5G Wireless Technology: Millimeter Wave Health Effects

Electromagnetic Radiation Safety
https://www.saferemr.com/2017/08/5g-wireless-technology-millimeter-wave.html

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The emergence of **5G**, fifth-generation telecommunications technology, has been in the news lately because the wireless industry has been pushing controversial legislation at the state and federal level to expedite the deployment of this technology. The legislation would block the rights of local governments and their citizens to control the installation of cellular antennas in the public "right-of-way." Cell antennas may be installed on public utility poles every 10-20 houses in urban areas. According to the industry, as many as 50,000 new cell sites will be required in California alone and at 800,000 or more new cell sites nationwide.

Although many major cities and newspapers have opposed this legislation, the potential health risks from the proliferation of new cellular antenna sites have been ignored. These cell antennas will expose the population to new sources of radio frequency radiation including millimeter waves.

5G will employ low- (0.6 GHz - 3.7 GHz), mid- (3.7 – 24 GHz), and high-band frequencies (24 GHz and higher). In the U.S., the Federal Communications Commission (FCC) has allocated "low-band" spectrum at 0.6 GHz (e.g., 600 MHz), "mid-band" spectrum in the 3.5 GHz range, and 11 GHz of "high-band" frequencies including licensed spectrum from 27.5-28.35 GHz and 37-40 GHz, as well as unlicensed spectrum from 64-71 GHz which is open to all wireless equipment manufacturers.

Prior to widespread deployment, major cell phone carriers are experimenting with new technologies that employ "high-band" frequencies in communities across the country. The "high-band" frequencies largely consist of millimeter waves (MMWs), a type of electromagnetic radiation with wavelengths of one to ten millimeters and frequencies ranging from 30 to 300 GHz (or billions of cycles per second).

The characteristics of MMWs are different than the "low-band" (i.e., microwave) frequencies which are currently in use by the cellular and wireless industries. MMWs can transmit large amounts of data over short distances. The transmissions can be directed into narrow beams that travel by line-of-sight and can move data at high rates (e.g., up to 10 billion bits per second)

with short lags (or latencies) between transmissions. The signals are blocked by buildings, and foliage can absorb much of their energy. Also, the waves can be reflected by metallic surfaces. Although antennas can be as small as a few millimeters, “small cell” antenna arrays may consist of dozens or even hundreds of antenna elements.

What does research tell us about the biologic and health effects of millimeter waves?

Millimeter waves (MMWs) are mostly absorbed within 1 to 2 millimeters of human skin and in the surface layers of the cornea. Thus, the skin or near-surface zones of tissues are the primary targets of the radiation. Since skin contains capillaries and nerve endings, MMW bio-effects may be transmitted through molecular mechanisms by the skin or through the nervous system.

Thermal (or heating) effects occur when the power density of the waves is above 5–10 mW/cm^2. Such high-intensity MMWs act on human skin and the cornea in a dose-dependent manner—beginning with heat sensation followed by pain and physical damage at higher exposures. Temperature elevation can impact the growth, morphology and metabolism of cells, induce production of free radicals, and damage DNA.

The maximum permissible exposure that the FCC permits for the general public is 1.0 mW/cm^2 averaged over 30 minutes for frequencies that range from 1.5 GHz to 100 GHz. This guideline was adopted in 1996 to protect humans from acute exposure to thermal levels of radiofrequency radiation. However, the guidelines were not designed to protect us from nonthermal risks that may occur with prolonged or long-term exposure to radiofrequency radiation.

With the deployment of fifth generation wireless infrastructure (aka **5G)**, much of the nation will be exposed to MMWs for the first time on a continuous basis. Due to FCC guidelines, these exposures will likely be of low intensity. Hence**, the health consequences of 5G exposure will be limited to non-thermal effects produced by prolonged exposure to MMWs in conjunction with exposure to low- and mid-band radiofrequency radiation.**

Unfortunately, few studies have examined prolonged exposure to low-intensity MMWs, and no research that I am aware of has focused on exposure to MMWs combined with other radiofrequency radiation.

