5G Technology Analysis in Relation to Electromagnetic Waves

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Abstract

Electromagnetic waves are present in most of the main equipment used by humans. The advancement of 5G mobile network technology has been gaining ground in the telecommunications market and with it both positive and potentially negative consequences as it is used. Fundamental research has been conducted to gain knowledge and familiarity with 5G technology, how it works and its millimeter waves, which is a new range of the electromagnetic spectrum, which works with this new very high frequency and the first time used in technology. mobile network, as well as exploratory research through techniques such as bibliographic surveys in search of data such as frequency, related to 5G and the equipment transmitting electromagnetic waves, and conducting a comparative study to determine through the data collected from both , pointing out studies that present the evils that may cause the human being due to the use of high frequency. According to the results obtained on the 5G, the use of mobile network frequency presents no risks compared to other equipment that humans have been using. Therefore, despite the research results, it is still too early to point out possible damage over the years with the use of this technology, not ruling

out possible consequences.

Keywords: 5G; Electromagnetic waves; Millimeter waves; Mobile Network;

1. Introduction

Although we cannot see them, electromagnetic waves are part of our daily lives, either in a natural way, such as light from the sun's rays, but also electronics such as microwaves, Wi-Fi networks, television, smartphones. Like the other examples cited, mobile technology also ensures the propagation of these waves. In recent years 5G technology has gained more and more shape and name in the telecommunication market, providing benefits and improvements of use, as well as integrating new technologies and equipment.

Like previous mobile technologies, 5G relies on signals carried by radio waves across the electromagnetic spectrum transmitted from an antenna to the cell phone. The 5G uses higher frequency waves than previous mobile networks, ensuring a much faster speed as well as allowing devices to access the internet simultaneously.

However, data indicate that this technology could cause serious problems for those exposed to this type of wave propagated by it, and could affect nearby animals, according to the "alternative" medicine site Health Nut News, reporting the alleged deaths of hundreds of birds in tests conducted in a city in the Netherlands, as well as other animals subject to such consequences, such as bees, or even humans, according to the International Cancer Research Agency, linked to the World Health Organization (WHO). , has since 2011 classified electromagnetic fields of radiofrequency as "possibly carcinogenic to humans", with long-term damage to cells, causing modification of their DNA.

In Brazil, although it does not currently have 5G facilities, and with its forecast only for the year 2020, tests are already planned and some have already been conducted through the Chinese company Huawei, with local operators in some cities like: Sao Paulo, Rio de Janeiro, Fortaleza, among others. However, in the state of Santa Catarina a bill has already been made to prevent testing in the capital, Florianópolis, being the same being under analysis, alleging the possible consequences that both inhabitants and animals may have when exposed. waves from fifth generation mobile technology.

From another point of view, in the international scenario, in first world countries like China and the United States, they are a few steps to introduce the 5G once and for all. However, in another, as in South Korea, it is already a reality where the benefits that this technology brings to the social environment and technological development are clear, guaranteeing the exclusion of any consequences to those that are subject to the use of 5G until the moment.

However, studies will be presented on 5G technology, as well as comparing it with other means that propagate electromagnetic waves in relation to their frequencies and showing the amount of radiation expelled by each one, demonstrating the load that a body can carry through them without there being. consequences and, finally, to present the results regarding the possible damages, or not, that it can cause in certain environments and who is in them.

2. Methodology

The nature of the research will be, at first, done in a fundamental way, seeking more knowledge about the

recent 5G technology, since there are many doubts present about this subject, thus obtaining familiarity and understanding of how it works, as well as respect to electromagnetic waves.

Regarding the research, an exploratory study was performed in which the necessary data were collected to obtain results through technical procedures. For this, a literature review was carried out through theorists and scientific-based documents about this technology, specifically seeking data on: frequency, range and amplitude of the wave, as well as data from the following equipment: microwave, radio , television and mobile network.

In the procedure of data analysis, comparisons will be made with other emitting equipment that are part of the social quoted above.

These comparisons used in studies already carried out will demonstrate if this equipment can have a more or equivalent influence with the 5G technology, regarding the radiation levels expelled by them.

