International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

# 5G Wireless Communication and Its Adverse Effects on the Human Body: Distinguishing Falsehoods from Reality

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**Submitted**: 17/09/2023 **Revised**: 28/10/2023 **Accepted**: 15/11/2023

**Abstract:** 5G is the newest technology for wireless communication available. It allows gadgets like smartphones and Bluetooth-enabled gadgets to share information with one another. Electromagnetic radiation is the sort of energy that 5G uses to function. It's speedier and more efficient since it employs greater frequencies than other wireless connections. Electromagnetic fields (EMFs) are created when electromagnetic frequencies, such those generated by 5G, are introduced to a region. EMFs are thought to be harmful by some. Therefore, many are worried about the effects of 5G on their health. However, 5G has not yet been connected to any serious health concerns. There were various suggestions about the relationship among 5G and COVID'19, but neither of them was backed by evidence. There had been no real-world analogies, therefore it was reasonable to believe they were all hoaxes. With this article, we have made an effort to explore the various cases that justify these claims.

***Keywords:*** *5G, communication hazard, RF-EMF, Bio-effects, Tissue heating, Neurological*

## 1. Introduction

Information and communication technologies (ICTs), such as cell phones that are utilized for mobile phone service and, such example, Wi-Fi, by exploiting electromagnetic fields (EMFs), have had an unmatched growth rate in the past few decades. In a few nations in the late 1980s, individuals and private consumers could purchase the first generation of portable cellular telephones. There are now more gadgets on the planet than people, thanks to huge increases in the penetration rates of the second (2G), third (3G), and fourth (4G, LTE) generations in society. Wi-Fi alongside other wireless data transmission technologies have also spread widely and are currently commonplace [1]. The future rollout of 5G mobile networks will guarantee much higher mobile internet speeds and progressively large amounts of mobile data use. The adoption of extra bands with greater frequencies enables this. The goal of 5G is to serve as a connectivity hub for everything from VR to self-driving cars, the IIoT, and smart cities. Additionally, 5G is regarded as the foundational technology for the IoT, which enables M2M communication between devices.

At the same time, a shift in how people and the environment are exposed to EMF is anticipated. Numerous studies with a focus on health issues have been drawn to the launch of Wireless Communication (WC) devices which operate in the extremely high-frequency regions of the EM spectrum. They cover research on in vitro systems, living things, and people (including epidemiological and experimental investigations). National and global committees that include pertinent specialists often publish conclusions and findings from such research [2-4]. MMW frequencies are employed in multiple medical fields as well as in sonar technology. A number of epidemiological investigations have looked at industrial contact with radars, but the general conclusion is that the exposure doesn't represent a risk to the affected personnel's health. This is because doses are, for all intents and purposes, below the recommended limits and are not warming tissue. However, it is believed that further research is required to fully understand the potential cancer risk among exposed personnel. MMW's potential for use in medicine has recently been evaluated, indicating that there may be some therapeutic uses, albeit the exact mechanisms of action remain unknown [5-8].

In this work, we attempt to bring out the key aspects of 5G and if the radiation affects humans or it is just a confusion in the society.

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***Evolution 1G to 5G***

- The Original (1G): The first generation (1G) of mobile phones, built around analog technology, appeared in the 1970s and 1980s and functioned in the same way as traditional landline phones. Its battery life, calling experience, and reliability are just a few of the areas where it falls short. The highest possible rate in 1G were 2.5 Kbps [9-12].
- The Next Generation When the initial second-generation 2G digital network became available in the year 1991, it vastly increased the quality of mobile conversation over its predecessor. Techniques from the global system for Mobile, or GSM, and Code-Division Multiple Access (CDMA) were also covered. The highest speed possible with second-generation 2G was 1 M.
- Users of 3G universal mobile telecommunication system foundations have reported faster network speed, speedier download speeds, and continual video calling as a result of the transition from 2G GSM frameworks. The third generation (3G) mobile broadband network is the initial one to be developed to supplement voice communication with multimedia. High-speed Network Access (HSPA) and its successor, HSPA+ [13-14], were the foundation of 3G. the 3G network utilized Multiple-Input Multiple-Output to increase the capacity of wireless networks and packet switching in order to expedite data transfers.
- The most recent version of cell phone broadband technology is called 4G. It has been noted that the data rate in 4G electronic mobile communications has increased from 20 Mbps to 60 Mbps. It supports Volte and WiMAX networks and offers increased bandwidth of as much as 100 Mhz.
- 4.5G, or 4th Generation the LTE-A It's a step up from regular 4G LTE speeds. For both transmission and reception, LTE-A use MIMO technology, which combines several antennas. LTE-A is three times as fast as regular 4G thanks to MIMO, which allows several signals and antennas to work together at once. With LTE-A, users could gain access to three types of communication (data, voice, and video) simultaneously over a wireless connection, regardless of their location. Throughputs of as much as 90 Mbps are possible on the LTE-A networks.
- Generation 5G (5G): When compared to earlier wireless network generations, 5G stands as a linchpin of digital change. Extreme mobile broadband (eMBB) is one of three new services made possible by 5G for consumers. It provides blazing rapid access to the web, increased bandwidth, reasonable latency, UltraHD video streaming, AR/VR media, and much more. eMTC, or extensive machine-to-machine communication, enables low-cost, high-bandwidth machine-to-machine communication over vast distances. For Internet of Things (IoT) applications, eMTC offers fast data costs, minimal energy consumption, and broad coverage with minimally sophisticated devices. URLLC provides low-latency, ultra-high dependability, as well as extensive quality of service (QoS), that is impossible to achieve with the current state of mobile network architecture. Remote surgery, V2V communication, Industry 4.0, smart grids, intelligent transport systems, etc. are just few of the many examples of where real-time interaction is required and where URLLC shines. There are no lags or interruptions in 5G's autonomous operations over a dependable network. The throughput in the downlink direction is 20 Gbps. IPv6 as is the foundation of 5G, which also enables 4G WWWW (Fourth Generation World Wide Wireless Web). With 5G's incredibly fast speeds, high capacity, low-latency, increased dependability and flexibility, and environmentally friendly mobile communication technologies, you can stay online whenever and anywhere you choose. There are two primary categories of 5G technology: six GHz (GHz) and Millimetre wave (mmWave).

