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Senate Finance Committee

HB 110 Opponent Testimony

6-03-2021

Chairman Dolan, Vice-Chairman Gavarone, Ranking member Sykes and members of the Finance Committee, my name is Kathy Dirr. I am the founder of "Ohio 4 Safe Tech" and the Ohio Liaison for the national organization "We are the Evidence," which is an advocacy group for those suffering from electromagnetic radiation sickness and injury.

We are not against technology-- but we ARE advocates for SAFE technology.

Unless amended, we strongly oppose HB110 which includes 170 million tax dollars for grants to increases rural broadband speeds. As is, HB110 provides funding for HB2 which allows for scientifically-proven and biologically-harmful radiation exposure levels via small cells to be installed in rural Ohio. This bill will allow small cells to be placed in **the front yards of** rural residents and placed on or near our schools, daycares, nursing homes etc. Just as **HB478, passed in April of 2018,** will not allow families/citizens to object to the 24/7 harmful radiation exposure – **they will be subjected, without their knowledge or consent, to microwave radiation that will harm their health, as well as the health of their children.**

HB2 does <u>not</u> require that this faster speed technology planned for rural Ohio use safe Fiber- to- the- Premises or copper-wire connectivity. It permits the small cells and micro-wireless infrastructure seen below:

West Chester – Butler County
Pulsing Microwave Radiation
exceeds 8,000 microwatts/sq meter

Mason Middle School – Warren County
Pulsing Microwave Radiation exceeds
29,900 microwatts/sq meter

The levels of microwave radiation emitted by these small cells exceeds safety limits per the safety guidelines of the Bio-initiative Report, are dangerously high, and jeopardize human health, particularly for children, who are the most vulnerable. Scientific peer-reviewed research demonstrates that microwave radiation in amounts as low as 2,000 microwatts per square meter causes harmful biological effects, including but not limited to: fatigue, depression, headaches, sleep disorders, concentration difficulties, cardiovascular problems, DNA damage, cancer, and in particular a two-fold increase in childhood leukemia, as well as a decreased survival rate for childhood leukemia.

Eyesores such as seen below have become commonplace in suburban Ohio and will proliferate in rural Ohio. Per HB 478 passed in 2018, this infrastructure attached to fiber lines has been given a special exemption with NO PERMIT required. These small cells are within feet of our homes, daycares, schools etc. exposing citizens 24/7 with no ability to opt-out. Which one of these devices is a small cell? Are there more than one? Charter/ Spectrum cable won't tell the family living within feet of this infrastructure and there are no permits on file to find out. Do rural and suburban Ohioans have a right to know if dangerous small cells are installed within feet of their homes and their children's bedrooms? Better yet, why is this allowed when fiber to the premises/copper connectivity causes no harm, is more secure and more reliable?

The allowable radiation levels set by the FCC are unsafe. They have represented the interests of the industry and not the public and are considered a "Captured Agency". Please see: *Captured Agency: How the Federal Communications Commission is Dominated by the Industries it Presumably Regulates*)

We are the Evidence, Environmental Health Trust (EHT) and the Children's Health Defense (CHD) have filed a landmark lawsuit against the Federal Communications Commission (FCC). They charge that the outdated "Safety Standard**s," that are more than two decades old and erroneously based on thermal radiation effects, are unsafe and must be revised. Over 11,000 pages of evidence in support of their claims** have been **filed. This case is currently awaiting a ruling.**

- One groundbreaking study by the National Institutes of Health, Toxicology Program (NIH/ NTP) , the largest of its kind, found that non-ionizing radiation causes three rare cancers, breaks the blood-brain barrier, and damages our DNA. These results were again confirmed by the Italian Ramazzini study later that year.

- The World Health Organization classified EMF (electromagnetic radiation) to be a Class 2B carcinogen in May of 2011. This is the same classification as lead and asbestos. History tells us once again that previously thought "safe" casually-used items are later discovered to be dangerous: lead, asbestos, tobacco and now non-ionizing microwave radiation.

- January 2020 An Electrical Engineering Association IEEE Published a whitepaper entitled Electronic Radiation due to cellular, Wi-Fi and Bluetooth technologies: How safe are we? It warns of the dangers of exposures and offers suggestions on how to help mitigate harm and raises ". . . valuable concerns regarding EMR safety in the upcoming 5G networks."

- These small cells may use the new 5G millimeter wave technology to achieve faster speeds. The telecom executives themselves admitted in a congressional hearing that there are no safety studies proving 5G is safe. In fact, 5G is an untested application of a KNOWN carcinogen. There are international and national moratoriums demanding a halt to this technology.

- For decades the Military has documented harm from EMFs. A research report by the Navy Medical Research Institute (NMRI) compiled in 1971 by Dr. Zorach Glaser cites 2000 references on the biological response to RF/EMF radiation. It revealed that non-ionizing radiation is responsible for major organ damage, altered fetal development, infertility, harms the nervous system, endocrine and digestive system, affects the heart, brain and even damages our eyes. (Again, this is not a complete list.)

The dangers of microwave radiation are further vividly demonstrated by the fact that telecommunication companies are completely unable to get insurance; for example, Lloyds of London, refuses to insure against "non-ionizing radiation". The telecom industry warns shareholders it is facing serious litigation regarding its "products". See attached: What the Telecom Industry Doesn't Tell You…But Does Tell Its Investors.

It's also telling that Frank Clegg, former President of Microsoft Canada, notes that "I have never had Wi-Fi or Wi-Fi routers in my home. I have always had Ethernet connections. . . Anything you can do to get rid of Wi-Fi in your office, school or home you should do. "

In addition, property values go down 20% when a small cell appears in the front yard or near a homeowner. Many consider this to be an unconstitutional "takings".

Rapid expansion of high speed internet using small cells is being sold as the CoronaVirus solution:

- We are told that "at-home learning" requires this bill be passed; this is false-- children have used textbooks for more than 200 years to learn, and in fact studies show that using tech for long periods is harmful to kids and rewires their brains. Excessive use of tech has been proven to cause mental health and cognitive learning problems, including memory and attention disorders. The American Academy of Pediatrics, the largest US medical association of pediatricians and pediatric specialists, recommends that the US government *tighten* wireless exposure limits and that the public **reduce children's exposure** to devices that emit wireless radiation. I**f technology must be used, however, this bill should require it be done safely using wired connections.**
- Telemedicine can't justify HB2. Tele-med is not an acceptable substitute for in-person medicine: vitals cannot be taken, care is substandard, and malpractice insurance doesn't cover tele-med, since it is considered an unsafe way to receive care. This money would be better used for REAL access to REAL doctors with clinics established in rural poverty- stricken Ohio areas.
- The idea that rural businesses need this bill to compete is bogus. Faster **wired** internet services will serve the same purpose, improving productivity, lowering healthcare costs, and increasing the competitive edge of businesses. Again, research shows that microwave radiation exposure from Wi-Fi and small cells causes migraine headaches, insomnia, memory problems, attention deficit and cognitive disorders, depression, and anxiety.

Since the workforce is the most important asset of any business, preventing these health issues has a significant impact on employee productivity and any competitive edge:

- OSHA requires safe workplaces, something that cannot be guaranteed with wireless infrastructure. What will be the cost to businesses when they are held liable for serious health consequences from dangerous workplace exposure to microwave radiation? Again, the small cells providing faster speeds by using 5G mmW technology operate without safety standards; there are no safety studies proving 5G is safe. 5G mmW is an untested application of a KNOWN carcinogen. Furthermore, this 5G mmW technology is being installed indoors, increasing harmful exposure levels. Military studies confirm there is biological harm from exposure to mmW radiation.
- ADA requires that employers protect those who suffer from Microwave Radiation Sickness. What is the cost to shield an employee's office to make it safe? Businesses may well be held liable for full healthcare costs from illness and injury of employees working on site. If employees work from home and are exposed to Wi-Fi as well as small cells outside or near their home, those healthcare costs are absorbed by the employer as most offer healthcare coverage as a workplace benefit. Healthcare is the largest expenditure most businesses have today and, as Dr. Sharon Goldberg pointed out when testifying to the Michigan General Assembly, there are numerous cases of costly medical issues resulting from this technology.

While faster technology may be desired, it should not come at the expense of the health of Ohioans. This bill should be amended to require safe wired technology and not permit "last mile" wireless infrastructure.

Thank you for the opportunity to speak regarding our objections to this bill. I would be pleased and honored to answer any questions you have for me today.

Attachments:

- IEEE Electronic Radiation Due to Cellular, Wi-Fi and Bluetooth Technologies: How Safe Are We?
- Wi-Fi in Schools: Experimenting with the Next Generation (Epoch Times)
- What the Telecom Industry Doesn't Tell You…But Does Tell It's Investors
- Oxidative Mechanisms of Biological Activity of Low Intensity Radiofrequency Radiation – 100 studies
- Dr. M. Herbert, PhD, MD – Harvard Medical School – On Wireless Harm | Children
- NTP/NIH Peer Reviewed Summary page

Important links to Government Reports and Studies Proving Wireless Radiation Health Effects

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$25 Million US National Toxicology Program Study Proving Wireless Radiation Can Cause Cancer Non-Thermally Below Our Current FCC Safety Guidelines

Peer Review Expert Panel of Pathologists Peer Review: Click Here for (PDF)
NTP Study Report 1 Click Here for (PDF) | NTP Study Report 2 Click Here for (PDF)

Ramazzini Institute Study replicates findings of NTP study with Heart and Brain cancer being caused by wireless radiation non-thermally below current FCC safety guidelines and at exposure levels 60-1000 lower than in NTP

Click Here (Study)

US Naval Medical Research Institute: BIBLIOGRAPHY OF REPORTED BIOLOGICAL PHENOMENA ('EFFECTS') AND CLINICAL MANIFESTATIONS ATTRIBUTED TO MICROWAVE AND RADIO-FREQUENCY RADIATION

Click Here for Navy Report 1 (122 symptoms of Microwave Sickness identified & 2300 studies cited)
Click Here for **Naval Report 2** (Another 3700 studies identified showing biological effects from EMF)

EPA REPORT:

ELECTRIC AND MAGNETIC FIELDS: AN EPA PERSPECTIVE ON RESEARCH NEEDS AND PRIORITIES FOR IMPROVING HEALTH RISK ASSESSMENT

Click Here For EPA Report

Air Force Materiel Command:

RADIOFREQUENCY/ MICROWAVE RADIATION BIOLOGICAL EFFECTS AND SAFETY STANDARDS: A REVIEW

Click Here to Download Full Air Force Review

NASA Report:

ELECTROMAGNETIC FIELD INTERACTIONS WITH THE HUMAN BODY:
OBSERVED EFFECTS AND THEORIES

Click Here For NASA Report

U.S. Department of The Interior:

LETTER TO NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION, US DEPT OF COMMERCE

(citing harm and death to birds near cell towers due to cell tower wireless RF radiation)
Click Here for Department of The Interior Letter

To Learn More Please Visit

- Environmental Health Trust
- Physicians for Safe Technology
- Americans for Responsible Tech

- Bioinitiative Report
- Microwave News
- EMF Portal

- International Moratorium on 5G
- US Doctors call for Moratorium on 5G
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- EHT- Scientific Research Summaries

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TO: Los Angeles Unified School District
FROM: Martha R Herbert, PhD, MD
RE: Wireless vs. Wired in Classrooms
DATE: February 8, 2013

I am a pediatric neurologist and neuroscientist on the faculty of Harvard Medical School and on staff at the Massachusetts General Hospital. I am Board Certified in Neurology with Special Competency in Child Neurology, and Subspecialty Certification in Neurodevelopmental Disorders.

I have an extensive history of research and clinical practice in neurodevelopmental disorders, particularly autism spectrum disorders. I have published papers in brain imaging research, in physiological abnormalities in autism spectrum disorders, and in environmental influences on ndurodevelopmental disorders such as autism and on brain development and function.

I recently accepted an invitation to review literature pertinent to a potential link between Autism Spectrum Disorders and Electromagnetic Frequencies (EMF) and Radiofrequency Radiation (RFR). I set out to write a paper of modest length, but found much more literature than I had anticipated to review. I ended up producing a 60 page single spaced paper with over 550 citations. It is available at http://www.bioinitiative.org/report/wp-content/uploads/pdfs/sec20_2012_Findings_in_Autism.pdf.

In fact, there are thousands of papers that have accumulated over decades – and are now accumulating at an accelerating pace, as our ability to measure impacts become more sensitive – that document adverse health and neurological impacts of EMF/RFR. Children are more vulnerable than adults, and children with chronic illnesses and/or neurodevelopmental disabilities are even more vulnerable. Elderly or chronically ill adults are more vulnerable than healthy adults.

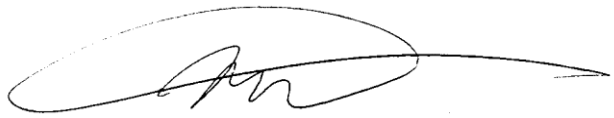
Current te chnologies were designed and promulgated without taking account of biological impacts other than thermal impacts. We now know that there are a large array of impacts that have nothing to do with the heating of tissue. The claim from wifi proponents that the only concern is thermal impacts is now definitively outdated scientifically.

EMF/RFR from wifi and cell towers can exert a disorganizing effect on the ability to learn and remember, and can also be destabilizing to immune and metabolic function. This will make it harder for some children to learn, particularly those who are already having problems in the first place.

Powerful industrial entities have a vested interest in leading the public to believe that EMF/RFR, which we cannot see, taste or touch, is harmless, but this is not true. Please do the right and precautionary thing for our children

I urge you to step back from your intention to go wifi in the LAUSD, and instead opt for wired technologies, particularly for those subpopulations that are most sensitive. It will be easier for you to make a healthier decision now than to undo a misguided decision later.

Thank you.



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SPECIAL SECTION ON ANTENNA AND PROPAGATION FOR 5G AND BEYOND

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Electromagnetic Radiation Due to Cellular, Wi-Fi and Bluetooth Technologies: How Safe Are We?

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ABSTRACT The electromagnetic radiation (EMR) emitted out of wireless communication modules in various IoT devices (especially used for healthcare applications due to their close proximity to the body) have been identified by researchers as biologically hazardous to humans as well as other living beings. Different countries have different regulations to limit the radiation density levels caused by these devices. The radiation absorbed by an individual depends on various factors such as the device they use, the proximity of use, the type of antenna, the relative orientation of the antenna on the device, and many more. Several standards exist which have tried to quantify the radiation levels and come up with safe limits of EMR absorption to prevent human harm. In this work, we determine the radiation concern levels in several scenarios using a handheld radiation meter by correlating the findings with several international standards, which are determined based on thorough scientific evidence. This study also analyzes the EMR from common devices used in day to day life such as smartphones, laptops, Wi-Fi routers, hotspots, wireless earphones, smartwatches, Bluetooth speakers and other wireless accessories using a handheld radio frequency radiation measurement device. The procedure followed in this paper is so detailed that it can also be utilized by the general public as a tutorial to evaluate their own safety with respect to EMR exposure. We present a summary of the most prominent health hazards which have been known to occur due to EMR exposure. We also discuss some individual and collective human-centric protective and preventive measures that can be undertaken to reduce the risk of EMR absorption. This paper analyses radiation safety in pre-5G networks and uses the insight gained to raise valuable concerns regarding EMR safety in the upcoming 5G networks.

INDEX TERMS EMR, wireless, safety, standards, health, protection.

I. INTRODUCTION

The ever-increasing adoption of wireless communication has created a very complex situation of electromagnetic radiation (EMR) exposure. With new technologies such as 5G, the number of devices will increase exponentially and operate on a broader frequency spectrum. With this upcoming technology, the society will be more connected than ever before, and would witness huge economic growth. However, it is very important to identify beforehand, if any, harmful or adverse effects resulting from increased exposure of human beings.

Currently, there are about 15 billion wireless local area network (WLAN) devices ranging from Wi-Fi routers to Internet of Things (IoT) devices [1], 9 billion mobile connections, and about 67% of the world population currently uses mobile phones [2]. Any unidentified or unaddressed health hazard due to the use of these devices or exposure to their radiation could impact the health of people globally.

Several organizations at both national and international levels have established guidelines for limiting EMR exposure in residential as well as occupational scenarios. Scientific research on EMR exposure-related biological effects began as early as the 1940s [3], but gained significant pace in the early 2000s with the widespread increase of EMR exposure due to cellular communications.

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has issued regulatory limits on EMR exposure for the general public and workers. ICNIRP's 1998 guidelines have been adopted by most of the countries in the world today [4]. But these limits only take into account the thermal effects of EMR and dismiss evidence on the biological effects of EMR exposure as unclear or

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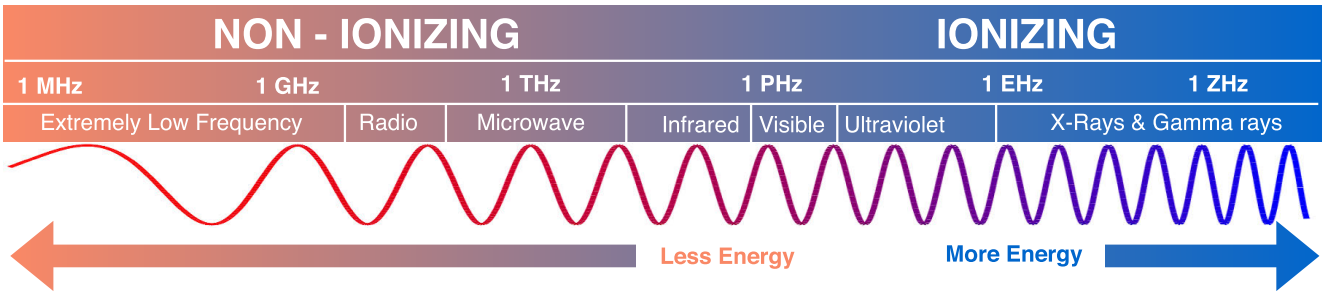


FIGURE 1. Ionizing and Non-ionizing radiation sources and there frequency bands.

unsatisfactory findings. In addition, there are several standards prescribed by medical bodies such as the Building Biology, BioInitiative, and Austrian Medical Association Standards. These limits have been arrived at after extensive scientific research of thermal, non-thermal, chronic exposure, and biological effects carried out by health experts from across the world. On comparing these limits with those prescribed by the ICNIRP, it can be seen that the limits prescribed by the medical bodies are several orders of magnitude lower than those prescribed by the ICNIRP. Therefore, a clear understanding of the differences between these limits, and an assessment of the current exposure levels in accordance with both kinds of exposure limits mentioned above is the need of the hour.

In the literature, many research studies have analyzed health hazards due to EMR exposure [5]. Numerous adverse health conditions such as cancer, infertility, damage to the auditory system, alteration of blood cells and blood flow, mental, cognitive and sleep disorders, and impaired childhood development have been identified in various studies. We have explored the literature in this area and presented a section describing various health risks associated with EMR exposure.

The major contributions of this paper are highlighted below.

- We analyse radiation levels of commonly used cellular, Bluetooth, and Wi-Fi devices to estimate how safe they are to human beings in terms of radiation.
- The procedure followed in this work serves as a tutorial for the general public who can arrive at a good estimate of their radiation exposure with minimal technical knowledge or expertise.
- We review several works which have identified various health hazards resulting from EMR exposure and presents the findings to highlight dangers of excessive EMR exposure.
- Then, we suggest techniques for people as well as societies/organizations to protect themselves from excessive EMR exposure and also presents ways to minimize ambient EMR levels in different environments like schools, hospitals, and homes.

The rest of this paper is organized as follows. In Section II, we discuss the nature of EMR used in wireless communication devices and the need to analyze EMR from various common sources such as mobile phones, laptops and other cellular, Wi-Fi, Bluetooth and IoT devices. In Section III, we discuss a few important standards and guidelines for EMR exposure which have been determined by scientific organizations/commissions to avoid EMR related health hazards in humans. In Section IV, we present our findings on the radiation levels present in common use cases of popular devices. In section V, we summarize the important health hazards of EMR exposure that have been documented and reported. In section VI, we describe some measures to protect ourselves from EMR and also discuss ways to minimize ambient EMR in public places. In section VII, we recommend some proactive prevention techniques which can be immediately adopted at both individual and societal levels to prevent harmful EMR exposure. In section VIII, we discuss our findings from section IV in light of sections II, III, V and VI. We finally conclude the paper in section IX.

II. PRELIMINARY BACKGROUND AND MOTIVATION

A. IONIZING AND NON IONIZING RADIATION

When referring to interaction of EMR with biological systems, EMR is categorized into two types: ionizing and non-ionizing. About 60% of the human body is water. Based on whether the incoming radiation is high enough to break the chemical bonds of water or not, it is categorized as ionizing radiation (if it can break the bonds) and as non-ionizing radiation (if it is not able to). Several classes of electromagnetic waves are classified as non-ionizing and ionizing radiation as depicted in Fig. 1. The frequencies we are interested in (radio frequencies) fall in the category of non-ionizing radiation. Some of the most common electronic/IoT devices which people use today such as mobile-phones, smartphones, laptops, wireless speakers and headphones, and smartwatches, all communicate using radio frequencies. Broadly, they can be categorized into devices which use cellular, Wi-Fi or Bluetooth technology as shown in Fig. 2. This kind of radiation has been linked with various adverse health effects in human beings. The severity of these effects varies with the power of radiation, distance of the radiation source, the kind of device, the type of antenna used in the device, the modulation technique used in the communication and the duration of exposure.

Electromagnetic radiation in the frequency range 20 KHz - 300 GHz is referred to as radio frequency (RF) radiation. Most of the commonly used communication services such as FM radio, television broadcast, satellite, cellular, Global

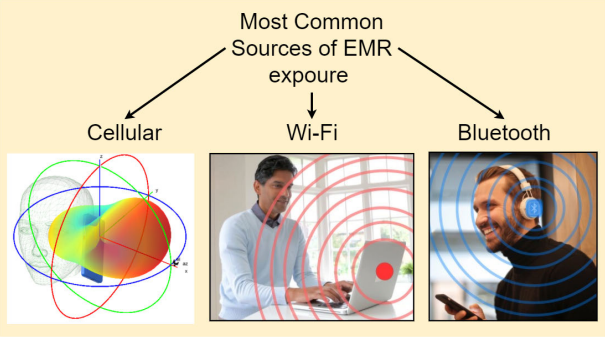


FIGURE 2. Most common sources of EMR exposure.

TABLE 1. Common wireless communication technologies.