According to the results obtained, the approach used will be quantitative, both in the comparison of 5G with the mentioned equipment and in the sampling of the acquired results, which will be presented through paired graphs according to their data, determining to what point and frequency level can be supported or not by a living being, and conclude whether 5G technology is harmful or not.

2.1 Methodological Materials

The materials used: research and official tests already done with 5G and the following equipment, such as microwave, radio, television and mobile network. The procedure will be used to show the comparison of technology as this electromagnetic wave emitting equipment, gathering the different data found in our consultation sources and listing the main characteristic factors about them.

3. Theoretical Reference

3.1 Electromagnetic Waves

Electromagnetic waves are waves formed from the combination of magnetic and electric fields that propagate in space carrying energy. This concept began with Scottish physicist James C. Maxwell, who drew on equations from scientists Coulomb, Ampere, Gauss, and Faraday, giving them a new view and forming a set of four equations that demonstrate the interaction between the electric field. and magnetic field and its relationship to voltage and electric current. [16]

There are seven types of electromagnetic waves which are radio waves, microwaves, infrared, visible light, ultraviolet, x-rays and gamma rays. Each of these wave types is classified according to their frequency and oscillation with which they are emitted. [18]

That is, the higher the frequency, the shorter the length of a gravitational wave. These waves are measured by the so-called electromagnetic spectrum. Through this range you can check the distribution of its intensity. [16], [17]

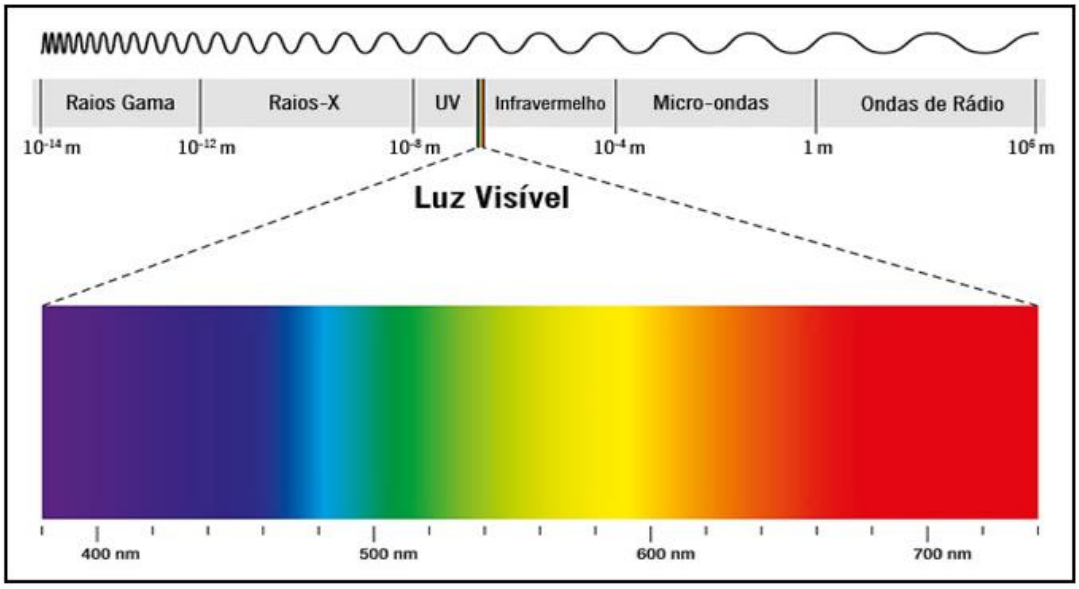

Figure 1 - Electromagnetic Spectrum Source: [18]

Wireless communication technology and mobile networks are increasingly developing with technological advances, bringing improvements in everyday communication, making it common to communicate through various modes, without the need for connected cables. Therefore, since the beginning of wireless communication, there were several ways of signal propagation of mobile network generations, where it began in 1896, developed by the scientist Guglielmo Marconi, who created the first wireless telegraph, that is, sent Airborne messages, better known as radio waves, which are a type of energy that carries electrical signals through the air, thus initiated communication through the air through these waves. [8]

With all this, from there emerged studies and new forms of transmission and creation of mobile networks, these advances also had an impact on society as well as in the health area, affecting the mode of relationship of human beings in their daily lives.

