections that are multitudes faster than previous mobile technology with average download speeds of around 1Gbps. The global population is concerned about the potential health hazards associated with the Radio Frequency (RF) emissions from 5G equipment. This concern has made several communities to respond actively towards stopping the 5G deployment. This paper adopted numerous national, international scientific and governmental organizations that have reviewed epidemiologic studies of health and biological endpoints in association with the RF exposure in environments accessible to the public. It was observed that the widely perceived health risks that are attributed to 5G are not supported by scientific evidence. In conclusion, the various health hazard of 5G exposure and the latest studies associated with the concerns are presented.

1. Introduction

The development of wireless technology started in the early 1970 and the projection of telecommunications in the past four decades has been so rapid beyond the contemplation of even the brightest engineers in the 1970s and 1980s. It all started when James Clark Maxwell in the 1860s, discovered the electromagnetic waves and suggested that they could travel at a speed close to that of light. Not long after, Heinrich Hertz found a way to produce and detect the electromagnetic waves, which was called the 'Radio Waves'.

The First Generation (1G) of telecommunication technology was first used by the Americans and Europeans in the late 1940s and 1950s in their communication devices. Though these devices were marketed to be 'mobile phones', they were heavily restrained by their size, security concerns and the obstruction in the transmission of signals. The first time when a proper cell phone was introduced was in 1979, when Nippon Telegraph and Telephone (NTT) introduced the automated cellular network, known as First Generation Cellular Network (1G). 1G was a very primitive way of wireless communications as the data were transmitted in the form of analog signals [1].

The second generation of telecommunication technology came when signal transmission radically changed. Unlike the previous generation, this generation used the digital signal transmission rather than analog. It was launched by Radiolinja in 1991, when the world officially received a paradigm

shift in cellular technology. This technology addressed the problems the previous generation had which were in analog form and transmitted the signals in digital form, and that were digitally encrypted so that only the intended receiver could receive and access it. This was followed by 2.5G and 2.75G when the General Packet Radio Service (GPRS), EDGE technologies, the mobile internet systems had a theoretical bandwidth of 50-kilobits per second and 1 megabit per second [2].

The third generation (3G) of telecommunication technology was introduced in Japan by the NTT in the early 2000s. Though there was not much improvement over the phone calls and messaging, one area where 3G outshone 2G were the data rates. With the introduction of 3G, the data rates were boosted up to 7.2 Megabits per second. It was also designed to become secure by using end-to-end security and 3G technology was subsequently followed by 3.5G and 3.75G which increased the data rate caps. These two technologies were revolutionary because it had a potential to provide its users access to the internet from any location [3].

The fourth generation (4G) of telecommunication technology was first released in 2009 in Oslo and Stockholm. The 4G is commercially called Long Term Evolution (LTE) which provided significantly faster data speeds with download capping at over a hundred megabits per second (100Mbps) and upload capping at over 50 megabits per second. The other significant improvement in the 4G technology, other than a better security and encryption, is the latency. 4G technology boasts a 50 ms response time which is well over enough for any imaginable task at the time of its release [4].

The fifth generation (5G) technology is a highly intelligent technology which adds up a large number of specifications to the 4G technology and makes its wireless capability to be enhanced. Based on the 4G network, 5G mobile communication will be able to provide users with better services through the internet platform and wireless transmission technology. The fifth-generation wireless mobile technologies offer tremendous data capabilities and unrestricted calls and in addition to an infinite data broadcast with latest mobile operating system. The idea of World-Wide Wireless Web (WWWW) started with 4G technology and completed with the 5G mobile technology. This innovation helps in making the world connected with continuous access to data, correspondence and diversion [5].

The large-scale adoption of each new technology has always been accompanied by a mixture of positive and negative feelings by the population. Nowadays, a similar controversy involves the 5G technology, i.e., a non-negligible number of people firmly convinced that 5G constitutes a real danger for human health. As a consequence, 5G and risks are often associated together with a negative impact on the perception of 5G among the population. For example, Google retrieves more than 88 million results when searching 5G health risks [7].

The fear of 5G technology is mainly due to a biased feeling among the population, which is often driven by weak theories developed without solid scientific evidence. Again, such theories can be easily debunked when considering 5G frequencies below 6 GHz. Also, there is currently a lack of well-done scientific studies focused on the assessment of health effects from 5G devices operating in the mm- Wave band. Presently, majority of the population is convinced that exposure to Electro Magnetic Fields (EMFs) generated by 5G gNBs and 5G UE is dangerous for health [6].

