



Impacts of RF radiation from mobile phones on human health and its remedies

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Abstract: The mobile phone is one of the most unavoidable electronic gadgets in our day-to-day life. As all devices are fully automated through the Internet of Things (IoT), a mobile phone help us controlling and connecting with other devices. In spite of many advantages of the use of mobile phones in the field of communication automation, the RF radiation from mobile phones or towers is causing many health issues. The main drawback of this effect is not known initially but the effect becomes adverse after a long period. This paper lists the impact of mobile phones both on the positive and negative side. Further research is done to avoid the RF exposure in the field of communication and absorbing material to reduce the impact. As the effect of prolonged use of mobile phones is known only after long time, the general suggestions on their use are listed to avoid deadly diseases and other psychological effects.

Keywords: SAR (specific absorption rate), IoT (Internet of Things), RF (radio frequency)

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1. Introduction

Human beings are capable of viewing the EM wave through their eyes in the frequency range of 405- 790 THz and hear the sound waves in the frequency range of 20Hz -20kHz. There is also the presence of frequencies that are not viewable and heard by the human beings. EM spectrum is generally classified as non-ionizing and ionizing region. Ionizing spectrum lies in the high frequency region. As the frequency increases the wavelength of the wave is less leading to penetration of the wave into the material or absorption of the wave to the material. Nature has all the frequency and the required frequency with limited power is absorbed or accepted by the human being. The man-made frequencies with large power affect the health of the human being. After the invention of electricity and electromagnetic induction, the antennas are used for the transfer of the message from the source to the destination. The data in the form of analog or digital are modulated to the higher frequency so that it can be sent for a long distance. Using the antenna at the receiver side the electromagnetic fields are converted back to electrical signal. Nowadays RF pollution is high as the number of mobile user is increasing day by day. In addition to the power of the EM wave, the distance of the user from the transmitter also decides effect and is classified as near field and far field. The electric field induces the charges and magnetic field induces the electric current whose magnitude depends on the strength of the field, frequency of the field.

The use of mobile phones mainly affects the human body to the large extent (Lin, 2012). Advancement in the field of wireless communication, made people to communicate even in movement. As the medium is open to all noises the data is corrupted and the main aim of the receiver is to extract the main data from the medium. The receiver should be used with the minimum sensitivity. The transmitter power is used based on the path loss and the receiver sensitivity. The thermal effect of RF exposure on the living organism depends on the size of the organism when the same power is involved. Each body will have thermo sensitivity, and to compensate the temperature thermoregulatory action takes place by varying the blood circulation. But when the frequency is made high then the thermoregulatory process becomes impossible. Generally the influence of mobile phones includes the psychological effect, biological effect, and mental effect. Certain measures or parameters are used to analyse the statistical data. The parameters used (Vally & Hichami, 2019) are problematic mobile phone use (MPPUS-10), Centre for Epidemiological Studies Depression Scale (CESD-10), Rosenberg Self-Esteem Scale (RSES). The questions are based under these scales are compared with the cut off value.

This paper discusses the influence of the use of mobile phone on human beings and nature, and the discussion on the methods to reduce risks. The paper is divided into 5 sections: Section II tells the evolution of communication and the innovation of mobile phones; Section III deals with the terms used as the marginal value for RF exposure in the mobile devices; Section IV and V describe the positive and negative impacts of mobile phones; Section VI discusses the different methods introduced in the field of communication to reduce the impact.

2. Mobile phones in the field of communication

2.1. Evolution

There is a need for communication among the people since ancient period where the drums, beacon fires are used as a signal to gather the people. Due to the technological and social reforms, the way of communication started with the heliograph that uses the sunrays as the signal. Due to the development in the electronics, telegraph and landline telephone became the mode of communication. To have entertainment and to know the occurrences of the society, leads to the invention of radio and television. With an aim to provide the required information at any time emerged the field of Internet, which made many changes in the life of an individual. Till the invention of wired communication, there is no harmful effect on the society and human beings. With the advancement in the field of electromagnetics and mobile phones, wireless communication combines both voice communication and Internet. Recent advancements in the mobile phone make user to communicate with the machines in our home through IoT. Though it seems advantageous and giving a belief of living a comfortable life the effect of RF exposure is adverse on human beings and also on the nature.