Given the beginning of this wireless communication, generations of mobile networks were created. In the following, we will present a brief explanation according to the arrival of the generations and their main characteristics to the present day.

3.1.1 Zero Generation (0G)

0G refers to pre-cellular mobile phone technology beginning in 1970. These phones were generally mounted on cars or trucks, although their installation was in the trunk of vehicles and connected to the interior of the car, having the function of transceiver. (transmitter and receiver), although case models were also made. [9]

The cordless phone started with what might be called 0G if you can remember it back so far. In that decade, before cell phones, there were few mobile operators to set up calls and there were only a few channels available. The technologies used for the 0G system to operate were: PTT (Push to talk), MTS (Mobile Phone System), IMTS (Enhanced Mobile Phone System), AMTS (Advanced Mobile Phone System). [10]

3.1.2 First Generation (1G)

The first generation of mobile telephony was characterized by the use of analog signal in its communication form. It was popularized in the 1980s, but only voice communication was employed and has a very poor call quality due to interference with its propagation. [10], [11].

The communication system for its use was called AMPS (Mobile Telephone System), standard used in North America and Australia, around 1983, where the technique of frequency division multiple access (FDMA) was used. Frequency Division), in 284-MHz-894MHz bands and a 30 KHz band frequency modulated channel. [12]

3.1.3 Second Generation (2G)

Its implementation began in the 1990s, with the implementation of the digital signal, converting the old analog voice signal to the digital one. Its main standard used was GSM (Global System for Mobile Communication), and was established as the main conversation feature due to offering all the necessary tools to the operators.

This shift to digital technology has influenced the fact that it supports a larger number of users with a much higher quality of communication in the same coverage area. [8], [13].

The main technologies for using 2G were: GSM, GPRS and EDGE [15]. The average download speed provided to users for using each technology was:

Table 1: 2G Downlink Data Rate

Technology	Average Downlink Rate
GSM	10-40 Kbps
GPRS	40-50 Kbps
EDGE	100-130 Kbps

Source: Adapted from [15]

3.1.4 Third Generation (3G)

In 1995, the International Telecommunication Union (ITU) defined the third generation (3G) of IMT 2000 mobile phone standards to facilitate growth, increase bandwidth and support more diverse applications. [8], [15]

The main feature of 3G was to offer not only voice services but also data transfer through images, videos and audio.

This generation of mobile network is currently still used by most mobile internet users, including Brazil, the main technologies used for its use were WCDMA, HSPA and HSPA +. [15] The average download speed used by users according to the technologies used were:

Table 2: 3G Downlink Data Rate

Technology	Average Downlink Rate
WCDMA	128-384 Kbps
HSPA	0,3-1 Mbps
HSPA+	3-6 Mbps

Source: Adapted from [15]

3.1.5 Fourth Generation (4G)

The fourth generation of mobile network technology has advanced with many qualities over its previous generations, one of its new features being the composition of working via IP networks. This protocol allowed multiple users to access the Internet simultaneously for the use of data, photo and video services and to improve their quality calls from wherever they were. [13]

Its main technologies of use are: LTE, LTE Advanced and LTE Advanced PRO.

Table 3: 3G Download Data Rate

Technology	Average Download Rate
LTE	5-12 Mbps
LTE ADVANCED	Undefined
LTE ADVANCED PRO	Undefined

Source: Adapted from [15]

3.2 5G Network and Its Operation

With the arrival of the fifth generation (5G), all its infrastructure will be adapted and expanded for the operation of the new generation, that is, already being coupled to existing antennas, because the 5G technology still depends on 4G.

The 5G will be a more powerful, faster, smarter and more efficient mobile phone network. One of its main features will be broader coverage for users, able to control connected devices such as smartphones, appliances, cars, presence sensors. , security and lighting, supermarket cashiers, restaurants, among others. It will also enable higher throughput (greater than 10 Gbit / s), lower latency (under 1 ms), high reliability, higher connectivity density and greater mobility than previous technologies. To support a wide range of services with varying performance requirements, 5G networks require a scalable, adaptable, and programmable mobile network architecture.