The 6 GHz [15] frequency range provides the optimal conditions for 5G networks because it strikes a balance between capacity and coverage. The increased bandwidth and enhanced network performance made possible by 6 GHz spectrum will amaze you. It provides always-on, everywhere-accessible 5G connection at a price that is affordable regardless of whether mid band bandwidth is not readily available [16-18]

When it comes to constructing a powerful network, 5G relies heavily on mmWave technology. Incorporating 5G mmWave technology into 5G deployment plans is essential because of the wide range of services it enables. Despite the fact that several service providers have already implemented 5G mmWave, simulation results reveal that this spectrum is significantly underutilized. Extremely fast wireless communication is made possible, as is ultra-broadband for the upcoming generation of mobile networks.

## 2. 5G Radiation: A Know How

**What is 5G?**

The state of wireless technology is dynamic. A fresh generation of wireless technology is released by mobile businesses around once every ten years. All succeeding generations improve upon and replace their predecessors in every conceivable way.

The first 5G networks went live in the year 2022. "5G" refers to the fifth generation of wireless technology. 5G

makes mobile communications much quicker. The proliferation of electronic gadgets and services should benefit from this; autonomous vehicles, gadgets for simulated reality, Medical Remote Monitoring using Telemedicine, telesurgery [17-20]

Higher electromagnetic spectrum frequencies are the key to 5G's operation. The bandwidth is between 3.5 and many tens of gigahertz (GHz). Such more powerful frequencies were not utilized by mobile phone networks prior to the introduction of 5G. A common application is in security scanners. Beam-forming is another technique used by 5G to transmit information straight to terminals. This is in contrast to earlier versions, which broadcast in every possible direction.[6]

Millimeter waves, the kind of wave used by 5G, have a greater frequency, a shorter range, and a dense infrastructure arrangement; they can generate a highly powerful radio waves electromagnetic field (RF-EMF). The electromagnetic field, or EMF, is an invisible source of power. Figure 1 shows the difference between ionizing and non-ionizing radiation and how the former is much more dangerous to human health because it can induce cell damage and even cancer. Although non-ionizing radiations pose no immediate danger to humans or the environment, some researchers have hypothesized that continued exposure to even low doses could have harmful impacts on human health and the natural world.

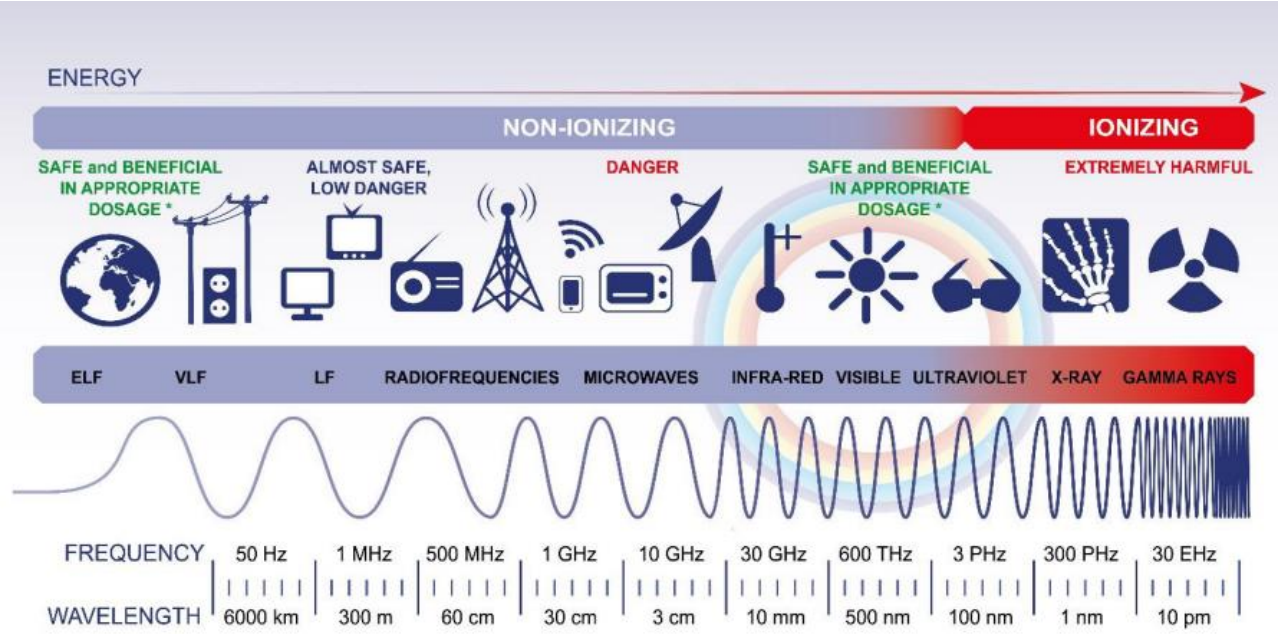


**Fig 1.** RF-EMF Spectrum [21]

Scientists have warned that the high electromagnetic waves produced by the 5G mobile phone network will worsen the negative effects of EMF exposure. A growing number of researchers have signed an appeal made to the UN in 2015 and the European Union in 2017 (268 academics and medical professionals as of the 18th of December 2019). While half of scientists have concluded that 5G technology radiation is safe, many others have cast doubt on this conclusion owing to a lack of data. Most of the studies were conducted at mono carrier wave frequencies in the lab, which produce weak EMF (because EMF is pulsating and modulated). However, the actual deployment of the 5G network involves the superimposition of different frequencies (the lower frequency is additionally utilized in telephony), which would result in substantial EMF.