2. Effect of 5G Wireless Communication on Human Health

With uninterrupted fifth generation, wireless communication can only be achieved by creating a very dense network of antennas and transmitters. Again, the number of higher frequency base stations and other devices will increase significantly. This raises the question as to whether there is

a negative impact on human health and environment from higher frequencies and billions of additional connections, which, according to research, will mean constant exposure for the whole population, including children. Whereas researchers generally consider such radio waves not to constitute a threat to the population and research to date has not addressed the constant exposure that 5G would introduce.
Again, a section of the scientific community considers that more research on the potential negative biological effects of electromagnetic fields and 5G is needed notably on the incidence of some serious human diseases. A further consideration is the need to bring together researchers from different disciplines, in particular medicine and physics or engineering, to conduct further research into the effects of 5G [7].

2.1 Health Concerns of RF Signals from Cell Phones

Researchers have conducted studies of many types to find out whether RF Signal levels produced from common devices, principally cellphones, might adversely affect health, including whether they can cause cancer. Numerous national and international scientific and governmental organizations have reviewed epidemiologic studies of health and biological endpoints in association with the RF exposures that would be encountered in typical environments accessible to the public [8]. These agencies concluded that the outcomes of these studies do not provide sufficient evidence to conclude that RF exposure causes any adverse health effect. Despite this consensus, research continues to test hypotheses and make sure that even a small risk is not overlooked.

2.2 Health Hazards of 5G On Human Health

The low frequency band of forthcoming 5G networks, where the carrier frequency is less than 3 GHz is not very different from the frequency bands used in current wireless systems. The small cells planned to be deployed by network providers will be placed in close proximity to urban areas and will be transmitting much less energy compared to today's base stations. Again, we do not expect a significant difference in exposure to wireless network's operations at low frequencies. However, exposures will be different at higher frequencies, especially in the high-band. The high-band of the 5G frequencies fall into the millimeter Wave (mmW) category, which indicate that the wavelength of the electromagnetic wave is in the millimeter ranges. These waves are mostly absorbed within 1 to 2 millimeters of human skin and in the surface layers of the cornea [9].

In the United States, the Federal Communications Commission (FCC) determines the rules and regulations related to communication systems as well as the limits of the electromagnetic energy that a device can transmit. In order to protect humans from acute exposure to thermal levels of radio frequency radiation, FCC allows a maximum 1.0 mW/cm^2 of exposure for the general public.

However, the World Health Organization has already emphasized the need for high quality scientific studies in this area due to the current widespread use of technology, the degree of scientific uncertainty and the levels of public opinion.

2.3 Difference Between 5G and Current Technology

When employing millimeter waves and higher frequencies than other technologies, 5G needs a much more extensive network of antennas and other transmitting devices. Electromagnetic fields are invisible areas of energy measured in Watts (W). Longer wavelengths with lower frequency are less powerful in terms of energy while shorter wavelengths at higher frequencies are more powerful.

Depending on the frequency, there are two categories of EMF, namely ionizing and non-ionizing radiation as shown in Figure 1. Ionizing radiation includes ultraviolet rays, x-rays and gamma rays. The energy from ionizing radiation can damage human cells and cause cancer. Non-ionizing

radiation has lower frequencies and larger wavelength. Many experts are of the opinion that non-ionizing radiation produces only thermal effects, or tissue heating and at high exposure levels, temperature-sensitive biological structures including humans and processes can become damaged [10].

Microwave and millimeter wavelength radiation is non-ionizing. Millimeter wave range from around 10 to 1 millimeter. This is a very effective spectrum with large bandwidth but it is also very sensitive to external variables and can be subject to interference from walls, trees and rain. For the first time, 5G will use millimeter waves in addition to the microwaves that have been used in 2G, 3G and 4G technology. Due to the limited coverage to implement 5G, cell antennas will have to be installed very close to one another, which will result in constant exposure of the population to millimeter wave radiation. The use of 5G will also require new technologies to be employed such as active antennas capable of beam forming massive MIMO.

With higher frequencies and shortened ranges, base stations will be more closely packed into an area to provide complete coverage and get rid of mobile phone signals. This could mean possible ranges of 20-150 meters with smaller coverage areas per small cell. Again, 5G will employ higher frequencies than previous generations networks and greater bandwidth which will enable users to transfer wireless data faster. Figure 1 shows the electromagnetic spectrum.