Although biologic effects of low-intensity MMWs have been studied for decades, particularly in Eastern Europe, study results are often inconsistent because the effects are related to many factors including the frequency, modulation, power density, and duration of the exposures, as well as the type of tissue or cells being investigated.

Results vary across studies—MMWs have been shown to induce or inhibit cell death and enhance or suppress cell proliferation. Some studies found that the radiation inhibits cell cycle progression, and some studies reported no biologic effects (Le Drean et al., 2013)

A review of the research in 2010 noted that “A large number of cellular studies have indicated that MMW may alter structural and functional properties of membranes.” Exposure to MMWs may affect the plasma membrane either by modifying ion channel activity or by modifying the phospholipid bilayer. Water molecules also seem to play a role in these effects. Skin nerve endings are a likely target of MMWs and the possible starting point of numerous biological effects. MMWs may activate the immune system through stimulation of the peripheral neural system (Ramundo-Orlando, 2010).

In 1998, five scientists employed by U.S. Army and Air Force research institutes published a seminal review of the research on MMWs. They reported:

"Increased sensitivity and even hypersensitivity of individual specimens to MMW may be real. Depending on the exposure characteristics, especially wavelength, a low-intensity MMW radiation was perceived by 30 to 80% of healthy examinees (Lebedeva, 1993, 1995). Some clinical studies reported MMW hypersensitivity, which was or was not limited to a certain wavelength (Golovacheva, 1995)."

"It is important to note that, even with the variety of bioeffects reported, no studies have provided evidence that a low-intensity MMW radiation represents a health hazard for human beings. Actually, none of the reviewed studies with low-intensity MMW even pursued the evaluation of health risks, although in view of numerous bioeffects and growing usage of MMW technologies this research objective seems very reasonable. Such MMW effects as alterations of cell growth rate and UV light sensitivity, biochemical and antibiotic resistivity changes in pathogenic bacteria, as well as many others are of potential significance for safety standards, but even local and short-term exposures were reported to produce marked effects. It should also be realized that biological effects of a prolonged or chronic MMW exposure of the whole body or a large body area have never been investigated. Safety limits for these types of exposures are based solely on predictions of energy deposition and MMW heating, but in view of recent studies this approach is not necessarily adequate." (Pakhomov et al., 1998)

Microbes are also affected by MMW radiation. In 2016 a review of the research on the effects of MMWs on bacteria was published (Soghomonyan et al., 2016). The authors summarized their findings as follows:

"…bacteria and other cells might communicate with each other by electromagnetic field of sub-extremely high frequency range. These MMW affected Escherichia coli and many other bacteria, mainly depressing their growth and changing properties and activity. These effects were non-thermal and depended on different factors. The significant cellular targets for MMW effects could be water, cell plasma membrane, and genome….The consequences of MMW interaction with bacteria are the changes in their sensitivity to different biologically active chemicals, including antibiotics….These effects are of significance for understanding changed metabolic pathways and distinguish role of bacteria in environment; they might be leading to antibiotic resistance in bacteria."

"Changing the sensitivity of bacteria to antibiotics by MMW irradiation can be important for the understanding of antibiotic resistance in the environment. In this respect, it is interesting that bacteria [that] survived near telecommunication-based stations like Bacillus and Clostridium spp. have been found to be multidrug resistant (Adebayo et al. 2014)." (Soghomonyan et al., 2016)

In sum, the peer-reviewed research demonstrates that short-term exposure to low-intensity millimeter wave (MMW) radiation not only affects human cells, it may result in the growth of multi-drug resistant bacteria harmful to humans. **Since little research has been conducted on the health consequences from long-term exposure to MMWs, widespread deployment of 5G or 5th generation wireless infrastructure constitutes a massive experiment that may have adverse impacts on the public's health.**

Early Russian research on millimeter radiation

Russian scientists conducted much of the early research on the effects of exposure to millimeter radiation. The U.S.Central Intelligence Agency collected and translated the published research but did not declassify it until decades later.

In 1977, N.P. Zalyubovskaya published a study, "Biological effects of millimeter waves," in a Russian-language journal, "Vracheboyne Delo." The CIA declassified this paper in 2012.