Name of technology	Frequency	Deployment year
1G	800 MHz	1970-1980
2G 2.5G	850/900/1800/ 1900 MHz	1990 1985
3G	800/850/900/ 1800/1900/ 2100 MHz	2004
3.5G	1.8 GHz/2.6 GHz	2007
3.75G	3.5 GHz/5.8 GHz	2012
4G	1.8 GHz/2.6 GHz	2009
WIMAX	2.3 GHz, 2.5 GHz and 3.5 GHz	2008-2015
5G	600 MHz to 6 GHz and 24-86 GHz	2018
Wi-Fi	2.4/5 GHz	1997
Bluetooth (versions 1-5)	5 GHz	2000

Positioning System (GPS), Wi-Fi and Bluetooth all lie in this frequency range.

B. MOTIVATION

An antenna is a transducer which converts AC. electric currents flowing in metal conductors to radio frequency electromagnetic waves and vice-versa. Antennas are used in all wireless radio frequency communication devices. During transmission, AC. electric current is supplied to the antenna's terminals, which induces the antenna to radiate EMR waves in the radio frequency range. During reception, the antenna intercepts radio waves to generate an AC. electric current at its terminals, which is applied to a receiver before amplification. In the latest smartphones which are in use today, there are several antennas for different communication purposes such as cellular, GPS, Wi-Fi and Bluetooth. Table 1 lists the most commonly used wireless technologies at present and their frequency ranges. Fig. 3(a) shows the usage of multiple antennas in a smartphone. Similarly Fig. 3(b), Fig. 3(c) and Fig. 3(d) show the antennas used in the Jio-Fi 4G Hotspot, the Wi-Fi antennas present in a laptop, and the Bluetooth antenna used in a wireless earphone respectively.

A cell phone communicates wirelessly with a cellular base station that is typically hundreds of meters away. The antennas on a mobile phone are not directive, i.e, they transmit and receive EMR roughly in all directions. Their radiation pattern is roughly omni-directional. This enables good communication, because the user does not necessarily orient the phone in the direction of the cell tower. These antennas ensure the propagation of the electromagnetic waves to the, enabling communication. The omni-directional nature of these antennas can cause radiation energy to dissipate in all directions. But this means that a mobile phone emits radiation directly into the head of the user. Moreover, when the phone is situated in areas with weak reception such as the far end of its closest cell tower or in the basement of a building, its radiation increases by several magnitudes in order to ensure good connection with the cellular base station.

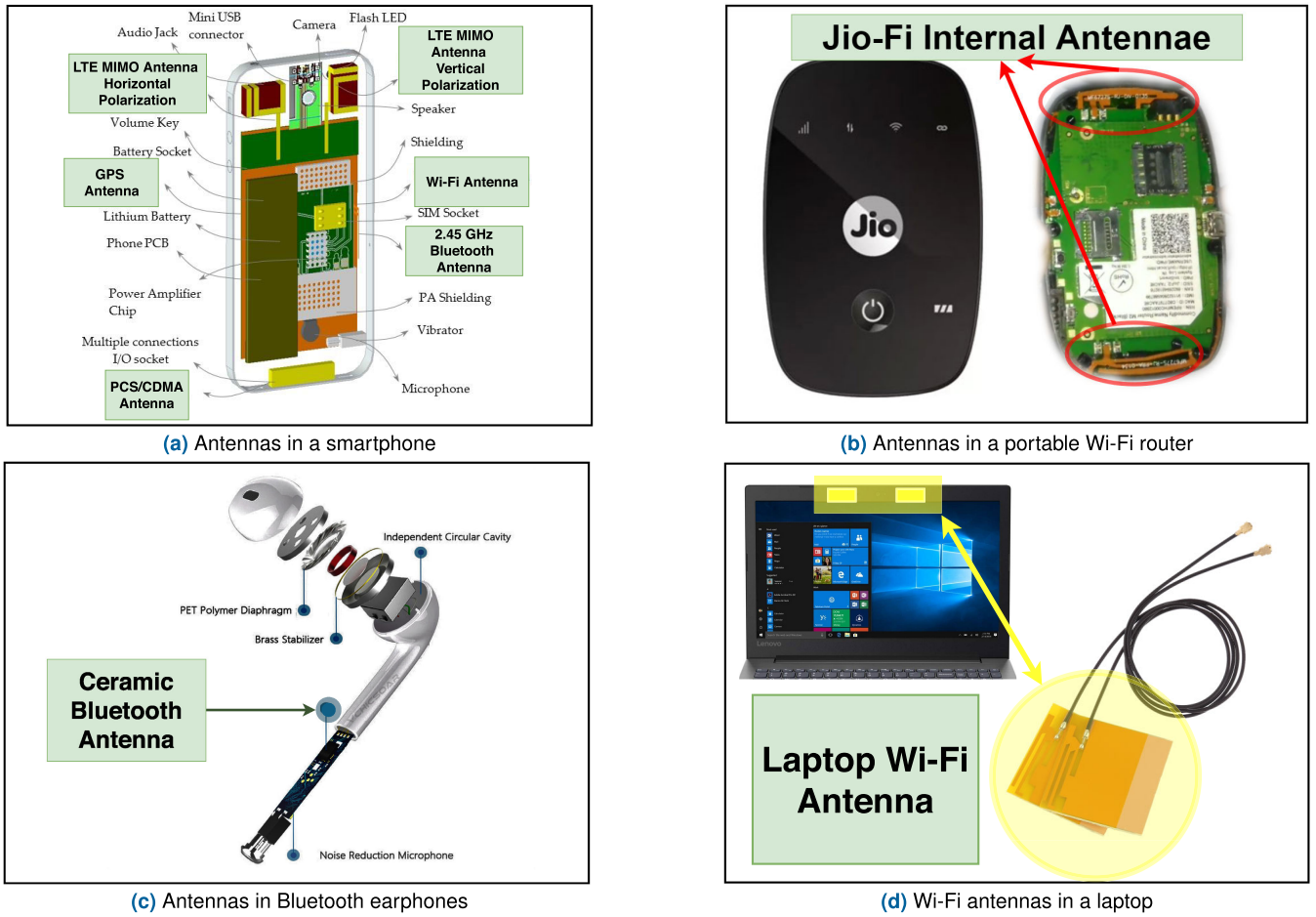
Laptops communicate with both Wi-Fi and Bluetooth technology, but Wi-Fi is used more extensively to connect to wireless routers located nearby. Just as for mobile-phones, the laptop antennas are designed to ensure good connection regardless of its orientation or position in a Wi-Fi zone. Hence, even laptop Wi-Fi antennas are roughly omnidirectional in nature. Laptops are mostly used either on the lap or on a desk. When used on the lap, severe amounts of radiation directly enter the legs, groin and torso region. Moreoever, since the antenna is located very close to the body, the magnitude of radiation is extremely high. When used on desks or tables, the face of the user directly faces the antenna. Most laptops have their antennas located at the top of the display. Laptops are used for several hours at a time in very close proximity and hence raise more concern than mobile phones which may be held next to the ears for just a few minutes during a call.

In the last few years, the popularity of Bluetooth headphones and earphones have increased drastically. Some of these earphones such as the one shown in Fig. 3(c) have the antenna extremely close to the ear. These devices are worn by users almost throughout the day and kept active almost continuously. In addition to the radiation from the earphone itself, the connected smartphone or mobile phone, kept in the pocket also emits Bluetooth radiation continuously.

For a common user, it is very difficult to measure the three-dimensional radiation pattern to estimate his own safety in regards to EMR exposure. Therefore, in this document we analyze the radiation levels from the most common sources to and scenarios of EMR exposure. We then correlate our findings with a few well-defined, scientifically and holistically determined safety limits.

III. STANDARDS AND GUIDELINES FOR ELECTRO-MAGNETIC RADIATION

Ideally, it is expected that a well defined, safe exposure limit would apply to people of all countries. But, there are striking differences that arise due to thermal effects, non-thermal



(a) Antennas in a smartphone

(b) Antennas in a portable Wi-Fi router

(c) Antennas in Bluetooth earphones

(d) Wi-Fi antennas in a laptop

FIGURE 3. **Antennas in a smartphone.**

health effects, and precautionary measures considered in determining the limits. Different countries across the world adopt different RF EMR exposure limits based on these considerations. For example, the United States adopts limits based only on thermal effects. Russia and China have taken non-thermal effects into account while determining their standards. Switzerland and Italy have taken precautionary measures to account for any adverse health effects which may be discovered in the future, and therefore adopt exposure limits even below non-thermal effects [6]. Damage arising from only tissue heating is considered while determining thermal exposure limits. Such safety limits are prepared based on the assumption that it is sufficient to consider only heating effects while trying to minimize harm to the human body. But in the last few decades, it has been well established that biological and adverse health effects occur at radiation levels which are too low to cause any heating, sometimes several hundred thousand times lower [7].

In this section, we discuss the guidelines on exposure limits prescribed by the ICNIRP, Building Biology, the Austrian Medical Association, and the BioInitiative. The ICNIRP guidelines is the most widely adopted guidelines in the world at present, being adopted by around 50 countries. But it only takes into account the thermal effects of EMR, while the standards prescribed by Building Biology, Austrian Medical Association, and the BioInitiative take into account thermal, non-thermal, chronic exposure, and biological effects of EMR as well. In this section, we present a comprehensive summary of the above-mentioned guidelines and standards in light of the requirement of this work, i.e., electromagnetic radiation due to cellular, Wi-Fi, and Bluetooth technologies.

A. ICNIRP

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) is an international commission which specializes in non-ionizing radiation protection. The EMR exposure limits of more than 50 countries in the world today [8] are based on ICNIRP's 1998 publication [9]. This document provides different guidelines for occupationally exposed individuals and members of the general public. They have prescribed two types of restrictions, namely Basic Restrictions and Reference levels. Basic Restrictions are difficult to measure, especially for people who are not experts in the field of antennas and do not have access to sophisticated experimental setups. They require sophisticated experimental setups and costly equipment. But, Reference levels can be easily measured using simple handheld RF radiation meters. Here, we only consider the Reference levels for general public

TABLE 2. ICNIRP reference values for general public.

Name	Upper Band Frequency	Exposure Limit (in $\mu W/m^2$)
1G	800 MHz	4,000,000
2G	1900 MHz	9,500,000
3G	2100 MHz	10,000,000
4G	2.6 GHz	10,000,000
Wi-Fi	2.5 GHz	10,000,000
Bluetooth	5 GHz	10,000,000

exposure in the frequency ranges of the wireless technologies considered in this work. The Reference levels at these frequencies for general public exposure are listed below, where f is the frequency of the concerned EMR source. Table 2 lists the reference values (in $\mu W/m^2$) calculated for some wireless technologies.

$$\textbf{400-2000 MHz}: f/200\ \mu W/m^2$$
$$\textbf{2-300 GHz}: 10\ \mu W/m^2$$

B. BUILDING BIOLOGY STANDARD

The Building Biology Standard [10] takes into account the physical, chemical and biological hazards present places where people work, live and sleep. It considers the influence of various factors such as different electric fields, magnetic fields, waves, radiation, indoor toxins, pollutants, fungi bacteria and allergens. Radio Frequency EMR is also included and addressed as a critical influence in their standard. It aims to enable an individual to identify, minimize and avoid all such factors in their own life without any need sophisticated equipment or scientific expertise.

Their evaluation guidelines are intended to be used in areas where there is risk of repeated long term-exposure such as sleeping and resting areas. Their guidelines are precautionary in nature and define four levels of concern which are listed below.

1) **Extreme Concern**: The values categorized under extreme concern require an immediate attention and swift correction. Short term exposures to radiation under this category will cause problems like headache, nausea, dizziness while long term exposures can lead to more serious diseases as discussed in section VI.
2) **Severe Concern**: The radiation values coming under this category are tagged as unacceptable from the point of view of building biology and they must be addressed. These values are unnatural for human beings. Chronic exposures to these radiation levels can sow the seeds of future health diseases.
3) **Slight Concern**: This is a precautionary category as radiation levels categorized under slight concern can affect sensitive population like pregnant women, small children and unhealthy people.
4) **No Concern**: This category ensures that the radiation levels are safe and will not cause any health hazard. The radiation levels in upper range of this category signify the background radiation level of our modern living environment which is inevitable in the current society.

In the case of RF EMR, the quantity to be measured is power density in the units of $\mu W/m^2$. Power densities (in $\mu W/m^2$) less than 0.1 indicate **no concern**, between 0.1 and 10 indicate **slight concern**, 10 - 1000 indicate **severe concern** and values greater than 1000 indicate **extreme concern**.

$$\textbf{No concern}: \leq 1\mu W/m^2$$
$$\textbf{Slight concern}: 1-10\mu W/m^2$$
$$\textbf{Severe concern}: 10-1000\mu W/m^2$$
$$\textbf{Extreme concern}: \geq 1000\mu W/m^2$$

According to the standard, the values mentioned above refer to peak measurements and are applicable to single RF sources such as GSM, UMTS, WiMAX, TETRA, Radio, Television, DECT cordless phone technology and WLAN except radar signals.

The standard treats pulsed or periodic signals (such as mobile phone technology, DECT, WLAN and digital broadcasting) as more critical sources and recommends that they should be assessed more seriously, especially in the higher concern ranges. Non pulsed and non periodic signals such as F.M, short, medium, long wave and analog broadcasting can be addressed more generously, especially in the lower concern ranges.

The exposure limits prescribed by the medical associations of many other countries are based on the Building Biology Standard. For example, the guidelines prescribed by the Austrian Medical Association (AMA) [11] suggest the same limits mentioned above as 'Within normal limits', 'Slightly above normal', 'Far above normal' and 'Very far above normal'.

C. BIOINITIATIVE STANDARDS

The BioInitiative report [11] is the work of renowned health professionals and many scientists on the potential hazards of exposure to EMR arising from the use of wireless technologies. The first edition of the BioInitiative report was

released in 2007 and then updated in 2012. This report includes an extensive documentation of adverse biological health effects on both general and sensitive populations because of exposure to EMR. Their focus is primarily on chronic exposure to low frequency, extremely low frequency and radiofrequency EMR fields. BioInitiative claims to be an independent body, comprising of medically acclaimed professionals who believe that deployment of wireless technology always happens before the health risks are assessed. This report urges the necessity to reconsider the current situation regarding excessive use of wireless communication technology.

The following is a summary of the latest BioInitiative standards. The standard justifies the cumulative outdoor RF EMR limit to be reduced from 1000 $\mu W/m^2$ to just a few $\mu W/m^2$. Based on several studies related to health effects caused by mobile phone and base station radiation, the benchmark for 'lowest observed effect level' was found to be 30 $\mu W/m^2$. Considering the higher electrosensitivity of children, and a safeguard for chronic and long term exposures, the above mentioned value of 30 $\mu W/m^2$ is reduced by 10 times to set the *precautionary action level for chronic exposure to pulsed RF Radiation* between 3 and 6 $\mu W/m^2$. The BioInitiative report also states that this level is not definite, i.e., based on information from newer studies, it may decrease or increase this level.

IV. RESULTS

With the advent of technology, there are more wireless devices today than ever before, such as LTE phones, 3G phones, GSM and CDMA phones, wireless speakers, smartwatches, wireless earphones, portable Wi-Fi routers, wireless mice and keyboards, voice-controlled smart speakers like Alexa, health monitoring devices, etc. In places such as universities, offices and homes, multiple devices are communicating using different technologies at a given time. Note that a majority of devices communicate either using Wi-Fi, Bluetooth or cellular technology. Therefore we have investigated the power flux densities (PFD) of the EMR emitted from specific devices which are used very extensively in our day to day life.

A. METHODOLOGY

For our measurements, we have used the *HF32D RF Analyzer* by *Gigahertz Solution* which is a very easy to use RF radiation meter. This detector covers frequencies from 800MHz to 2.7GHz and therefore can be used to measure 4G/LTE, UMTS/3G, GSM, GPS, Radar, WLAN (Wi-Fi), and Bluetooth radiation densities. The device works on the principle of **Geiger counter effect** by deploying three log periodic antennas in three orthogonal directions.

In order to avoid disturbances from low-frequency EMR sources, the *HF32D RF Analyzer* suppresses sub 800MHz frequencies. The range and signal values of these devices are tuned to assess the EMR in accordance with the *Building Biology Standards* discussed in section III-B. If the power density exceeds the designated range, an attenuator *DG20* is used which increases the range by a factor of 100.

To execute the process of measurement taking, the EMR source devices were placed along the length of a measuring tape. The RF Analyzer was held from its rear end to avoid any reflections of EMR from the hand of the device holder. To accurately evaluate the radiation of the test device,the following procedure was followed:

- **Step 1**: The area around the test device was probed with RF Analyzer approximately 50 cm from the test device to obtain the direction with the highest level of radiation.
- **Step 2**: Next, the direction of the RF Analyzer was fixed at the point where the highest radiation level was recorded, and then the analyzer was rotated along it's longitudinal axis to maximize the reading of the instrument. This ensured that the antenna of the RF Analyzer was aligned with the plane of polarization of the EMR source.
- **Step 3**: Now, the relative orientation of the RF Analyzer and the test device was fixed and then the two devices were moved such that the RF Analyzer was placed on the measuring tape with it's direction of antenna parallel to the measuring tape, and it's base lying flat on the plane of the measuring tape.
- **Step 4**: For the remaining part, the test device was fixed at the beginning of the measuring tape in the orientation as obtained after step 3. If they were two devices being used in a particular scenario, the same steps were performed to fix the second device at the other end of the measuring tape.
- **Step 5**: Finally, the relative distance between the RF Analyzer and the test device was varied by shifting the RF Analyzer in fixed steps along the measuring tape to record the power flux density values. Let's call this relative orientation as 'x' and the corresponding values of power flux density obtained as P_x. Then by changing the orientation of the antenna to its orthogonal directions 'y' and 'z' we obtained two more sets of values, P_y and P_z respectively at the same positions where P_x was recorded.

Finally, the total magnitude of the power density at each position was calculated using equation 1 where P_x, P_y and P_z represent the power density levels received by the antennas oriented in the 'x', 'y' and 'z' orientation respectively.

$$\mathrm{P}_r = \sqrt{P_x^2 + P_y^2 + P_z^2} \tag{1}$$

An attenuator (*DG20*) was used with the RF Analyzer whenever the measured power density was beyond $2000\mu W/m^2$. The attenuator increases the range of the analyzer by a factor of 100.

For our investigation, we devised few scenarios based on frequently encountered situations in the day to day life of a normal user. The testing was done in an open field free from any sources of electromagnetic radiation as shown in Fig 4.

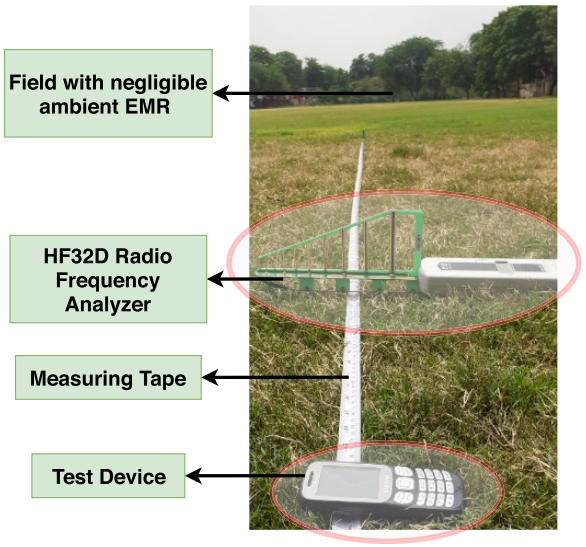
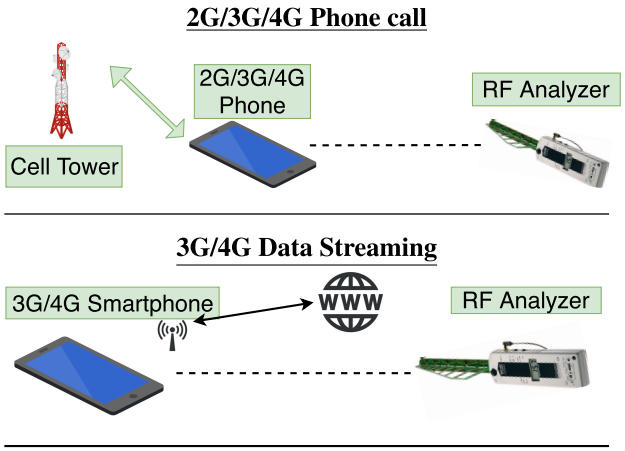
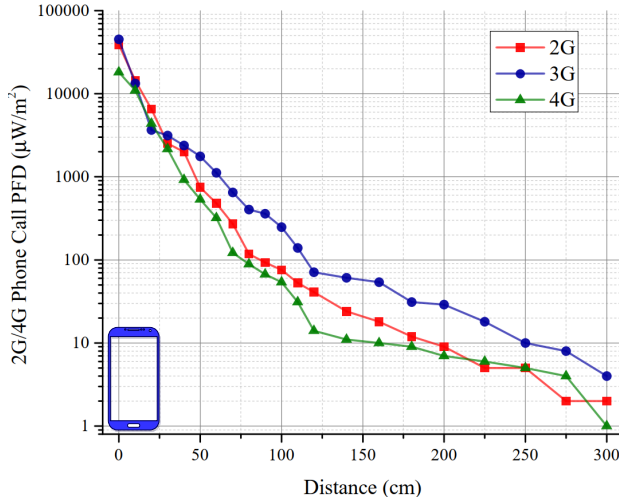


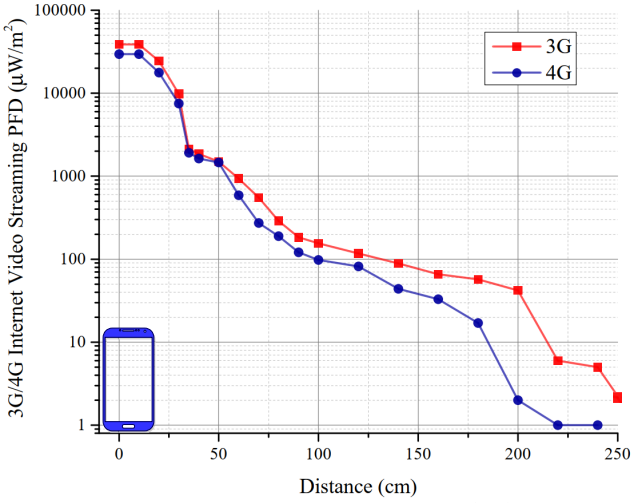
FIGURE 4. The location for testing was an open field with ambient Power Flux Density less than 5 $\mu W/m^2$.