Second, all of the experiments were done on mice and rats in the laboratory, and different kinds have varied radiation absorption properties. Here, the depth to which irradiation can penetrate varies as a result of frequency, cells, and other parameters that are not universal among species. Depending on the energy density, electromagnetic fields can damage organs and tissues deep inside a living thing's body. By the year 2020, a large number of continents, including the United States and Europe, had adopted fifth-generation infrastructures to strengthen their economies and improve their public, commercial, and military sectors.

## 3. How Does 5G Effect Health?

The WHO (World Health Organization) Trusted Source reports that there is insufficient data on the frequencies utilized in 5G.

The impact of electromagnetic radiation on human health are increasingly the subject of study. However, there is no consistency in the findings. Possible health effects linked to EMFs thus far include:

***Tissue heating:***

An informal 2017 research [7]: According to reliable research, mobile phones [13] operate between 1.8 and 2.2 GHz. According to WHO, exposure to these frequencies can lead to tissue heating. Absorption of electromagnetic energy by the skin causes tissue warmth. The result is an increase in core body and brain temperature. Research due in 2021[8]: According to a reputable source, tissue heating caused by electromagnetic fields increases with age. They also receive more of the electromagnetic fields the greater the level. This is due to decreased thickness of the skin and flow of blood typical of elderly people. Tissue heating, nevertheless, is thought to be transient and low-impact. The FCC also reports that people are subjected to extremely low frequency of electromagnetic fields. Tissue heating would be minimal at those levels. More study is needed to establish the exact effects of 5G on tissue from humans.

***Intellectual processing:***

The impact of 5G on brainpower hasn't been investigated just yet. Some studies have included extraterrestrial electromagnetic fields. The effects of cellphone use on mental acuity were investigated in a modest 2017 study [7]. The study participants who used their phones for a minimum of ninety minutes every day had more trouble paying attentive.

***Cancer:***

The International Association for Research on Cancer, or IARC, concluded in 2011[9] that electromagnetic fields are "conceivably hazardous" to humans. Thirty experts from 14 different countries came up with the classification. Most research has focused on whether or not EMFs may increase the risk of developing brain cancer. But the outcomes have been all over the place. Electromagnetic fields from cell phones, for instance, has been linked to tumors such as a kind of brain cancer, according to a 2017 [10] assessment of the relevant studies. However, a study conducted in 2018[11] found no conclusive link between exposure to high frequencies electromagnetic fields and the development of brain cancers.

**Effects on animals:**

The effects of 5G on animals have only been studied to a limited extent. Mice and rats have been used extensively in research. In 2019, for instance, researchers observed that mice and rats exposed to electromagnetic fields (EMFs) from mobile phones experienced increased DNA damage. Being exposed to electromagnetic radiation of any frequencies is harmful to the nervous system, according to another animal research published in 2016. A look at the research in 2020, the effects of electromagnetic fields on many creatures, including snails and frogs, were also studied by Reliable Source. According to the findings, the question of whether or not EMFs have harmful effects on animals remains unanswered.[6]

**Neurological Effects**

According to Navarro EA et al, those who live in close proximity to electromagnetic radiation are at an increased risk of experiencing a wide range of adverse health effects, including but not limited to: anxiety, irritability, insomnia, lack of desire to eat, fainting, blurred vision, and heart disease [12].

**Transcriptional Regulation**

The replication of a gene is the procedure through which the gene's instructions for making a protein are carried out. Gene expression may be affected by electromagnetic fields (EMF) at a frequency greater than 30 GHz, according to some research.[12]

**Fertility**

Multiple researchers have found that prolonged exposure to electromagnetic fields (EMFs) has a significant negative effect on the quality of sperm. The rate of egg loss and follicular remodeling, two factors in female fertility, are also affected. Overexposure to electromagnetic fields (EMFs) has been linked to a decrease in human fertility of up to 50%, according to a number of studies.

**Changes in Hormone Levels**

Humans exposed to 5G radiation may see a decrease in corticosteroid levels of hormones and a rise in various hormonal levels. Skin rashes, thyroid issues, abnormal organ development, and changes in appetite are just some of the side effects that can occur when a person's hormone levels fluctuate.

## 4. Health Issues Due to Various Wireless Communication Technologies: Probable Solutions and Comparison

With the advent of 3G technology, internet connectivity took a giant leap forward. From advances in multimedia to breakthroughs in high-speed data transfer, this age saw widespread use of several novel technologies. In order to improve connection and multimedia services for end users, an enormous amount of ground stations was set up at this time. Depending on the overall population number in the area, suppliers of services must adhere to strict ICNIRP guidelines. Different levels of population necessitate different sets of rules and laws to ensure everyone's safety. Researchers have found problems with wireless technology; thus, precautionary measures have to be taken. For all the latest 4G and 5G network protocols, the regulatory agency has offered comparable safety requirements and safety guidelines, albeit with some enhancements. Exposure to EMF-RF has both immediate and delayed consequences.