The study examined the effects of exposing mice to millimeter radiation (37-60 GHz; 1 milliwatt per square centimeter) for 15 minutes daily for 60 days. The animal results were compared to a sample of people working with millimeter generators.

Here is a brief summary of the paper:

Declassified and Approved For Release 2012/05/10 : CIA-RDP88B01125R000300120005-6
GOVERNMENT USE ONLY

BIOLOGICAL EFFECT OF MILLIMETER RADIOWAVES

Kiev VRACHEBNOYE DELO in Russian No 3, 1977 pp 116-119

[Article by N. P. Zalyubovskaya, Khar'kov Scientific Research Institute of Microbiology, Vaccines and Sera imeni Mechnikov]

[Text] Morphological, functional and biochemical studies conducted in humans and animals revealed that millimeter waves caused changes in the body manifested in structural alterations in the skin and internal organs, qualitative and quantitative changes of the blood and bone marrow composition and changes of the conditioned reflex activity, tissue respiration, activity of enzymes participating in the processes of tissue respiration and nucleic metabolism. The degree of unfavorable effect of millimeter waves depended on the duration of the radiation and individual characteristics of the organism.

Excerpts:

The conducted investigations showed that the irradiation of animals by millimeter waves caused changes of the processes of oxidative phosphorylation in the liver, kidneys, heart and brain of the animals. The irradiation inhibited the oxygen consumption rate by the mitochondria of those organs in the active phosphorylating state and slowed down the rate of respiration upon exhaustion of the ATP. In the liver and kidneys of irradiated animals the intensity of phosphorylation decreased by 64%, the values of the respiratory controls decreased by 26 and 28% respectively and the changes were less expressed in the heart and brain.

The conducted experimental investigations were compared with observations of the state of health of 97 persons working with generators of the millimeter range on the basis of systematic conducting of biochemical analyses. The obtained data confirmed the existence of an influence of radiowaves on the state of metabolic processes in the organism, in particular, changes of the indicators of protein and carbohydrate metabolism were revealed and disturbances of the indicators of immuno-biological reactivity and of the blood system were established.

The paper can be downloaded from http://bit.ly/MMWstudy1977.

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Scientists and Doctors Demand Moratorium on 5G
Cell Tower Health Effects
Electromagnetic Hypersensitivity

Following are summaries of research reviews of the effects of MMW exposure and a list of recently published studies.

Millimeter Wave Research Reviews
(Updated May 20, 2019)

Belyaev IY, Shcheglov VS, Alipov ED, Ushakov VD. Nonthermal effects of extremely high-frequency microwaves on chromatin conformation in cells in vitro—Dependence on physical, physiological, and genetic factors. IEEE Transactions on Microwave Theory and Techniques. 2000; 48(11):2172-2179.

Abstract

There is a substantial number of studies showing biological effects of microwaves of extremely high-frequency range [i.e., millimeter waves (MMWs)] at nonthermal intensities, but poor reproducibility was reported in few replication studies. One possible explanation could be the dependence of the MMW effects on some parameters, which were not controlled in replications. The authors studied MMW effects on chromatin conformation in Escherichia coli (E. coli) cells and rat thymocytes. Strong dependence of MMW effects on frequency and polarization was observed at nonthermal power densities. Several other factors were important, such as the genotype of a strain under study, growth stage of the bacterial cultures, and time between exposure to microwaves and recording of the effect. MMW effects were dependent on cell density during exposure. This finding suggested an interaction of microwaves with cell-to-cell communication. Such dependence on several genetic, physiological, and physical variables might be a reason why, in some studies, the authors failed to reproduce the original data of others.

http://www.avaate.org/IMG/pdf/IEEE_MTT_paper.pdf

Le Drean Y, Mahamoud YS, Le Page Y, Habauzit D, Le Quement C, Zhadobov M, Sauleau R. State of knowledge on biological effects at 40–60 GHz. Comptes Rendus Physique. 2013; 14(5):402-411.