TABLE 3. Experimental setup for cellular devices.





(a) EMR results pertaining to a phone call on 2G/3G/4G networks.



(b) EMR results pertaining to data streaming on 3G/4G networks.

FIGURE 5. EMR results pertaining to cellular devices.

B. EMR DUE TO CELLULAR DEVICES

Table 3 shows schematics of the experimental setups used for analysing cellular devices. Two cases were considered: Phone calls on 2G/3G/4G networks and data streaming on 3G/4G networks.

1) 2G/3G/4G PHONE CALL

The power flux density getting emitted from the mobile device which is put on call is recorded according to the above procedure. All other communication channels from the device such as Bluetooth, infrared, Wi-Fi and GPS were turned off. The results are plotted in Fig. 5(a).

In Fig. 5(a), we can see that the same smartphone emits most radiation on the 3G network, second highest on 2G network and least on the 4G network at almost all distances. While performing a phone call, at a very close range, the PFD measured is 43112, 38907 and 18172 $\mu W/m^2$ on 3G, 2G and 4G networks respectively. The close range radiation in all three cases is above 1,000 $\mu W/m^2$ which is classified as 'extreme concern' according to the Building Biology Standards and 'very far above normal' according to the AMA standards. The radiation is around 10,000 times higher than the precautionary action level recommended by the BioInitiative Guidelines (3 - 6 $\mu W/m^2$). But these values are certainly within the ICNIRP reference values for general public exposure which are between 9,500,000 $\mu W/m^2$ for 2G networks and 10,000,000 $\mu W/m^2$ for 3G and 4G networks. This implies that phone calls performed on 2G, 3G and 4G devices are safe in terms of thermal effects, i.e., a user will not face any health issues arising from tissue heating, but he/she is certainly at risk of developing health issues from non-thermal, chronic exposure and biological effects.

Near the test location, it was found that the nearest 2G, 3G and 4G BSs were all located on the same cell tower. Therefore, the observation of PFD levels (3G > 4G > 2G) network cannot be attributed to farther 3G/4G BSs. To be able to explain the exact reason for higher EMR emission of the smartphone on 3G networks compared to 4G and 2G networks requires thorough analysis of 2G, 3G and 4G antennas used on the smartphone, including their three-dimensional

radiation patterns, and antenna configurations which are beyond the scope of this work.

At about 50cm away from the phone, the radiation level drops below 1,000 $\mu W/m^2$ which comes in the next category of 'severe concern' and 'far above normal'. Therefore the use of wired handsfree earphones/headphones is recommended which generally have a standard length of 1.2m, and by keeping the phone at about 1 m from the user, a good level of safety can be achieved.

2) 3G/4G DATA STREAMING

The mobile device used for this setup was Samsung Galaxy M30. To ensure continuous data transmission from the cell tower to the smartphone, a long HD video was streamed on the phone. The measured power flux density values are plotted in Fig. 5(b).

From Fig. 5(b), it is evident that the PFD of a 4G network is lesser than 3G networks at all distances during data transfers. At very close distances the radiation reaches 38798 and 29682 $\mu W/m^2$ for 3G and 4G networks respectively which is a situation of 'extreme concern' or 'very far above normal' according to Building Biology standards. At a distance of approximately 50 cm, the radiation in both cases drops down to about 1,000 $\mu W/m^2$ which is categorized as a situation of 'severe concern' or 'far above normal'. Smartphones are extensively used to stream videos and therefore it is recommended to keep the phone at least 50 cm away on a table to ensure that the user is exposed to a PFD less than 1,000 $\mu W/m^2$. Therefore, 4G networks must be preferred to 3G networks for data consumption. The scenario of 3G/4G Data streaming is similar to the situation of 2G/3G/4G since all the measured PFDs are well within the range of ICNIRP reference values for general public exposure, but pose serious health risks when seen in accordance with the Building Biology, AMA and BioInitiative standards.

3) 5G AND BEYOND

The testing of all the devices in this work has been carried out in India, where 5G networks are projected to be deployed by the year 2021. Therefore, measuring PFD levels for devices communicating on 5G networks could not be included in this work. 5G is set to use frequencies between 30 GHz and 100 GHz and would have a bandwidth of 60 GHz, which is much higher than all previous generations. Owing to the increased frequency, the wavelengths in 5G communications will be in the order of few millimeters. Shorter wavelengths travel shorter distances; therefore, 5G networks will be much denser compared to existing networks. This necessitates that more base stations be placed at much closer distances in order to achieve good coverage. In 3G cellular networks, the density of BSs is about 4-5 BSs/km^2, and the area served by each BS is large and therefore called a *macrocell*. In the case of 4G (LTE) networks, the BS density is about 8-10 BSs/km^2, the coverage of each BS is lesser and referred to as a *microcell*. However, in the case of 5G networks, the BS density is expected to be increased to about 40-50 BSs/km^2 due to the high propagation loss of millimeter wave technology. The area served by each BS in 5G networks is very small and is commonly called a *small cell*. The shorter millimeter waves would also not be able to penetrate building walls effectively. Therefore, the 5G architecture will separate indoor and outdoor networks, which means there will be separate access nodes for indoor users. 5G BSs will also be installed on street light poles meaning that people will be extremely close to the BS antennas, whether they are indoors or outdoors. In addition, 5G will also employ relay nodes that amplify the wireless signals from the BSs before they reach the device. The high data rate requirement of 5G, which is around 1000 times more than 4G, is expected to be solved by the use of massive-MIMO, which incorporates a large number of antennas. Thus, 5G networks contain *Macrocells*, *microcells*, *relays*, street light access points and separate indoor nodes, which operate simultaneously all the time.

Due to the extremely high density of BSs, street light access points, separate indoor BSs, relays and Massive MIMO technology employed in 5G, a person will be exposed to very high levels of PFDs, whether he is indoors or outdoors, or whether or not he is using any wireless devices in close proximity. In other words, it may be suspected that even the ambient PFD which a person is exposed to in most situations throughout the day may fall under the category of 'Severe Concern' according to the Building Biology Standard, 'Far above normal' according to the AMA standards, and may be higher than the precautionary action level recommended by the BioInitiative Guidelines. If 5G networks are deployed without careful analysis of expected exposure levels, almost all people in the area of coverage may be exposed to dangerous levels of PFD, the outcomes of which, in the near future, may turn out to be calamitous.

Currently, South Korea, United Kingdom, Germany, and the United States are at the forefront of 5G network deployment, with several companies already providing 5G services in these countries [12]. It is strongly suggested that a study similar to the one in this paper be conducted in these countries, by correlating the findings with the standards mentioned in section III in order to get a consistent view of radiation exposure in 5G networks as compared to previous generations. This would provide much-needed insight and caution to all countries that are yet to adopt 5G.

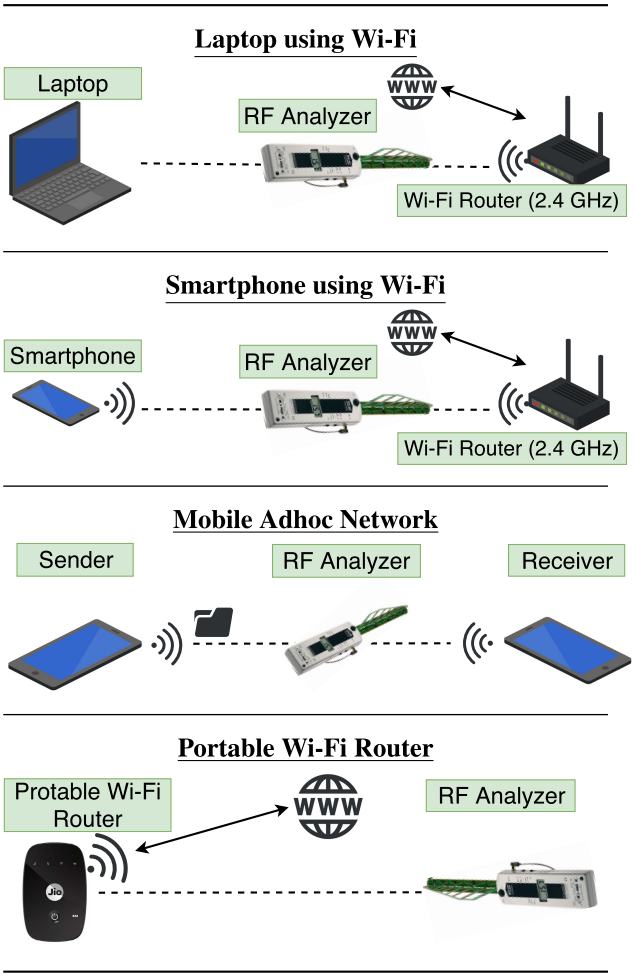
C. EMR DUE TO Wi-Fi DEVICES

Table 4 shows schematics of the experimental setups used for analysing Wi-Fi use cases. Three cases were considered: Laptops/Smartphones connected to Wi-FI routers, Wi-Fi Mobile adhoc networks, and portable Wi-Fi hotspots/routers.

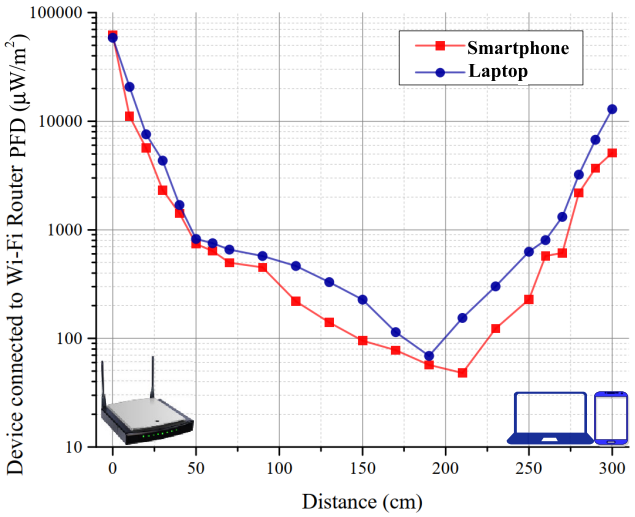
1) LAPTOP AND SMARTPHONE CONNECTED TO Wi-Fi ROUTER

The laptop used for this setup was Lenovo Z51-70 which was put on airplane mode with only Wi-Fi turned on. The laptop was connected to the Wi-Fi Router operating at 2.4 GHz. The devices were kept facing each other as shown in Table 4. The power flux density readings are plotted in Fig. 6(a).

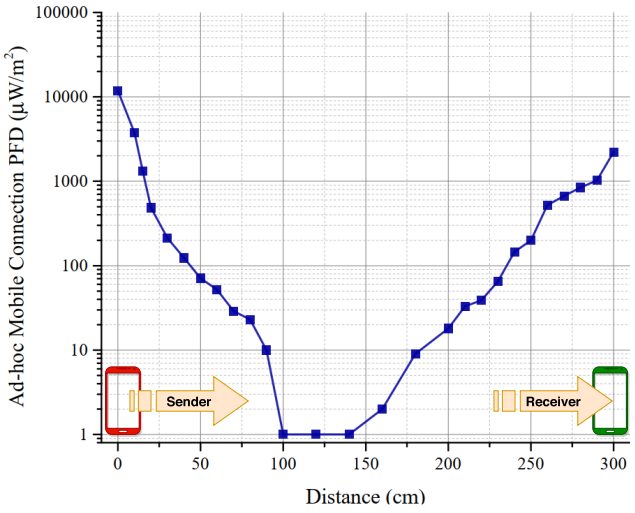
TABLE 4. Experimental setup for Wi-Fi devices.



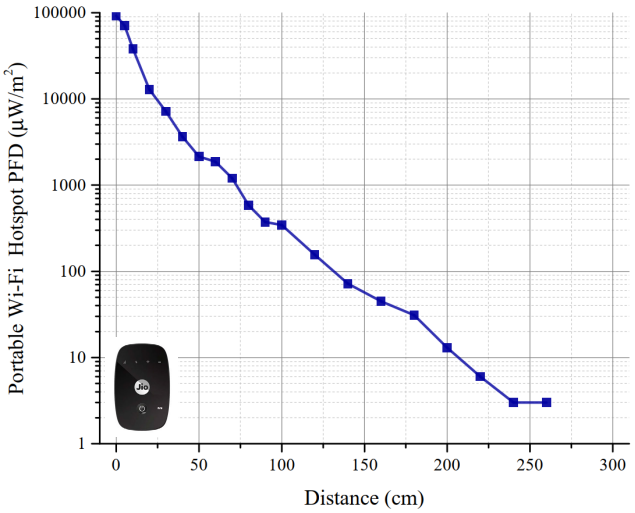
Comparing the scenario of a laptop and a smartphone connected to a Wi-Fi router, it can be inferred from Fig. 6(a), that the effect of the router on the PFD dominates until a distance of about 1.7m from the router. Just next to the router the PFD is about 60,000 $\mu W/m^2$ and drops below 100 at 1.7m from it. So, it advisable to always stay 1.7m away from any Wi-Fi router, whether you are using a laptop or a smartphone. Up to a distance of about 100 cm, the effect of the smartphone or laptop on the PFD dominates. The PFD measured at close proximity of the smartphone is 5123 $\mu W/m^2$ and 12886 $\mu W/m^2$ in the case of a laptop, which is more than 2 times greater than the latter. The reason for this is attributed to PCIe antennas used in the laptop which are designed for better connectivity in terms of range and data speeds. Therefore, smartphones should always be preferred in use cases where a laptop is not absolutely necessary. The PFD in both cases drops below 1000 $\mu W/m^2$ at a distance of approximately 50 cm. Although this PFD still falls in the category of 'severe concern' or 'far above normal' according to the AMA standards and is not to be considered safe, it is still better than the category of 'Extreme concern' or 'very far above normal'. Thus, it is better to keep laptops on a table and operate them from an arm's distance or keep the smartphone



(a) EMR results pertaining to a smartphone/laptop connected to a Wi-Fi router.



(b) EMR results pertaining to smartphone ad-hoc network.



(c) EMR results pertaining to portable Wi-Fi router.

FIGURE 6. EMR results pertaining to Wi-Fi devices.

on a table while watching lengthy videos. Keeping a laptop on the lap or keeping a smartphone connected to the router in the

pocket for long durations would result in dangerous amounts of radiation directly entering the body.

2) MOBILE AD-HOC NETWORK

Two smartphones (Samsung Galaxy M30 and Redmi Note 5) were connected using Wi-Fi Direct technology to form a mobile Ad-hoc Network and a large file was transferred between them. The power flux density readings along their line of sight are plotted in Fig. 6(b).

A hotspot is created between two devices and is meant to handle several connections at a time, which explains why the PFD on the side of a sender (11819 $\mu W/m^2$) is 5 times higher than that of the receiver (2223 $\mu W/m^2$) at a very close range as shown in Fig. 6(b). At a distance of about 1 m from both the devices, the PFD drops below 10 $\mu W/m^2$ which is a situation of 'slight concern' or 'slightly above normal'.

3) PORTABLE Wi-Fi ROUTER

Nowadays, portable Wi-Fi routers/hotspots which work on the 4G network are very popular due to their portability, ease of use with almost no setup time. In our measurement, we used the portable Wi-Fi hotspot to measure the power flux density emitted from the device upto 3 m in the direction of maximum radiation. The readings are plotted in Fig. 6(c). Although these devices are very easy to use and portable, they emit a high amount of radiation 92237 $\mu W/m^2$ at very close distances. This is because portable Wi-Fi routers are connected to the 4G network and simultaneously function as Wi-Fi routers capable of handling multiple connections at a time. This is the highest reading we recorded among the devices considered in this paper and falls in the category of 'extreme concern' or 'very far above normal'. The PFD drops below 1000 $\mu W/m^2$ at about 75 cm and below 10 $\mu W/m^2$ at 200 cm. By keeping the device about 200 cm or 2 m away from the user, one can attain a situation of 'slight concern' or 'slightly above normal'. From all the cases mentioned above, the lowest radiation observed while accessing the internet is in the case of a smartphone connected to a Wi-Fi router followed by a laptop connected to the Wi-Fi router. It should also be noted that accessing the internet via Wi-Fi routers involves less radiation in general than accessing the internet via cellular networks.

In terms of health risks, it can be concluded that Wi-Fi technologies also pose serious health risks in terms of chronic exposure, non-thermal, and biological effects of EMR but will not lead to any tissue heating or health risks arising from tissue heating.

D. EMR DUE TO BLUETOOTH DEVICES

1) BLUETOOTH SPEAKERS WITH AUDIO STREAM

Table 5 shows the schematic of the experimental setup used for analysing a Bluetooth speaker. A Bluetooth speaker was connected to a smartphone via Bluetooth wireless technology kept 3m away from the speaker. The power flux density between the two devices was measured and the results are plotted in Fig. 7.

TABLE 5. Experimental setup for bluetooth speaker.

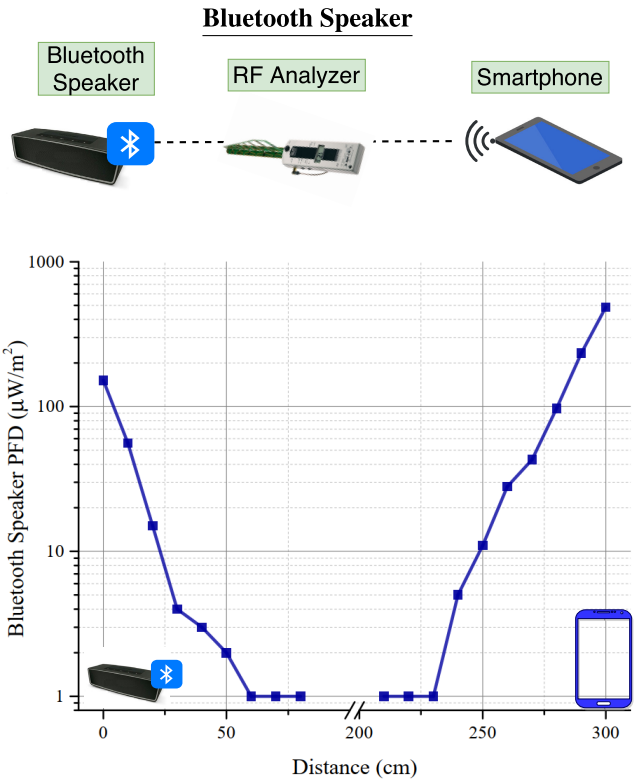


FIGURE 7. EMR results pertaining to Bluetooth speaker.

In Fig. 7, it can be seen that the highest reading just next to the Bluetooth speaker is 487 $\mu W/m^2$ and just 152 $\mu W/m^2$ near the smartphone. The PFD drops below 10 $\mu W/m^2$ at about 50 cm from the smartphone and 25 cm from the speaker which is a scenario of 'slight concern' or 'slightly above normal'. Therefore it is recommended to keep the smartphone at least 50 cm away, and the speaker at least 25 cm away from the user while playing the music.

2) BLUETOOTH EARPHONE

Wireless earphones are very quickly replacing wired earphones due to ease of use. A subject was chosen to wear Bluetooth earphones connected wirelessly to a smartphone (Samsung galaxy M30) kept in his trouser's right pocket. A long audio file was played to ensure continuous communication between the devices. We measured power flux density in different areas around the body as shown in Fig. 8.

3) SMARTWATCH CONNECTED WITH PHONE

Many people these days are using smartwatches to track their health and routine. Therefore it becomes very important to study whether the radiation coming from the usage of smartwatch is adversely affecting users health or not. The subject was made to wear a smartwatch on his right hand which was connected to smartphone (Samsung Galaxy M30) via Bluetooth, and the smartphone was kept in the subject's right trouser pocket. The power flux density was measured in different areas around the body as shown in Fig. 9.

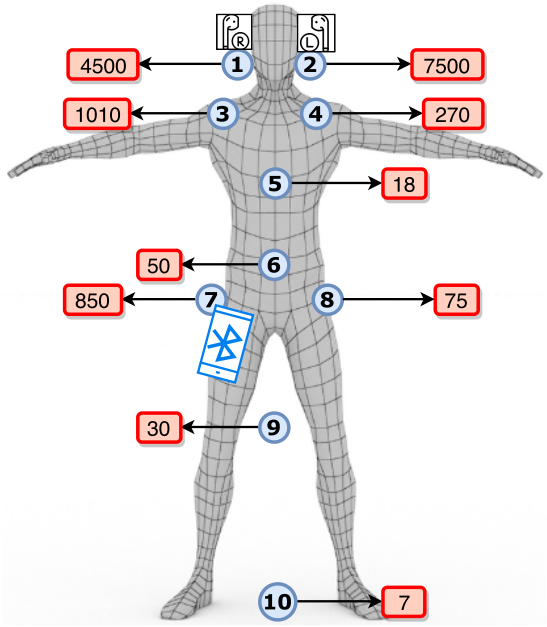


FIGURE 8. EMR readings on different parts of the body while wearing bluetooth earphones (in $\mu W/m^2$).

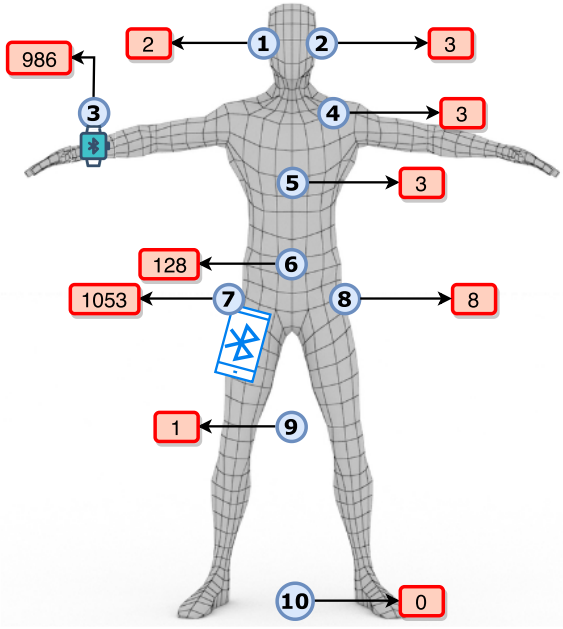


FIGURE 9. EMR readings on different parts of the body while wearing a smartwatch (in $\mu W/m^2$).