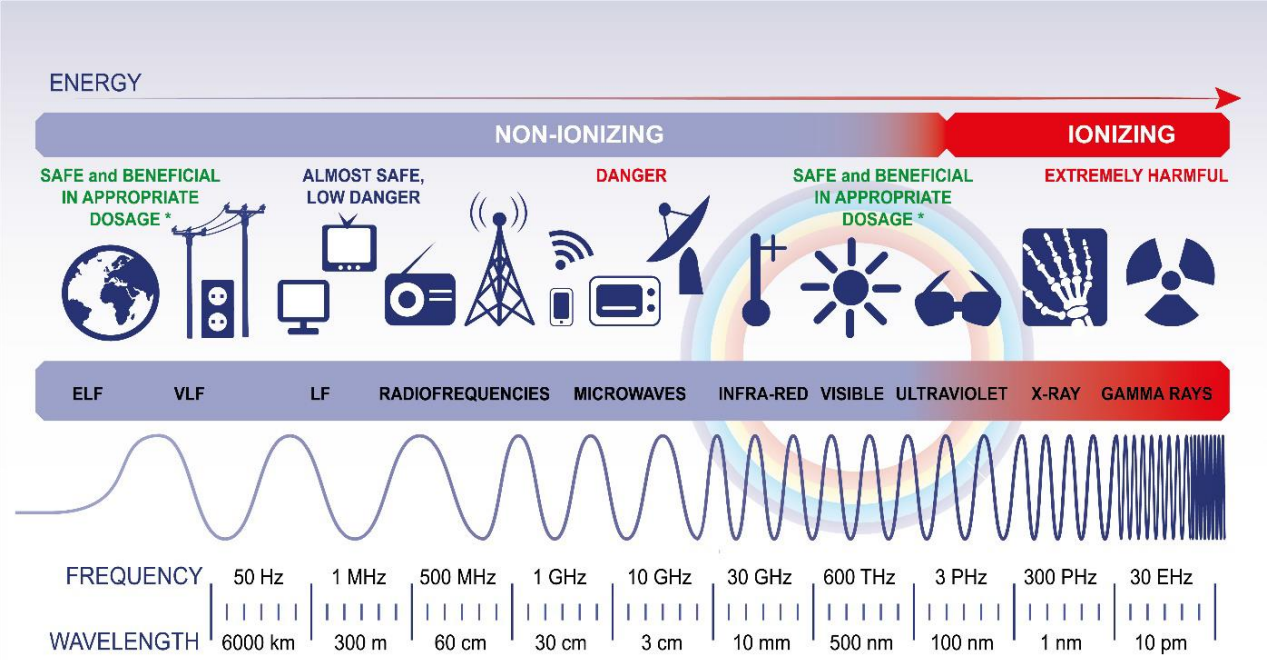

Figure 1: Electromagnetic Spectrum Source: [11]

3. Principles of Radio Frequency Exposure

The exposure from EMF can be categorized according to the effects on the cells generated by the electromagnetic waves. In particular, we distinguish between ionizing radiations and non- ionizing radiation. The ionizing radiations include the waves that have enough energy to remove the electrons from the atoms in the living cells causing the atom to become ionized. Depending on the dose level, the cells exposed to ionizing radiation can die or become cancerous, thus posing a risk for the health effects [12].

The EMFs belonging to the non-ionizing radiation group are composed of waves that do not have enough energy to ionize the cells, thus avoiding cancer and death for the exposed cells. However, the waves can have enough energy to vibrate the molecules causing a possible health issue. The exposure from RF communication equipment falls within the non-ionizing radiation category. The biological effects of RF radiation can be further classified into thermal effects and non-thermal effects. In thermal effect, it is characterized by an RF exposure that can produce a heating of the exposed tissues. In non-thermal effects, the majority of the reports of international organization state that there is not a clear causal correction between EMF exposure levels generated by sources operating below maximum limits defined by law and emergence of biological effects [3].

UE radiate close to users by generating an EMF that is localized either on the head or chest. Again, base stations radiate over the whole body and large portion of the territory compared to UE. The EMF generated by base stations tends to rapidly decrease in intensity as the distance from the RF source increases. Again, a shielding effect from base station EMF occurs inside buildings. Also, the RF exposure from base stations is lower compared to the one radiated from UE. The population associates higher health risks to base station emission with respect to UE radiation.

3.1 Alleged Health Effects from RF Exposure

The impact of brain-related diseases, including brain tumors and sleeping disorders is highly critical in modern society. The following are some of the alleged health effects speculated by the general public.

3.2 Cancer

The International Agency on Research on Cancer (IARC) listed non-ionizing RF radiation from cell phones as possibly carcinogenic to humans in 2010. This action was taken based on different experiments that analyze the carcinogenic effect on animals, which were exposed to EMF levels generated by RF equipment. More recently, different works have found a statistically significant increase of rare cancers associated to RF exposure in rats [13].

