

# Wireless Communications Health Hazards

Awn B. Rifai, Saeed A. Sheikhi  
Department of Information and Communication Technologies  
Arab Open University  
Jeddah, Saudi Arabia



**ABSTRACT:** *This paper investigates the potential hazards on human health caused by the radiation of wireless communications, and attempts to consolidate the outcomes of earlier studies in this respect. A review of causes and effects is carried out, and different views are discussed owing to the disagreement amongst researchers on the existence of hazards. Independent study and sample measurements have been attempted in this research, and have been compared with international radiation safety standards. The conclusion drawn by the authors indicates the existence of many health hazards that should be properly managed. It has not been possible to quantify the effects due to the multiplicity of sources, the varying sensitivities of people to radiation, and the long time it takes for the effects to appear. As most of the published research has been non-empirical, follow-up research is recommended to reveal more details.*

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## 1. Introduction

The expansion and pervasiveness of wireless communications over the past few decades to fulfill the users' requirements and to bypass the limitations of fixed terrestrial networks have brought about human health hazards. Such hazards have been investigated by many researchers, but have unfortunately led to inconclusive outcomes. This is understandable, partly because the fast pace of developing wireless systems has surpassed the regulatory steps governing safety considerations, and partly because many of the health effects normally take a span of several years to surface. This research aims at throwing in another study to complement, support or deny such claims. The opinion of the authors would hopefully shed some light on this intricate subject, and would help evading or reducing any potential hazards. The paper is presented by highlighting the wireless systems under study, specifying the affected human organs and diseases, identifying the international standards, and benchmarking the current study against the internationally recognized levels for safe wireless communication. As mobile phones are the most publicly ubiquitous devices, special attention is paid to their biological effects.

## 2. Methodology

The research deals with some aspects of human exposure to non-ionizing wireless radiation. The systems investigated are Bluetooth, Wi-Fi (Wireless Fidelity), WiMAX (Worldwide Interoperability for Microwave Access), cellular mobile phone, antennas, towers and broadcasting [Table 1]. Some of the internationally accepted safety levels for signal power and period

of exposure are highlighted. The health hazards are categorized as effects on healthy and sick adults, pregnant women, and children. Field tests were attempted in selected locations in Jeddah city, but they have not been completed. It has been found that this subject is more complex than anticipated, as it extends to technological and biological grounds. Further dosimetry measurements would need to be undertaken for more definite results.

### 3. Wireless Radiation Effects

Electromagnetic radiation can be ionizing or non-ionizing. The wavelengths of ionizing radiation, such as Gamma-rays and X-rays, are shorter than human cells, and they can affect the cell structure. Non-ionizing radiation has longer wavelengths and could be used for communications. The hazards of non-ionizing radiation depend on the signal power, frequency, directionality of the antenna, propagation medium characteristics, source-to-body distance and polarization, and period of exposure.

Source	Frequency (MHz)
<b>Transmitters: AM Radio</b>	0.535 - 1.605
<b>Transmitters: FM Radio</b>	88 – 108
<b>Transmitters: VHF TV</b>	54-72, 76-88, 174-216
<b>Transmitters: UHF Radio</b>	470 – 890
<b>Transmitters: Dish Antenna</b>	800 - 15,000
<b>CB Radio</b>	27.12
<b>Cordless Telephone</b>	46- 49, 915, 2450
<b>Two-way Handheld</b>	30, 50, 150, 450, 800
<b>Cellular Telephone System</b>	824 – 850, 1850 – 1990
<b>Bluetooth</b>	2400 – 2483.5
<b>Wi-Fi</b>	2400 – 2483.5
<b>WiMAX</b>	2300, 2500, 3500

Table 1. Sources of Wireless Communication

#### 3.1 Bluetooth

The Bluetooth technology, based on the IEEE 802.15 standard for wireless Personal Area Networks (PAN), uses the ISM (Industrial, Scientific and Medical) frequency range 2.4 GHz to 2.4835 GHz. Bluetooth operates with low power and omnidirectional antennas, and covers a small area. The three classes of Bluetooth are based on the maximum permitted power and range of coverage [Table 2]. The maximum power is 100 mW, which is low and omnidirectional, and has no effect on health even with a number of devices operating concurrently.