As in previous versions, 5G will be propagated by electromagnetic waves, being differentiated by increasing the fourth generation (4G) band frequency.

In 4G, the bandwidth was approximately 2 - 8 GHz. Serving dynamic information services, HD broadcasts, simultaneous accesses, video calls, among others. 4G now has its core network by IP, different from 3G, which worked by packet network.

With 5G technology, in turn, it will have a very significant increase compared to previous versions, and its frequency will be approximately between 600 and 700 MHz, 26 and 28 GHz and 38 and 42 GHZ, working via network over IP and 5G interface. network (5G-NI) to serve millions of simultaneous accesses.

5G network interface

For an adaptation of the 5G network, it will be necessary to use new technologies capable of supporting all the necessary requirements of access to the great demand of services, aiming at the improvement of higher speed, lower latency, increased transmission frequency, thus demonstrating better efficiency. regarding the use of previous technologies. Below are the technology standards created and used for 5G:

3.2.1 New Radio NR (5G NR)

A standard mobile network access technology called 5G NR (NEW RADIO) was created, this new technology was created by 3GPP to become standard in the use of 5G mobile network technology. It is currently improving, making use of other technologies, with new features, modulation, architectures and spectrum.

Here is the flexibility to support multiple bands, including two frequency bands, which are: FR1 which will operate below 6GHz, and FR2 which includes frequency bands between 20 to 60 GHz.

These frequencies include mmWaves bands (millimeter waves) for the first time that will be implemented with massive pampering technology infrastructure that will produce much larger bandwidth, facilitating the formation and direction of the radio beam.

With the new frequency ranges, the range is limited to a certain transmission power, ie, health, safety and environment will be tightened. For this, the 5G NR will use the beamforming concept, manipulate the signals fed and received from antennas, and focus the energy in a specific direction where use is required. This serves to control the channels, increasing accuracy and overall adaptation to different climatic and structural conditions.

The use of this technology facilitates in: [1] [2] [3]

Improves and increases signal coverage for devices that need instantaneous and simultaneous signaling;

Reduces dead spots by avoiding sending signal to places where there is no need;

Improves download / upload throughput.

Massive treat

Infrastructure pampering has drawn attention to addressing 5G technology, as previously mentioned, 5G wants to cater for the higher capacity of higher speed devices, benefiting users with more reliable and faster network services.

MIMO MASSIVE (Multiple Input, Multiple Output), also known as large-scale antenna systems, tends to be the evolution to wireless communication, compared to current 4G technology, which only allows the placement of 8 antennas (transmitter). + receiver) at its base, which would not sufficiently meet the capacity of millions of users connected to 5G technology, resulting in slow access, delayed transmission and reception of information.

Using this technology, the 5G network would use two or more simultaneous transmitters and receivers, allowing data exchange at least one radio channel.

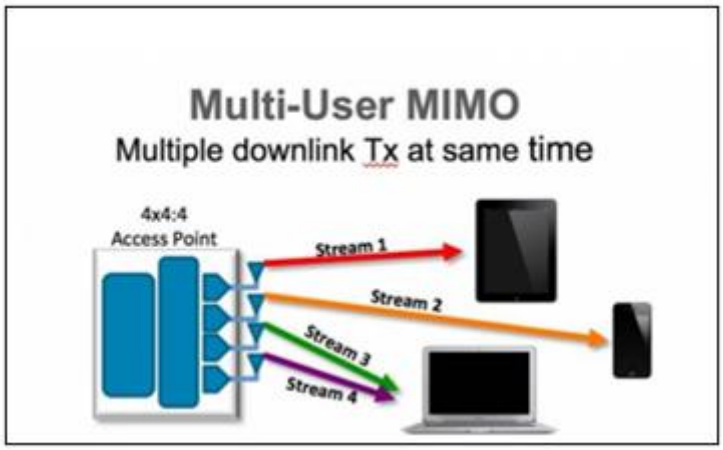

Figure 2 - Scheme of using Mimo technology

Source: Authors, (2019).

thus, looking for the best data traffic path for users, leading to higher performance.