Abstract

Millimetre waves correspond to the range of frequencies located between 30 and 300 GHz. Many applications exist and are emerging in this band, including wireless telecommunications, imaging and monitoring systems. In addition, some of these frequencies are used in therapy in Eastern Europe, suggesting that interactions with the human body are possible. This review aims to summarise current knowledge on interactions between millimetre waves and living matter. Several representative examples from the scientific literature are presented. Then, possible mechanisms of interactions between millimetre waves and biological systems are discussed.

https://doi.org/10.1016/j.crhy.2013.02.005

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Pakhomov AG, Akyel Y, Pakhomova ON, Stuck BE, Murphy MR. Current state and implications of research on biological effects of millimeter waves: a review of the literature. Bioelectromagnetics. 1998; 19(7):393-413.

In recent years, research into biological and medical effects of millimeter waves (MMW) has expanded greatly. This paper analyzes general trends in the area and briefly reviews the most

significant publications, proceeding from cell-free systems, dosimetry, and spectroscopy issues through cultured cells and isolated organs to animals and humans. The studies reviewed demonstrate effects of low-intensity MMW (10 mW/cm^2 and less) on cell growth and proliferation, activity of enzymes, state of cell genetic apparatus, function of excitable membranes, peripheral receptors, and other biological systems. In animals and humans, local MMW exposure stimulated tissue repair and regeneration, alleviated stress reactions, and facilitated recovery in a wide range of diseases (MMW therapy). Many reported MMW effects could not be readily explained by temperature changes during irradiation. The paper outlines some problems and uncertainties in the MMW research area, identifies tasks for future studies, and discusses possible implications for development of exposure safety criteria and guidelines.

https://www.ncbi.nlm.nih.gov/pubmed/9771583

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Ramundo-Orlando A. Effects of millimeter waves radiation on cell membrane - A brief review. Journal of Infrared, Millimeter, and Terahertz Waves. 2010; 31(12):1400–1411.

Abstract

The millimeter waves (MMW) region of the electromagnetic spectrum, extending from 30 to 300 GHz in terms of frequency (corresponding to wavelengths from 10 mm to 1 mm), is officially used in non-invasive complementary medicine in many Eastern European countries against a variety of diseases such gastro duodenal ulcers, cardiovascular disorders, traumatism and tumor. On the other hand, besides technological applications in traffic and military systems, in the near future MMW will also find applications in high resolution and high-speed wireless communication technology. This has led to restoring interest in research on MMW induced biological effects. In this review emphasis has been given to the MMW-induced effects on cell membranes that are considered the major target for the interaction between MMW and biological systems.

https://link.springer.com/article/10.1007%2Fs10762-010-9731-z

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Ryan KL, D'Andrea JA, Jauchem JR, Mason PA. Radio frequency radiation of millimeter wave length: potential occupational safety issues relating to surface heating. Health Phys. 2000; 78(2):170-81.

Abstract

Currently, technology is being developed that makes use of the millimeter wave (MMW) range (30-300 GHz) of the radio frequency region of the electromagnetic spectrum. As more and more systems come on line and are used in everyday applications, the possibility of inadvertent exposure of personnel to MMWs increases. To date, there has been no published discussion regarding the health effects of MMWs; this review attempts to fill that void. Because of the shallow depth of penetration, the energy and, therefore, heat associated with MMWs will be deposited within the first 1-2 mm of human skin. MMWs have been used in states of the former Soviet Union to provide therapeutic benefit in a number of diverse disease states, including skin disorders, gastric ulcers, heart disease and cancer. Conversely, the possibility exists that hazards might be associated with accidental overexposure to MMWs. This review attempts to

critically analyze the likelihood of such acute effects as burn and eye damage, as well as potential long-term effects, including cancer.

https://www.ncbi.nlm.nih.gov/pubmed/10647983

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Soghomonyan D, Trchounian K, Trchounian A. Millimeter waves or extremely high frequency electromagnetic fields in the environment: what are their effects on bacteria? Appl Microbiol Biotechnol. 2016; 100(11):4761-71. doi: 10.1007/s00253-016-7538-0.

