



Book

(screen shots of abstracts 14 January 2022)

Electromagnetic Fields of Wireless Communications: Biological and Health Effects

Edited By Dimitris J. Panagopoulos

Edition	1st Edition
First Published	2022
eBook Published	29 December 2022
Pub. Location	Boca Raton
Imprint	CRC Press
DOI	https://doi.org/10.1201/9781003201052
Pages	544
eBook ISBN	9781003201052
Subjects	Engineering & Technology

Share

Citation

ABSTRACT

This book reflects contributions from experts in biological and health effects of Radio Frequency (RF)/Microwave and Extremely Low Frequency (ELF) Electromagnetic Fields (EMFs) used in wireless communications (WC) and other technological applications. Diverse topics related to physics, biology, pathology, epidemiology, and plausible biophysical and biochemical mechanisms of WC EMFs emitted by antennas and devices are included. Discussions on the possible consequences of fifth generation (5G) mobile telephony (MT) EMFs based on available data and correlation between anthropogenic EMF exposures and various pathological conditions such as infertility, cancer, electro-hypersensitivity, organic and viral diseases, and effects on animals, plants, trees, and environment are included. It further illustrates individual and public health protection and the setting of biologically- and epidemiologically-based exposure limits.

Features:

- Covers biological and health effects, including oxidative stress, DNA damage, reproductive effects of mobile phones/antennas (2G, 3G, 4G), cordless phones, Wi-Fi, etc.
- Describes effects induced by real-life exposures by commercially available devices/antennas.
- Illustrates biophysical and biochemical mechanisms that fill the gap between recorded experimental and epidemiological findings and their explanations.
- Explores experimental and epidemiological facts and mechanisms of action. Provides explanations and protection tips.
- Transcends across physical, biological, chemical, health, epidemiological, and environmental aspects of the topic.

This book is aimed at senior undergraduate/graduate students in physics, biology, medicine, bioelectromagnetics, electromagnetic biology, non-ionizing radiation biophysics, telecommunications, electromagnetism, bioengineering, and dosimetry.

Chapter | 14 pages

[Introduction](#)

By Dimitris J. Panagopoulos

[Abstract ^](#)

Static electric fields are generated by standing electric charges, and static magnetic fields are generated by direct and constant electric currents. Only static E- or B-fields can each exist alone without the coexistence of the other. In nature, all electric charges oscillate in all possible directions, and the generated EMFs/EMR have similarly random polarizations; in other words, they are not polarized, apart from specific occasions that are locally and partially polarized. A diagram shows the frequencies and corresponding wavelengths of the electromagnetic spectrum with the ionizing part occupying the highest frequencies, the ultraviolet, visible, and infrared parts at descending frequencies, and the subinfrared part occupied by the man-made EMFs. While the first-generation mobile phones in the 1980s were analog and of limited use, digital MT technology since the mid-1990s has evolved fast by producing the existing second, third, and fourth generations of devices/antennas with each next generation transmitting increasing amounts of information/data.

Chapter 1 | 60 pages

Defining Wireless Communication (WC) Electromagnetic Fields (EMFs):

A. Polarization Is a Principal Property of All Man-made EMFs
B. Modulation, Pulsation, and Variability Are Inherent Parameters of WC EMFs
C. Most Man-made EMF Exposures Are Non-thermal
D. Measuring Incident EMFs Is More Relevant than Specific Absorption Rate (SAR)
E. All Man-made EMFs Emit Continuous Waves, Not Photons
F. Differences from Natural EMFs. Interaction with Matter