As shown in figure 2, the technology tends to serve multiple connected devices at the same time, which is the equivalent of 4x4: 4, with 4 dedicated transmission, 4 receive and 4 special antennas, maintaining performance and a better flow to connected devices.

Imagine that in a house there are 3 devices capturing 5G signal, targeting access Tablet, Smartphone and Notebook.

Stream 1: Tablet is on a YouTube access.

Stream 2: Smartphone in an online game.

Stream 3: Notebook with access to Netflix.

With the MIMO system in place, the access of each stream would be dedicated to each antenna present in the access point. Thus, there would be no decrease in speed, accesses would be simultaneously unstable. [5]

3.3 Mimo System Advantages

As for the advantages of the Mimo System, the 5G has been aiming for higher simultaneous connections, speed and latency reduction, but this will increase the frequency, so the Mimo system will take care of this mobile broadband capacity. propagate your signal over different paths until your end users receive it

Signal receivers gain according to the combination of Mimo system antennas, the composition of these elements offers superior quality to previous generations, thus transmitting higher frequencies of different points mounted according to the signal path, leading to higher reliability. in its transmission. [7]

3.4 Millimeter Waves (mmWaves)

Millimeter waves are waves that belong to a part of the electromagnetic spectrum between microwaves and infrared waves, with their wavelengths of 1 to 10 millimeters. They will have to work at very high frequencies in the 24 and 60 GHz bands.

However, we know that the lower the frequency, the greater the range of the signal that will be transmitted, which in this case is contrary to the millimeter waves that operate at these higher frequencies, which present difficulties in penetration through objects, walls and even the hand in the Signal reception on the mobile phone, to improve this transmission problem, will be made an analysis of the installation infrastructure of the 5G mobile network.

Some of the alternatives designed to deal with these indoor restrictions would be to use signal pickups on the outside and relay internally, which may present a solution to deal with the difficulty of reception indoors with signal barriers.

3.5 Interferences

We already know that the use of this frequency will be used for the first time in mobile network, however, there are consequences that may influence the use in existing equipment and devices, as in the case of weather forecast. This is because the frequency is near and used by satellites that observe water vapor and

predict changes in weather, with this influence, it would affect the discovery of more extreme events, because their use is observed to alert people about storms, hurricanes etc. [4]

3.6 5G Use Requirements

According to Ekram Hossain and colleagues in the article "Evolution Towards 5G Multi-tier Cellular Wireless Networks: An Interference Management Perspective" (2014) [7], with the arrival of the new 5G technology, we will have a set of different systems to increase efficiency, but for this to occur there are necessary requirements for its use:

Latency Data Rate: The forecast for dense urban areas with 5G networks is that the data rate will be 300 Mbps downlink and 60 Mbps uplink, 95% of the sites.

Machine Communication Type (MTC) and devices: The number of traditional wireless devices with internet connectivity (smart phones, smartphones and tablets) can be outnumbered by MTC devices that can be used in vehicles, appliances, home devices. surveillance and sensors.

Millimeter wave communication: The increase in traffic and different devices, as well as the increase in services, will consequently require a greater spectral area increase than that allocated for the 4G standard. The solution will be to use millimeter wave frequency bands (28 GHz and 38 GHz) to solve the problem of low spectral capability that allows the transmission of larger bands than the conventional 20 MHz band used by the 4G system.

Multiple RATs (Radio Technology Access): The purpose of the 5G standard is not to replace existing technology, but to improve existing technologies such as GSM (Global Mobile Communications System), HSPA + (High Speed Packet Access Network).) and LTE (Long Term Evolution) providing system evolution for better performance.

Prioritized spectrum access: Priority access in both traffic and tiers will exist in 5G networks. This restriction is due to different user needs such as reliability, latency requirements, and power restriction. Layer-based priority is to ensure protection for users who have shared access to the spectrum between larger and smaller cells in a two-tier network, as small cells can create downlink "dead zones" for larger cell users. But the user of both larger and smaller cells will play high priority (HPUEs) and low priority (LPUEs) roles.