Class	Maximum permitted power		Range: up to (m)
	(mW)	(dBm)	
<b>Class 1</b>	<b>100</b>	<b>20</b>	<b>100</b>
<b>Class 2</b>	<b>2.5</b>	<b>4</b>	<b>10</b>
<b>Class 3</b>	<b>1</b>	<b>0</b>	<b>5</b>

Table 2. Bluetooth Signal Power

#### 3.2 Wi-Fi

Wi-Fi networks are based on the IEEE 802.11 standards and use the frequency range 2.4 GHz to 2.4835 GHz. Their antennas are omnidirectional with a maximum allowed signal power of 1000 mW. The Communication and Information Technology

Commission (CITC) of Saudi Arabia specifies the maximum permitted power of Wi-Fi devices as in Table III, while Table IV shows typical values for the IEEE 802.11 standards.

The Wi-Fi power is considered low and the effects on health are not obvious. The devices emit power in non-directional manner and the emitted power gets attenuated by barriers. Based on a study conducted by the Health Protection Agency (HPA) in the USA, the amount of exposed power of a wireless network over a year is equal to the exposed power from a mobile phone when it is used for 20 minutes, but the study did not specify the Wi-Fi device power and distance from the user. The effect of a Wi-Fi access device gets weaker with distance, but an important concern here is the power emitted by a laptop wireless adapter that is close to the user, and communicating with the Wi-Fi device.

Device Specification	Permitted Power	Frequency Band (MHz)
EN 300 328	100 mW	2400 - 2483.5
EN 301 893 & ITU-R M1652	200 mW	5150 - 5250
EN 301 893 & ITU-R M1652	200 mW	5250 - 5350
EN 301 893,ITU-R M1652 & IEEE802.11 a	1 W	5470 - 5825

Table 3. Wi-Fi Maximum Power Limit by CITC

802.11	Freq. (GHz)	Data rate (Mbps)	Range (m) indoor and outdoor		Normal (N) and Possible (P) Maximum Power (mW)	
			in	out	N	P
-----	2.4	1, 2	20	100	30	1000
a	5	upto 54	35	120	50,250 and 10000	
	3.7		---	5000		
b	2.4	5.5, 11	38	140	30	1000
g	2.4	upto 54	38	140	1000	
n	2.4	upto 72.2	70	150	1000	
	5	upto 150	70	150		
ac	5	upto 6.93 Gbps				

Table 4. IEEE 802.11 Wi-Fi Power Values

However, Wi-Fi networks generally have no obvious hazards on health, except for inconclusive evidence regarding people who experience sensitivity towards electromagnetic radiation. Such people may suffer harmful symptoms like headache, memory loss, dizziness, fatigue, anxiety, depression and sleep disruption.

### 3.3 WiMAX

WiMAX technology provides wireless communication over long distances with high data rate, complying with the IEEE 802.16 standards. High speed connections like optical fibers and microwave links are used for backhaul. Broadband Wireless Access (BWA) could be provided for both fixed and mobile stations. For fixed stations, coverage of service can reach up to 50 km, and for mobile stations the coverage lies between 5 and 15 km. WiMAX technology uses three licensed frequencies for transmission: 2.3 GHz, 2.5 GHz and 3.5 GHz. For connection between WiMAX towers, high frequencies up to 66 GHz are used. Antennas used for WiMAX networks could be omnidirectional, directional (sector), or panel. The hazards of WiMAX are discussed in the Sub-section “E. Mobile Phone and WiMAX Towers” below.