3.3 Skin Effects

The RF exposure with high power density can lead to an increase in the temperature of the exposed body tissue. Again, a modest localized heat exposure can be compensated by the human body heat regulation system. High doses of absorbed RF exposure can cause a sensation of warmth in the skin causing mild skin burns [14].

3.4 Ocular Effects

High levels of RF exposure with sufficiently high-power density can cause several ocular effects including cataracts, retina damages and cornea issues [15].

3.5 Glucose metabolism

The RF exposure can affect the glucose metabolism process in human cells. The effects can be noticed in the body organs exposed to high levels of EMFs [16].

3.6 Male Fertility

High levels RF exposure can be associated with negative effects on reproductive health in terms of sperm-fertility ability. Also, the connection of such effects with RF exposure from communications equipment is scientifically not proven.

3.7 Electromagnetic Hypersensitivity

Some individuals report that RF exposure causes several sensitivity symptoms to them like headache, fatigue, stress, burning sensations and rashes. Again, many independent studies have demonstrated that such symptoms are not correlated with the levels of RF exposure [17].

3.8 Spreading of the COVID-19 Disease

Presently, different fake theories claim that there is a connection between the RF from 5G equipment and the spreading of the COVID-19 disease [18].

3.9 Oxygen Effects

Another widespread allegation that links RF from 5G equipment and health diseases includes a supposed oxygen absorption of 5G equipment out of the lungs and the increase of carbon dioxide due to the cutting of the trees to improve the signal coverage of 5G.

3.10 Fifth Generation (5G) Exposure Metrics

The following metrics are used to characterize 5G exposures, namely, Electromagnetic Field Strength, Power Density (PD) and Specific Absorption Rate (SAR).

3.10.1. Electromagnetic Field Strength

In electromagnetic field strength, each RF source generates an EMF that is spread over the environment. The field is composed of an electric component and a magnetic component. If we denote the electric field as E, with a measurement unit in terms of volt per meter (V/m) and also denote the magnetic field as H, with a measurement unit in terms of Ampere (A). Both E and H, is time-averaged values and are estimated over a sufficiently long-time-interval. Again, when the EMF is evaluated under near-field conditions, both H and E are needed to fully characterize the EMF strength. The EMF can be computed as an average from different points in the space. For instance, the spatially averaged electric field strength Eavg over volume V is computed by applying a root mean square operation as shown in equation (1).

$$E_{avg} = \sqrt{\frac{1}{V}\int \lceil E \rceil^2 dv} \qquad \left[{}^{V}/_{m}\right] \tag{1}$$

3.10.2. Power Density

A second metric used to assess the level of exposure is the power density, which can be either the absorbed power density S_{ab} or the incident power density $S_{inc.}$ The absorbed power density S_{ab} is expressed as shown in equation (2)

$$S_{ab} = \iint_A \frac{1}{A} Re[E\ X\ H^*]ds, \qquad \left[{}^{W}/_{m^2}\right] \tag{2}$$

where the body surface is at position 0 (cm), A(cm^2) is the x-y integral area, E is the electric field, $H$is the magnetic field, ds is the integral variable vector whose direction is orthogonal with respect to A.

The incident power density S_{inc} is defined as the modulus of the complex Poynting vector. S_{inc} is expressed as shown in equation (3).

$$S_{inc} = |E\ X\ H^*|, \qquad \left[{}^{W}/_{m^2}\right] \tag{3}$$

Under far-field conditions or transverse electromagnetic plane wave, Equation (3) is simplified as shown in Equation (4).

$$S_{inc} = \frac{[E]^2}{Z} = [H]^2\ X\ Z \qquad \left[{}^{W}/_{m^2}\right] \tag{4}$$

where $Z = 377\Omega$ is the characteristic impedance of the free space. The absorbed power density is related to the incident power density through the equation as shown in Equation (5).

$$S_{ab}=(1-|\Gamma|^2)\ X\ S_{inc} \qquad \left[{}^{W}/_{m^2}\right] \tag{5}$$

where Γ is a reflection coefficient which depends on multiple physical features (the body tissue)?

3.10.3. Specific Absorption Rate

SAR is the time derivative of the energy consumed by heating that is absorbed by a mass, included in a volume of a given mass density. When considering biological tissues or organs, the SAR is expressed as shown in Equation (6).

$$SAR = \frac{\sigma}{\rho}|E|^2, \quad [\text{W/kg}] \tag{6}$$

Where $\sigma[\frac{s}{m}]$ is the electrical conductivity, $\rho[\frac{kg}{m^3}]$ is the density of the tissue or organ and $E[\frac{v}{m}]$ is the internal electric field.