By Dimitris J. Panagopoulos, Andreas Karabarbounis, Constantinos Lioliousis

Abstract ^

All types of man-made electromagnetic fields (EMFs) and corresponding non-ionizing electromagnetic radiation (EMR) produced by electric/electronic circuits and antennas – in contrast to natural EMFs/EMR – are totally polarized and coherent. Polarized/coherent EMFs/waves can produce constructive interference and amplify their intensities at certain locations. Moreover, they induce parallel/coherent forced oscillations of charged/polar molecules – especially mobile ions – in living cells/tissues, which can trigger biological effects. The most bioactive man-made EMFs are those employed in wireless communications (WC). They are usually referred to simply as Radio Frequency (RF) or Microwave (MW) EMFs/EMR because they emit carrier signals in the RF/MW band. Yet, WC EMFs contain emissions in the Extremely Low Frequency (ELF), Ultra Low Frequency (ULF), and Very Low Frequency (VLF) bands as well in the form of modulation, pulsing, and variability. This complexity and variability of WC EMFs, combined with polarization, is what makes them even more bioactive. Man-made EMFs (including WC) at environmentally existing intensities do not induce significant heating in living tissues. The Specific Absorption Rate (SAR) was introduced by health agencies as the principal metric for the bioactivity of RF/microwave EMFs. Estimation of SAR from tissue conductivity is inaccurate, and estimation from tissue specific heat is possible only for thermal effects. Thus, SAR is of little relevance, and EMF exposures should better be defined by their incident radiation/field intensity at the included frequency bands, exposure duration, and other field parameters. The present chapter also explains that man-made EMFs/EMR, in contrast to light and ionizing electromagnetic emissions, do not consist of photons but of continuous “classical” waves and, thus, do not obey Planck’s formula connecting photon energy (ϵ) with frequency (ν), $\epsilon = h \nu$. Apart from polarization, man-made EMFs differ from natural EMFs in frequency bands and emission sources. Basic concepts of interaction with living tissue are discussed.

Chapter 2 | 18 pages

[Public Health Implications of Exposure to Wireless Communication Electromagnetic Fields](#)

By *Anthony B. Miller*

[Abstract ^](#)

Anthropogenic electromagnetic fields (EMFs) and corresponding electromagnetic radiation (EMR) exposure has long been a concern for the public, policy makers, and health researchers. Beginning 80with radar during World War II, human exposure to Radio Frequency (RF) radiation, and to modulated RF wireless communication (WC) EMFs/EMR has grown substantially over time. In 2011, a working group of the International Agency for Research on Cancer (IARC) reviewed the published literature and categorized WC EMR, termed as RF radiation, as a “possible” (Group 2B) human carcinogen. A broad range of adverse human health effects associated with WC EMFs/EMR have been reported since the IARC review. In addition, two large-scale carcinogenicity studies in rodents exposed to levels of WC EMR that mimic lifetime human exposures have shown significantly increased rates of Schwannomas and malignant gliomas, as well as chromosomal DNA damage. Of particular concern are the effects of WC EMR exposure on the developing brain in children. Compared with an adult male, a mobile phone held against the head of a child exposes deeper brain structures to greater radiation doses per unit volume, and the young, thin skull's bone marrow absorbs a roughly tenfold higher local dose. Experimental and observational studies also suggest that men who keep mobile phones in their trouser pockets have significantly lower sperm counts and significantly impaired sperm motility and morphology, including mitochondrial DNA damage as well as an increased risk of colon cancer. Pending an updated IARC working group review, current knowledge provides justification for governments, public health authorities, and physicians/allied health professionals to warn the population that having a cell phone next to the body is harmful, and to support measures to reduce all exposures to WC EMFs/EMR to as low as reasonably achievable.

Oxidative Stress Induced by Wireless Communication Electromagnetic Fields

By Igor Yakymenko, Oleksandr Tsybulin

Abstract ^

This chapter describes experimental data on oxidative effects induced by man-made electromagnetic fields (EMFs) and corresponding electromagnetic radiation (EMR) in living cells. Analysis of the currently available peer-reviewed scientific literature reveals important molecular effects induced by non-thermal exposures to man-made EMFs, especially wireless communication (WC) EMFs, in living cells. They include significant activation of key cellular pathways generating oxidative stress (OS) by reactive oxygen species (ROS), activation of peroxidation, oxidative damage of DNA, and changes in activities of antioxidant enzymes. Critically important features of man-made EMFs, compared to natural EMFs, are their totally polarized and coherent character and, in the case of WC EMFs, combined frequency bands and sophisticated modulation. These features provide these types of EMFs/EMR with the unique and unexpected capacity of inducing biological effects such as pronounced oxidative effects in exposed living cells. It is indicative that among 131 analyzed peer-reviewed studies dealing with oxidative effects of non-thermal Radio Frequency (RF) EMFs, mostly pulsed/modulated by Extremely Low Frequencies (ELF), 124 (95%) confirmed statistically significant oxidative effects on various types of biological systems. And among 39 analyzed studies on oxidative effects of purely ELF EMFs, 36 of them (92%) also revealed significant oxidative effects of the exposure. The wide pathogenic potential of induced ROS and their involvement in cell signaling explains a range of biological/health effects of non-thermal man-made EMF exposures, which includes both carcinogenic and non-carcinogenic pathologies. In conclusion, our analysis demonstrates that a) man-made EMFs, and especially those employed in WC combining both RF and ELF components, is a pronounced oxidative agent for living cells with high pathogenic potential; and b) the OS induced by man-made EMF exposures should be recognized as one of the primary mechanisms of biological activity of this new environmental agent.