Abstract

Millimeter waves (MMW) or electromagnetic fields of extremely high frequencies at low intensity is a new environmental factor, the level of which is increased as technology advance. It is of interest that bacteria and other cells might communicate with each other by electromagnetic field of sub-extremely high frequency range. These MMW affected Escherichia coli and many other bacteria, mainly depressing their growth and changing properties and activity. These effects were non-thermal and depended on different factors. The significant cellular targets for MMW effects could be water, cell plasma membrane, and genome. The model for the MMW interaction with bacteria is suggested; a role of the membrane-associated proton FOF1-ATPase, key enzyme of bioenergetic relevance, is proposed. The consequences of MMW interaction with bacteria are the changes in their sensitivity to different biologically active chemicals, including antibiotics. Novel data on MMW effects on bacteria and their sensitivity to different antibiotics are presented and discussed; the combined action of MMW and antibiotics resulted with more strong effects. These effects are of significance for understanding changed metabolic pathways and distinguish role of bacteria in environment; they might be leading to antibiotic resistance in bacteria. The effects might have applications in the development of technique, therapeutic practices, and food protection technology.

https://www.ncbi.nlm.nih.gov/pubmed/27087527

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Torgomyan H, Trchounian A. Bactericidal effects of low-intensity extremely high frequency electromagnetic field: an overview with phenomenon, mechanisms, targets and consequences. Crit Rev Microbiol. 2013; 39(1):102-11.

Abstract

Low-intensity electromagnetic field (EMF) of extremely high frequencies is a widespread environmental factor. This field is used in telecommunication systems, therapeutic practices and food protection. Particularly, in medicine and food industries EMF is used for its bactericidal effects. The significant targets of cellular mechanisms for EMF effects at resonant frequencies in bacteria could be water (H_2O), cell membrane and genome. The changes in H_2O cluster structure and properties might be leading to increase of chemical activity or hydration of proteins and other cellular structures. These effects are likely to be specific and long-term. Moreover, cell membrane with its surface characteristics, substance transport and energy-conversing processes is also altered. Then, the genome is affected because the conformational changes in DNA and the transition of bacterial pro-phages from lysogenic to lytic state have been detected. The consequences for EMF interaction with bacteria are the changes in their sensitivity to

different chemicals, including antibiotics. These effects are important to understand distinguishing role of bacteria in environment, leading to changed metabolic pathways in bacteria and their antibiotic resistance. This EMF may also affect the cell-to-cell interactions in bacterial populations, since bacteria might interact with each other through EMF of sub-extremely high frequency range.

https://www.ncbi.nlm.nih.gov/pubmed/22667685

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Betskii OV , Devyatkov ND, Kislov VV. Low intensity millimeter waves in medicine and biology. Crit Rev Biomed Eng. 2000;28(1-2):247-68.

Abstract

This paper provides evidence on the interaction of objects. Basic regularities of that interaction are discussed.

Conclusions

Summarizing the results of the 30-year study of biological effects of low-intensity MM waves, we may ascertain the following. As it often happens, applied research and commercialization have outdistanced fundamental investigations. The wide application of MM waves in medicine, biotechnology, animal husbandry, and plant cultivation has taken a giant step forward. By this time, Russia has manufactured more than 10,000 MM-wave therapy devices, organized more than 2,500 MM-wave therapy rooms, and treated over 2,500,000 patients....

https://www.ncbi.nlm.nih.gov/pubmed/10999395

Open access version of
paper: https://pdfs.semanticscholar.org/d0f5/d75d92b7fb8f4d13ae5461e26afa62e87e60.pdf

Recent Millimeter Wave Studies
(Updated: January 21, 2020)

Bantysh BB, Krylov AY, Subbotina TI, et al. Peculiar effects of electromagnetic millimeter waves on tumor development in BALB/c mice. Bull Exp Biol Med. 2018 Sep;165(5):692-694. https://www.ncbi.nlm.nih.gov/pubmed/30225701

Christ A, Samaras T, Neufeld E, Kuster N. RF-induced temperature increase in a stratified model of the skin for plane-wave exposure at 6-100 GHz. Radiat Prot Dosimetry. 2020 Jan 16. pii: ncz293. doi: 10.1093/rpd/ncz293. https://www.ncbi.nlm.nih.gov/pubmed/31950182