World Health Organization (WHO) has confirmed that the cell phone radiation is considered to be a carcinogenic to humans. Many surveys show that teenagers are mostly addicted to mobile phones (Lin, 2010a). Based on the study conducted on students from different engineering, medical, pharmacy colleges, the effect of the use of mobile phones leads to lack of sleep, strain in eyes, headache, migraine, irritability caused during phone calls, restlessness, eye strain, continuous watching and skipping of meals, hearing problem and sometimes road accident because of the use of phones while driving etc. Another common impact is digital thumb because of continuously using the thumb to type in the small screen of mobile phones. The effect of mobile phones' radiation is having more impact on person with age below 20 (Lin 2006; 2010b). One of the suggestions to minimize the effect is to reduce the time of use of mobile phones, else the radiation may cause cancer or adverse health issues (Lin, 2013).

2.2. Types of study

The human beings are not only the victim of RF exposure the animals are also affected. The effect of RF exposure and mobile phones on rats are studied (Kesari & Behari, 2008; Sekar & Kalkan, 2002) The study based on this is known as In Vivo. The human cells affected by RF exposure have genetic effect or non genetic effect and the study on human cells are known as In-Vitro. Apart from the genetic and non-genetic effect on the human cells effect on the epidemic layer of the human is known as Epidemiological study.

2.3. Parameters for RF exposure

Even though the phone is not used for talking or any other entertainment it continuously sends the signal to nearer base station for continuous connection. In that case the exposure to electric field, magnetic field, electromagnetic field, contact currents causes biological effect on human beings and other living organisms. According to IEEE ICES SCC 28, there is a minimal effect on health in the frequency range from 3kHz to 5MHz, the effect is adverse for the frequency range 100kHz to 300GHz. The Basic Restriction (BR) values, Specific Absorption Values (SAR), Maximum Permissible Exposure (MPE) values are specified to know the standard allowable value. The effect of RF exposure leads to thermal and non-thermal effect. The thermal effect on the tissues causes burns spots, headache, blindness if eyes tissues are affected. The non-thermal effect includes damage in DNA, immune system, change in chemical and electrical signals in the cell membrane. The biological effect is not only on the humans but also on the birds in the environment. Recently, while testing the 5G technology in Netherlands many birds died due to the effect of the microwave radiation.

As the number of users is increasing day by day, the power required by the base station to cover a very large distance is high. When the power is increased, the person near the base station is exposed more and effect is more. Nowadays people are more interested in choosing the service provider, who gives the fastest access. This requires more bandwidth requirement and it should compete with ever growing users. This leads to the use of higher frequency bands, which provides larger bandwidth. When frequency is increased it the wavelength of the wave is decreased resulting in absorption of the wave by the human body. The demand for higher bandwidth and faster data is achieved with the help of optical communication. With the help of optic fiber this is transmitted to a large distance, effect of electromagnetic interference that finds applications in aircraft and medical field. Though optical communication provides larger data rate and high bandwidth, the technology is not wireless. If it is made wireless then the data sent is lost and presence of small obstacle makes the data lost. Radio waves are mostly used for the wireless communication mainly because of its bending property when

there is an obstacle. According to Dr. Gerard Hyland, Physicist, nominee for Nobel Prize in Medicine, "Existing safety guidelines for cell phone towers are completely inadequate." Though the power radiated by the cell tower is limited within the standard value, the time duration for exposure causes more energy to be absorbed.

$$Energy = Power * Time \tag{1}$$

From Eq.1 it is well known that the energy absorbed by the person when exposed to 1mW power for 1000s is equal to exposure of 1W of power for 1s.

IEEE ICES SCC 28 defines two tier levels namely upper tier level and lower tier level.

Fig. 1 shows the different levels indicating the safety measure. Below 100kHz the safety factor is not required for upper tier level as electro stimulation has no adverse effects but requires safety measures in lower tier level. 100kHz being thermal crossover frequency above which the thermal effect dominance is based on the average time of exposure. If the duration is less than the average timing then energy density, specific absorption rate (SAR) values shows their time dependence. The safety factor is 10 to 17 dB for upper tier and additional 7 dB for lower tier, if the exposure time is greater than the average time.