### 3.4 Mobile Phone

The effect of the power emitted from a mobile phone is measured by SAR (Specific Absorption Rate). SAR is the power absorbed by a kilogram of the body tissue in one second. There are two standards for the SAR value. The Federal Communication Commission (FCC) in the USA has determined the safe SAR value to be 1.6 W/kg. Some countries like Germany use another standard permitting SAR to reach up to 2 W/kg. The transmission power in the handset is limited to a maximum of 2 watts in GSM, and 6 to 7 mW in CDMA [7]. This power is usually emitted very close to the user's head and brain. Mobile phone manufacturers should ascertain that their devices do not exceed the recognized limits, and users should select a low SAR device [Table 5].

Smartphone	SAR value (W/kg)
Samsung Galaxy S II	0.338
HTC Desire S	0.353
Nokia Lumina 800	0.940
Apple iPhone 4S	0.988

Table 5. Typical SAR Values

There are many designs of mobile phone antennas, including smart antennas. Most smartphone manufacturers use internal antennas located at the bottom of the device. The iPhone 4 has an external non-directional stainless steel strip antenna surrounding the phone periphery. The antenna has two strips; one piece forms the Wi-Fi, Bluetooth and GPS antenna, and the other is used for GSM and UMTS cellular communication systems. Mobile phones operate in three frequency bands: 872-960 MHz, 1710-1875 MHz and 1920-2170 MHz, and the operational power lies between 0.1 and 2 W. A mobile phone may have adverse effects on health because its power radiates close to the head or body. Radiation activity between the mobile phone and the mobile services network is continual even if the mobile is inactive. Mobile phones may be used in the active state for long hours by adults, children, pregnant women, old and sick people, and the health hazards depend on the proximity with the mobile unit and with the tower antennas.

A two-way handheld walkie-talkie radiates an average power of 2-5 W and operates in the push-to-talk mode, while a cordless telephone radiates tens of milliwatts. For vehicular mobile telephones (not cellular) and radios, the metal surface of the vehicle and the distance between the user and the external antenna shield the user from the antenna RF energy, resulting in little exposure, even though the average radiated power is significant, between 10 and 100 W [23].

### 3.5 Mobile Phone and WiMAX Towers

Towers or masts hold equipment of wireless services which could have directional or non-directional antennas. Towers can be roof-top mounted or ground erected. The power emitted from a cellular mobile phone tower varies depending on type, equipment, number of devices and extent of coverage, with an average radiated power of a few hundred milliwatts [23]. The tower could hold mobile phone antennas, WiMAX antennas and microwave dishes. Mobile phone service and WiMAX antennas could be directional or omnidirectional while directional microwave dishes are used for point-to-point connections. In some configurations the tower itself is used as an omnidirectional antenna. With adequate high power, the usual coverage is between 5-50 km for WiMAX, and about 700 m for mobile phone. People who reside within this coverage are continually exposed to the radiation.

The effects of such antennas on human health are difficult to measure because their radiation depends on the propagation medium, and the exposed power is mixed with other sources of radiation from the surroundings. Some scientists have studied the effects of mobile phone towers on people who live in the same building having the tower on its top, as well as people who live in adjacent buildings. Results have shown that people experience headache, memory loss, involuntary tremor, dizziness, loss of concentration, fatigue, anxiety, depression and sleep disruption. Scientists also observed that the effects on people in the same building are less significant than on those in adjacent buildings, apparently due to the direction of propagation, polarization and the absorption by the concrete roof. Another study found that people who live within 300 m from the tower feel tired, and people who live within 200 m feel headache, discomfort and sleep disturbance, whereas people who live within 100 m have irritability, depression, decline in activity, memory loss, dizziness and irregular blood circulation. It was obvious that women are more sensitive to radiation exposure than men, and experience nausea and appetite loss as well. One of the studies mentioned that the possibility of developing cancer increases with people who live within a circle of radius 200 m. A

test conducted in Australia exposed volunteers to radiation similar to that emitted from an 80m-distant mobile phone tower, and the consequences were some electrical changes in the brain, sickness, increase in heart beat, breathing problems, irritation, headache and tremor.