It is possible to express the SAR by considering the temperature rise as shown in Equation (7).

$$SAR = c\frac{\Delta T}{\Delta t} \tag{7}$$

Where C [J/(kgC)] is the tissue specific heat, $\Delta T[Celsius]$is the temperature rise and $\Delta t[s]$ is the exposure duration.

However, when considering SAR, the limit exposure metric assumes two distinct spatially-averaged values, namely whole-body SAR and local SAR. The whole-body SAR takes into account the body mass and the total energy absorbed by the body while the local SAR assumes a given small volume with a given mass [19].

3.10.4. Health Risks Associated With 5G Features

It is necessary to analyze the health risks associated with key 5G features that trigger health concerns among the population. The following controversial aspects are considered, namely densification of 5G sites over the territory, adoption of frequencies in the mm-Wave bands, connection of millions of IoT devices and extensive adoption of massive MIMO and beam forming.

3.10.5. Densification of 5G Sites Over the Territory

This aspect among the population is that the pervasive installation of 5G gNBs over the territory results in an exponential increase of exposure, thus leading to an unacceptable increase of the health risks. The results from different authors demonstrate that the average received power is reduced when the number of 5G gNB is increased. This minimizes the associated health risks among individuals.

Moreover, another aspect that can be considered from the network densification is the harmonization of exposure. When a network is composed of few gNBs, the users in close proximity to the sites tend to be exposed to higher levels of exposure compared to the ones that are far from the gNB. On the other hand, when the number of gNB is increased, the exposure tends to be more uniform over the territory. This issue is usually neglected by the population and can have a significant impact on the perceived health risks due to proximity to the sites [3].

3.10.6. Adoption of Frequencies in the mm-Wave bands

This section triggers concerns by the population in the adoption of mm-Wave in 5G. Again, WHO is currently conducting a health risk assessment of exposure over the entire range of RF range including millimeter wave. This step will be beneficial to reduce the health risks of 5G that are perceived by the population. However, it is important to remark that mmWaves are subject to very large path losses compared to microwaves. Also, other effects including low penetration capabilities

inside the buildings, severely impact of the maximum distance between a gNB and a UE operating at these frequencies [17]. As a consequence, 5G deployments exploiting mm-Waves will be mainly realized through micro and small gNB, which will be placed in close proximity to the service area. This limits the scope of application of mm-Waves, which will not be deployed on the whole territory, but rather at traffic-demanding hotspots (e.g., airports, stadiums, shopping malls).

3.10.7. Connection of Millions of IoT Devices

Another controversial aspect among the population is the effect on exposure due to the huge number of 5G terminals that will be pervasively connected in the same area. In this context, a common opinion is that massive deployments of IoT terminals connected through 5G networks will result in an unacceptable and continuous exposure for users [21], [22]. The problems are analyzed in the following areas: First, current specifications defined by 3GPP always impose very low values of maximum transmitted power for each terminal and even for 5G network.

Second, when considering IoT terminals, more stringent power requirements can be introduced in order to reduce the consumption and to increase the battery lifetime of Low Power Wide Area Networks architectures (LoPWAN). Third, international guidelines always impose maximum SAR and PD values to control the exposure from the terminals, thus guaranteeing safely for the population. Fourth, even in the presence of millions of terminals in the same area, the distance between the user and the terminals will play a major role in determining the exposure. Fifth, IoT communications are in general very different compared to human communication. Also, IoT devices will need to communicate with the rest of the world at a small pace with a limited data rate and with pretty large delays compared to human-centered communications. This will be translated into extremely low power levels in the uplink directions and consequently in very low levels of exposure.

3.10.8. Extensive Adoption of Massive MIMO and Beam forming

The impact of massive MIMO and beam forming on the exposure from 5G devices are analyzed under the following: (i) increase of power and number of radiating elements (ii) introduction of statistical exposure models and (iii) measurement of exposure levels.

3.10.9. Increase of Power and Number of Radiating Elements

When considering 5G devices implementing MIMO and beforming, two essential differences emerge with respect to legacy devices, namely a general increase in the maximum output power and increase in the number of radiating elements. Focusing on the total power radiated by 5G gNB data sheet of macro equipment reports a maximum output power equal to 200W.

The main idea of MIMO is to exploit multiple antennas taking advantage of independent propagation paths to improve the transmission. With massive MIMO, the number of antenna element is radically increased to further improve the system capacity [23].

Spatial multiplexing and beam forming are two key features implemented in 5G system exploiting massive MIMO. Spatial multiplexing allows transmitting independent data over multiple uncorrelated paths.