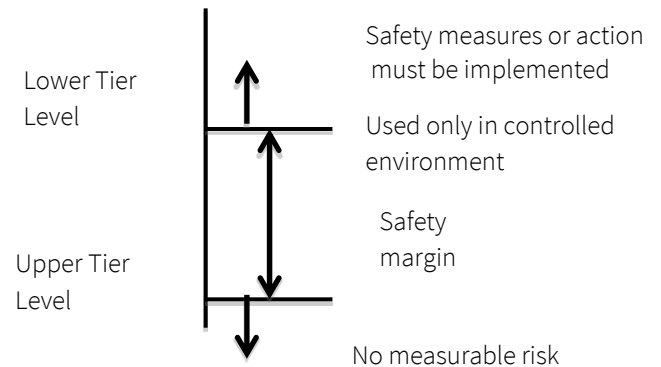


Figure 1. Levels for safety measure.

2.4. Levels

Human bodies should be exposed to the limited value of sound, heat and other stimuli. In the same way, the limit for RF exposure should also be within the limit. The different levels used for setting the limit for RF exposure. Some of them are:

- Specific Absorption Rate:

SAR value tells the value or amount of power absorbed by the body due to RF emission of the mobile phone. The unit for SAR is watts per kilogram. The normal value used is 1.6W/kg but it is extended to 4W/kg.

- Basic Restriction value and Maximum Permissible value:

Basic restriction value is the minimum value to which human body can be exposed. This value can be extended to a certain limit called Maximum Permissible value.

The Table 1 shows the SAR value for different types of the mobile phone (RF SAFE n.d.). The values are given separately absorbed by head issues and body issues. The effect of SAR on the body is reduce to <20% if the mobile phone is kept at a distance of 5 mm away from the body (Gandhi, 2019).

Table 1. SAR values of the phone.

Phone Model	SAR Value
iPhone 7	Head :1.142 W/kg
	Body: 1.142 W/kg
Samsung Galaxy S10E	Head : 0.36 W/kg
	Body : 0.92 W/kg
Google Pixel 3	Head : 1.34 W/kg
	Body : 1.34 W/kg

2.5. Positive impact

In spite of many negative effects on humans and animals (Relova et.al, 2010), there is also a positive impact of RF power when used under reduced power (Aly, Deris, & Zaki, 2008). The positive impact of mobile phones is increasing along with its negative effect. The main reason for the high use of mobile phones is that everything is available in the mobile phone with the help of the Internet. The manufactures are interested in integrating every possible device and making any device communicating among each other. This enables the social link among the people and enables marketing easier (Hollebeek, Glynn, & Brodie, 2014).

The influence of mobile phones has also an effect in the field of medicine. The growth has increased in such a way that mobile applications are developed and the status of the patients is addressed to the doctors at the right time. The advantage of detecting deficiency for pregnant women using mobile applications is mentioned (Dunsmuir et al., 2014). They are connected to the health centers through the app and provide the suggestions after analysing various data from the user.

In the field of medicine, RF is used in a controlled manner for cancer treatment. Though RF exposure may cause cancer or tumor cells, by the controlled power of microwave frequencies the cancer cells die. As the microwaves have very high frequency, the time period will be less. This fast switching of positive and negative field cause quick heating of food, which is used in the microwave oven.

2.6. Negative impact

The mobile phone has become the vital tool for knowing the problem and solving it or communicating at the right time to the right person. In spite of these advantages, the negative impact of the use of mobile phones is increasing day by day as the number of users has increased and time of use of mobile phones is increased. To provide the effective communication the information that is received should be the same as the transmitted value. This is achieved by increasing the power of the signal. The negative impact of RF exposure on the human health is divided into 4 groups namely

- Group 1- carcinogenic to human
- Group 2 – possibly carcinogenic
- Group 3 – not classified as carcinogenic
- Group 4 – not carcinogenic

Though the microwaves are used for cooking the food, (Sakurai, Narita, Shinohara, & Miyakoshi, 2013) the impact of using the inductive heating cook top on pregnant women. The exposure of the magnetic field at 23 kHz and its effect on the fetus derived astroglia cell line showed that there is no change in the gene if exposed up to 6 hours.

2.6.1. Accidents

The percentage of accidents due to the use of mobile phones has been analysed for different age groups (Korpinen & Pääkkönen, 2012). Mann-WhitneyU-tests have been conducted for different age groups and questions related to the impact of the use of mobile phones on accidents are studied. The results of this test show that 15% of males and 12.7% of females say that the accident in the leisure time happens because of the use of mobile phones. If the count of accidents is based on the gender then male are more affected than female. Particularly, male of younger age encounters more accidents as they use mobile phones while driving. Frequent use of mobile phones lead to the symptom of mental disturbance and headaches that causes close call situation.