### 3.6 Microwave and Satellite Dishes

Microwaves are applied in broadband communication systems, radar, communication with satellites and spacecraft, and ISM devices. The antennas are mostly directional and dish-shaped. The power of the dish-reflected radiation is low, and increases with bigger dish size. The hazards are restricted to people who deal directly with these antennas. A two-way satellite dish is usually operated on top of, or on the outer walls of buildings, and directed towards the satellite. Microwave tower devices are operated at positions higher than the surrounding buildings, with point-to-point line-of-sight connection. Usually, only engineers and technicians are exposed to such radiation, unless the line-of-sight beamwidth crosses intermediate buildings. Exposure to the power between two microwave dishes is not a prime issue because towers are erected at high altitudes, and in the case of two-way satellite dish the antenna is directed towards space. Nevertheless, with direct and close exposure, such devices could cause harmful heating of the internal body tissues.

### 3.7 Broadcast Stations

The antennas of commercial broadcast AM/FM radio and TV antennas radiate power levels of several megawatts but, these antennas are generally placed on high towers away from humans. Humans absorb more RF energy from AM/FM radios and TV antennas than from cellular systems, and once the energy is absorbed the effects are basically the same. An Australian group claimed that living near television towers causes an increase in childhood leukemia, although this was denied by other studies [23].

## 4. Biological Effects

Exposure to electromagnetic radiation from any source causes an increase in body temperature; and this is the only proven, agreed upon and recognized effect all over the world. Adverse thermal effects were observed at  $100 \text{ mW/cm}^2$  of incident power density, and a safety factor of 10 was imposed on this value [10]. In the case of the mobile phone the brain temperature could rise by up to  $2^\circ\text{C}$  in 30 minutes. Non-thermal effects have not been adequately investigated [11].

**Brain:** Recent studies carried out in Finland emphasize that mobile phone radiation causes changes in brain activity and harms the blood barrier that protects the brain. Other studies in Spain have concluded that a two-minute mobile phone call causes disturbance to the brain natural electrical waves for one hour. Another recent study supervised by the International Agency for Research on Cancer (IARC) emphasizes that heavy mobile phone use, of more than 30 minutes daily for over 10 years, increases the possibility of glioma (brain cancer) and acoustic neuroma (tumors which can destroy the brain and nerves) by 40% on the side of head adjacent to the phone.

**Nucleic acid (DNA):** When Nucleic Acid is exposed to mobile phone radiation it experiences destruction of the chemical chain, especially in brain cells. There is a direct relationship between the dose of radiation and the number of fractures in Nucleic acid. Scientists found that when human lymphoid cells are exposed to test doses at 167 MHz and at 935.2 MHz some changes resulted in the chromosomes.

**Premature ageing:** Heavy use of mobile phone could lead to premature ageing because it does not give the cell a chance to repair its failure, especially in fractures of nucleic acid.

**Infertility:** Scientists found that when a mobile phone is used more than 6 hours daily for five consecutive days it will cause weakness in the sexual ability of men, where the semen loses 30% of its active cells. Scientists caution against holding mobile phones close to the reproductive system even when they are not activated.

**Heart and blood vessels:** Scientists found that exposure to mobile phone radiation for over 20 minutes leads to temporary reduction in heart pulses, while the blood pressure increases by 10 mm.

**Alzheimer:** Mobile phone radiation could enhance developing Alzheimer. Some tests on mice showed that radiation destroys brain parts responsible for learning, memory and movement.

**Vision loss:** There are some concerns that mobile phone radiation could cause vision loss; tests made on rabbits showed reduction in vision.

**Back pain:** A recent study cautions people who use mobile phones while walking that they are susceptible to back pain. The human body is designed to exhale when the foot is placed on the ground, and this protects the backbone from sudden shocks. Back muscles which support the backbone do not function properly when people speak while walking, leading to back pain.

**Skin allergy:** A Japanese doctor has declared that the mobile phone could cause increasing skin rash and allergy towards dust. The doctor emphasized that mobile phone waves motivate some materials in the blood stream causing sensitivity reactions.

**Effects on teeth:** Some British dentists have stressed the likelihood of developing cancer in the mouth, and this possibility increases with teenagers who use orthodontic metals.