3.11. Introduction of Statistical Exposure Models

Traditional methods to estimate the exposure from base stations are based on very conservative assumptions, including maximum transmission power and static beams in all the covered area directions. Although such assumptions are in general, valid for legacy technologies, they tend to be overly conservative when considering 5G gNB [11]. The application of conservative assumptions to estimate the exposure from 5G gNB is detrimental for the health risks due to two main reasons. Firstly, the exclusion zone of each 5G gNB tends to be very large and secondly, the predicted exposure levels tend to be pretty high, thus triggering health concerns by the population. Therefore,

the exposure estimation of 5G gNB is based on the introduction of statistical models which allow on one side to better assess the size of the exclusion zone of the gNB and on the other one to estimate the predicted exposure levels over the territory in a more realistic manner[24]. The results show that, by applying the Statistical model, the largest maximum power is less than 15% with respect to the corresponding theoretical one. Consequently, the exclusion zone can be reduced by a factor of 2.6 compared to a traditional methodology.

3.12. Measurement of Exposure Levels

These aspects deal with the measurement of exposure levels due to the large adoption of MIMO and beam forming features. Focusing on gNB, the methodologies used to measure the exposure in legacy networks are not always suitable for assessing the exposure of 5G gNBs exploiting massive MIMO and beam forming. Such features can cause uncertainties in the estimation of the field strength. This aspect can be an issue for the health risks that are perceived by the population. The measurement procedure of 5G gNB involves either wide-band probes operating on a given range of frequencies, or narrow-band probes that are able to retrieve information on the field strength on a set of selected frequencies [11].

3.13. Regulation of Electromagnetic fields and 5G Exposure

The following professional bodies and government of various countries provide responsibility for protecting the population from the potential harmful effects of EMFs through their regulation.

3.14. National Institute of Health

According to the national institute of health, no mechanism by which ELF-EMF's or radio frequency radiation could cause cancer has been identified. Unlike high-energy (ionizing) radiation, EMFs in the non-ionizing part of the electromagnetic spectrum cannot damage DNA or cells directly [12].

3.15. American Cancer Society

Some people have expressed concern that living, working or going anywhere near a cell phone tower might increase the risk of cancer or other health problems. At this time, there is very little evidence to support this idea [25].

3.16. World Health Organization

The level of RF exposure from base stations and wireless network are so low that the temperature increases are insignificant and do not affect human health [26].

3.17. Federal Communications Commission

There is no specific evidence to date that proves that wireless phone usage can lead to cancer or a variety of other health effects, including headaches, dizziness or memory loss. However, studies are ongoing and key government agencies such as the Food and Drug Administration (FDA) continues to monitor the results of the latest scientific research [27] and [28].

3.18. Commission Inter-Americana de-Telecommunication (CITEL)

The general public is requested to consult international reputable sources based on scientific knowledge on the subject of exposure of human beings to radio frequency emissions, in order to prevent false information from spreading undermining the efficient development of telecommunications [29].

3.19. International Telecommunications Union (ITU)

The link between 5G and COVID-19 is a "Hoax that has no technical basis" on human health [30] and [31].

3.20. Federal Communications Commission on Twitter

5G technology does not cause coronavirus. Rumors can easily circulate within communities during a crisis. Individual should always go to trusted sources for information.

3.21. International Commission on Non-Ionizing Radiation Protection

The new guidelines provide better and more detailed exposure guidance for the higher frequency range above 60Hz, which is of importance to 5G and future technologies using these higher frequencies. The most important thing for people to remember is that 5G technologies will not be able to cause harm when these new guidelines are adhered to [8].

3.22. US Food and Drug Administration

The weight of scientific evidence has not linked exposure to radio frequency energy from cell tower use with any health problems at or below the radio frequency exposure limits.

3.23. Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)

Current research indicates that there is no established evidence for health effects from radio waves used in mobile telecommunications. This includes the up-coming roll-out of the 5G network. ARPANSA assessment is that 5G is safe.

3.24. Norwegian Institute of Public Health

The knowledge base in this health risk assessment provides no reason to assert that adverse health effects will occur from the typical exposure. This also applies to the use of wireless communications in office environment.

3.25. Swedish Council for Working Life and Social Research

Extensive research for more than a decade has not detected anything new regarding interaction mechanisms between radio frequency fields and the human body and has found no evidence for health risks below current exposure guideline.

3.26. European Commission

Scientific committee on formerly and newly identified Health Risks (SCENIHR) reported that the epidemiological studies on mobile phone RF EMF exposure do not show an increased risk of brain tumors." Furthermore, they do not indicate an increased risk for the cancers of the head and neck region [32].