Based on the values of PFD shown in Fig. 8, it can be observed that the use of Bluetooth earphones heavily impacts the head region with PFDs in the range of 4000 - 8000 $\mu W/m^2$ which comes under the category of 'extreme concern' or 'very far above normal'. In the region of the pocket where smartphone is kept, the PFD is 850 $\mu W/m^2$ which is a situation of 'severe concern' or 'far above normal'. In the remaining regions, the PFD is not as significant. Thus, it can be said using Bluetooth earphones puts a person at risk of developing health issues related to non-thermal, chronic exposure and biological effects in the head, shoulder and pocket regions but is safe from any thermal effects of EMR exposure. In the case of a Bluetooth smartwatch, the radiation in the pocket region as well as near the smartwatch is about 1000 $\mu W/m^2$ (see Fig. 9) which can be considered a case of 'Extreme concern' and or 'Very far above normal'. Therefore, it is expected that a person may develop health issues arising from non-thermal, chronic exposure and biological effects only in the pocket and wrist regions. The observed radiation levels indicate that a user is not in any risk of health issues arising from thermal effects.

E. COLLECTIVE EXPOSURE

In most practical situations, there are several wireless devices functioning simultaneously in the vicinity of a person, which makes it becomes important to understand the collective radiation exposure due to all these devices. Here, we consider the case where a person is being exposed to EMR from Wi-Fi, Cellular and Bluetooth devices, namely, a laptop, smartphone, Wi-Fi router, smartwatch, Bluetooth earphones, and a Bluetooth speaker. We have considered these devices to ensure the best balance between worst-case exposure and the most probable set of devices that a person may use. In all practical situations, ambient EMR is always present. Therefore, our readings were taken in a practical test location where there was an ambient EMR of 5 $\mu W/m^2$.

For our measurements, we consider a test subject using his laptop kept on a desk, wearing a Bluetooth smartwatch on his left hand, and neck-band type Bluetooth earphones around his neck and also holding a smartphone to his right ear. The laptop is connected to a Wi-Fi router kept 50 cm away on the same table. The Bluetooth earphones are connected to the smartphone and playing music. The smartphone is put on call over the 4G network. A Bluetooth speaker is also kept on the same desk, which is connected to the laptop. Fig. 10 shows the test subject and the placement of various devices near him, and Fig. 11 the measured PFDs at several points near the test subject. At each test point, the orientation of the RF analyzer was adjusted to ensure the maximum reading.

As can be seen in Fig. 11, the measured PFD exceeded 10,000 $\mu W/m^2$ in all points except the leg region where a PFD of 500 $\mu W/m^2$ was recorded. This implies that the EMR in the leg region comes under the category of 'severe Concern' or 'far above normal,' while all other points showed a PFD of more than 10,000 $\mu W/m^2$ and thus come under the category of 'extreme concern' or 'very far above normal.' A PFD of 133,400 $\mu W/m^2$ near the Wi-Fi router, was the highest reading recorded in our test scenario, indicating that of all the devices, the Wi-Fi router was the most contributing factor to the cumulative exposure. Therefore, it is highly recommended to avoid keeping a Wi-Fi router on the table. Due to the proximity of the mobile phone, the region near the right ear is exposed to PFD of 36, 700$\mu W/m^2$. A PFD of 33, 600$\mu W/m^2$ recorded near the left arm can be attributed to the Wi-Fi router, smartwatch and laptop together. The PFD recorded near the chest, torso and groin region: 12300, 5700

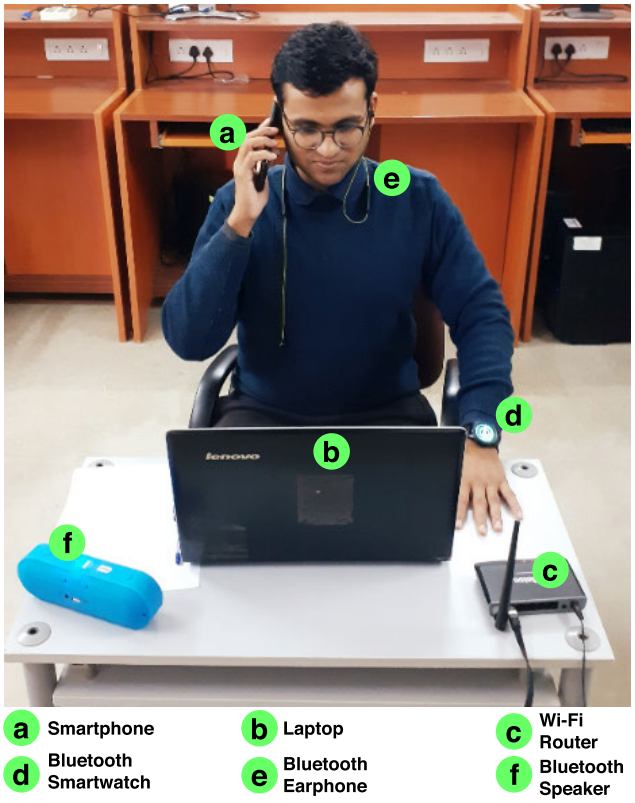


FIGURE 10. Placement of different devices in a collective exposure scenario (in $\mu W/m^2$).

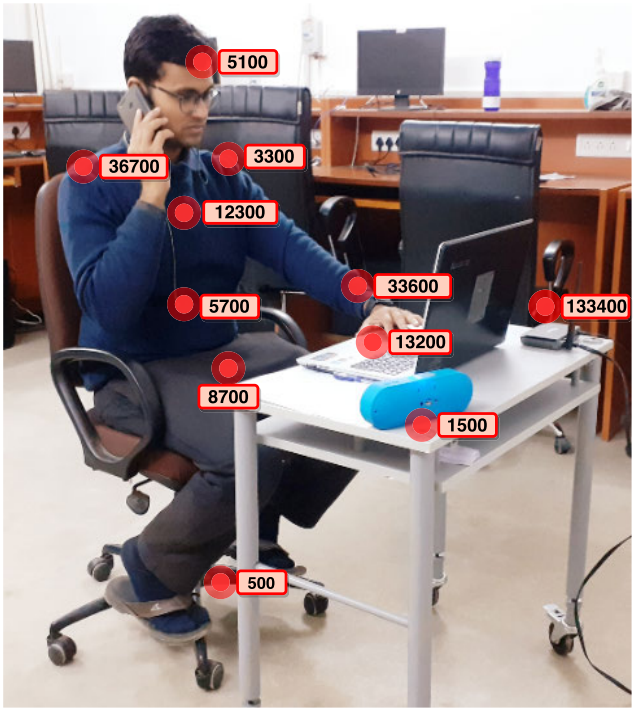


FIGURE 11. EMR readings at different points of in a collective exposure scenario (in $\mu W/m^2$).

and $8700\mu W/m^2$ respectively are all in the category of 'extreme concern' or 'very far above normal.' The exposure in the groin region in a cumulative exposure scenario is several times higher than the case considered in section IV-D.2, and IV-D.3, where a smartphone was kept in the pocket while being connected via Bluetooth to wireless earphones and smartphones respectively. A PFD of 13, $200\mu W/m^2$ was recorded near the keyboard of the laptop. This high reading is attributed to the laptop's Wi-Fi antennas, which are located on top of the screen. Thus, a wired connection to the router should always be preferred to Wi-Fi. Based on the above discussion, it can be concluded that keeping many wireless devices in close proximity is extremely dangerous in terms of non-thermal, chronic exposure and biological health effects but will not lead to any thermal effects since all measurements are within the ICNIRP reference values for general public exposure.

V. HEALTH RISKS AND HAZARDS OF EMR EXPOSURE

From released reports and published articles it is evident that there is a strong correlation between distance from cell towers and variety of EMR related health complaints. People who lived in the vicinity of cell towers or base stations reported health issues such as insomnia, fatigue, headaches and nausea. Some of these people were even diagnosed with serious health diseases such as leukemia, Alzheimer's, Autism, ASD, neuro-psychiatric issues, brain tumors and breast cancer. BioInitiative report has compiled more than 1800 scientific research articles which report serious impact on human and animal bodies like abnormal gene transcriptions, genotoxicity, DNA damage, chromatin condensation, loss of DNA repair capacity, reduction in free-radical scavengers, neurotoxicity, decreased sperm morphology and impaired development of brain and cranial bone. In this section we have summarized the adverse health effects of EMR exposure.

A. CANCER

The International Agency for Research on Cancer (IARC), an independently financed organisation classified Radio-frequency RF EMR under Group 2B carcinogen which means that there is a possibility that RF may be carcinogenic to humans [13]. However, Hardell and Carlberg [14] claim that there is clear evidence of cancer from long term, low level exposure to pulsating and non-ionizing EMR. Their findings warrant IARC to put RF EMR in Group 1: known carcinogen. Another study by The National Toxicology Program (NTP) conducted studies to evaluate potential health hazards and the risk of cancer from RF Radiation. Mice and rats were used as test subjects and were tested on exposure to RF Radiation in the 2G and 3G spectrums (700 - 2700 MHz). This study reported clear evidence of tumor in the hearts, brains and adrenal glands of male rats [15].

Although, not many biophysical mechanisms have been proposed regarding how RF Radiation leads to tumor causing effects, the thermal exposure limits are set solely based on one observed phenomenon which is the amount of power absorbed per mass of tissue or in other words, how much the tissue is getting heated. The thermal limits are specified

such that any RF radiation above these limits starts to heat the body and shows observable effects like disturbance of blood flow and metabolism. Nonetheless, few studies have reported that even at radiation levels below the accepted limit (and legally defined) for human exposure there are signs of tumor-promoting effects [14].

B. PREGNANCY AND INFERTILITY

A strong correlation between male infertility and EMR from mobile phones has been asserted by several researchers [16]. A case study [17] was conducted on male wistar albino rats who were exposed for 14 days, 15 minutes each day to high EMR. The radiation had impacted their testicular architecture and enzyme activity. It was shown that EMR from mobile phones induces an oxidative stress in testicular tissues and ultimately results in decrease of semen quality and lower sperm motility. The severity of oxidative stress depends on usage patterns of the mobile phone owner [17]. In a 2017 study to evaluate the effect of 4G-LTE EMR on sperm formation in male rats, it was concluded that longer durations of exposure results in decreased spermatogenesis [18]. Incidents have been reported where telecom workers who were accidentally exposed to high EMR doses developed skin burns and injury to heat-sensitive tissues such as the lens of the eyes, the testicles and the brain, leading respectively to cataract, male infertility and seizures [19]–[21].

The carcinogenic nature of EMR which results in mutation of sperm cells as well as testicular cancer has also been reported [22]. Thus, the probability that future generations will inherit unhealthy or low-immunity genes is also increased. In a case study which involved exposing pregnant rats to EMR during different stages of pregnancy, uterine congestions, dead and reabsorbed fetuses, hemorrhage, unequal and asymmetrical distribution of fetus implantation sites, malformation, hematoma, short tails and growth restrictions were observed [23].

According to [24], children whose mothers used cell phones during pregnancy had 25% more emotional problems, 35% more hyperactivity, 49% more conduct problems and 34% more peer problems.

C. AUDITORY SYSTEM DAMAGE

When a mobile device is actively connected with the cellular network, all the components of the auditory system including the skin, external, middle and inner ear, cochlear nerve and the temporal lobe surface absorb RF energy. Moreover, it is known that the outer hair cells in the cochlea are highly sensitive to a wide variety of exogenous and endogenous agents which include externally applied electric and magnetic fields [25]. EMR is damaging to unprotected or externally exposed biological tissue such as the outer hair cells in the cochlea. People who have an overactive cortical stress network in the brain are more vulnerable to tinnitus [26].

A common disease or effect is *Tinnitus*, which is in most cases a neurological disorder. A person suffering from tinnitus perceives high-frequency ringing among other sounds which are externally non-existent. Such people generally report poor quality of sleep, and several difficulties throughout their daily life. In the worst cases, even suicides have been reported. In light of EMR, it is relevant to note that the number of tinnitus cases reported since the last few decades has increased several folds [27]. Studies have shown the evidence that the main cause for such an increase can be attributed to the widespread and long-term usage of cellular phones, particularly in those cases where one ear is much dominantly used over the other [28].

Another phenomenon to be aware of is *RF Hearing* which was confirmed to exist as early as 1960s. Although RF energy is electromagnetic in nature, some of it is converted into acoustic energy both within and outside the cochlea and is perceived as a sound centered at about 5 KHz. The exact frequency may vary depending on the dimensions of the subject's head [29].

Dabholkar *et al.* [30] reviewed several long term case studies and concluded that long term intensive use of mobile phones does lead to hearing losses. Prolonged use (> 1 year) of mobile and cellular technology may decrease the ability of a person to hear high-frequency sounds. The person is also more likely to develop acoustic neuroma, in which non-cancerous tissue develops on a nerve which links the inner ear with the brain. In advanced stages of acoustic neuroma, pressure is exerted on the brain which may result in dangerous neurological effects including vertigo, confusion, unsteadiness, facial numbness and headaches. But casual or infrequent usage does not lead to any immediately recognizable adverse effects or any significant damage to the auditory system.

D. EFFECTS ON CHILDHOOD DEVELOPMENT

Statistics show that in recent years, more children have begun using cellphones or smartphones compared to the elder generation. In addition, it is observed that the average age at which children nowadays begin using smartphones is also significantly lesser than before. Therefore it is expected that this population will absorb significantly more EMR radiation throughout their lifetime. The existing public safety limits for EMR exposure are not acceptably protective of public health, especially the young population including babies, neonate, fetus and embryo. EMR exposure to pregnant women have detrimental consequences on the future health of the child. The time a foteus spends in the mother's womb is a critical time of devleopment because the health problems that are once laid down in the cells or in epigenetic changes in the genome have life-long consequences on the health of that individual [31]

The young population are more vulnerable to EMR exposure because of their smaller body mass and rapid physical development, both of which magnify the impact of EMR on body. The differences in bone density and the amount of fluid in a child's brain compared to an adult's brain allow children to absorb greater quantities of RF energy deeper into their brains than adults [32]. It is known in the field of

medicine that the brain tissue in children shows more electrical conductivity when compared with adults. This allows for more EMR penetration in proportion to the dimensions of the head. Effects on the nervous system which is still in developmental stages are also causes of concern. While anatomical development of the nervous system in children is finished, EMR could still hamper the functional development which generally progresses into adulthood [33].

E. BLOOD RELATED DISORDERS

Exposure to even very low intensity EMR can affect the blood-brain barrier by increasing it's permeability. Blood-brain barrier prevents the flow of toxins into sensitive brain tissues and when it's permeability increases due to exposure from EMR it no longer provides the protective barrier. Salford *et al.* [34] conducted a study and found that just single two hour exposure to EMR from cell phone results in an increased leakage of blood-brain barrier, and 50 days of such exposure can lead to neuronal damage. The EMR level as low as 0.001 W/kg can affect the blood-brain barrier and this limit is about 1000 times lower than the FCC (1.6 W/kg) and ICNIRP (2 W/kg) limits allowed. Research is required to investigate the damage done by EMR exposure on other barriers like the blood-placenta barrier (that protects the developing fetus), the blood-testes barrier (that protects developing sperm), the blood-ocular barrier (that protects the eyes) and the blood-gut barrier (that protects proper digestion and nutrition).

F. DNA DAMAGE

DNA molecules in our body directly interact with EMR. The double helical structure of DNA causes it to act like a *fractal antenna* [35]. The characteristic of a *fractal antenna* is that it interacts with wide range of frequencies. Therefore, the structure of DNA makes it vulnerable to damage from EMR exposure over the entire range of non-ionizing frequencies i.e. from extremely low frequency range (300 Hz to 3 kHz) to radio frequency range (3 kHz to 300 GHz). This interaction of DNA and EMR generates free radicals, produces stress proteins and causes gene mutations. Human DNA and stems cells are permanently damaged by EMR exposure as they do not have the ability to adapt to chronic exposures of EMR and thus DNA repair is not possible [36].

G. EFFECTS ON MENTAL AND COGNITIVE HEALTH

Many neurodegenerative diseases like Parkinson's disease, Alzheimer's disease and motor neuron disease are found to be caused and triggered by EMR exposure [37]. EMR damages the neurons of the brain, reduces the neuronal reactivity, prolongs their refractory period and increases the neural membrane conductivity. All such diseases mentioned above involve death of specific neurons and therefore are called neurodegenerative diseases.

As mentioned in the introduction of this section, people living in vicinity of cell towers and base stations are prone to develop many neuropsychiatric problems like tremors, numbness, headache, nausea, memory loss, dizziness, altered reflexes, depression and many other severe brain and cognition related health problems such as paralysis, stroke and psychosis [38], [39].

VI. PROTECTIVE MEASURES AND AMBIENT EMR MINIMIZATION

Based on the discussion in section V, it becomes very clear that the people exposed to EMR must adopt some preventive measures to limit their exposure to harmful RF EMR. In many situations such as those discussed in Section IV, we are exposed to EMR almost daily for prolonged periods of time. While it may not be possible to entirely eliminate such exposure, such as in workplaces, some protective measures could be taken by people to reduce the amount of EMR they absorb and thereby reduce the damage done to their bodies. In this section we present some techniques which are either based on externally attenuating the EMR before it hits the body and some techniques based on monitoring and deploying the EMR sources effectively and efficiently so as to minimize the ambient EMR levels. The techniques based on external attenuation have to practised on an individual level, while the ambient EMR minimization techniques can be practised on government and society levels only.

A. PROTECTIVE MEASURES

1) EMR ABSORBING CLOTHES

As a result of the research in the past decade suggesting the dangers of EMR on the human body, a variety of EMR absorbing clothing solutions began surfacing the market. Such clothing options incorporate surface-metallized fiber woven fabric in their apparels. Metals like copper, silver or aluminium are chemically deposited on ordinary knitting fabrics to obtain surface-metallized fiber knitted fabric. Such metals are known to attenuate EMR by scattering incident radiation [40]. While many manufacturers do claim a specific EMR absorbing efficacy in decibels over a certain frequency range, it cannot be said for sure whether the attenuation rating claimed by such clothes was obtained through well-designed tests. Such clothes are generally bi-layered, where the first layer reflects some of the incident EMR and the second (inner) layer absorbs the radiation which passed through the first layer [41]. The higher the decibel value, greater is the shielding capability. Most of the materials have a characteristic range of frequencies which they absorb. For example, a product that has an effect of 30 dB at 1 to 5 GHz would mean that the product blocks 99.9% of radiation in the wavelength range of 1 to 5 GHz, which includes most of the RF EMR encountered commonly: cell phones, Wi-Fi routers and bluetooth devices.

Metals are the best solution to reflect EMR. Hence, such clothing generally has metallic strands or metal silk fibers embedded within them which reflect incident EMR away from the wearer's body. Metal silk fibers are also blended with regular fabrics to obtain specially designed electromagnetic shielding fabrics which are used to make different

clothing products such as curtains and blankets. Chemical deposition processes are also used to form a conductive metal plating on top of regular fabric. In any of the above mentioned varieties of EMR protective clothing, the shielding capability increases with the amount of metal used in the product.

Pregnant women, young infants and children, are especially recommended to wear radiation protective clothing due to their higher vulnerability to radiation absorption and damage. Workers who are exposed to abnormally high levels of EMR, such as cell tower repairmen need specially designed EMR reflective and protective clothing designed specifically for their occupation.

2) EMR ABSORBING/REFLECTING PAINTS

Many households are located very close to cell towers which have multiple antennas operating on them. The wall facing in the direction of the tower is most exposed to RF EMR. If it is unprotected, i.e, it does not have any absorptive/reflective coating, the people living in such homes are more prone to develop EMR related health issues as discussed in Section V. One very effective way to prevent high levels of EMR from penetrating the home is to use EMR absorbing/reflecting paints which are specially designed to absorb, reflect or scatter EMR in the RF frequency range as is emitted by the cell towers.It is desired to achieve high levels of attenuation across a wide frequency range.

Materials which have numerically equal values of permittivity and permeability and high loss tangents are more suited to be used in making EMR absorbing paints. The former characteristic guarantees good impedance mathching with the air and thus enable incident signals to enter the surface without any reflection. The latter characteristic enables the material to attenuate the EMR rapidly before it enters the home. By using such materials the reflection is also minimized. So, people standing outside the homes are also protected from high power EMR reflected from the walls of the homes. The power radiated from cell towers at certain frequencies may be much higher than others. EMR absorbing paints can address this problem as well because the frequency range at which maximum attenuation is achieved can be set by varying the thickness of the paint applied on the wall. Choosing a thickness to match complex permittivity and permeability can result in a considerable increase in the absorption bandwidth both at normal and oblique incidence of EMR. For example Folgueras *et al.* [42] have prepared two varieties of paints to absorb EMR. Both their formulation have a polyuerthane matrix. Carbonyl iron powder (10% w/w) and polyaniline (10% w/w) are the chemicals dispersed in the matrices of the two formulations respectively by mechanical agitation. The attenuation plots of these paints are shown in Fig. 12 (a) and (b) respectively. The paint of Fig 12 (a) achieves attenuation of 8 dB (84.1%) at 10 GHz and the paint of Fig 12 (b) achieves attenuation of 4 dB (60.1%) at 12 GHz. Such paints could be used to shield the EMR coming from 5G towers which are much higher than any RF communication used till date. To ensure the best protection, on-site testing can be done to accurately determine the frequency at which there is maximum radiation and also the minimum attenuation required to ensure that the residents are protected from any harmful effects. The customers can pass on these specifications to the manufacturer who can then adjust the chemical composition and also suggest the thickness required according to the customers' needs. This would ensure maximum protection at minimum expenditure.