**Effects on pregnancy:** Use of mobile phone, especially throughout the first three months of pregnancy, or close to children within the first two years of birth, could cause destruction to the brain blood barrier due to the skull not being completely healed, and this paves the way to the development of tumors. Such use also increases the likelihood of autism.

**Effects on children:** Being in the phase of growth, children have smaller bodies and heads, thinner skulls and higher tissue conductivity. They may absorb more energy from a given phone than adults, rendering them at a higher risk of radiation effects [7].

**Cancer:** Exposure to radiation could lead to cancer, although there is no firm evidence on this issue. The nature of such cancerous tumors and how they emerge requires additional research, long-term observation and consideration.

**Effects on medical devices:** Some medical devices are susceptible to the effects of radiation, such as interference or malfunctioning. Mobile phones disturb implantable cardiac pacemakers that regulate heart pulses.

## 5. Contradictory Outcomes

On the other hand, many researchers deny any harmful effects of radiation due to wireless communications, other than raising the body temperature, and they declare that this rise is minimal, of the order of  $0.1^{\circ}\text{C}$ , which is in any case within what people are exposed to daily by sun radiation. The researchers emphasize that exposure is safe, that there is no consistent or conclusive evidence on hazards, that most of the tests were conducted on laboratory animals with results that do not reflect reality, that any effects of mobile phone on brain activities are insignificant, and that computer and television monitors emit radiation similar to mobile phones with no perceived hazards. The researchers also argue that the human body itself produces power at a basal metabolic rate of  $1\text{W/kg}$  of body mass in the relax state, and ten times this amount in the active state, which is more than the average absorbed radiation thermal power of  $28\text{W}$  for a body of  $70\text{ kg}$  [14]. Besides, there are many people who get exposed to high electromagnetic power over long periods without any health effects. These include air traffic and air defense controllers, civilian and military pilots, engineers and other personnel who get subjected to radars and wireless devices at high power (up to  $10\text{ W}$ ) over their lifetime. Other workers at satellite ground stations and radio and TV broadcast stations which operate with huge power have not reported any severe symptoms. Such conflicting results by scientists are coupled with adverse commercial reports that only add to the ambiguity surrounding this topic. According to Motorola, wireless communications products and services operating within recognized guidelines pose no known health risk [20].

## 6. Measuring Radiation Levels

Safety exposure standards are commonly set by the Institute of Electrical and Electronics Engineers (IEEE), American National Standards Institute (ANSI), International Commission on Non-Ionizing Radiation Protection (ICNIRP), and National Council on Radiation Protection and Measurements (NCRP). ANSI/IEEE standard is  $1.2\text{ mW/cm}^2$  for antennas in the  $1800\text{-}2000\text{ MHz}$  range, and  $0.57\text{ mW/cm}^2$  for antennas operating in the  $900\text{ MHz}$  range. ICNIRP standards are slightly lower, and NCRP standards are identical. FCC guidelines include standards for mobile base station antennas that are essentially the same as those of (ANSI/IEEE) [14]. ICNIRP has specified safety limits for exposure to radio signals emitted by mobile phone towers [Table 6].

Communications companies use specialized computer software to analyze signal strength and measure it as power density in  $\text{W/cm}^2$ . Saudi Telecom Company (STC) uses software called TEMS, by Ericsson, to provide signal information. In order to check signal power within an area, a worker uses a mobile phone with a Subscriber Identity Module (SIM) from STC, and connects the mobile phone using a suitable cable to a laptop computer where TEMS is installed. TEMS recognizes the connection and uses the mobile phone for its analysis and calculations. For individuals, there are several types of software,

such as G-Mon and RF Signal Tracker, which can give some information about signal strength, albeit to a lesser extent than TEMS. RF Signal Tracker operates on Android-driven smart phones. It provides helpful data about the used mobile phone network in addition to the local wireless network [Figure 1]. After carrying out some tests, it has been found that the above software is not suitable for the purpose of this research, and that it provides inaccurate information about the power from network towers. The reason is that the communication companies use several mixed technologies to provide services, and each of these technologies emits power in different conditions, an issue that complicated the measurements.