3.27. Government of Canada

With respect to cell phone towers exposures the limits set in Health Canada's guidelines indicated that there is no scientific reason to consider cell phone towers dangerous to the public.

3.28. Memorial Sloan Kettering Cancer Center

The argument that cells phones cause cancer lacks biological plausibility because the energy contained in the waves is too low to cause damage.

4.0. Conclusion

This study confirmed that global experts have thoroughly researched into the health effects of 5G but all the outcome of the research has shown that there are no real health hazards associated with 5G networks. The usual radiation effect that is associated with the previous mobile technologies is also the same that is associated with 5G network and does not really affect humans as observed. The suspicion and concern the global populace have on 5G networks will require more installation of more base stations and these base stations will be install as close as possible to each other. In conclusion, this paper suggests that the health concerns about 5G network are not supported by scientific evidences. Many of the researches are in the medical science field and many have also

refuted the claims of the concerns. Hence, there is no adequate compelling motivation to stop the deployment which has been slowed down due to the various claims from so many quarters. This paper has analyzed the basic metrics to characterize 5G exposures in terms of incident EMF Strength, PD and SAR.

References

[1] M. R. Bhalla and A. V. Bhalla, "Generations of mobile wireless technology: A survey," *Int. J. Comput. Appl.*, vol. 5, no. 4, pp. 26–32, 2010.

[2] T. S. Rappaport, *Wireless communications: principles and practice*, vol. 2. prentice hall PTR New Jersey, 1996.

[3] M. A. Jamshed, F. Heliot, and T. W. C. Brown, "A Survey on Electromagnetic Risk Assessment and Evaluation Mechanism for Future Wireless Communication Systems," *IEEE J. Electromagn. RF Microwaves Med. Biol.*, vol. 4, no. 1, pp. 24–36, 2020, doi: 10.1109/JERM.2019.2917766.

[4] A. Bria *et al.*, "4th-generation wireless infrastructures: scenarios and research challenges," *IEEE Pers. Commun.*, vol. 8, no. 6, pp. 25–31, 2001.

[5] A. Tudzarov and T. Janevski, "Design for 5G mobile network architecture," *Int. J. Commun. Networks Inf. Secur.*, vol. 3, no. 2, pp. 112–123, 2011.

[6] D. A. Nelson, M. T. Nelson, T. J. Walters, and P. A. Mason, "Skin heating effects of millimeter-wave irradiation-thermal modeling results," *IEEE Trans. Microw. Theory Tech.*, vol. 48, no. 11, pp. 2111–2120, 2000, doi: 10.1109/22.884202.

[7] L. Chiaraviglio *et al.*, "Planning 5G Networks under EMF Constraints: State of the Art and Vision," *IEEE Access*, vol. 6, pp. 51021–51037, 2018, doi: 10.1109/ACCESS.2018.2868347.

[8] A. Di Ciaula, "Towards 5G communication systems: Are there health implications?," *Int. J. Hyg. Environ. Health*, vol. 221, no. 3, pp. 367–375, 2018.

[9] R. K. Singh, D. Bisht, and R. C. Prasad, "Development of 5G mobile network technology and its architecture," *Int. J. Recent Trends Eng. Res.*, vol. 3, no. 10, pp. 196–201, 2017.

[10] M. Simkó and M. O. Mattsson, "5G wireless communication and health effects—A pragmatic review based on available studies regarding 6 to 100 GHz," *Int. J. Environ. Res. Public Health*, vol. 16, no. 18, p. 3406, 2019, doi: 10.3390/ijerph16183406.

[11] R. Pawlak, P. Krawiec, and J. Zurek, "On measuring electromagnetic fields in 5g technology," *IEEE Access*, vol. 7, pp. 29826–29835, 2019, doi: 10.1109/ACCESS.2019.2902481.

[12] C. L. Russell, "5 G wireless telecommunications expansion: Public health and environmental implications," *Environ. Res.*, vol. 165, pp. 484–495, 2018, doi: 10.1016/j.envres.2018.01.016.

[13] "IARC classifies Radiofrequency Electromagnetic Fields as possibly carcinogenic to humans – IARC." https://www.iarc.who.int/pressrelease/iarc-classifies-radiofrequency-electromagnetic-fields-as-possibly-carcinogenic-to-humans/ (accessed Jan. 13, 2022).

[14] R. Roelandts, "Cellular phones and the skin," *Dermatology*, vol. 207, no. 1, pp. 3–5, 2003, doi: 10.1159/000070932.