Painful sensations, headaches, decreased motility of sperm, stinging or scorching sensation, anxiety, tension, and irritation are some of the immediate impacts, whereas malignancies, tumors in the brain, damaged DNA, modified cells, and neurological conditions are some of the long-term repercussions. Because the brains of kids are still developing, they are more vulnerable to the side consequences of 5G radiation than adults' brains are. According to table 1, studies suggest that exposure to electromagnetic radiations causes behavioral issues and slows down brain growth in youngsters.

**Table 1.** Impacts of various wireless communication technologies [12]

| Comparative Analysis | 3G | 4G | 5G |
|---|---|---|---|
| Technology | WCDMA | LTE | Millimetre |
| Skin Tissue (Heating) | No | Yes | Yes |
| Body Temperature | Not rise | Rise | Not rise |
| Penetration Depth on Skin | More (>10mm) | Less (approx. 1mm) | Less (0.41 mm for 42.24 GHz) |
| Absorption of Energy | Low | High | Extremely High |
| EMF-RF Exposure | Less | More | Extremely More |

From the numbers in the table above, we may infer that 5G networks cause greater amounts of tissue in the skin heating than 3G networks do. The crowd is subjected to greater exposure to hazardous electromagnetic waves due to the perfectly positioned grid antennae of 5G technology stations, which focus in a specific direction, causing additional cell heating and burning. Yet, this issue is no longer present in 3G networks, and the tissue heating effect of 4G networks is minimal at best. When opposed to 3G radiation, the health risks associated with 5G radiation exposure are milder. This is why 5G electromagnetic waves have a lower penetrating effect on human tissue. Millimeter waves, the type used by 5G networks, have a far shorter range and weaker penetration strength. According to the data in the following table, [14] 42 GHz band radiation can go as far as 0.41 mm into human skin, while 4G rays can go as deep as 1 mm into human skin. However, as was said before, various kinds of skin result in different levels of penetration. The heat absorption rate of 5G electromagnetic waves is sky high. Since the network used by 5G employs millimeter waves, these are taken in readily by human beings when combined with perspiration despite their limited ability to penetrate the skin on their own. The primary lobes of the antenna's radiation pattern are directed more powerfully towards the body of a person when directional grid antennas are used. Millimeter waves, which are used by 5G, are able to traverse short distances, hence a high number of base stations with antennas are required. Thus, additional the BSs are employed in dense populations as a result of widespread rollouts. As a result, 5G poses a greater risk of electromagnetic and radiofrequency (EMF-RF) exposure than earlier generations of mobile technology

## 5. Protective Measures to Avoid 5G Adverse Effects

5G relies on wireless networks as its primary communication channel, and there is currently no solution to mitigate the risks associated with these networks. For this reason, it is crucial that all users take precautions and that service providers adhere to stringent norms and safety regulations when implementing the network. The dangers of cell phone radiation to people, plants, and animals are explored. The same study recommends preventative actions to lessen the severity of these side effects, some of which are discussed below.

- Avoid being as close to a cell phone or other wireless device as possible.
- Avoid using your phone as much.
- Avoid using your cell phone when the signal is poor or your battery is low.
- You must pause between speaking and listening until the call is connected.
- Put the phone in a headset and use the toggle method.
- Use a cell phone with a low specific absorption rate (SAR).
- Reduce your cell phone use.
- The best way of shielding a home from radiation is to surround it with a highly conductive in closure and paint the windows a radiation-absorbing hue.
- If you're not using your wireless router, turn it off.
- Don't bring your phone into the bedroom when you want to sleep. Protect yourself from radiation by installing a smart meter shield if you have one installed in your home.

## 6. 5G EMF-RF Exposure on Human Body- Use Cases

The effects of electromagnetic radiation (EMF) on human health have been widely discussed, and one major area is how it affects skin color. Pulsed electromagnetic fields (PEMFs) (60 Hz) were found to induce skin pigmentation in zebrafish, illustrating how the production of melanin and melanocytes may be affected by EMFs, through raising the

expression of TRP-1, that is controlled by phosphorylation of ERK and p38. Extremely low frequency (ELF) electromagnetic fields (EMFs) at low intensities can also induce melanogenesis in melanocytes. However, the absence of a well-characterized 5G exposures system makes it difficult to determine if millimeter waves, particularly 5 G EMR, can influence skin pigmentation. These are the below use cases of 5G effects on human body and health

i. With the introduction of 5G wireless communication, concerns about the effects of electromagnetic energy (EMR) with a frequency of 28 GHz on the health of people have recently come to the forefront. In this study, we found that exposure to 5G (28 GHz) EMR reduced pigmentation of the skin in murine melanoma cells (B16F10) in a 3D pigmented human epidermis model (MelanodermTM). Four hours a day of 5G (28 GHz) was applied to B16 cells with or without -MSH. It's interesting that 5G dampened the -MSH-induced production of melanin. Fontana-Masson staining verified that 5G exposure attenuated the dendritic development of -MSH activated B16 cells. The anti-melanogenic impact of 5G EMR was confirmed by irradiating MelanodermTM with 5G technology at an electrical level of 10 W/m2 for 4 hours every day for 16 days, and then detecting melanin dispersion by Fontana-Masson staining. Tyrosinase, transient receptor potential (TRP) kinase 1, and tyrosinase 2 activation by -MSH was consistently inhibited by 5G EMR. Reactive oxygen species (ROS) are essential for the manufacture of melanin, although 5G EMR has been shown to dampen ROS formation driven by -MSH and H2O2. System for In Vitro 5G Testing

ii. For this research, we developed a 28 GHz vitro 5G exposure device (Figure 2). All of the parts of the system are combined into one convenient package in an "all-in-one" system. For consistent field strength, an exposure chamber was built in accordance with earlier research. Planimetric analysis was used to verify the claimed uniformity within the chamber. According to the relationship among intensity and the power that was input inside the chamber, the exposed cells were located 140 millimeters away the antenna having a power input of 0.4 W. Controlling the ventilation speeds of the incubators based on cell temperature monitored by the infrared, or IR, camera provided real-time feedback to reduce heat impacts throughout exposure, particularly in high-powered settings. Throughout the experimental circumstances, a personal computer was used for recording and tracking all data.