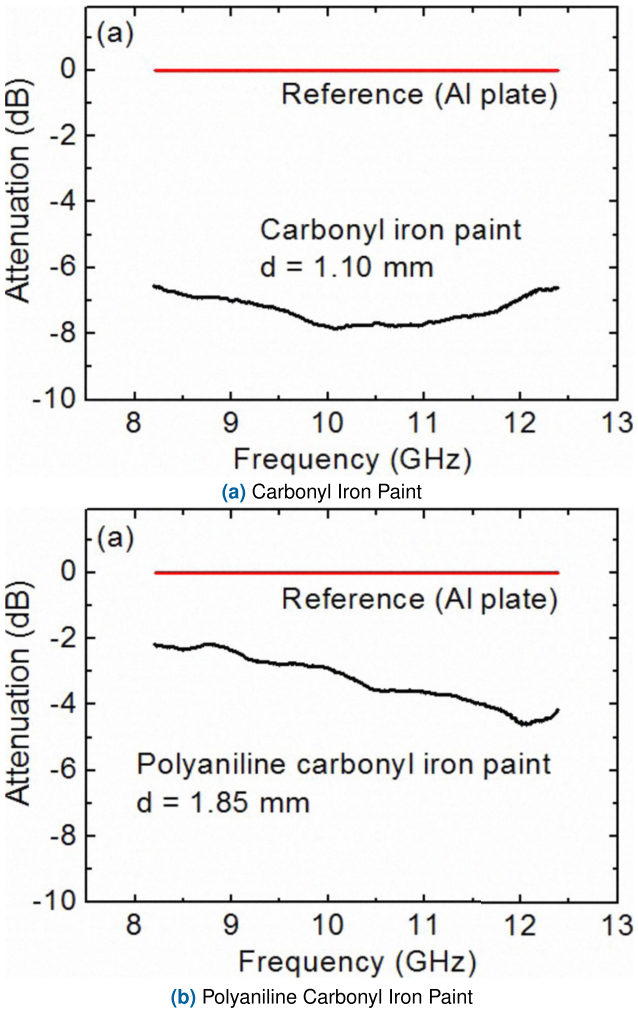


FIGURE 12. Performance of EMR absorbing paints [42].

3) AEROGEL

Aerogels are a class of high performance EM radiation absorbing materials designed by fitting several nanosheets of graphene into three-dimensional structures [43]. Their excellent absorption characteristics is due to their high surface area and dielectric loss [44]. The reflection loss (RL) of a material is a characteristic of the input impedance Z_{in}, and output impedance Z_o. RL and Z_{in} are evaluated as follows:

$$\mathrm{RL(dB)} = 20\log\left|\frac{Z_{in}-Z_0}{Z_{in}+Z_0}\right| \tag{2}$$

$$Z_{in} = Z_0\sqrt{\frac{\mu_r}{\varepsilon_r}}\tanh\left(j\frac{2\pi fd}{c}\sqrt{\varepsilon_r\mu_r}\right) \tag{3}$$

TABLE 6. Comparison of different aerogels.

Name of Aerogel	EA Bandwidth	Highest Reflection Loss	Range for EMR absorption
Three Dimensional Polypyrrole [3D-PPy/Paraffin]	6.2 GHz	-25 dB @ 3 mm pellet at 10 GHz	7 GHz ∼13 GHz
Graphene Aerogel Composites [CF@G]	4.1 GHz	-30.53 dB @ 2.5 mm pellet at 14.6 GHz	12 GHz ∼16 GHz
Graphene Aerogel Composites with polypyrrole coating [CF@G@PPy]	4.1 GHz	-45.12 dB @ 2.5 mm pellet at 14.6 GHz	12 GHz ∼16 GHz
Spongelike Polypyrrole aerogel with Reduced Graphene Oxide [S-PPy/RGO]	6.76 GHz	-54.44 dB @ 3 mm pellet at 12.76 GHz	10.20 GHz ∼16.96 GHz

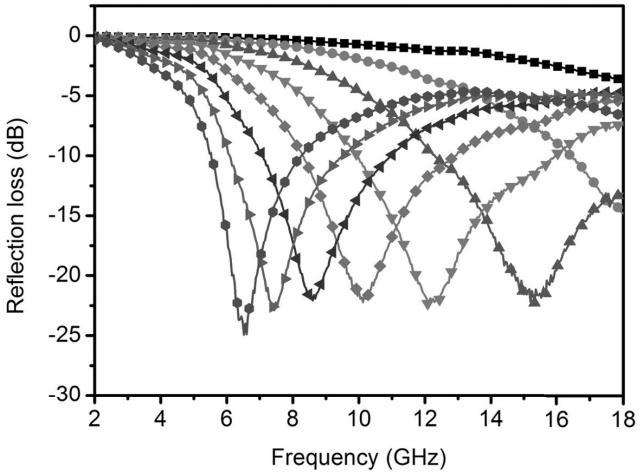


FIGURE 13. RL vs frequency of 3D-PPy aerogel (thickness varying from 1.5 to 5.0mm). [47].

In the above equations, Z_o is the impedance of the, ε_r is the complex permittivity, μ_r is the relative complex permittivity, f is the frequency, d is the material thickness, and c is the speed of light. According to fundamental mechanism of electromagnetic absorption, the most effective absorption would take place when the impedance matching conditions between the material and the free space is achieved [45]. Plots of reflection loss (RL) vs frequency such as in Fig. 13 are prepared for various thicknesses of the aerogel material. Such plots may be used to choose the best material for an application considering into account the most prominent frequency of radiation and the thickness of absorbing material permissible. The frequency at which highest RL occurs varies with the thickness of the aerogel as can be seen in Fig. 13. As the thickness of the aerogel pellet is varied, new phase matching conditions have to be established in order to maintain the RL [46].

Wang *et al.* [43] have prepared ultralight and mechanically strong 3D composite graphene aerogels with the use of waste cigarette filters. Their composite aerogel showed a minimum RL of −30.53 dB with a bandwidth of 4.1 Ghz. On coating with polypyrrole, a conducting material, the new composite showed minimum RL of −45.12 dB. Similarly, Xie *et al.* [47] prepared a self-assembled ultralight 3D polypyrrole (3D-PPy) aerogel, a composite which can reach an effective Electro-Magnetic bandwidth of 6.2 GHz with minimum RL of −25 dB. Wu *et al.* [48] prepared a spongelike self-assembled ultralight aerogel which showed a minimum RL of −54.44 dB with a bandwidth of 6.76 GHz. The above mentioned aerogels and their absorption characteristics are summarized in Table 6.

B. AMBIENT EMR MINIMIZATION

1) OPTIMAL MOBILE NETWORK DEPLOYMENT

With ever-growing consumer demands for telecommunication services and the deployment of 5G technology soon to come, many new base stations will have to be deployed over the already existing 2G/3G and 4G network. Therefore, it becomes very important to achieve optimal deployment of cellular Base stations or wireless access points in order to minimize radiation levels. Compared to most optimization solutions in research [49]–[52], which have considered deployment cost, coverage level and base station capacity in the objective function, Salcedo-Sanz *et al.* [53] have considered an additional criterion, electromagnetic pollution. They have proposed a solution called Grouping Coral Reefs Optimization (GCRO) and demonstrated its effectiveness when applied to a Mobile Network Deplyment Problem (MNDP). Deruyck *et al.* [54] have presented a tool which achieves different levels of optimization for power consumption and human exposure in LTE networks. Plets *et al.* [55] have developed a gentic optimization algorithm for Wireless Local Area Networks (WLANs) which optimizes the Exposure Index (EI) [56] taking into account all sources of exposure such as uplink, downlink and the uplink of other users, realistic duty cycles while simultaneously ensuring Quality of Service (QoS) to all users.

Chiaraviglio *et al.* [57] have proposed important guidelines to be followed during deployment of 5G base stations in order to achieve EMR-aware 5G networks. These guidelines include modelling of 5G radio technologies which helps to select the proper configuration of the installed equipment for each considered site, modelling of the generated EMR levels over the territory which allows for a fine-grained antenna site characterization based on the knowledge of the radiation pattern and the emitted power of each antenna in the site, integration of current and future EMF limits, modelling of the set of candidate sites based on idealized distributions and operator-based constraints, modelling of 5G traffic demands and QoS based on spatial and temporal fluctuations that can characterize the radiated power demand and modelling of 5G network topologies.

2) ELECTROMAGNETIC POLLUTION MONITORING USING WIRELESS SENSOR NETWORKS

With new base stations being installed on daily basis, monitoring EMR pollution on a real-time basis becomes essential to detect and locate potentially dangerous EMR levels and notify corresponding authorities to ensure safety of nearby people. In this regard, Nouh *et al.* [58] have proposed an EMR pollution monitoring system using a Wireless Sensor Network (WSN) based framework. Their system uses a genetic algorithm on EMR data acquired from WSN nodes do detect and report any EMR limit violations. The WSN nodes are deployed uniformly over an area and are equipped with sensors to detect EMR in the frequencies which are most prevalent.

VII. PROACTIVE PREVENTIVE TECHNIQUES

Certain simple steps can be taken by any individual to avoid EMR exposure. Spreading awareness about dangers and health hazards of EMR in schools, hospitals and other areas having sensitive population such as pregnant women, small children and old people, and giving them simple suggestions based on their surroundings, can help lot of citizens avoid EMR related health issues without spending resources on integrating and deploying EMR attenuating technology. We have listed few such *proactive and common sense* measures to minimize unnecessary and needless EMR exposures keeping in mind various environments and operating conditions:

1) In residential places such as homes, at study table and other places where people sit for long periods to use internet, we can have ethernet cable to avoid getting exposed to 2.4 GHz Wi-Fi signal. Many switches to control the power to Wi-Fi router can be installed throughout the house to readily switch off the Wi-Fi radiation when not in use. The windows can be covered with transparent EMR absorbing/reflecting thin film and outer walls can be painted with EMR absorbing paints. Use of landlines for long talks should be preferred over mobile phones and cordless phones. Rooms of children below the age of 12 should be particularly safeguarded from EMR as they are more prone to EMR related health issues.
2) In hospitals and medical institutions, it is especially important to implement guidelines regarding EMR safety as hospitals cater to very sensitive population such as pregnant women, newborn babies, and unhealthy people. Hospitals should not adopt full Wi-Fi coverage technology. Preferably they should give ethernet ports to all the doctors and hospital wards. Government should lay guidelines to not allow deployment of Base Station or Cell tower in near vicinity of hospitals. Units for sensitive population like ICU, CCU, NICU and operation theaters should avoid all sorts of devices which use wireless communication such as wireless incubators and remotely operated instruments. Only those sources of EMR should be used which are meant for medical purposes. Pregnant women should be educated to avoid prolonged use of mobile devices, laptops and other wireless devices.
3) In educational institutions, there is a trend to shift to modern technology like wireless projectors in smart classrooms, campus wide Wi-Fi access, use of digital notebooks, etc. As we have mentioned in section V, children are very sensitive to EMR and health issues like autism and impaired mental development are becoming very common among young population. Schools where children spend almost 8 to 10 hours need to minimize the ambient EMR levels inside the classroom by using EMR absorbing paints and window films. School authorities should give special rules and guidelines for high population density zones such as classrooms and school buses, which get really high EMR levels due to everyone using wireless devices simultaneously. If all classrooms cannot be made to comply with EMR safety standards, schools should construct special classrooms to maintain 'no wireless' condition, and allow students to opt for it who believe their academic, social or behavioural progress is being hindered by EMR related health issues.

VIII. DISCUSSIONS

Currently employed public exposure limits do not provide sufficient protection to people both in terms of long-term and short-term exposure. The exposure limits specified by ICNIRP take into account only the thermal effects and not the non-thermal biological effects in determining their limits. The ICNIRP safe exposure limits for general public for the wireless technologies discussed in this paper are between 4,000,000 $\mu W/m^2$ to 10,000,000 $\mu W/m^2$ which is several orders of magnitude higher than the limits prescribed by the Building Biology, AMA and the BioInitiavtive standards. While exposure levels within the limits prescribed by ICNIRP only guarantee safety from the thermal effects of EMR

TABLE 7. Recommendations for using cellular, Wi-Fi and Bluetooth devices.

Device Type	Recommendations
Cell Phones/ Smartphones on cellular networks	1. Network: For internet connectivity, prefer Wi-Fi. If not available, prefer to use 4G networks for both calling and browsing/data streaming. 2. Calling: Use wired headphones and keep the phone at least 1m away while calling. 3. Browsing/ Video Streaming: Keep device on a table/platform at least 50 cm away.
Wi-Fi Devices	1. Prefer smartphones over laptops for casual work such as e-mails/ browsing. 2. Keep smartphone/laptop on a table and operate from an arm's distance (50cm). 3. Avoid keeping smartphone in the pocket while it is connected to a Wi-Fi router. 4. Avoid keeping laptop on the lap while it is connected to a Wi-Fi router. 5. Wireless (Adhoc transfer) : Stay at least 1m away from both sender and receiver. 6. 4G Wireless Hotspot: Stay at least 2m away from the device while it is active.
Bluetooth Devices	1. Speakers: Keep speakers at least 25 cm away and connected smartphones at least 50 cm away. 2. Smartwatch: Avoid unless absolutely necessary. 3. Earphones: Avoid unless absolutely necessary.

exposure, there are numerous scientific studies, suggesting that even non-thermal effects pose a significant threat. These non-thermal effects are observed at several orders of magnitude of radiation lower than those of thermal effects. Along with the thermal and non-thermal effects, several other factors such as frequency, duration of exposure, pulse shaping, power level also contribute to health risks of EMR.

It has already been several years since the wireless-technologies have been deployed, meaning that the public has already been exposed to a lot of harmful EMR without their knowledge. It may be anticipated that this section of the population will suffer from many of the health hazards discussed in section V. If corrections are not made now, especially when the number of wireless devices are growing exponentially which leads to an exponential increase in public EMR exposure, the current and future public will be at even greater risks of both known and unknown health hazards. In particular, women, children and fetus are hypersensitive to EMR and special care must be taken to protect these groups from both short and long term exposure.

Smartphones, laptops, Wi-Fi routers, Wi-Fi Hotspots and Bluetooth devices such as speakers, earphones and smartwatches are the most common sources of exposure today. These devices are used extensively in very close proximity. Based on the discussion in section IV, it is clear that usage of mobile phones for calling or data streaming, using laptops and smartphones on Wi-Fi networks, using 4G wireless hotspots are especially dangerous. Exposure to radiation from one or two devices, such as a smartwatch on the wrist and a connected smartphone may result in high radiation levels only near the hand and pocket region, a cumulative and simultaneous exposure to several sources of EMR, such as laptop, smartphone, Wi-Fi router, Bluetooth earphones, smartwatch and speaker leads to dangerous levels of EMR all throughout the body and must be avoided. While it may take very long for the exposure levels of these devices to be corrected, the users can take some steps to minimize the risk of using these devices. A summary of the recommendations regarding usage of these devices is given in Table 7.

There are wired solutions in each of these use cases which can be adopted to greatly minimize EMR exposure. Using handsfree earphones to make phone-calls, using LAN cables instead of Wi-Fi, wired earphones, switching off Wi-Fi routers when not in use, maintaining a good distance from the wireless devices, are some of the measures to minimize exposure. A two-fold approach can be followed to minimize harm from EMR pollution. Firstly, measures can be taken to protect people from the already existing high levels of EMR. Second, proactive prevention techniques can be adopted in environments such as households, schools and hospitals to greatly minimize EMR exposure. These have been explained in detail in Section VI and VII of this paper.

Both individuals and governments must be aware of the fact that the current population has already been exposed to dangerous levels of radiation and the resulting adverse health effects may surface in people at any time. In this regard, proper planning and execution, both on governmental and individual levels is required to properly handle a breakout of EMR related health issues in large numbers of people in all areas of the world. Specifically, it must be noted that the radiation in 5G networks is suspected to increase by several folds. It will not only affect regions near cell towers and 5G devices but all indoor and outdoor environments in the region of coverage. Thus, almost all people in the area of coverage of 5G networks may be exposed to dangerous levels of EMR. Without thorough research and well-designed safety measures in place, wide-spread deployment of 5G networks could prove to be dangerous.

IX. CONCLUSION

People should be made aware that the EMR from using day to day cellular, Wi-Fi and Bluetooth devices are harmful to human health. The levels of radiation observed in most cases such as phone calls, internet browsing on laptops and smartphones, using wireless routers and hotspots, Bluetooth smartwatches and smartphones are unsafe when compared with radiations limits determined by medical bodies. According to the current medical literature, various adverse health effects from exposure to RF EMR have been well documented. For now, wireless technologies must be avoided as much as possible. New and innovative wired solutions which provide the same level of user-friendliness should be encouraged. Intervention of government and medical bodies with the main purpose of protecting human health is of utmost necessity to ensure good economic development without compromising the health of the population. Countries must adopt the guidelines suggested by medical bodies which take into account both thermal and non-thermal effects of EMR. At present, all individuals must take preventive and protective measures to protect themselves from harmful EMR exposure.

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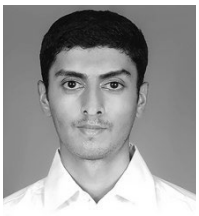

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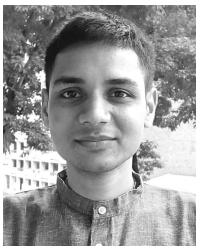

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31 May 2016

Cell Phone Radiation Study Confirms Cancer Risk

Orebro University, Sweden May 31, 2016

The National Toxicology Program under the National Institutes of Health has completed the largest-ever animal study on cell phone radiation and cancer. The results confirm that cell phone radiation exposure levels within the currently allowable safety limits are the "likely cause" of brain and heart cancers in these animals, according to Dr. John Bucher, Associate Director of the NTP. One in twelve (12) male rats developed either malignant cancer (brain and rare heart tumors) or pre-cancerous lesions that can lead to cancer. Tumors called schwannomas were induced in the heart, in the same kind of cells in the brain that have lead to acoustic neuromas seen in human studies. The NTP says it is important to release these completed findings now given the implications to global health. No cancers occurred in the control group.

Lennart Hardell, MD, PhD of Orebro University says *"(T)he animal study confirms our findings in epidemiological studies of an increased risk for glioma and acoustic neuroma among people that use wireless phones, both cell phones and cordless phones (DECT). Acoustic neuroma is a type of Schwannoma, so interestingly this study confirms findings in humans of increased risk for glioma and acoustic neuroma. In 2013 we called for upgrading the risk in humans to Group 1, the agent is carcinogenic to humans. It is now time to re-evaluate both the cancer risk and other potential health effects in humans from radiofrequency radiation and also inform the public."* says Hardell. "*This NTP evidence is greatly strengthening the evidence of risk, is sufficient to reclassify cell phone radiation as a known cancer-causing agent, and confirms the inadequacy of existing public safety limits."*

The World Health Organization's 10-year study of human use of mobile phones concluded there is an increased risk for malignant brain tumors among the heavier mobile phone users, particularly where it is used mostly on one side of the head. The 2010 Interphone mega-study of cancer in humans using mobile phones found higher cancer risk, but at that time there was little animal testing to support the risks identified in humans. Now, this NTP study has shown statistically significant risks with a dose-response relationship to the amount of exposure. It proves that non-ionizing radiation can plausibly cause cancer, not just ionizing radiation like x-rays and puts to rest the traditional scientific argument that cell phone radiation can't do harm.

Dr. Bucher said the animals' exposure was about the same as for people who are heavy users of cell phones. He also confirmed that the exposure of 1.5 W/Kg is lower than currently allowed under FCC public safety limits. Testing on rats is standard in predicting human cancers.

The BioInitiative Report (2014) documents nervous system effects in 68% of studies on radiofrequency radiation (144 of 211 studies). This has increased from 63% in 2012 (93 of 150

studies). Genetic effects (damage to DNA) from radiofrequency radiation is reported in 65% (74 of 114 studies); and 83% (49 of 59 studies) of extremely-low frequency studies.

Dr. Christopher Portier, formerly with the NTP commented **this is not just an associated finding—but that the relationship between radiation exposure and cancer is clear. *"I would call it a causative study, absolutely. They controlled everything in the study. It's [the cancer] because of the exposure*. "*This is by far—far and away—the most carefully done cell phone bioassay, a biological assessment. This is a classic study that is done for trying to understand cancers in humans"***

http://www.bioinitiative.org/cell-phone-radiation-study-confirms-cancer-risk/

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REVIEW ARTICLE

Oxidative mechanisms of biological activity of low-intensity radiofrequency radiation

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ABSTRACT

This review aims to cover experimental data on oxidative effects of low-intensity radiofrequency radiation (RFR) in living cells. Analysis of the currently available peer-reviewed scientific literature reveals molecular effects induced by low-intensity RFR in living cells; this includes significant activation of key pathways generating reactive oxygen species (ROS), activation of peroxidation, oxidative damage of DNA and changes in the activity of antioxidant enzymes. It indicates that among 100 currently available peer-reviewed studies dealing with oxidative effects of low-intensity RFR, in general, 93 confirmed that RFR induces oxidative effects in biological systems. A wide pathogenic potential of the induced ROS and their involvement in cell signaling pathways explains a range of biological/health effects of low-intensity RFR, which include both cancer and non-cancer pathologies. In conclusion, our analysis demonstrates that low-intensity RFR is an expressive oxidative agent for living cells with a high pathogenic potential and that the oxidative stress induced by RFR exposure should be recognized as one of the primary mechanisms of the biological activity of this kind of radiation.

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Introduction

Intensive development of wireless technologies during the last decades led to a dramatic increase of background radiofrequency radiation (RFR) in the human environment. Thus, the level of indoor background RFR in industrialized countries increased 5,000-fold from 1985 to 2005 (Maes, 2005). Such significant environmental changes may have a serious impact on human biology and health. As a proof of such impact, a series of epidemiological studies on the increased risk of tumorigenesis in "heavy" users of wireless telephony exists (Hardell et al., 2007, 2011; Sadetzki et al., 2008; Sato et al., 2011). Some studies indicate that long-term RFR exposure in humans can cause various non-cancer disorders, e.g., headache, fatigue, depression, tinnitus, skin irritation, hormonal disorders and other conditions (Abdel-Rassoul et al., 2007; Buchner & Eger, 2011; Chu et al., 2011; Johansson, 2006; Santini et al., 2002; Yakymenko et al., 2011). In addition, convincing studies on hazardous effects of RFR in human germ cells have been published (Agarwal et al., 2009; De Iuliis et al., 2009).

All abovementioned studies dealt with the effects of low-intensity RFR. This means that the intensity of radiation was far below observable thermal effects in biological tissues, and far below safety limits of the International Commissions on Non-Ionizing Radiation Protection (ICNIRP) (ICNIRP, 1998). To date, molecular mechanisms of non-thermal effects of RFR are still a bottleneck in the research on the biological/health effects of low-intensity RFR, although recently many studies have been carried out on metabolic changes in living cells under low-intensity RFR, and comprehensive reviews were published (Belyaev, 2010; Consales et al., 2012; Desai et al., 2009; Yakymenko et al., 2011). In the present work, we analyze the results of molecular effects of low-intensity RFR in living cells and model systems, with a special emphasis on oxidative effects and free radical mechanisms. It might seem paradoxical that, despite being non-ionizing, RFR can induce significant activation of free radical processes and overproduction of reactive oxygen species (ROS) in living cells. We believe that the analysis of recent findings will allow recognition of a

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general picture of the potential health effects of already ubiquitous and ever-increasing RFR.