[15] J. A. Elder, "Ocular Effects of Radiofrequency Energy," *Bioelectromagnetics*, vol. 24, no. SUPPL. 6, pp. S148–S161, 2003, doi: 10.1002/bem.10117.

[16] N. D. Volkow *et al.*, "Effects of cell phone radiofrequency signal exposure on brain glucose metabolism," *JAMA - J. Am. Med. Assoc.*, vol. 305, no. 8, pp. 808–813, 2011, doi: 10.1001/jama.2011.186.

[17] G. J. Rubin, J. Das Munshi, and S. Wessely, "Electromagnetic hypersensitivity: A systematic review of provocation studies," *Psychosom. Med.*, vol. 67, no. 2, pp. 224–232, 2005, doi: 10.1097/01.psy.0000155664.13300.64.

[18] W. Ahmed, F. L. Seguí, J. Vidal-Alaball, and M. S. Katz, "COVID-19 and the 'Film Your Hospital' conspiracy theory: Social network analysis of Twitter data," *J. Med. Internet Res.*, vol. 22, no. 10, p. e19458, 2020, doi: 10.2196/22374.

[19] "ICNIRP." https://www.icnirp.org/en/activities/news/news-article/rf-guidelines-2020-published.html (accessed Jan. 13, 2022).

[20] T. S. Rappaport *et al.*, "Millimeter wave mobile communications for 5G cellular: It will work!," *IEEE Access*, vol. 1, pp. 335–349, 2013, doi: 10.1109/ACCESS.2013.2260813.

[21] J. Zhang, M. Ma, P. Wang, and X. dong Sun, "Middleware for the Internet of Things: A survey on requirements, enabling technologies, and solutions," *J. Syst. Archit.*, vol. 117, no. 5, p. 102098, 2021, doi: 10.1016/j.sysarc.2021.102098.

[22] D. Zhang, Z. Zhou, S. Mumtaz, J. Rodriguez, and T. Sato, "One integrated energy efficiency proposal for 5G IoT communications," *IEEE Internet Things J.*, vol. 3, no. 6, pp. 1346–1354, 2016.

[23] B. Thors, A. Furuskar, D. Colombi, and C. Tornevik, "Time-Averaged Realistic Maximum Power Levels for

the Assessment of Radio Frequency Exposure for 5G Radio Base Stations Using Massive MIMO," *IEEE Access*, vol. 5, pp. 19711–19719, 2017, doi: 10.1109/ACCESS.2017.2753459.

[24] M. D. Migliore, "Some Notes on the Verification of the Exposure Limits in 5G Systems," in *2019 IEEE International Symposium on Measurements and Networking, M and N 2019 - Proceedings*, 2019, pp. 1–5, doi: 10.1109/IWMN.2019.8805045.

[25] P. Elliott *et al.*, "Mobile phone base stations and early childhood cancers: Case-control study," *BMJ*, vol. 340, no. 7762, 2010, doi: 10.1136/bmj.c3077.

[26] R. Singh, R. Nath, A. K. Mathur, and R. S. Sharma, "Effect of radiofrequency radiation on reproductive health," *Indian J. Med. Res.*, vol. 148, no. 7, pp. 92–99, 2018, doi: 10.4103/ijmr.IJMR_1056_18.

[27] P. A. Valberg, "Radio frequency radiation (RFR): The nature of exposure and carcinogenic potential," *Cancer Causes Control*, vol. 8, no. 3, pp. 323–332, 1997, doi: 10.1023/A:1018449003394.

[28] "Radio Frequency Safety | Federal Communications Commission." https://www.fcc.gov/general/radio-frequency-safety-0 (accessed Jan. 13, 2022).

[29] L. Chiaraviglio, G. Bianchi, N. Blefari-Melazzi, and M. Fiore, "Will the Proliferation of 5G Base Stations Increase the Radio-Frequency 'Pollution'?," in *IEEE Vehicular Technology Conference*, 2020, vol. 2020-May, pp. 1–7, doi: 10.1109/VTC2020-Spring48590.2020.9128888.

[30] "K.52 : Guidance on complying with limits for human exposure to electromagnetic fields." https://www.itu.int/rec/T-REC-K.52-202106-I (accessed Jan. 13, 2022).

[31] "Coronavirus: NHS director 'outraged and disgusted' at 5G conspiracy attacks | Science & Tech News | Sky News." https://news.sky.com/story/coronavirus-celebrities-criticised-for-fanning-the-flames-of-5g-conspiracies-11968570 (accessed Jan. 13, 2022).

[32] S. Nicole, "Mobile phones and health: Where do we stand?," in *EPRS*, no. March, European Parliament, 2019.