To avoid such life loss, engineers working in the field of embedded systems and communication have come up with an idea to detect the sleepiness of the driver in the car and also trigger the jammer in case of new arrival of calls. This avoids the use of mobile phones while driving and avoids distraction of users, which is the main reason for accidents. To avoid the call from driver phone, the energy detector is used. As the mobile sends more energy while dialing a call, is sensed by the energy detector circuit and compared with the threshold value. If it is greater than the threshold value then jammer is activated resulting in no call cancellation.

The drivers use the mobile phone only when they need distraction during non driving time such as in traffic jam, stoppings, signals etc (Oviedo-Trespalacios, Haque, King, & Washington, 2019). The model is designed for deciding the risk of using the mobile in that particular time using machine learning. As advancement to this technique inclusion awareness notification can also done.

Based on the data (Shults et al., 2019), teenage drivers accidents are more compared to the adult driver accidents. The distraction of the driver while driving is the main reason for the accidents. Another result found is that the speed of the youngsters was high than the adult drivers.

2.6.2. Biological effect and health issues

The accidents occur mainly due to distraction of the user while driving. The main unknown impact of the RF exposure is the health issues due to prolonged exposure to RF radiation. Finite Difference Time Domain (FDTD) method is used for analysing the electromagnetic wave when half wave dipole antenna is used as the microwave source (Chen & Wang, 1994). The head is modeled as the material with the dielectric constant, conductivity as that of the tissues in the head. For a transmitted power of 0.6W, the SAR of the model is 1.23W/kg to 2.63W/kg. The lower level fixed by Federal Communication Commission is 1.6W/kg. To avoid the impact at higher

According to (Miyakoshi, 2013), the genotoxic effects include

- DNA strand breaks – Under alkaline and neutral conditions the DNA when exposed to RF exposure (X rays)
- Micronucleus formation- If RF exposure > 10W/kg the DNA splits and forms micro nucleus. Figure 2 shows the formation of splitting of nucleus and formation the new one.

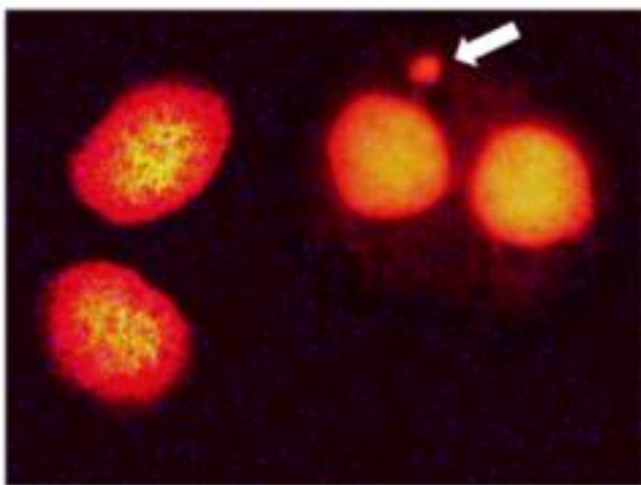


Figure 2. Micronucleus Formation.

Micronucleus formation due to RF exposure (Miyakoshi, 2013),

- Chroma aberration and mutation – Due to MN formation and DNA strand breakage the genetic pattern is changed.

The non- genetic effect includes,

- Change in the cell proliferation cycle
- Gene expression
- Damage in the immune system.

The fertility of the human beings both male and female is affected by the RF hazards. Based on the study conducted (Al-Quzwini, Al-Tae, & Al-Shaikh, 2016), the reason for sub-fertility in the male is also due to work and environmental hazard. 29% of males were affected by sub fertility as they are living near the mobile base stations or working near that region. From the analysis (Karger, 2005), the effect of microwave on the brain causes the change in the permeability if the microwave radiation SAR is above 7.5 W/kg. The changes in the EEG, secretion of melatonin in pineal gland, Calcium efflux is caused due to microwave absorption.