Energy capture for efficient communication: One of the key challenges of the 5G system will be to improve the energy efficiency of battery-restricted wireless devices and extend battery life, as well as improving energy efficiency, an interesting solution. will be to capture environmental energies (solar and wind energy). In addition, energy can also be captured from ambient radio signals (RF energy). Simultaneous information and power transfer (SWIPT) are a promising technology for 5G wireless networks, but power capture circuits are not yet available for the conventional receiving architecture and are only designed for information transfer, which may not it works for SWIPT. This impasse is due to the fact that both energy and transfer information operate with different receiver sensitivities (-10dBm and -60dBm), so the solution will be to combine different technologies to capture energy.

4. Data Presentation

Many usual equipment is present in our daily lives. To make the necessary comparisons in the results from this stage, a survey will be made to collect data from the main equipment that emits electromagnetic waves, as well as tests or studies already done with them.

Radio Waves, TV and Cell Phones

In this context, radio, television and cellular equipment, although not having the same type of wave within the electromagnetic spectrum as the 5G technology, operate with waves called radio frequency, where it is common to divide these waves into frequency bands ranging from 3KHz to 300 GHz, see Table 1 for information collected.

Table 4 - Radio, television and cell phone frequency waves.

Equipment	**AM Broadcast TV (VHS) and**	**AM Broadcast TV (VHS) and**	**AM Broadcast TV (VHS) and**	**AM Broadcast TV (VHS) and**
Frequency Ranges (values)	530 KHz a 1600 KHz	30 MHz a 300 MHz	3 GHz a 30 GHz	300 MHz a GHz

Source: Authors (2019)

Studies carried out through its use, through the International Cancer Research Agency (AIPC), linked to the World Health Organization (WHO), classified, in 2013, radiofrequency electromagnetic fields as possibly carcinogenic to humans. long term. [19]

Earlier in 2012, an independent group called “Bio Initiative 2012” was created, made up of scientists and experts from ten countries (Sweden, USA, India, Italy, Greece, Canada, Denmark, Austria, Slovak Republic and Russia). The possible risks of wireless technologies and electromagnetic fields to human health were discussed. The goal was to develop studies of the growing health problems caused by chronic exposure to electromagnetic fields and radio frequency radiation through equipment used in the daily lives of millions of people around the world. [20]

According to the article “Electromagnetic waves and the impact on human health”, based on the study by the group “Bio Initiative 2012”, the risk of generating brain tumors from radiofrequency waves was presented; cause damage to DNA and genes; of negative effects on memory, learning, and behavior, attention; sleep disturbances; cancer and neurological diseases such as Alzheimer's disease. Effects on reproduction and fertility, fetal and child brain development, and effects on classrooms with children and adolescents were also analyzed. The study is detailed, and the conclusions are presented by areas related to the various aspects studied. Specifically, with regard to wireless networks, the final report warns that the continued release of unrestricted commerce wireless technologies and devices puts global public health at risk unless new precautionary warnings for their use are made. implemented. It also warns that safety standards for sensitive populations will need to be set at more specific levels than for healthy adult populations. Sensitive populations include the developing fetus, infants, children, the elderly, those with

pre-existing chronic diseases, and those with developed electrical sensitivity (EHS). Electromagnetic hypersensitivity, then, is considered, although not recognized as a disease. [21]

Microwave appliance

The microwave appliance, equipment used to heat food and present in almost all kitchens of the world, is classified within the electromagnetic spectrum by presenting waves called microwaves, these waves have a frequency range of 1GHz to 300 GHz. The frequency used in the device itself acts in the range of 2.45 GHz, enough to make the molecules vibrate at the same time, generating heat, releasing it and heating the food. [22]

Studies conducted by WHO (World Health Organization) show that through its internal structure and the material used to inhibit the propagation and reflect the waves generated by the device, the microwave does not pose risks to human health, nor does it allow The radiation used for heating remains in the food, because the heat is generated by the agitation of the water particles present in the food, and not by the absorption of the rays generated by the waves. [23]

According to an article from the "Mundo Boa Forma" website, it shows that a lot of research shows that the microwave cooking process can affect many nutrients present in food, mainly due to the heating that occurs. Some vitamins are sensitive to heat, such as vitamin C, which can be degraded during the process. Proteins are also greatly affected by heat and may decompose.