Radiofrequency radiation

RFR is a part of electromagnetic spectrum with frequencies from 30 kHz to 300 GHz. RFR is classified as non-ionizing, which means that it does not carry sufficient energy for ionization of atoms and molecules. A part of RFR with the highest frequencies (300 MHz to 300 GHz) is referred to as microwaves (MWs). MW is RFR with the highest energy, which can potentially generate the highest thermal effects in the absorbing matter.

The main indexes of RFR are (i) frequency (Hz); (ii) intensity or power density (PD) of radiation (W/m^2 or $\mu W/cm^2$); (iii) its modulated or non-modulated nature; and (iv) continuous or discontinuous pattern of radiation. For the absorbed RFR energy, a parameter of specific absorption rate (SAR) is used (W/kg). The most common digital standard of RFR for mobile communication is still GSM (Global System for Mobile communication), which utilizes frequencies at about 850, 900, 1800 and 1900 MHz. This radiation is frequency modulated, with channel rotation frequency of 217 Hz, and belongs to the radiation of the pulsed mode (Hyland, 2000).

As to the international safety limits, the ICNIRP recommendations restrict intensity of RFR to 450–1000 $\mu W/cm^2$ (depending on the frequency of radiation) and the SAR value to 2 W/kg, as calculated for human heads and torsos (ICNIRP, 1998). These indexes were adopted by ICNIRP based on the behavioral response of laboratory rats, which were exposed to gradually increased intensities of RFR to determine the point at which the animals became thermally distressed (Gandhi et al., 2012).

Low-intensity RFR is referred to as radiation with intensities which do not induce significant thermal effects in biological tissues. Accordingly, any intensity of RFR under the ICNIRP limits can be referred to as low-intensity. In this paper we will analyze only the effects of low-intensity RFR.

Physical/biophysical effects of low-intensity RFR in living cells

RFR, especially MW, can produce thermal effects in matter due to interaction with charged particles, including free electrons, ions or polar molecules, inducing their oscillations in electromagnetic field. The thermal effect of MW can be seen when warming food in the microwave. The effect strongly depends on the intensity of radiation and is mostly negligible under low-intensity RFR conditions. On the other hand, energy of RFR/MW is insufficient not only for the ionization of molecules, but even for activation of orbital electrons. Hence, RFR was often assessed as a factor producing only thermal effects. Nevertheless, evident biological effects of low-intensity RFR promoted research on physical mechanisms of non-thermal biological effects of this kind of radiation.

A biophysical model of a forced-vibration of free ions on the surface of a cell membrane due to external oscillating electromagnetic field (EMF) was proposed (Panagopoulos et al., 2000, 2002). According to the authors, this vibration of electric charges can cause disruption of the cellular electrochemical balance and functions.

A "moving charge interaction" model was proposed for low-frequency EMF (Blank and Soo, 2001). The authors explained activation of genes and synthesis of stress proteins under EMF exposure due to interaction of the field with moving electrons in DNA (Blank and Soo, 2001; Goodman and Blank, 2002). They also demonstrated that EMF increased electron transfer rates in cytochrome oxidase and accelerated charges in the Na,K-ATPase reaction. Moreover, they demonstrated acceleration of the oscillating Belousov–Zhabotinski reaction in homogeneous solutions due to the application of low-frequency EMF (Blank and Soo, 2003).

An ability of low-strength magnetic fields to trigger onset- and offset-evoked potentials was demonstrated (Marino et al., 2009). Effectiveness of a rapid magnetic stimulus (0.2 ms) has led the authors to a conclusion on direct interaction between the field and ion channels in plasma membrane. A plausible mechanism of overproduction of free radicals in living cell due to electron spin flipping in confined free radical pairs in magnetic field of RFR was proposed (Georgiou, 2010).

A significant effect of low-intensity RFR on ferritin, an iron cage protein present in most living organisms from bacteria to humans, was revealed (Céspedes and Ueno, 2009). Exposure of ferritin solution to low-intensity RFR significantly, up to threefold, reduced iron chelation with ferrozine. The authors explained that magnetic field of RFR plays a principle role in the observed effect, and that this effect is strongly non-thermal. The non-thermal mechanism of the interaction of RFR magnetic fields with ferritin is supposedly mediated by an inner super-paramagnetic nanoparticle ($9H_2O \times 5Fe_2O_3$ with up to 4500 iron ions), which is a natural phenomenon intrinsic to the cells. It results in reduction of input of iron chelates into the ferritin cage. The authors underlined the potential role of ferritin

malfunction for oxidative processes in living cell due to the participation of Fe^{2+} ions in the Fenton reaction, which produces hydroxyl radicals. In this respect, it is interesting to point to the results of an *in vitro* study with RFR exposure of rat lymphocytes treated by iron ions (Zmyślony et al., 2004). Although RFR exposure (930 MHz) did not induce detectable intracellular ROS overproduction, the same exposure in the presence of $FeCl_2$ in the lymphocyte suspensions induced a significant overproduction of ROS.

Another set of studies indicates on a possibility of changes in protein conformation under RFR exposure. Thus, low-intensity 2.45 MHz RFR accelerated conformational changes in β-lactoglobulin through excitation of so-called collective intrinsic modes in the protein (Bohr and Bohr, 2000a, 2000b), which suggests a principal ability of RFR to modulate the non-random collective movements of entire protein domains. Similarly, a frequency-dependent effect on intrinsic flexibility in insulin structure due to applied oscillating electric field was demonstrated (Budi et al., 2007). Moreover, macromolecular structure of cytoskeleton was significantly altered in fibroblasts of Chinese hamster after the exposure to modulated RFR of the GSM standard (Pavicic and Trosic, 2010). Thus, a 3 h exposure of fibroblasts to modulated RFR (975 MHz) led to significant changes in the structure of microtubules and actin microfilaments, which have polar cytoskeleton structures, while non-polar vimentin filaments reportedly stayed unchanged. Taking into account an extensive regulatory potential of cytoskeleton on cell homeostasis, these data could obviously add to the nature of the biological effects of RFR.

It was shown that ornithine decarboxylase (ODC) can significantly change its activity under low-intensity RFR exposure (Byus et al., 1988; Hoyto et al., 2007; Litovitz et al., 1993, 1997; Paulraj et al., 1999).

In addition, so-called "calcium effects" under RFR exposure in living cells have been demonstrated (Dutta et al., 1989; Paulraj et al., 1999; Rao et al., 2008), which include a significant increase in intracellular Ca^{2+} spiking. Taking into account that calcium is a ubiquitous regulator of cellular metabolism, these data point to a possibility that non-thermal RFR can activate multiple Ca^{2+}-dependent signaling cascades.

Finally, an ability of low-intensity MW to dissociate water molecules was demonstrated in model experiments years ago (Vaks et al., 1994). In these experiments, MW of 10 GHz with radiated power 30 mW produced a significant level of H_2O_2 in deionized water (and also in $MgSO_4$ solution) under stable temperature conditions. According to the authors, a kinetic excitation of liquid water associates $C(H_2O)$ upon the absorption of MW leads to subsequent viscous losses due to friction between moving clusters of water molecules. It results in partial irreversible decomposition of water, including breaks of intramolecular bonds (H–OH) due to a mechanochemical reaction, and generation of $H^{\bullet}$; $OH^{\bullet}$; H^+ and OH^- groups. Among these, the hydroxyl radical ($OH^{\bullet}$) is the most aggressive form of ROS, which can break any chemical bond in surrounding molecules (Halliwell, 2007). The authors assessed that this type of mechanochemical transformation in water could be responsible for 10^{-4}–10^{-8} relative parts of the total MW energy absorbed. Given the fact that the water molecules are ubiquitous in living cells, even a subtle chance for dissociation of water molecules under low-intensity RFR exposure could have a profound effect on tissue homeostasis. It is of note here that one $OH^{\bullet}$ radical can initiate irreversible peroxidation of many hundreds of macromolecules, e.g. lipid molecules (Halliwell, 1991). Taken together, these data show that non-thermal RFR can be absorbed by particular charges, molecules and cellular structures, and in this way can potentially induce substantial modulatory effects in living cell.

Generation of reactive oxygen species under RFR exposure in living cells

NADH oxidase of cellular membrane was suggested as a primary mediator of RFR interaction with living cells (Friedman et al., 2007). Using purified membranes from HeLa cells, the authors experimentally proved that the exposure to RFR of 875 MHz, 200 $\mu W/cm^2$ for 5 or 10 min significantly, almost threefold, increased the activity of NADH oxidase. NADH oxidases are membrane-associated enzymes that catalyze one-electron reduction of oxygen into superoxide radical using NADH as a donor of electron, thus producing powerful ROS. This enzyme has been traditionally known due to its role in induction of oxidative burst in phagocytes as a part of immune response. Yet, later the existence of non-phagocytic NAD(P)H oxidases was revealed in various types of cells, including fibroblasts, vascular and cardiac cells (Griendling et al., 2000). Obviously, the presence of superoxide-generating enzyme in many types of non-phagocytic cells points to the considerable regulatory roles of ROS in living cells. On the other hand, an ability of low-intensity RFR to modulate the activity of the NADH oxidase automatically makes this factor a notable and potentially dangerous effector of cell metabolism. Notably, the authors pointed out that the acceptor of RFR is different from the peroxide-generating NADPH oxidases, which are also found in plasma membranes (Low et al., 2012).

The other powerful source of ROS in cells is mitochondrial electron transport chain (ETC), which can generate superoxide due to breakdowns in electron transport (Inoue et al., 2003). It was demonstrated that generation of ROS by mitochondrial pathway can be activated under RFR exposure in human spermatozoa (De Iuliis et al., 2009). The authors revealed a dose-dependent effect of 1.8 GHz RFR exposure on ROS production in spermatozoa, particularly in their mitochondria. The significantly increased level of total ROS in spermatozoa was detected under RFR with SAR = 1 W/kg, which is below the safety limits accepted in many countries. It was demonstrated recently in our laboratory that the exposure of quail embryos *in ovo* to extremely low-intensity RFR (GSM 900 MHz, 0.25 μW/cm^2) during the initial days of embryogenesis resulted in a robust overproduction of superoxide and nitrogen oxide radicals in mitochondria of embryonic cells (Burlaka et al., 2013). It is not clear yet which particular part of ETC is responsible for the interaction with RFR. To date, three possible sites of generation of superoxide in ETC have been shown: the ETC complex I (Inoue et al., 2003), complex II (Liu et al., 2002), and complex III (Guzy and Schumacker, 2006). A significant inverse correlation between mitochondrial membrane potential and ROS levels in living cell was found (Wang et al., 2003). As the authors underlined, such a relationship could be due to two mutually interconnected phenomena: ROS causing damage to the mitochondrial membrane, and the damaged mitochondrial membrane causing increased ROS production.

In addition to the well-established role of the mitochondria in energy metabolism, regulation of cell death is a second major function of these organelles. This, in turn, is linked to their role as the powerful intracellular source of ROS. Mitochondria-generated ROS play an important role in the release of cytochrome c and other pro-apoptotic proteins, which can trigger caspase activation and apoptosis (Ott et al., 2007). A few reports indicate on activation of apoptosis due to low-intensity RFR exposure. In human epidermoid cancer KB cells, 1950 MHz RFR induced time-dependent apoptosis (45% after 3 h) that is paralleled by 2.5-fold decrease of the expression of ras and Raf-1 and of the activity of ras and Erk-1/2 (Caraglia et al., 2005). Primary cultured neurons and astrocytes exposed to GSM 1900 MHz RFR for 2 h demonstrated up-regulation of caspase-2, caspase-6 and Asc (apoptosis associated speck-like protein containing a card) (Zhao et al., 2007). Up-regulation in neurons occurred in both "on" and "stand-by" modes, but in astrocytes only in the "on" mode. We should underline that, in that study an extremely high biological sensitivity to RFR was demonstrated, as a cell phone in the "stand-by" position emits negligibly low-intensity of radiation (up to hundredths μW/cm^2).

Based on the analysis of available literature data, we identified altogether 100 experimental studies in biological models which investigated oxidative stress due to low-intensity RFR exposures. From these 100 articles, 93 studies (93%) demonstrated significant oxidative effects induced by low-intensity RFR exposure (Table 1–3), while 7 studies (7%) demonstrated the absence of significant changes (Table 4). The total number includes 18 *in vitro* studies, 73 studies in animals, 3 studies in plants and 6 studies in humans. Majority of the research was done on laboratory rats (58 studies, with 54 positive results), while 4 studies out of 6 in humans were positive. From the *in vitro* studies, 17 were positive (94.4%), including 2 studies on human spermatozoa and 2 studies on human blood cells.

Most of the studies utilized RFR exposure in MW range, including a use of commercial or trial cell phones as sources of radiation. The power densities of RFR applied in positive studies varied from 0.1 μW/cm^2 (Oksay et al., 2014) to 680 μW/cm^2 (Jelodar et al., 2013) and SAR values varied from 3 μW/kg (Burlaka et al., 2013) to the ICNIRP recommended limit of 2 W/kg (Naziroglu et al., 2012a; Xu et al., 2010). Exposure times in positive studies varied from 5 min (Friedman et al., 2007) to 12.5 years, 29.6 h/month (Hamzany et al., 2013).

The most often used indexes of oxidative stress analyzed in the studies were ROS production, levels of lipid peroxidation (LPO)/malondialdehyde (MDA), protein oxidation (PO), nitric oxides (NO_x), glutathione (GSH), activity of antioxidant enzymes (superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GSH-Px)). It is important that some studies directly pointed to induction of free radicals (superoxide radical, NO) as a primary reaction of living cells to RFR exposure (Burlaka et al., 2013; Friedman et al., 2007). As we pointed out earlier, direct activation of NADH oxidase (Friedman et al., 2007) and the mitochondrial pathway of superoxide overproduction (Burlaka et al., 2013; De Iuliis et al., 2009) have been experimentally proven. Besides, a significant overproduction of nitrogen oxide was revealed in some studies (Avci et al., 2012; Bilgici et al., 2013; Burlaka et al., 2013), although it is unclear whether an induction of expression of NO-synthases or direct activation of the enzyme took place. It is however clear that significantly increased levels of these free radical species (superoxide and nitrogen oxide) in cells due to RFR exposure result in an activation of peroxidation and repression of activities of key antioxidant enzymes. It is indicative that many studies demonstrated effectiveness of different

Table 1. Publications which reported positive findings on oxidative stress caused by RFR exposure of cells *in vitro*.

Reference	Biological system exposed	RFR exposure	Statistically significant effects reported*
(Agarwal et al., 2009)	Human spermatozoa	Cell phone RFR, in talk mode, for 1 h	Increase in reactive oxygen species (ROS) level, decrease in sperm motility and viability.
(Campisi et al., 2010)	Rat astroglial cells	900 MHz (continuous or modulated), electric field 10 V/m, for5; 10; 20 min	Increase in ROS levels and DNA fragmentation after exposure to modulated RFR for 20 min.
(De Iuliis et al., 2009)	Human spermatozoa	1.8 GHz, SAR = 0.4–27.5 W/kg	Increased amounts of ROS.
(Friedman et al., 2007)	HeLa membranes	875 MHz, 200 μW/cm^2, for 5 and 10 min	Increased NADH oxidase activity.
(Hou et al., 2014)	Mouse embryonic fibroblasts (NIH/3T3)	1800-MHz GSM-talk mode RFR, SAR = 2 W/kg, intermittent exposure (5 min on/ 10 min off) for 0.5–8 h	Increased intracellular ROS levels.
(Kahya et al., 2014)	Cancer cell cultures	900 MHz RFR, SAR = 0.36 W/kg, for 1 h	Induced apoptosis effects through oxidative stress, selenium counteracted the effects of RFR exposure.
(Lantow et al., 2006a)	Human blood cells	Continuous wave or GSM signal,SAR = 2 W/kg, for 30 or 45 min of continuous or 5 min ON, 5 min OFF	After continuous or intermittent GSMsignal a different ROS production was detected in human monocytes compared to sham.
(Lantow et al., 2006b)	Human Mono Mac 6 and K562 cells	Continuous wave, GSM speaking only, GSM hearing only, GSM talk, SARs of 0.5, 1.0, 1.5 and 2.0 W/kg.	The GSM-DTX signal at 2 W/kg produced difference in free radical production compared to sham.
(Liu et al., 2013b)	GC-2 cells	1800 MHz, SAR = 1; 2 W/kg,5 min ON, 10 min OFF for 24 h	In the 2 W/kg exposed cultures, the level of ROS was increased.
(Lu et al., 2012)	Human blood mononuclear cells	900 MHz, SAR = 0.4 W/kg, for 1–8 h	The increased level of apoptosis induced through the mitochondrial pathway and mediated by activating ROS and caspase-3.
(Marjanovic et al., 2014)	V79 cells	1800 MHz, SAR = 1.6 W/kg, for 10, 30 and 60 min	ROS level increased after 10 min of exposure. Decrease in ROS level after 30-min treatment indicating antioxidant defense mechanism activation.
(Naziroglu et al., 2012b)	HL-60 cells	2450 MHz, pulsed, SAR = 0.1–2.5 W/kg, for 1; 2; 12 or 24 h	Lipid peroxide (LPO) levels were increased at all exposure times.
(Ni et al., 2013)	Human lens epithelial cells	1800 MHz, SAR = 2; 3; 4 W/kg	The ROS and malondialdehyde (MDA) levels were increased.
(Pilla, 2012)	Neuronal cells and human fibroblasts	27.12 MHz, pulsed, electric field 41 V/m, 2 min prior to lipopolysaccharide administration or for 15 min	Increased level of nitric oxide (NO).
(Sefidbakht et al., 2014)	HEK293T cells	940 MHz, SAR = 0.09 W/kg, for 15, 30, 45, 60 and 90 min	ROS generation increased in the 30 min exposed cells. A sharp rise in catalase (CAT) and superoxide dismutase (SOD) activity and elevation of glutathione (GSH) during the 45 min exposure.
(Xu et al., 2010)	Primary cultured neurons	1800 MHz, pulsed, SAR = 2 W/kg, for 24 h	An increase in the levels of8-hydroxy-2'-deoxyguanosine (8-OH-dG).
(Zmyślony et al., 2004)	Rat lymphocytes	930 MHz, PD of 500 μW/cm^2, SAR = 1.5 W/kg, for 5 and 15 min	Intracellular ROS level increased in exposed $FeCl_2$ treated cells compared with unexposed $FeCl_2$ treated cells.

*All effects were statistically significant (at least $p < 0.05$) as compared to control or sham exposed groups.

antioxidants to override oxidative stress caused by RFR exposure. Such effects have been reported for melatonin (Ayata et al., 2004; Lai and Singh, 1997; Oktem et al., 2005; Ozguner et al., 2006; Sokolovic et al., 2008), vitamin E and C (Jelodar et al., 2013; Oral et al., 2006), caffeic acid phenethyl ester (Ozguner et al., 2006), selenium, L-carnitine (Turker et al., 2011) and garlic (Avci et al., 2012; Bilgici et al., 2013).

It is worthwhile to emphasize a strict non-thermal character of ROS overproduction under RFR exposure described in the cited reports. As low as 0.1 μW/cm^2 intensity of RFR and absorbed energy (specific absorption rate, SAR) of 0.3 μW/kg were demonstrated to be effective in inducing significant oxidative stress in living cells (Burlaka et al., 2013; Oksay et al., 2014). This observation is particularly important as the modern international safety limits on RFR exposure are based solely on the thermal effects of radiation and only restrict RFR intensity to 450–1000 μW/cm^2 and SAR to 2 W/kg (ICNIRP, 1998). Moreover, studies where high (thermal) intensities of RFR have been used could not reveal oxidative effects (Hong et al., 2012; Kang et al., 2013; Luukkonen et al., 2009), which might point to the variety of molecular mechanisms for different radiation intensities.

Taken together, the analysis of the contemporary scientific literature on the biological effects of RFR persuasively proves that the exposure to low-intensity RFR in living cells leads to generation of significant levels of ROS and results in a significant oxidative stress.

Oxidative damage of DNA under RFR exposure

To date more than hundred papers have been published on mutagenic effects of RFR and most of them revealed significant effects (Ruediger, 2009). There is a substantial number of studies which demonstrated the formation of micronuclei (Garaj-Vrhovac et al., 1992; Tice et al., 2002; Zotti-Martelli et al., 2005) or structural anomalies of metaphase chromosomes (Garson et al., 1991; Kerbacher et al., 1990; Maes et al., 2000) in living

Table 2. Publications which reported positive findings on oxidative stress caused by RFR exposure of animals and plants.