Foster KR, Ziskin MC, Balzano Q. Thermal response of human skin to microwave energy: A critical review. Health Phys. 2016; 111(6):528-541. (Note: This work was sponsored by the Mobile Manufacturers Forum. The authors state that MMF had no control over the contents.) https://www.ncbi.nlm.nih.gov/pubmed/27798477

Gajda GB, Lemay E, Paradis J. Model of Steady-state Temperature Rise in Multilayer Tissues Due to Narrow-beam Millimeter-wave Radiofrequency Field Exposure. Health Phys. 2019 Feb 15. doi: 10.1097/HP.0000000000001036. https://insights.ovid.com/pubmed?pmid=31125321

Gandhi OP, Riazi A. Absorption of millimeter waves by human beings and its biological implications. IEEE Transactions on Microwave Theory and Techniques. MTT-34(2):228-235. 1986. http://bit.ly/2oS3rKD

Haas AJ, Le Page Y, Zhadobov M, et al. Effects of 60-GHz millimeter waves on neurite outgrowth in PC12 cells using high-content screening. Neurosci Lett. 2016 Apr 8;618:58-65. https://www.ncbi.nlm.nih.gov/pubmed/26921450

Haas AJ, Le Page Y, Zhadobov M, et al. Effect of acute millimeter wave exposure on dopamine metabolism of NGF-treated PC12 cells. J Radiat Res. 2017 Feb 24:1-7. https://www.ncbi.nlm.nih.gov/pubmed/28339776

Hovnanyan K, Kalantaryan V, Trchounian A. The distinguishing effects of low intensity electromagnetic radiation of different extremely high frequences on Enterococcus hirae: growth rate inhibition and scanning electron microscopy analysis. Lett Appl Microbiol. 2017. https://www.ncbi.nlm.nih.gov/pubmed/28609553

Kojima M, Tsai C-Y, Suzuki Y, et al. Ocular response to millimeter wave exposure under different humidity levels. J Infrared Millimeter Terahertz Waves. 40(5):474-484. 2019. https://link.springer.com/article/10.1007/s10762-019-00586-0

Koyama S, Narita E, Shimizu Y, et al. Effects of long-term exposure to 60 GHz millimeter-wavelength radiation on the genotoxicity and heat shock protein (Hsp) expression of cells derived from human eye. Int J Environ Res Public Health. 2016 Aug 8;13(8). pii: E802. https://www.ncbi.nlm.nih.gov/pubmed/27509516

Le Pogam P, Le Page Y, Habauzit D, et al. Untargeted metabolomics unveil alterations of biomembranes permeability in human HaCaT keratinocytes upon 60 GHz millimeter-wave exposure. Sci Rep. 2019 Jun 27;9(1):9343. doi: 10.1038/s41598-019-45662-6. Open access paper: https://www.nature.com/articles/s41598-019-45662-6

Romanenko S, Harvey AR, Hool L, Fan S, Wallace VP. Millimeter wave radiation activates leech nociceptors via TRPV1-like receptor sensitization. Biophys J. 2019 Apr 25. pii: S0006-3495(19)30340-6. doi: 10.1016/j.bpj.2019.04.021. https://www.ncbi.nlm.nih.gov/pubmed/31103236

Sivachenko IB, Medvedev DS, Molodtsova ID, et al. Effects of millimeter-wave electromagnetic radiation on the experimental model of migraine. Bull Exp Biol Med. 2016 Feb;160(4):425-8. doi: 10.1007/s10517-016-3187-7. http://www.ncbi.nlm.nih.gov/pubmed/26899844

Wang Q, Zhao X, Li S, et al. Attenuation by a human body and trees as well as material penetration loss in 26 and 39 GHz millimeter wave bands. International Journal of Antennas and Propagation. 2017. https://doi.org/10.1155/2017/2961090.

Wu T, Rappaport TS, Collins CM. The human body and millimeter-wave wireless communication systems: Interactions and implications. *IEEE International Conference on Communications (ICC)*, Jun 2015. https://ieeexplore.ieee.org/document/7248688