2.6.3. Eye damage

The effect of the use of mobile phones causes the more impact on the eyes. The artificial light from the mobile phone affects the particular area of the eye. According to (Moneda, Ioannidou, & Chrissoulidis, 2003) suggested the suitable model for studying the effect of radiation and its rise in temperature. The model used is based on the versatile Eccentric spheres. The temperature of the eye is detected for various sources at different temperature. The results show that the eye being a small part of the head absorbs more power when the mobile phone is kept at the front of the head. As frequency increases the wavelength of the wave decreases causing the easy penetration of the waves easily inside the eyes. The study of eye model in CAD tool is performed (Buccella, Santis, & Feliziani, 2007) and the value of change in temperature in the lens and tissues for different frequencies and SAR values. This is done for different distance between the eye and the source. The maximum temperature rise of 0.1320C is obtained in the lens for the distance of 1.2cm.

Based on the study (Elder, 2003) showed that the radiation causes the formation of cataracts in the rabbit eye when exposed to 2450MHz RF radiation for greater than 30 minutes causing the temperature greater than or equal to 41 degree Celsius. Though the monkey eye does not have the same effect for the same level of exposure, but other ocular effects such as change in vascular permeability, retinal effects occurs. The study on both pulsed wave exposure and continuous wave exposure were done. (Eker, Arslan, Yildirim, Akar, & Aras 2018) conducted an experiment to analyse the impact of RF radiation at 1800MHz on the rat eye and found the effect on

heat shock protein 27 (Hsp27), Epidermal growth factor receptor (EGFR), p38 mitogen-activated protein kinase (p38MAPK), caspase-3 gene expression. The result of the study showed that the Electromagnetic field radiation developed the stress level in the rat eye causing the caspase-3 and p38MAPK gene expressions to be activated.

2.6.4. Cancer

The negative impact of high RF radiation leads to deadly diseases such as cancer (Lin, 2005; 2009; 2010c). As the use of mobile phones is widely spread to communicate, ear and head are the most part of the body. To analyse the effect of RF radiation the TARO model has been developed for the brain.

Figure 3 shows the TARO model used for analysing the brain. The different regions are listed in the Table 2 that gives the SAR values for different regions of the brain:

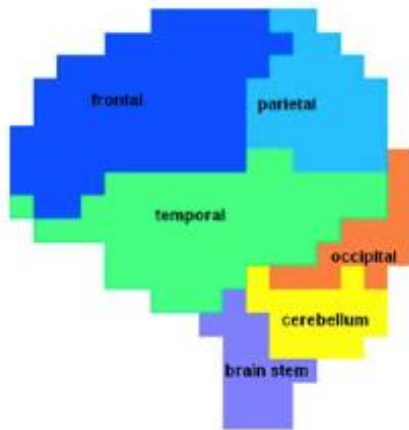


Figure 3. TARO model for brain.

Table 2. SAR values of the phone.

Regions	Size in cm ³
Temporal	340
Parietal	352
Frontal	352
Occipital	96
Cerebellum	123
Brain stem	81

Based on the experiment (Varsier, Wake, Taki, & Watanabe, 2009) on the TARO model of the brain by the cell phone radiation. The effect of the brain cancer depends on the way the phone used and the type of mobile phone. The results shows that the temporal lobe is the most affected part. The

antenna position also affects the cerebellum part and the analysis on the different frequency bands such as 800MHz and 1500MHz is analysed

According to the study (Lin, 2005) on the tumor of Auditory nerve due to the use of mobile phones, the effect is high if their use lasts for more than 10 years. The study was conducted before the wide spread of the use of digital phones. But with the mixed use of the analog and digital phones, the effect has been studied.

3. Steps to reduce the RF impact

The above discussed negative impacts are reduced by the use of suitable absorbing material so that the region is protected from the RF radiation. The signal is sent with the reduced power so that the required information is extracted from the lower power signal. This enables the use of coding techniques.

3.1. Reduction in power by coding

The advancement in the field of electronics and communication and coding has made mobile communication system an efficient and ever growing technology in all aspects. Mobile communication uses the radio waves for wireless communication. Because of insufficient bandwidth, the new technology based on 5G uses the millimeter wave for the transmission. The RF exposure is there because the continuous connection between the base station and the mobile phone. The base station acts as a central access point through which the call gets connected to the destination user. To get the new calls from the base station, the mobile phone continuously transmits the signal to indicate it as alive under the current base station. Lots of research is done in terms of reducing the power of the data to be sent in the wireless medium. The lower power limit is given by the Shannon's limit, which tells the minimum power used for the efficient transmission of the data for the required bandwidth. The main purpose of increasing the power is to extract the data back from the erroneous channel. Some of the methods are implemented to reduce the power level reduced for the same error rate. Error Control Coding techniques are used so that additional bits are used. This method helps in spreading the energy to be retrieved in the extra bits. This also enables to check whether the data sent is affected by noise.