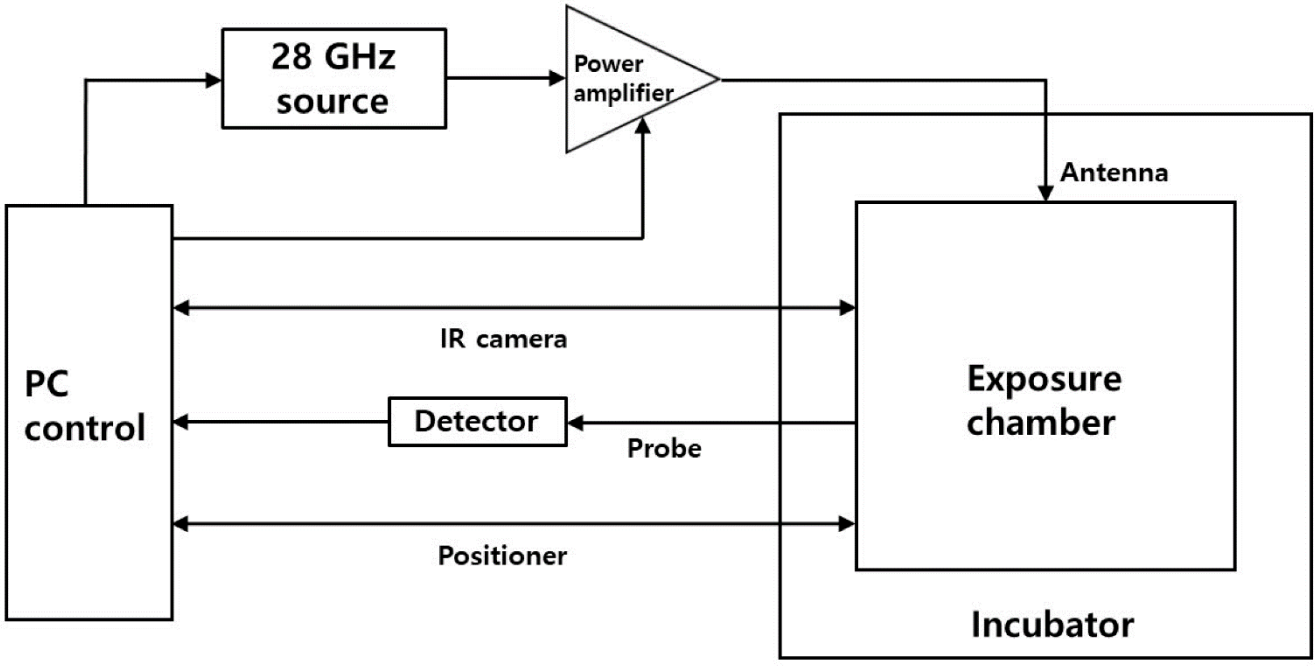


**Fig 2.** Schematic diagram of 5G exposure system [16]

iii. MelanodermTM, a human skin model with pigmentation, and the Impact of 5G on Pigmentation. To verify the anti-melanogenic impact of 5G EMR, a synthetic human pigmented epidermis model called MelanodermTM was used. MelanodermTM was subjected to 5G EMR once daily for 14 days after being stabilized in a 37 °C carbon dioxide (CO2) environment night before to use. The tissues had been fixed and colored with H&E or Fontana-Masson on the final days of the research. Data from immunohistochemistry (IHC) on 5G-exposed and -unexposed MelanodermTM (Figure 3) demonstrated that 5G exposure inhibited melanosome accumulation and dendritic formation of melanocytes in the basal layer of MelanodermTM.

iv. The eventual development of wireless healthcare systems will include widespread use of sensors that are worn and implanted medical equipment (to monitor and send health recorded data). Many implantable and wearable medical devices are already making a significant difference in patients' lives and making their lives easier, such as cochlear implants, cardio defibrillators, pacemakers, and insulin pumps. Future prospects and challenges for connecting such mobile sensors with 5G are substantial.

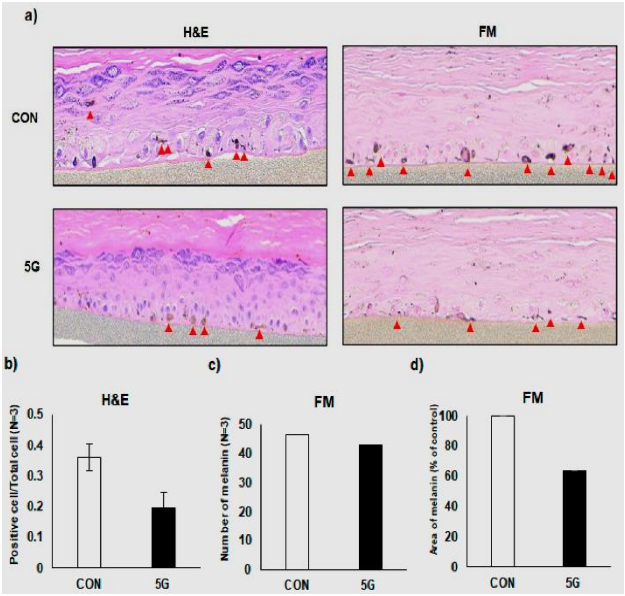


**Fig 3:** 5G's impact on the artificially pigmented skin model MelanodermTM [16]

Several technological limitations (such as slow data transfer speeds, spotty network coverage, security worries, etc.) now impede widespread uptake of home health monitoring solutions. To overcome these limitations, the next-generation 5G network will offer improved security, faster data rates, more reliable transmissions, and pervasive connectivity. This will greatly improve the ability of health service providers to convey information to patients and boost the availability of communication tools for health monitoring.[17]