Reference	Biological system exposed	RFR exposure	Statistically significant effects reported*
(Akbari et al., 2014)	Rat whole body	RFR from base transceiver station	Glutathione peroxidase (GSH-Px), SOD, and CAT activity decreased and level of MDA increased. Vitamin C reduced the effect.
(Al-Damegh, 2012)	Rat whole body	Cell phone RFR, 15, 30, or 60 min/day for 2 weeks	Levels of conjugated dienes, LPO and CAT activities in serum and testicular tissue increased, the total serum and testicular tissue GSH and GSH-Px levels decreased.
(Avci et al., 2012)	Rat whole body	1800 MHz, SAR = 0.4 W/kg, 1 h/day for 3 weeks	An increased level of protein oxidation (PO) in brain tissue and an increase in serum NO. Garlic administration reduced protein oxidation in brain tissue.
(Ayata et al., 2004)	Rat whole body	900 MHz, 30 min/day for 10 days	MDA and hydroxyproline levels and activities of CAT and GSH-Px were increased, andsuperoxide dismutase (SOD) activity was decreased in skin. Melatonin treatment reversed effect.
(Aynali et al., 2013)	Rat whole body	2450 MHz, pulsed, SAR = 0.143 W/kg,60 min/day for 30 days	LPO was increased, an administration of melatonin prevented this effect.
(Balci et al., 2007)	Rat whole body	"Standardized daily dose" of cell phoneRFR for 4 weeks	In corneal tissue, MDA level and CAT activity increased, whereas SOD activity was decreased. In the lens tissues, the MDA level was increased.
(Bilgici et al., 2013)	Rat whole body	850–950 MHz,SAR = 1.08 W/kg,1 h/day for 3 weeks	The serum NO levels and levels of MDA and the PO in brain were increased. An administration of garlic extract diminished these effects.
(Bodera et al., 2013)	Rat whole body	1800 MHz, GSM, for 15 min	Reduced antioxidant capacity both in healthy animals and in those with paw inflammation.
(Burlaka et al., 2013)	Quail embryo *in ovo*	GSM 900 MHz, power density (PD) of 0.25 μW/cm^2, SAR = 3 μW/kg, 48 sec ON - 12 sec OFF, for 158–360 h	Overproduction of superoxide and NO, increased levels of thiobarbituric acid reactive substances (TBARS) and 8-OH-dG, decreased SOD and CAT activities.
(Burlaka et al., 2014)	Male rat whole body	Pulsed and continuous MWin the doses equivalent to the maximal permitted energy load for the staffs of the radar stations	Increased rates of superoxide production, formation of the iron-nitrosyl complexes and decreased activity of NADH-ubiquinone oxidoreductase complex in liver, cardiac and aorta tissues 28 days after the exposure.
(Cenesiz et al., 2011)	Guinea pig whole body	900; 1800 MHz RFR from base station antennas, 4 h/day for 20 days	Difference in guinea pigs subjected to 900 and 1800 MHz for plasma oxidant status levels. NO level changed in 900 MHz subjected guinea pigs, as compared to the control.
(Cetin et al., 2014)	Pregnant rats and offspring	900; 1800 MHz RFR, 1 h/day during pregnancy and neonatal development	Brain and liver GSH-Px activities, selenium concentrations in the brain and liver vitamin A and β-carotene concentrations decreased in offspring.
(Dasdag et al., 2009)	Head of rats	900 MHz, 2 h/day for 10 months	The total antioxidant capacity and CATactivity in brains were higher than that in the sham group.
(Dasdag et al., 2012)	Head of rats	900 MHz, cell-phones-like, 2 h/day for 10 months	Protein carbonyl level was higher in the brain of exposedrats.
(Dasdag et al., 2008)	Rat whole body	900 MHz, PD of 78 μW/cm^2, 2 h/days for10 months.	Increased levels of MDA and total oxidative status in liver tissue.
(Deshmukh et al., 2013)	Rat whole body	900 MHz, 2 h/day, 5 days a week for 30 days	The levels of LPO and PO were increased.
(Esmekaya et al., 2011)	Rat whole body	900 MHz, pulsed, modulated, SAR = 1.2 W/kg, 20 min/day for 3 weeks	The increased level of MDA and NOx, and decreased levels of GSH in liver, lung, testis and heart tissues.
(Furtado-Filho et al., 2014)	Rat whole body	950 MHz, SAR = 0.01–0.88 W/kg,30 min/day for 21 days during pregnancy (or additionally 6 or 15 days of postnatal period)	Neonatal rats exposed in utero had decreased levels of CAT and lower LPO, and genotoxic effect.
(Guler et al., 2012)	Rabbit infant whole body	GSM 1800 MHz, 15 min/day for 7 days (females) or 14 days (males)	LPO levels in the liver tissues of females and males increased,liver 8-OH-dG levels of females were increased.
(Guney et al., 2007)	Rat whole body	900 MHz, 30 min/day for 30 days	Endometrial levels of NO and MDA increased, endometrial SOD, CAT and GSH-Px activities were decreased.Vitamin E and C treatment prevented these effects.
(Gürler et al., 2014)	Rat whole body	2450 MHz, 3.68 V/m, 1 h/day for 30 days	Increased 8-OH-dG level in both plasma and brain tissue whereas it increased PO level only in plasma. Garlic prevented the increase of 8-OH-dG level in brain tissue and plasma PO levels.
(Ilhan et al., 2004)	Rat whole body	900 MHz, from cell phone,1 h/day for 7 days	Increase in MDA, NO levels, andxanthine oxidase (XO) activity, decrease in SOD and GSH-Px activities in brain. These effects were prevented by Ginkgo bilobaextract treatment.
(Jelodar, et al., 2013)	Rat whole body	900 MHz, PD of 680 μW/cm^2, 4 h/day for 45 days,	The concentration of MDA was increased and activities of SOD, GSH-Px and CAT were decreased in rat eyes. An administration of vitamin C prevented these effects.
(Jelodar et al., 2013)	Rat whole body	900 MHz, daily for 45 days	Increased level of MDA and decreased antioxidant enzymes activity in rat testis.
(Jing et al., 2012)	Rat whole body	Cell phone RFR, SAR = 0.9 W/kg,3 x 10; 30 or 60 min for 20 days during gestation	After 30 and 60 min the level of MDA was increased, the activities of SOD and GSH-Pxwere decreased.

(*Continued*)

Table 2. (Continued).

Reference	Biological system exposed	RFR exposure	Statistically significant effects reported*
(Kerman & Senol, 2012)	Rat whole body	900 MHz, 30 min/day for 10 days	Tissue MDA levels were increased, SOD, CAT and GSH-Pxactivities were reduced. Melatonin treatment reversed these effects.
(Kesari et al., 2010)	Male rat whole body	Cell phone RFR, SAR = 0.9 W/kg,2 h/day for 35 days	Reduction in protein kinase activity, decrease in sperm count and increase in apoptosis.
(Kesari et al., 2011)	Rat whole body	900 MHz, pulsed, SAR = 0.9 W/kg,2 h/day for 45 days	Increase in the level of ROS, decrease in the activities of SOD and GSH-Px,and in the level of pineal melatonin.
(Kesari et al., 2013)	Rat whole body	2115 MHz, SAR = 0.26 W/kg,2 h/day for 60 days	The level of ROS, DNA damage and theapoptosis rate were increased.
(Khalil et al., 2012)	Rat whole body	1800 MHz, electric field 15–20 V/m, for2 h	Elevations in the levels of 8-OH-dG in urine.
(Kismali et al., 2012)	Rabbit whole body (non-pregnant and pregnant)	1800 MHz, GSM modulation, 15 min/day for 7 days	Creatine kinases levels' changes.
(Koc et al., 2013)	Male rat whole body	Cell phone RFR at calling or stand-by	Oxidative stress detected at both calling and stand-by exposures.
(Koylu et al., 2006)	Rat whole body	900 MHz	The levels of LPO in the brain cortex and hippocampus increased.These levels in the hippocampus were decreased by melatonin administration.
(Koyu et al., 2009)	Rat whole body	900 MHz	The activities of XO, CAT and level of LPO increased in liver.XO, CAT activities and LPO levels were decreased by caffeic acid phenethyl ester (CAPE) administration.
(Kumar et al., 2014)	Rat whole body	Cell phone 1910.5 MHz RFR, 2 h/day for 60 days day (6 days a week).	Increase in LPO, damage in sperm cells and DNA damage.
(Lai & Singh, 1997)	Rat whole body	2450 MHz, pulsed, PD = 2 mW/cm^2, SAR = 1.2 W/kg	Melatonin or spin-trap compound blocked DNA strand breaks induced by RFR exposure in rat brain cells.
(Luo et al., 2014)	Rat whole body	900 MHz imitated cell phone RFR, 4 h/day for 12 days	Contents of liver MDA and Nrf2 protein increased, contents of liver SOD and GSH decreased.
(Mailankot et al., 2009)	Rat whole body	900/1800 MHz,GSM,1 h/day for 28 days	Increase in LPO and decreased GSH content in the testis and epididymis.
(Manta et al., 2013)	Drosophila whole body	1880–1900 MHz, DECT modulation, SAR = 0.009 W/kg, for 0.5–96 h	Increase in ROS levels in male and female bodies, a quick response in ROS increase in ovaries.
(Marzook et al., 2014)	Rat whole body	900 MHz from cellular tower, 24 h/day for 8 weeks	SOD and CAT activities were reduced in blood, sesame oil reversed the effect
(Meena et al., 2013)	Rat whole body	2450 MHz, PDof 210 μW/cm^2, SAR = 0.14 W/kg, 2 h/day for 45 days	Increased level of MDA and ROS in testis. Melatonin prevented oxidative stress.
(Megha et al., 2012)	Rat whole body	900; 1800 MHz, PD of 170 μW/cm^2, SAR = 0.6 mW/kg, 2 h/day, 5 days/week for 30 days	The levels of the LPO and PO were increased; the level of GSH was decreased.
(Meral et al., 2007)	Guinea pig whole body	890–915 MHz,from cell phone, SAR = 0.95 w/kg, 12 h/day for 30 days (11 h 45 min stand-by and 15 min spiking mode)	MDA level increased, GSH level and CAT activity weredecreased in the brain. MDA, vitamins A, D_3 and E levels and CAT enzyme activity increased, and GSH level was decreased in the blood.
(Motawi et al., 2014)	Rat whole body	Test cellphone RFR, SAR = 1.13 W/kg, 2 h/day for 60 days	Increments in conjugated dienes, protein carbonyls, total oxidant status and oxidative stress index along with a reduction of total antioxidant capacity levels.
(Naziroglu & Gumral, 2009)	Rat whole body	2450 MHz,60 min/day for 28 days	Decrease of the cortex brain vitamin A, vitamin C and vitamin E levels.
(Naziroglu et al., 2012a)	Rat whole body	2450 MHz, 60 min/day for 30 days	LPO, cell viability and cytosolic Ca^{2+} values in dorsal root ganglion neurons were increased.
(Oksay et al., 2014)	Rat whole body	2450 MHz, pulsed, PD of0.1 μW/cm^2, SAR = 0.1 W/kg, 1 h/day for 30 days	LPO was higher in exposed animals. Melatonin treatment reversed the effect.
(Oktem et al., 2005)	Rat whole body	900 MHz, 30 min/day for 10 days	Renal tissue MDA level increased, SOD, CAT and GSH-Px activities were reduced. Melatonin treatment reversed these effects.
(Oral et al., 2006)	Rat whole body	900 MHz, 30 min/day for 30 days	Increased MDA levels and apoptosis in endometrial tissue.Treatment with vitamins E and C diminished these changes.
(Ozguner et al., 2005a)	Rat whole body	900 MHz, 30 min/day for 10 days	Heart tissue MDA and NO levels increased, SOD, CAT and GSH-Px activities were reduced. CAPE treatment reversed these effects.
(Ozguner et al., 2006)	Rat whole body	900 MHz, from cell phone	Retinal levels of NO and MDA increased, SOD, GSH-Px and CAT activities were decreased.Melatonin and CAPE treatment prevented effects.
(Ozguner et al., 2005b)	Rat whole body	900 MHz	Renal tissue MDA and NO levels increased, the activities of SOD, CAT and GSH-Px were reduced. CAPE treatment reversed these effects.
(Ozgur et al., 2010)	Guinea pig whole body	1800 MHz,GSM, SAR = 0.38 W/kg, 10 or 20 min/day for 7 days	Increases in MDA and total NO(x) levels and decreases in activities of SOD, myeloperoxidase and GSH-Px in liver. Extent of oxidative damage was proportional to the duration of exposure.
(Ozgur et al., 2013)	Rabbit whole body	1800 MHz, pulsed, 15 min/day for 7 days in pregnant animals, for 7 or 15 days in infants	The amount of LPO was increased in the prenatal exposure group.

(*Continued*)

Table 2. (Continued).

Reference	Biological system exposed	RFR exposure	Statistically significant effects reported*
(Özorak et al., 2013)	Rat whole body	900; 1800; 2450 MHz, pulsed, PD of 12 μW/cm^2. SAR = 0.18; 1.2 W/kg, 60 min/day during gestation and 6 weeks following delivery	At the age of six weeks, an increased LPO in the kidney and testis, and decreased level of GSH and total antioxidant status.
(Qin et al., 2014)	Male mouse whole body	1800 MHz, 208 μW/cm^2, 30 or 120 min/d for 30 days	Decreased activities of CAT and GSH-Px and increasedlevel of MDA in cerebrum. Nano-selenium decreased MDA level, and increased GSH-Px and CAT activities.
(Ragy, 2014)	Rat whole body	Cell phone 900 MHz RFR, 1 h/d for 60 days	Increase in MDA levels and decrease total antioxidant capacity levels in brain, liver and kidneys tissues. These alterations were corrected by withdrawal of RFR exposure during 30 days.
(Saikhedkar et al., 2014)	Rat whole body	Cell phone 900 MHz RFR, 4 h/d for 15 days	A significant change in level of antioxidant enzymes and non-enzymatic antioxidants, and an increase in LPO.
(Shahin et al., 2013)	Mouse whole body	2450 MHz, PD of 33.5 μW/cm^2, SAR = 23 mW/kg, 2 h/day for 45 days	An increase in ROS, decrease in NO and antioxidant enzymes activities.
(Sharma et al., 2009)	Plant(mung bean) whole body	900 MHz, from cell phone, PD of 8.55 μW/cm^2; for 0.5; 1; 2, and 4 h	Increased level of MDA,H_2O_2 accumulation and root oxidizability, upregulation in the activities of SOD, CAT, ascorbate peroxidases, guaiacol peroxidases and GSHreductases in roots.
(Singh et al., 2012)	Plant (mung bean) whole body	900 MHz,from cell phone	The increased level of MDA, hydrogen peroxide and proline content in hypocotyls.
(Sokolovic et al., 2008)	Rat whole body	RFR from cell phone, SAR = 0.043–0.135 W/kg, for 20, 40 and 60 days	An increase in the brain tissue MDA and carbonyl group concentration. Decreased activity of CAT and increased activity of xanthine oxidase (XO). Melatonin treatment prevented the effects.
(Sokolovic et al., 2013)	Rat whole body	900 MHz, SAR = 0,043–0.135 W/kg,4 h/day for 29; 40 or 60 days,	The level of LPO and PO, activities of CAT, XO, number of apoptotic cells were increased in thymus tissue. An administration of melatonin prevented these effects.
(Suleyman et al., 2004)	Rat whole body	Cell phoneRFR,SAR = 0.52 W/kg,20 min/day for 1 month	MDA concentration was increased in brains.
(Tkalec et al., 2007)	Plant Lemna minor (duckweed)	400 and 900 MHz, 10, 23, 41 and 120 V/m, for 2 or 4 h	LPO and H_2O_2 content increased: CAT activity increased, pyrogallol peroxidase decreased.
(Tkalec et al., 2013)	Earthworm whole body	900 MHz, PD of 30–3800 μW/cm^2, SAR = 0.13–9.33 mW/kg, for 2 h	The protein carbonyl content was increased in all exposures above 30 μWc/m^2. The level of MDA was increased at 140μW/cm^2.
(Tök et al., 2014)	Rat whole body	2450 MHz, Wi-Fi RFR, 60 min/day for 30 days	Decreased GSH-Px activity. GSH-Px activity and GSH values increased after melatonin treatment.
(Tomruk et al., 2010)	Rabbit whole body	1800 MHz, GSM-like signal, 15 min/day for a week	Increase of MDA and ferrous oxidation in xylenol orange levels.
(Tsybulin et al., 2012)	Quail embryo *in ovo*	900 MHz, fromcell phone, GSM, PD of 0.024–0.21 μW/cm^2, intermittent for 14 days	Increased level of TBARS in brains and livers of hatchlings.
(Turker et al., 2011)	Rat partial body	2450 MHz, pulsed, SAR = 0.1 W/kg,1 h/day for 28 days	The increased level of LPO, the decreased concentrations of vitamin A, vitamin C and vitamin E. There was a protective effect of selenium and L-carnitine.
(Türedi et al., 2014)	Pregnant rat whole body	900 MHz, 13.7 V/m, 50 μW/cm^2, 1 h/day for 13–21 days of pregnancy	MDA, SOD and CAT values increased, GSH values decreased in exposed pups.
(Yurekli et al., 2006)	Rat whole body	945 MHz, GSM, PD of 367 μW/cm^2, SAR = 11.3 mW/kg	MDA level and SOD activity increased, GSH concentration was decreased.

*All effects were statistically significant (at least $p < 0.05$) as compared to control or sham exposed groups.

Table 3. Publications which reported positive findings on oxidative stress caused by RFR exposure of humans.

Reference	Biological system exposed	RFR exposure	Statistically significant effects reported*
(Abu Khadra et al., 2014)	Human male head	GSM 1800 MHz from cell phone, SAR = 1.09 W/kg, for 15 and 30 min	SOD activity in saliva increased.
(Garaj-Vrhovac et al., 2011)	Human whole body	3; 5.5; 9.4 GHz, pulsed, from radars	Increased level of MDA, decreased level of GSH.
(Hamzany et al., 2013)	Human head/ whole body	RFR from cell phone a mean time of 29.6 h/ month for 12.5 years	Increase in all salivary oxidative stress indices.
(Moustafa et al., 2001)	Human male body	Cell phone in a pocket in standby position, for 1; 2 or 4 h	Plasma level of LPO was increased, activities of SOD and GSH-Px in erythrocytes decreased.

*All effects were statistically significant (at least $p < 0.05$) as compared to control or sham-exposed groups.

cells due to low-intensity RFR exposure. However, majority of the studies on the mutagenic effects of RFR successfully used a comet assay approach (Baohong et al., 2005; Belyaev et al., 2006; Diem et al., 2005; Kim et al., 2008; Lai and Singh, 1996; Liu et al., 2013a). Particular studies identified specific marker of oxidative damage of DNA, 8-hydroxy-2'-deoxyguanosine (8-OH-dG) (Burlaka et al., 2013; De Iuliis et al.,

Table 4. Publications which reported no significant oxidative effects after RFR exposure.

Reference	Biological system exposed	RFR exposure	Effects reported
(Hook et al., 2004)	Mammalian cells *in vitro*	835.62 MHz (frequency-modulated continuous-wave, FMCW) and 847.74 MHz (code division multiple access, CDMA), SAR = 0.8 W/kg, for 20–22 h	FMCW- and CDMA-modulated RFR did not alter parameters indicative of oxidative stress.
(Ferreira et al., 2006a)	Rat whole body	800–1800 MHz, from cell phone	No changes in lipid and protein damage, and in non-enzymatic antioxidant defense in frontal cortex or hippocampus.
(Ferreira et al., 2006b)	Pregnant rat whole body	RFR from cell phone	No differences in oxidative parameter of offspring blood and liver, but increase in erythrocytes micronuclei incidence in offspring.
(Dasdag et al., 2003)	Rat whole body	Cell phone RFR, SAR = 0.52 W/kg, 20 min/day for 1 month	No alteration in MDA concentration.
(Demirel et al., 2012)	Rat whole body	3G cell phone RFR, "standardized daily dose" for 20 days	No difference in GSH-Px and CAT activity in eye tissues, in MDA and GSH levels in blood.
(Khalil et al., 2014)	Human head/whole body	Cell phone RFR (talking mode) for 15 or 30 min	No relationship between exposure and changes in the salivary oxidant/antioxidant profile.
(de Souza et al., 2014)	Human head/whole body	Cell phone RFR	No difference in the saliva from the parotid gland exposed to cell phone RFR to the saliva from the opposite gland of each individual.

2009; Guler et al., 2012; Khalil et al., 2012; Xu et al., 2010). Thus, the level of 8-OH-dG in human spermatozoa was shown to be significantly increased after *in vitro* exposure to low-intensity RFR (De Iuliis et al., 2009). Likewise, we demonstrated that the exposure of quail embryos *in ovo* to GSM 900 MHz of 0.25 μW/cm^2 during a few days was sufficient for a significant, two-threefold, increase of 8-OH-dG level in embryonic cells (Burlaka et al., 2013).

It would be logical to assume that most mutagenic effects due to the RFR exposure are caused by oxidative damage to DNA, as the overproduction of ROS in living cells due to RFR exposure was reliably documented. It is known that superoxide itself does not affect DNA. The most aggressive form of ROS, which is able to affect the DNA molecule directly, is hydroxyl radical (Halliwell, 2007). The hydroxyl radicals are generated in cell in the Fenton reaction ($Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + OH^{\bullet} + OH^-$) and in the Haber–Weiss reaction ($O_2^{\bullet -} + H_2O_2 \rightarrow O_2 + OH^{\bullet} + OH^-$) (Valko et al., 2006). On the other hand, increased concentration of NO in addition to superoxide in the RFR-exposed cells can lead to the formation of other aggressive form of ROS, peroxynitrite ($ONOO^-$), which can also cause DNA damage (Valko et al., 2006).

Free radicals induced under the RFR exposure can perturb cellular signaling

Taking into account the abovementioned data, we can state that the exposure to RFR leads to overproduction of free radicals/ROS in living cell. Certainly, free radicals can induce harmful effects via direct damage due to oxidation of biological macromolecules. To that, it becomes clear nowadays that free radicals/ROS are an intrinsic part of the cellular signaling cascades (Forman et al., 2014). Thus, hydrogen peroxide appears as a second messenger both in insulin signaling and in growth factor-induced signalling cascades (Sies, 2014). These species are also implicated in biochemical mechanism of oxidation of ethanol and in other metabolic processes (Oshino et al., 1975) and is also required for initiation of wound repair (Enyedi and Niethammer, 2013). In addition, ROS at relatively low concentrations can modulate inflammation via activation of NF-kB pathway (Hayden and Ghosh, 2011). Therefore, even subtle exposures to RFR with generation of hardly detectable quantities of free radicals can have their meaningful biological consequences.

We could ascertain the signaling effects of moderate levels of free radicals from our experiments in quail embryos irradiated with the commercial cell phone. Thus, we were able to show that the prolonged exposures of embryos *in ovo* led to robust repression of their development (Tsybulin et al., 2013), which was concomitant with significant overproduction of superoxide radical and NO radical, increased rates of lipid peroxidation and oxidative damage of DNA (Burlaka et al., 2013; Tsybulin et al., 2012). Notably, shorter exposures instead led to enhancement in embryonic development (Tsybulin et al., 2012, 2013). We demonstrated the favorable effects of shorter exposures also on the molecular level. Thus, after the short-time RFR exposure the DNA comets in embryonic cells were significantly shorter than in the control non-irradiated embryos, pointing to activation of mechanisms maintaining the integrity of DNA. The "beneficial" consequences of the irradiation could be explained by hormesis effect (Calabrese, 2008). However, one could hypothesize that the "beneficial" effects of the irradiation could be explained by the signaling action of free radicals induced at levels below the damaging concentrations.

Obviously, any seemingly beneficial effect of external environmental impact should be treated with caution and possibly minimized before careful evaluation of the long-term consequences. Altogether, this gives a clear warning of the adverse health effects of low-intensity RFR, which could be evoked both by the direct oxidative damage and by disturbed cellular signaling.