All techniques used in the mobile phone should reduce the power required to transmit the signal. The main challenge in the mobile communication is to retrieve the exact data from the low power signal. The suitable coding technique is used so that the better error correction is achieved with the same power. The different kinds of code such as

- Linear Block Codes
- Convolutional Codes
- BCH codes
- RS Codes
- Turbo Codes

The recent development of polar codes and LDPC codes are used in 5G technology to improve the coding gain of the system. The reduction of power is improvement in the coding gain, (Sun, Cho, & Zhang, 2017) proposed different post-processing methods in polar codes decoding method. The coding gain for the linear error correcting codes such as Hamming codes, Golay codes were defined for different lengths (Jovanovic & Budisin, 1984). The maximum coding gain for Hamming codes is achieved for (127,120) at 2.76db where 120 message bits are taken and the 7 additional parity bits are added as redundant bits making a total of 127 bits. (Tahir, Schwarz, & Rupp, 2017) suggested that for larger data length, the LDPC and Turbo codes are similar characteristics. The convolutional coding performs well lower data length but performance deteriorates at larger message and the complexity of the system increases. Once the data to be sent is used with the reduced power another major role played is the antenna in the power radiation. The main reason for increase in power at the transmitter side is that some amount of power is radiated as backlobe or minor lobe. This is the unwanted power which is absorbed by the user of the phone. Research is done to reduce the back lobe of the antenna by using reflector that reflects the backwards radiated power.

3.2. Power Absorbing materials

The importance of RF exposure is prevented by the research in the chemical field for designing a material that absorbs the RF power. This is used for hospitals or electromagnetic protected area. Different nano materials such as carbon fibers, sulfides, aluminum oxides, polymers, nitrides, metals, alloys their reflection characteristics under different frequencies are discussed (Green & Chen, 2019). Based on the requirements the corresponding materials of specified length is used.

The use of FeP nano particles that enables the absorption of the microwave frequency is proposed (Green et al., 2018). This nanoparticle absorbs more power at the 2.5GHz, which is widely used as Wifi range. This is suitable only for those under the safety-absorbing layer. The advancement in the field of frequency selective materials several filters can be designed to absorb the RF power of particular frequency.

3.3. General precautions

- The use of mobile phones is to be reduced to avoid the effect of RF exposure. Continuous speaking for 20 minutes through a mobile phone causes 10 C rise in temperature of the tissue nearer the ear (Osman & Saar 2015).
- As people are excited by the speed of the Internet, there is lack of knowledge about the negative effects of mobile phones' radiation. The awareness program is to be done through the Internet itself.
- Using a wired headset to answer the call instead of using the bluetooth module in the ear. This is because the wireless transmitter will radiate power near the ear and also at the place where the mobile phone is kept.
- Using mobile phones with very low battery level is to be avoided as the more power will be used for notifying its presence to the base station periodically.
- Using landline phones and wired Internet-connected laptops instead of using the wireless Wifi-connected devices
- Keeping the mobile phone out of reach for the children, as the impact of RF exposure is worst in new born babies. The head of the babies are at the stage of growing and the skull tissues are not as hard as for adults, which leads to an easy allowance of RF exposure.

4. Results and discussion

Mobile phones have become one of the essential devices for providing reliable and efficient wireless communication. The study shows the biological impact on the human body and also several diseases due to continuous exposure to RF. It is increasing currently as the number of users of mobile phone and use of the Internet anywhere at any time is improved. Though this technology makes us live in the comfort-sophisticated zone, the negative impact is to be noted in order to limit the use of mobile phones. The technology is successful only when all uses it and improvement should be done to reduce its negative impact. Considering the mobile phone technology it is widely used by the people and reducing its negative impact opens more research work in the field of antenna design, coding techniques, modulation techniques. The negative impact comes into picture only when there is unwanted use of mobile phones, which leads to health issues such as epidermal effects, eye strain, cancer and other deadly diseases.

5. Conclusion

Our research highlighted the significance of the impact of RF radiation on human health. Technology improvement makes us live in a comfort zone but, without proper knowledge of its use, may lead to health issues. It is necessary for the users to be responsible and use technology in the right way to enjoy its benefits. As a future scope, various nanoparticles can be developed so that they absorb the radiation after some level so that the RF radiation can be reduced.

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