There have been promising developments in the ease with which health monitoring can be performed at home. In contrast to the traditional method, which often involved a trip to the local hospital, individuals are able to gauge their vitals (for instance, using the AliveCor ECG application) within their homes using mobile devices, saving both time and money. Novel possibilities for the radar methods for tracking the well-being of the elderly (i.e., fall detection and numerical gait measurement) in a non-invasive manner will become available as a result of 5G's advancements, allowing healthcare to be delivered locally in homes, nursing centers, surgery centers, hospitals, recovery places, remote areas, and even in ambulances.

## 7. 5G Health Concerns, Facts and Myths

Cancer hazards were cited in a 2017 petition to halt the implementation of 5G in the European Union (EU) by medical professionals and scientists. Since 5G is still so new, there hasn't been enough time to thoroughly verify its safety, which is a cause for concern. Some researchers claim there is a dearth of research on the long-term effects of being constantly exposed to 5G networks in highly populated places.

Electromagnetic sensitivity is influenced by one's genetic makeup, which 5G may affect a wider variety of individuals than ever before. Factors like intensity, frequency, type of cell, & exposure time all have a role in how electromagnetic fields (EMF) alter genes and how they express themselves, as noted in a 2021 research that concludes its results are in line with observations that EMF produces biological damages.

The majority of the government's RF regulations were also adopted in the late 1990s, when there was little data to draw on. A few researchers are speaking out now that they no longer believe the problem to be black and white. Over 3,500 doctors from fields as diverse as preventative measures and ecological medicine, the field of toxicology and others have spoken out against 5G, citing cancer, cellular stress, genetic damage, reproductive changes and deficits, and neurological conditions as major risks associated with non-ionizing radiation exposure according to the literature on science.

The NIEHS also reports that certain studies from the 1990s suggested a modest relationship between exposure to strong EMF fields and an elevated incidence of pediatric leukemia. Concerns about probable links between EMF and severe health consequences have persisted, the group observes, "in the age of cell phones, Wi-Fi routers, or the IoT using EMFs" NIEHS recognizes the need for further studies and encourages ongoing education on realistic strategies for minimizing exposures to electromagnetic fields (EMFs).

There is growing concern regarding the potential health risks of 5G, with evidence appearing in the form of peer-reviewed studies and information published in a variety of medical publications.

### *5G Causes COVID-19: Fiction*

Some people believe that 5G either directly causes COVID-19 or impairs the body's defenses, making it more contagious. The assumption that 5G technology causes or may spread COVID-19 has been debunked by the scientific community.

The worldwide pandemic of Corona Virus 19 (COVID'19) began in Wuhan, China in December 2019, and it caught the whole globe by surprise. Without any serious argument or reasoned proof, conspiracy theorists and dark powers

fabricated their own story connecting the epidemic with 5G. The following hypotheses emerged as the most popular among all the conspiracies:

This idea has no substantial foundations since the roll out is done in stages and a global installation of 5G technology would have grabbed the attention of at least one person in this era of digital media. 1. The Corona Virus was purposely produced so that 5G developers could install the technology everywhere. Second, the global epidemic started when 5G was tested for the first time in Wuhan, China (this idea is completely unfounded, since 5G had already been rolled out in various regions of the globe) [20]. Third, unlike COVID'19, which spreads from person to person, 5G radio waves employ beam-forming technology to go straight to their destination. These and other hypotheses provide no hard proof that 5G is to blame for the epidemic. Iran is just one example of a country that was severely impacted despite not being part of the 5G roll out implementation group. The epidemic, however, has been successfully limited in South Korea, one of the world's major 5G rollout centers. Multiple, harmless exposures do not cumulatively have any negative biological impact, as stated in. Technically speaking, if the exposure limitations recommended by IEEE and ICNIPR are adhered to, there is no reason to believe that 5G will be harmful to human health.

***Bio-effects of 5G***

Several different biological consequences have been examined in experimental investigations of MMW exposure below ICNIRP occupational limits in [19]. Comet tests of exposed cells were primarily used to test for genotoxicity. In carefully conducted investigations, this method has never shown any DNA damage in skin cells. One research team found evidence of DNA strand breakage and alterations in enzymes that regulate ROS production in animals; however, their study was limited by its small sample size (only six animals were exposed), and their findings have not been repeated. Chromosomal abnormalities, micronucleation, and spindle dysfunction are some of the other signs of genotoxicity that have been studied. Studies looking at these markers have utilized usually rigorous methodologies, but have found conflicting outcomes. DNA damage markers in bacteria have also been reported by a Russian research group in two experiments, although these findings have not been independently confirmed.

Bacterial, yeast, and cancer cell proliferation have all been the subject of research into the impact of MMWs as reported in [19]. Insufficient dose measurement and regulation of temperature and strong RF energy accumulation heating, which may have contributed to the outcomes, but the studies were conducted by another group, which indicated a decrease in the growth of bacteria rate of exposed E. coli cells at various MMW frequencies. MMWs have been shown to have no influence on the development rate of E. coli cells by other writers. Cell proliferation studies in yeast exposed to MMWs yielded conflicting findings. Inadequate dosimetry and temperature control plagued the bulk of the investigations on tumor cells done by an Italian research group, which still revealed a decrease or no variation in the development of exposed cells.