A study published in the Journal of Agricultural and Food Chemistry showed the effects of microwave heating such as the loss of vitamin B12 in some foods, including raw meat, milk and pork. The results of this study showed a 30% to 40% reduction in this vitamin when food was microwaved, with a vitamin shift to an inactive form.

The truth is that saying that microwave food is bad is a myth, because there is no accumulation of radiation in food, there is only the loss of some nutrients, damaging their nutritional value. That is, the food can be consumed safely and safely, being only with a smaller amount of nutrients, which will be damaged by heat. [24]

5. Results

Being located in the magnetic spectrum between infrared waves and microwaves, the millimeter waves used in 5G, in relation to other equipment cited in the research presents the following data:

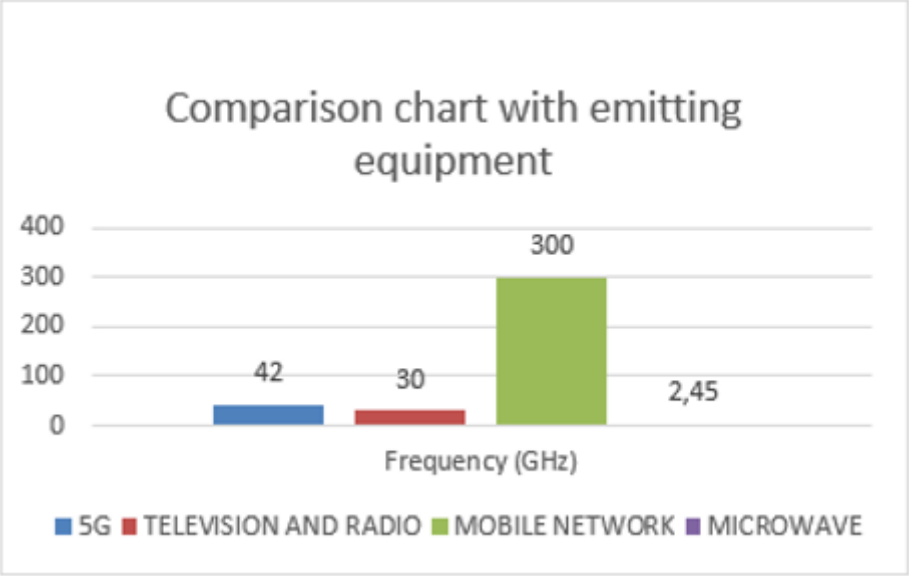

Figure 3 - Comparison with emitting equipment
Source: Authors, (2019).

As the graph above shows maximum frequency values that each element can reach. Indicating higher values that mobile telephony can reach, being 5G besides having individual data in the graph, it is contained within it indirectly.

Compared to the microwave data where they have the minimum values, there is a big difference compared to 5G and even other equipment.

Based on the data collected and studies done during the research, it shows that 5G technology has great potential to cause cellular degenerative diseases in the future, because as shown, the frequency range that a mobile network can reach is quite high in In relation to other equipment, besides studies by international organizations show that this type of wave, which is constant in the daily lives of humans, showed possible significant results in the area of medicine and causes of cancerous diseases.

6. Final Considerations

The benefits of this generation of mobile networking in all areas of society are notorious, as well as opening up to new technologies, possibilities, ideas or projects, and existing process improvements. But one should be wary of the possible negative consequences it may have on those subjects to exposure over the years.

It is concluded, therefore, that based on the results obtained through comparisons made with other equipment, 5G technology does not present risks to humans, depending on the frequency variation to be used, cited during the research. However, as it is a very recent technology and still does not have a worldwide coverage area, in some countries only, it is still too early to reach conclusions of possible long term consequences, and the possibility of presenting risks during constant periods is not ruled out. exposure periods in the future.

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