Exposed Body Part	Power Amount (SAR: W/kg)
Whole body	0.08
Head and torso	2
Extremities	4

Table 6. Typical Safety Limits

Moreover, each tower operator uses several frequencies at various power levels to cover the surroundings. When a mobile phone was used with the above-mentioned software, it showed the amount of received power from the tower it was connected to over a specific technology, and using the determined frequency; but this was only part of the existing radiation. Furthermore, such programs provide information just about the network of the service provider to whom the measurement SIM belongs. This result led to the consideration of another equipment, produced by Agilent, to measure the real amount of power emitted by various networks, communication companies, applied technologies and frequencies. This approach would form the subject of further future measurements.

A typical power of 100 W could be radiated by the antennas of cellular towers, and exposure to the public within several metres in front of the antennas exceeds safety limits. Safety compliant distances in other directions would be less. A typical power density in such case is 40 mW/m<sup>2</sup> with an antenna gain of 17 dB [18]. A survey has been conducted to check the number of the active sources emitting electromagnetic power for commercial and public use within a typical geographical area of 1 square km in Jeddah city. The result showed the combined existence of mobile coverage for three service providers, WiMAX coverage for two service providers, 18 wireless LANs, a satellite communications service, and a two-way radio communication service. This accumulation does not include wireless networks for police use, satellite broadcast and dishes, and radio and TV broadcast. The tests and measurements have to be well devised, as the accuracy of exposure assessment and its interpretation are crucial in deriving the conclusions. This applies to the tests related to the source of radiation and the environment, as well as those involving the medical aspects on the human body.



Figure 1. Snapshots of RF Signal Tracker

## 7. Conclusion

Electromagnetic radiation indisputably has harmful effects on human health. Research that cautions from hazards is much

more compelling than that denying them, and people should avoid excessive use of wireless devices pending definite conclusions by scientists. In another context, some public, military or private sector parties may have commercial or other interests in subduing the hazards, and they may even go further to fund research that negates any danger. The search for the hazards is hampered by the fact that it takes many years for the effects to appear, and hence to firmly establish the connection between radiation and health. Furthermore, most of the studies and conclusions were based on previous work that was undertaken over the past few decades, but that has not been updated by recent empirical data, despite the growth in wireless technologies and their applications. A substantial part of the conclusions was based on questionnaires, feedback or self-reporting from the subjects under test, and not on scientific or medical investigation, thereby introducing an error margin.

The hazards of non-ionizing radiation depend on the signal power and frequency, directionality of the antenna, propagation medium characteristics, source-to-body distance and polarization, and period of exposure. As humans move about in relation to the sources, with different periods of exposure for each source, the whole process of human-radiation interaction becomes multi-dimensional and requires elaborate computer modeling to estimate the hazards based on time- and space-diversity. The limitations and tolerances of the human body bear a lot on the outcome of the experiments, and on the effects that a human is subjected to in his lifetime. So far the body has been considered as a uniform passive receiver that has identical characteristics for all, but this assumption is far from being true. The general fitness of the human, any past exposure that could have previously caused hidden or dormant effects, the body mass and size, the chemical and physical composition, the organs and systems, the presence of fat, the thickness of skull, and other characteristics do influence the results, and do explain to a certain degree the variation in the sensitivity of humans to radiation. The interaction between the body and radiation, the resistance to radiation effects, and the inherent electromagnetism within the body need to be analyzed. The currently permitted limits of exposure are based on the resulting thermal effects, but the performed studies indicate that effects other than heat should be duly considered. In the event of multiplicity and type of sources and causes, the cumulative effects would not be the direct summation of individual effects; and this is for just part of the non-ionizing radiation. Overall, the biological effects of wireless communications should be determined in a concerted international effort involving governments, manufacturers, researchers, and standardization and professional bodies, in both the technological and the medical fields.

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