Expression of stress-sensitive genes and chaperone proteins, as well as the existence of a resonant impact in cells for clarifying DNA conformational state alterations, were the key indications studied in relation to gene expression. Many different experimental approaches have shown no impact of low-level MMWs on the expression of stress-sensitive genes or chaperone proteins; however, as these researches did not employ blinding, experimental bias cannot be ruled out. In a series of investigations, a team of Russian scientists proposed that MMWs' resonance impact might alter the shape of DNA complexes found in chromosomes. Their findings mostly rely on the AVTD technique for assessing DNA conformational changes, although this technique has not yet been independently confirmed for its biological significance.

Due to the absence of blinding in most investigations, researchers have reported a wide variety of results when investigating the relationship between cell signaling and electrical activity. Additionally, temperature interactions through traditional heating were explored and shown to be distinct from MMW effects, and hence could not be omitted from the experiments. Some studies only used a single sample, while others had weak power since the effects reported were only seen in a tiny fraction of the samples. The claimed effects of electrical activity could not be simply written off as random. This is supported by studies showing rapid recovery to pre-exposure levels after prolonged exposure. In this instance, no negative health consequences are implied.

Research on membrane impacts looked at how changes in membrane characteristics and permeability affected the system as reported in [19]. However, the statistical techniques employed in these investigations were not explained, making it impossible to verify the validity of these findings. Some studies detected alterations in transition from liquids to a gel-like phase or the other way around, and the authors suggested that MMWs altered cell hydration. Changes in vesicle shape, decreased cell volume, and morphological changes were reported in additional investigations observing membrane properties in synthetic suspensions of cells and dissected tissue; however, most of these studies had methodological flaws, such as inadequate control of temperature and no blinding. Although the same study team reported membrane permeability alterations in bacteria and yeast, attributing them to proliferation of cells effects, their investigations were plagued by poor dose measurement and temperature regulation. Although several

other membrane bioeffects have been described, none of them have been verified by further research.

Very few research has looked at the impacts of MMW exposure below the ICNIRP limits, and those that have found little or no consistent effects. Although there was just one in vivo investigation on cancer promotion, it found no impact despite the lack of sham controls. It's possible that the conflicting goals of studying negative health consequences and infertility therapy contributed to the mixed results found in studies of their impact on reproduction. Furthermore, no adverse effects of low-level MMWs were discovered in the single investigation on human sperm.

Since sperm is temperature sensitive, the impact of raising the temperature due to high radio frequency (RF) deposition may have led to studies finding an effect in reproduction studies that otherwise would not have shown one. Two different study teams have shown evidence of an association between ROS generation and reproductive and immunological function, although the in vivo experiments used only a small number of animals (only six animals per exposure), and the in vitro research often had poor dose measurement and temperature control. No significant benefits were found in investigations of fatty acid content or physiological markers, and poor temperature regulation was a common issue across the board. Several additional research looking at different biological consequences came to contradictory conclusions.

Many experimental research has identified various bioeffects, however these findings have not been replicated. Half of the investigations came from only five labs, while many others were the result of cooperation between researchers in different institutions. research exhibiting the largest impact magnitude tended to cluster about a PD of around 1 W/m2. However, there was a wide range of exposure parameters throughout the research. No dose-response association between exposures (either PD or SAR) and effect magnitude was found in the meta-analysis of experimental data included in our companion publication. In fact, counterfactually, studies with more exposure tended to indicate a smaller impact size. Research investigating the potential therapeutic benefits of MMWs, as opposed to any potential adverse health effects, has been concentrated on the 40–55 GHz frequency range. Bioeffects in the 26–28 GHz range, where the next phase of the 5 G network rollout will occur, should be the focus of future experimental study. Research throughout the MMW band is important since cellphone communications over the 5 G network aim to employ frequencies greater than 30 GHz.

The majority of the experimental studies failed to meet several quality criteria as reported in [19], such as paying enough attention to dosimetry, including positive controls, using blind evaluation, or precisely determining or managing the temperature of the biological system being tested, as revealed by an inquiry into the methods of the experimental studies. The work reported as meta-analysis in [19] revealed that the vast majority of studies had quality scores lower than 2, with just one research reaching the highest quality score of 5 out of a possible 5. The meta-analysis also revealed that lower quality studies tend to report larger effects. In order to minimize artifacts in future studies, researchers will need to pay close attention to experimental design.

PDs under the ICNIRP exposure limits were recorded in the experimental investigations included in this analysis. The resultant biological impacts were speculated by several scientists to be linked to non-thermal processes. The calculated SAR values in several of the investigations were significantly greater compared to the ICNIRP SAR limitations, as revealed in our meta-analysis, indicating that results from this research should be taken with care. SAR values much above those predicted for 5 G communications equipment are undoubtedly capable of creating considerable temperature increase. Proper temperature management to minimize heating effects should be a focus of future study into the low-level impacts of MMWs. All of these bio effects of 5G reported in [19,25] and depicted in Fig.4.

## 8. Discussion

Since many decades, there have been worldwide organizations monitoring radiation levels to ensure compliance with the rules. More funding for research is needed to dispel unfounded fears about radiation. A more secure ecosystem may be achieved by increased funding for studies of RF radiation levels in the current wireless communication system. When it comes to privacy, it's crucial that all platforms adequately handle the issue of privacy vulnerability. Network slicing, as outlined in the report, will be crucial in addressing security breach worries.