Oxidative effects and non-cancer health effects of RFR

A new medical condition, so-called electrohypersensitivity (EHS), in which people suffer due to RFR exposure, has been described (Johansson, 2006). Typically, these persons suffer from skin- and mucosa-related symptoms (itching, smarting, pain, heat sensation), or heart and nervous system disorders after exposure to computer monitors, cell phones and other electromagnetic devices. This disorder is growing continuously: starting from 0.06% of the total population in 1985, this category now includes as much as 9–11% of the European population (Hallberg and Oberfeld, 2006). In Sweden, for example, EHS has become an officially recognized health impairment.

To that, a high percentage, up to 18–43% of young people, has recently been described to be suffering from headache/earache during or after cell phone conversations (Chu et al., 2011; Yakymenko et al., 2011). Likewise, a number of psychophysical and preclinical disorders including fatigue, irritation, headache, sleep disorders, hormonal imbalances were detected in high percent of people living nearby cell phone base transceiver stations (Buchner and Eger, 2011; Santini et al., 2002).

An allergy reaction to RFR in humans has been confirmed by a significant increase in the level of mast cells in skin of persons under exposure to electromagnetic devices (Johansson et al., 2001). Likewise, higher level of degranulated mast cells in dermis of EHS persons has been detected (Johansson, 2006). In turn, the activated mast cells can release histamine and other mediators of such reactions which include allergic hypersensitivity, itching, dermatoses, etc. Importantly, an implication of ROS in allergic reactions is rather clear nowadays. For example, in case of airway allergic inflammation, the lung cells generate superoxide in nanomolar concentrations following antigen challenges (Nagata, 2005). Then, mast cells generate ROS following aggregation of FcεRI, a high-affinity IgE receptor (Okayama, 2005). In addition, pollen NADPH oxidases rapidly increase the level of ROS in lung epithelium (Boldogh et al., 2005); and removal of pollen NADPH oxidases from the challenge material reduced antigen-induced allergic airway inflammation. Thus, it seems plausible that EHS-like conditions can be attributed at least partially to ROS overproduction in cells due to RFR exposures.

Oxidative effects and potential carcinogenicity of RFR

During recent years, a number of epidemiological studies indicated a significant increase in incidence of various types of tumors among long-term or "heavy" users of cellular phones (Yakymenko et al., 2011). Briefly, reports pointed to the increased risk in brain tumors (Cardis et al., 2010; Hardell and Carlberg, 2009; Hardell et al., 2007), acoustic neuroma (Hardell et al., 2005; Sato et al., 2011), tumors of parotid glands (Sadetzki et al., 2008), seminomas (Hardell et al., 2007), melanomas (Hardell et al., 2011) and lymphomas (Hardell et al., 2005) in these cohorts of people. To that, a significant increase in tumor incidence among people living nearby cellular base transceiver stations was also reported (Eger et al., 2004; Wolf and Wolf, 2007). Similarly, experimental evidences of cancer expansion in rodents caused by long-term low-intensity RFR exposure were published (Chou et al., 1992; Repacholi et al., 1997; Szmigielski et al., 1982; Toler et al., 1997). To that, activation of ODC was detected in RFR-exposed cells (Hoyto et al., 2007). ODC is involved in processes of cell growth and differentiation, and its activity is increased in tumor cells. Although overexpression of ODC is not sufficient for tumorigenic transformation, an increased activity of this enzyme was shown to promote the development of tumors from pre-tumor cells (Clifford et al., 1995).

Significant overproduction of ROS leads to oxidative stress in living cells, induces oxidative damage of DNA and can cause malignant transformation (Halliwell and Whiteman, 2004; Valko et al., 2007). It is known that in addition to mutagenic effects, ROS play a role as a second messenger for intracellular signaling cascades which can also induce oncogenic transformation (Valko et al., 2006). Earlier we hypothesized (Burlaka et al., 2013) that low-intensity RFR exposure leads to dysfunctions of mitochondria, which result in overproduction of superoxide and NO, and subsequently to ROS-mediated mutagenesis. To that, it is well established that oxidative stress is associated with carcinogenesis; for instance, the oxidative stress elicited by Membrane-Type 1 Matrix Metalloproteinase is implicated in both the pathogenesis and progression of prostate cancer (Nguyen et al., 2011). Similarly, a progressive elevation in mitochondrial ROS production (chronic ROS) under both hypoxia and/or low glucose,

which leads to stabilization of cells via increased HIF-2alpha expression, can eventually result in malignant transformation (Ralph et al., 2010). These data, together with the strong experimental evidences on activation of NADH oxidase under RFR exposure (Friedman et al., 2007) suggest that low-intensity RFR is a multifactorial stress factor for living cell, significant feature of which is oxidative effects and potential carcinogenicity as a result.

Conclusions

The analysis of modern data on biological effects of low-intensity RFR leads to a firm conclusion that this physical agent is a powerful oxidative stressor for living cell. The oxidative efficiency of RFR can be mediated via changes in activities of key ROS-generating systems, including mitochondria and non-phagocytic NADH oxidases, via direct effects on water molecules, and via induction of conformation changes in biologically important macromolecules. In turn, a broad biological potential of ROS and other free radicals, including both their mutagenic effects and their signaling regulatory potential, makes RFR a potentially hazardous factor for human health. We suggest minimizing the intensity and time of RFR exposures, and taking a precautionary approach towards wireless technologies in everyday human life.

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What the Telecom Industry Doesn't Tell You… But Does Tell It's Investors

Verizon Communications Inc.

UNITED STATES SECURITIES AND EXCHANGE COMMISSION FORM 10-K
ANNUAL REPORT fiscal year ended December 31, 2014

"We are subject to a significant amount of litigation, which could require us to pay significant damages or settlements."

"...our wireless business also faces personal injury and consumer class action lawsuits relating to alleged health effects of wireless phones or radio frequency transmitters, and class action lawsuits that challenge marketing practices and disclosures relating to alleged adverse health effects of handheld wireless phones. We may incur significant expenses in defending these lawsuits. In addition, we may be required to pay significant awards or settlements."

http://verizon.api.edgar-online.com/EFX_dll/EdgarPro.dll?FetchFilingHTML1?SessionID=w2LAeu3KEb9YN9D&ID=10506387#D820819D10K_HTM_TX820819_3

AT&T

2014 Annual Report

“Unfavorable litigation or governmental investigation results could require us to pay significant amounts...

As we deploy newer technologies, especially in the wireless area, we also face current and potential litigation relating to alleged adverse health effects on customers or employees who use such technologies including, for example, wireless handsets.

We may incur significant expenses defending such suits or government charges and may be required to pay amounts or otherwise change our operations in ways that could materially adversely affect our operations or financial results.”

http://www.att.com/Investor/ATT_Annual/2014/downloads/att_ar2014_annualreport.pdf

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Our costs could increase and our revenues could decrease due to perceived health risks from radio emissions, especially if these perceived risks are substantiated."

"... If a scientific study or court decision resulted in a finding that radio frequency emissions pose health risks to consumers, it could negatively impact the market for wireless services, as well as our tenants, which could materially and adversely affect our business, results of operations or financial condition."

"We do not maintain any significant insurance with respect to these matters."

http://www.sec.gov/Archives/edgar/data/1053507/000119312512086162/d278077d10k.htm

CROWN CASTLE NTERNATIONAL GROUP

UNITED STATES SECURITIES AND EXCHANGE COMMISSION FORM 10-K

For the fiscal year ended December 31, 2014

"If radio frequency emissions from wireless handsets or equipment on our wireless infrastructure are demonstrated to cause negative health effects, potential future claims could adversely affect our operations, costs or revenues.

We cannot guarantee that claims relating to radio frequency emissions will not arise in the future or that the results of such studies will not be adverse to us.

If a connection between radio frequency emissions and possible negative health effects were established, our operations, costs, or revenues may be materially and adversely affected.

"We currently do not maintain any significant insurance with respect to these matters."

http://www.sec.gov/Archives/edgar/data/1051470/000105147015000034/cci10-k123114.htm

T-MOBILE US, INC

UNITED STATES SECURITIES AND EXCHANGE COMMISSION FORM 10-K

for the fiscal year ended December 31, 2014

"Our business could be adversely affected by findings of product liability for health/safety risks from wireless devices and transmission equipment, as well as by changes to regulations/RF emission standards."

"Allegations have been made that the use of wireless handsets and wireless transmission equipment, such as cell towers, may be linked to various health concerns, including cancer and brain tumors. Lawsuits have been filed against manufacturers and carriers in the industry claiming damages for alleged health problems arising from the use of wireless handsets. "

"There have also been other allegations regarding wireless technology, including allegations that wireless handset emissions may interfere with various electronic medical devices (including hearing aids and pacemakers)..."

http://www.sec.gov/Archives/edgar/data/1283699/000128369915000010/tmus12312014form10-k.htm

Children are being directed toward devices for their education in environments saturated with dangerous radiation from commercial Wi-Fi networks. (Shutterstock)

Wi-Fi in Schools: Experimenting With the Next Generation

Commercial wireless systems expose children to nation's highest radiation levels
By Conan Milner
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Print

The internet has unleashed human knowledge. Never before has it been so easy to learn so much. Of course, it has also drowned us in distraction and created a breeding ground for trolls and misinformation, but if the internet is redeemed by anything, it is its liberation of education.

When it comes to accessing this ocean of information, we have two basic choices: wired or Wi-Fi. The vast majority of schools have embraced the wireless revolution. It's easy to see why. Compared to wired internet, wireless is simpler, cheaper, and faster for schools to install.

Today, students are trading notebooks and textbooks for laptops, cellphones, iPads, and all manner of "smart" devices connected to a potent wireless infrastructure that lets them be used virtually anywhere on school grounds.

But that wireless web comes with a devastating downside. Doctors and scientists say that the students and teachers who attend these schools are risking their health.

Radiation Dangers

Dr. Martin Pall, Professor Emeritus of biochemistry and basic medical sciences at Washington State University made a grave case about the dangers involved in his paper, "Wi-Fi is An Important Threat to Human Health," published in the July 2018 issue of Environmental Research.

"The placement of Wi-Fi into schools around the country may well be a high-level threat to the health of our children as well being a threat to teachers and any very sensitive fetuses teachers may be carrying, as well," Pall writes.

Since Wi-Fi is found everywhere from private homes to public spaces, Pall's alarming claim seems hard to fathom. And yet his evidence is compelling: 23 controlled scientific studies demonstrating numerous adverse effects to Wi-Fi radiation exposure. And that's just the tip of the iceberg—there are dozens more studies on Wi-Fi harms which were not included in the paper.

Wireless radiation has become commonplace despite well-documented evidence of its harm, with thousands of studies going back several decades demonstrating health problems associated with exposure. Some of the strongest evidence came last year from the final report of a $30 million, 19-year study funded by the U.S. Food and Drug Administration. It was conducted by the National Toxicology Program (NTP)—the federal agency tasked with testing toxins—and was designed to be the final word on whether wireless radiation was harmful. It showed clear evidence of cancer and DNA damage linked to cellphone use.

Concentrated Risk

Schools are particularly worrisome, experts say, because they are where the most intense concentration of wireless radiation is found today. The Wi-Fi systems schools have adopted are much more comprehensive than your average home or coffee shop Wi-Fi. These commercial grade systems use several routers or "access points" throughout the classroom, often in the ceiling above students' heads. Now, add in all the radiation spewing from all the wireless devices operated by each student, and you'll find that kids are spending up to seven hours per day in a thick soup of electro-smog.

Even worse, the people we place in this remarkably concentrated field of wireless radiation are more vulnerable to it. Compared to adults, children are smaller and have smaller and thinner skulls so the radiation penetrates more easily and gets to larger parts of the brain. Also problematic, children's' immune and nervous systems are still developing. Plus, kids' cells divide at a faster rate, which increases the risk for mutations that can lead to cancer.

According to Pall, these factors make children more susceptible to the disease processes that wireless radiation has been consistently shown to cause: oxidative stress (which can lead to cancer and non-cancerous conditions, as well as DNA damage), sperm and testicular damage, neuropsychiatric effects, cell death, changes to the endocrine system, and calcium overload.

Evidence of Illness

These disease processes aren't merely theoretical. Epidemiological studies conducted by Dr. Lennart Hardell, an oncologist at Orebro University Hospital in Sweden, showed that children exposed to this radiation are more likely to develop cancer and develop it quicker.

Other doctors and scientists say exposure is likely a significant contributing factor to the rising rates of other childhood diseases. Dr. Hugh Taylor, a professor and chair of obstetrics, gynecology, and reproductive sciences at Yale University, has shown that fetal exposure to wireless radiation affects neuro-development and behavior and can lead to Attention Deficit and Hyperactivity Disorder (ADHD)— a condition that has doubled in the past 10 years.

Harvard Medical School professor and a pediatric neurologist at Massachusetts General Hospital, Dr. Martha Herbert, makes a compelling argument that the rise in autism spectrum disorders may also be related to our rise in wireless radiation exposure.

Herbert's 60-page report from 2012 doesn't provide evidence of cause, but it does reveal several similarities between symptoms known to occur with wireless radiation and biological manifestations in autism, such as cellular stress, tissue damage, protein misfolding, and injury of membranes.

Herbert describes autism, not as a condition of a broken brain, but of a brain that has a hard time regulating itself. And she believes that if such a brain is caught in a cloud of wireless radiation, it is confronted with a disruptive factor, making it even harder for behavior and biology to come into balance.

While the brains of children with autism may be most vulnerable to microwave radiation, Herbert says every brain is at the mercy of its influence.

"I really am concerned about people's brains," Herbert said. "It's not a joke to have this stuff getting into these three pounds of delicate, gel-crystalline structure in our heads that does this amazing stuff. It wasn't meant for this level of exposure."

Electromagnetic Neurology

Herbert explains that, just like our wireless devices, our brain communicates with electromagnetic signaling. In fact, as our instruments have become more sensitive, scientists have discovered that each cell in our body uses electromagnetic signaling.

Now that we live in a wireless world, where we all walk around in a field of electromagnetic radiation nearly all the time, Herbert believes there is enough scientific support to argue that this influence could be an important contributor to degrading the optimal chemical-electrical function of our bodies—thereby detuning our brains and nervous systems.

Autism was once considered strictly a genetic abnormality. But as knowledge of the condition has grown, researchers have uncovered a more complex landscape, where a host of environmental influences have shown an impact on gene expression.

This means that instead of one smoking gun tied to this fast growing condition (the latest estimate from the Centers for Disease Control is that one in every 40 children has autism, up from one in every 166 in 2005), there are likely many factors. Toxic chemicals, for example, have long been demonstrated to impact fetal brain development.

But Herbert argues that, due to electric nature of our bodies, wireless radiation may create more of a disruption than toxic chemicals.

"When you have a toxicant exposure, it can affect the brain, but it has to go through metabolic pathways that can influence the electromagnetics in order to do that," Herbert said. "But when you have electromagnetic radiation, it's a straight shot. It's the same language, so it can be more instantaneous."

Sick in Schools

Dafna Tachover is a former telecommunications officer turned lawyer who advocates for people harmed by wireless radiation. Her Supreme Court lawsuit in Israel led to the first limits on Wi-Fi in schools worldwide. Tachover showed evidence of 200 sick children from the Wi-Fi in just six schools.

Now in the United States, Tachover says she is contacted by several parents every week with children who have become sick from their school's wireless system. She says the most common symptoms include headaches, increased sensitivity to noise, nose bleeds, concentration and memory problems, nausea, exhaustion, and hyperactivity.

"Unfortunately, these harms are not potential but existing, and at an epidemic scale," Tachover said.

The acute or chronic illness that results from wireless radiation is known as electromagnetic sensitivity. It's the same illness the U.S. Navy dubbed "microwave sickness" when soldiers who had been working with technologies such as radar for extended periods of time displayed the same symptoms. The illness is named for the microwave frequencies that powers wireless technology. Those who contract microwave sickness can't be in the presence of wireless radiation without painful and sometimes debilitating symptoms.

One child Tachover is working with is a 13-year-old girl from Oregon whose desk was directly under the classroom's Wi-Fi router. After she developed microwave sickness, her parents enrolled her in a private Waldorf school, because they're one of few schools that don't use Wi-Fi.

In some cases, parents are forced to homeschool their children because they can't get access to schools without Wi-Fi. In other cases, sick kids are forced to make do.

Tachover said one parent had two sons who developed microwave sickness. This mother urged her sons' school to accommodate by hard wiring the classroom internet and even offered to pay for the accommodation, but the school refused. As a result, her children can only attend school for a few hours per week.

"When in the Wi-Fi environment they experience headaches, concentration problems, skin rashes and hyperactivity," Tachover said.

Risk to Teachers

Microwave sickness can impact teachers who work in Wi-Fi too. Laurie Brown, a teacher in the Los Angeles Unified School District (LAUSD), says she knew nothing about the health impacts from wireless until her school installed a commercial grade Wi-Fi system in April of 2015. Today, she says the damage caused by this technology is impossible for her to ignore.

"We had Wi-Fi before, but the upgraded system now had two access points in every single classroom, adding a total of 190 access points to the school, including additional boosters to prevent any loss of connectivity," Brown said. "All of this was for Common Core testing, and 21st-century teaching."

During Common Core testing, each of Brown's students used a wireless laptop (Chromebook) to access this new system. After just two hours in this new high tech environment, Brown started feeling several symptoms: tingling and burning in her skin, breathing problems, and a rising heart rate. Her ankles started itching and her nasal passages started to swell.

Symptoms grew worse and soon Brown could barely make it through the day. Before the new Wi-Fi system, Brown was rarely sick and had saved close to 800 hours of time off for illness. But after the installation of the new equipment, she was sick all the time. By the end of the school year, Brown was out at least two days every week.

“I just started to feel horrible,” she said. “I would go home from school feeling so lousy. I was never a headachy person, and I was getting all these headaches that were so strange.”

Brown knows of at least 10 teachers and staff members who complained of symptoms that they traced to the school’s Wi-Fi. Two retired, one from another school resigned, and at least three (including Brown) filed for workers compensation injuries with the LAUSD. All the claims were initially denied.

Brown is now on disability leave, but she would rather have her old life back. Today, if someone is just using a cellphone near her, Brown’s inflammatory symptoms, as well as other sometimes debilitating symptoms, can quickly return.

“It’s overwhelming and it’s sad because it takes away from the enjoyment of life and your lifestyle,” she said. “I’m someone who is accommodating, likes to please and is easy going. I wasn’t a high maintenance person. It makes me feel uncomfortable in my own skin to feel like I’m inconveniencing others.”

For schools that are willing to make accommodations, lives have been turned around. Appeals through the American with Disabilities Act have made some schools remove the Wi-Fi routers in the classrooms where there are microwave illness sufferers, even extending the router removal to neighboring classrooms when they still exert an influence.

Teacher Sheila Reavill contracted microwave sickness but she convinced her school to hardwire their internet access and connect laptops with an adapter. There is no Wi-Fi or Bluetooth in Reavill’s class, and the children who carry cellphones shut them off when they’re in the room.

“She says she not only she feels better in the classroom, but her students are also calmer and can focus better,” Tachover said.

Experts saw dangers in school Wi-Fi upgrades even before they were installed. In 2013, Herbert wrote a warning letter to the LAUSD, citing the thousands of papers that have accumulated over decades which document adverse health and neurological impacts of electromagnetic frequency and radiofrequency radiation (EMF/RFR).

“EMF/RFR from Wi-Fi and cell towers can exert a disorganizing effect on the ability to learn and remember, and can also be destabilizing to immune and metabolic function,” Herbert wrote. “This will make it harder for some children to learn, particularly those who are already having problems in the first place.”

The letter went viral, but the school district paid it little mind.

“You know who did react? The firefighters,” Herbert said. “They had this boondoggle going where they were putting cell towers right behind all the fire stations. So guess what? All the firefighters were getting sick.”

Pushing for Change

As more people become aware of the dangers associated with wireless radiation and Wi-Fi in schools, efforts are emerging from teachers unions, parent organizations, and physician groups to address the problem.

One widely proposed solution is for schools to adopt a wired system. This would allow students to have more reliable high-speed internet access but without the microwave radiation. The cost would only be slightly higher than a wireless system.

While installing a wired system would mean a greater cost up front, it could save schools millions in the long run, as well as ensuring the health of the children who attend these schools. Tachover says that most schools are not insured for health effects related to wireless radiation because most insurance companies learned their lesson from tobacco and asbestos and have made an exclusion with regard to wireless.

Some change may come in the form of new laws. In Massachusetts, seven bills have recently taken aim at the issue of wireless technology in a handful of schools.

Deb Mayer runs the Oregon chapter of Parents Across America (PAA). She says her organization has introduced three bills into the state legislature that target children's increasing exposure to wireless radiation.

"We aren't against technology. We're against unsafe use and irresponsible use," Mayer said.

One bill allows Wi-Fi wary parents to choose an alternative for their child. The bill also calls for kids to have recess so they get a chance to move around in the physical world for some part of their day.

The second bill focuses on better public understanding of the biological impact of wireless. It requires public and private schools to distribute information about the potential health risks of wireless network technology to employees, students and parents or guardians. It would also require the state's Health Authority to examine peer-reviewed, independently funded studies on the effects of exposure to microwave radiation in schools and similar environments, particularly exposure that results from the use of wireless network technologies. It then calls on the Health Authority to create guidelines based on this review.

The bill that Mayer believes has the best chance of passing is one which calls for something wireless manufacturers already do, but writ large. Buried deeply in your cell phone manual are tips about using your device more safely. The bill asks to have these tips more explicit with clear warning labels so that consumers take safety more seriously.

Oxidative Mechanisms of Biological Activity of Low Intensity RadioFrequeincy Radiaion – 100 studies

"Getting people to believe that what we say is real and true is really a heavy lift because they don't want to think there is a downside to their devices," Mayer said. "And they especially don't want to think that giving devices to their kids is a bad thing to do."

Herbert says another reason why people may be resistant to see this problem is that all this wireless radiation may be affecting our judgment.

"Your judgment is intrinsically off when your brain function is altered in some way. You could be missing things—missing distinctions, or being disorganized in ways you don't realize until you come out of it. Maybe you never come out of it," Herbert said. "Just something to contemplate as we try and look at our increasing exposure to electromagnetic waves."

Follow Conan on Twitter: @ConanMilner

https://www.theepochtimes.com/wi-fi-in-schools-experimenting-with-the-next-generation_2808921.