The only way to quell the growing antipathy against 5G is to put an end to the urban legends that are gaining traction on the internet. The best way to dispel these falsehoods is to host webcast and social networking conferences. However, in order to fully reap the advantages of 5G networks, scientists, physicians, engineers, and legislators must acknowledge the relevance of discussion over the financial, social, ecological, technical, and physical elements of 5G emission.

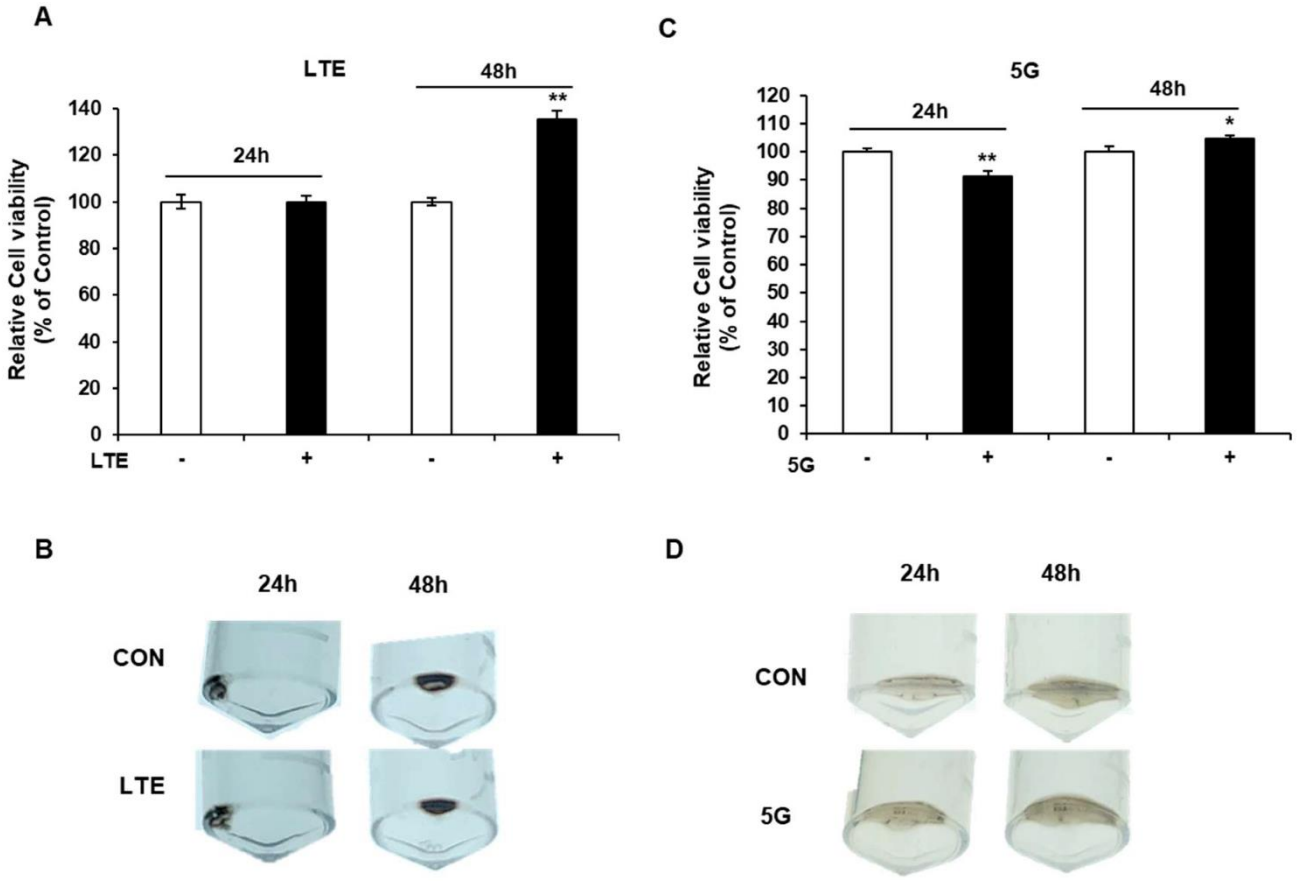


**Fig 4:** 5G Chronic evolutionary and its impact on cell survival and production of melanin [25].

## 9. Conclusion

Based on what has been discussed above, we can confidently say that 5G will be an improvement in technology. Due to the extremely high frequencies of 5G transmissions, obstructions such as structures, vegetation, and hills would need the installation of antennas towers in order to provide uninterrupted service. With increasing frequency, radiation penetrates less deeply into the human body, making significant biological effects very unlikely.

There were several hypotheses concerning the connection between 5G and COVID'19, but none of them were supported by proof. There had been no real-world parallels, thus it was safe to assume they were all hoaxes. Not very long ago, news outlets spread photos and speculation about the slaughter of birds, the odd actions of bees and sparrows, and the potentially disastrous effects of radiation on the ecology. All of this was disproved by the reality that the research didn't consider the alterations in action as a whole. There was no topographical or conceptual connection between the incidents.

Concerns have been growing that the rollout of 5G networks, despite their many advantages, might compromise national security. These dangers are an inevitable byproduct of any technological advancement, but a progressive regulatory framework may mitigate them. The United Nations created the ITU as a regulatory organization to oversee the worldwide allocation of radio frequency spectrum and the periodic review of international technical standards. Exposure to radiation measurements and usage directions are also investigated by a number of regional and national regulatory authorities across the globe. The Recommendation of the European Union Council establishes mandatory limits for exposure to RF EMF. However, it's crucial to revisit popular worries on sometimes. Despite these concerns, it is reasonable to conclude that 5G has no health risks and will ultimately be to our benefit.

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