Genotoxic Effects of Wireless Communication Electromagnetic Fields

By *Ganesh Chandra Jagetia*

Abstract ^

The tremendous development of wireless communications (WC) technology during the past 30 years has transformed telecommunications and popularized mobile phones so much that, today, their number exceeds the global population. In addition to electromagnetic fields (EMFs) and corresponding electromagnetic radiation (EMR) from natural sources like sun, cosmos, atmospheric discharges, etc., humans are exposed to man-made EMFs/EMR, especially at the Extremely Low Frequency (ELF) and the Radio Frequency (RF)/microwave bands. EMFs/EMR emitted by WC devices, such as mobile phones and corresponding antennas, contain RF carrier signals which are pulsed and modulated by ELF signals. We call these complex emissions WC EMFs. WC EMFs have generated great concern in the scientific community and the public, as they have been reported to cause headache, fatigue, tinnitus (microwave hearing), concentration problems, depression, memory loss, sleep, and hormonal disorders as short-term effects and even infertility and cancer as the long-term effects. This chapter has been written after collecting information from various search engines, including Google Scholar, PubMed, SciFinder, Science Direct, and other websites on the internet. The chapter focuses on the genotoxic cellular effects of WC EMFs on cultured cells, humans, and animals. Since WC EMFs combine both RF and ELF, in this chapter, both RF/WC and purely ELF man-made EMF studies are reviewed. Most studies conducted on the genotoxic effects of ELF or RF/WC EMFs have resulted in positive findings. Many human and animal studies have demonstrated that ELF or RF/WC man-made EMFs increased the frequency of micronuclei and induced chromosome aberrations or DNA damage, including single- and double-strand breaks. It has also been demonstrated that these EMFs trigger reactive oxygen species (ROS) formation, and changes in gene expression, particularly in genes involved in signal transduction, cytoskeleton formation, and cellular metabolism.

DNA and Chromosome Damage in Human and Animal Cells Induced by Mobile Telephony
Electromagnetic Fields and Other Stressors

By *Dimitris J. Panagopoulos*

Abstract ^

Induction of DNA fragmentation in fruit fly ovarian cells after *in vivo* exposure and chromatid-type aberrations in human peripheral blood lymphocytes (HPBLs) after *in vitro* exposure to mobile telephony (MT) electromagnetic fields (EMFs) from mobile phones are presented. In both cases, the biological samples were exposed in close distance to a commercially available second or third/fourth generation (2G or 3G/4G) mobile phone handset during an active phone call in “talk” mode. The DNA fragmentation in fruit fly ovarian cells induced by 2G MT EMFs was compared with that induced by 50 Hz magnetic fields (MFs) similar to or much stronger than those of high-voltage power lines or a pulsed electric field (PEF) of similar characteristics with EMFs of atmospheric discharges (lightning) under identical conditions and experimental procedures. Respectively, the degree of chromosomal damage induced by *in vitro* exposure of HPBLs to 3G/4G MT EMF was compared to that induced by a high caffeine dose (~ 290 times above the permissible single dose for an adult human) administered to blood samples of the same subjects under identical conditions and experimental procedures. In the first case, it was shown that MT EMFs are much more damaging than high-voltage power line MFs or the PEF and more damaging than previous other stressors tested on the same biological system, such as certain cytotoxic chemicals, starvation, and dehydration. In the second case, it was shown that MT EMFs are similarly and even more damaging than the above extreme caffeine dose. The combination of this caffeine dose and the 3G/4G MT EMF exposure increased dramatically the number of aberrations in the blood samples of all subjects, suggesting that MT EMF exposure may be significantly more dangerous when combined with other stressors. The above findings allow useful conclusions regarding EMF bioactivity, cell sensitivity, and relevant EMF exposure limits.

The Impacts of Wireless Communication Electromagnetic Fields on Human Reproductive Biology

By Kasey Miller, Kiara Harrison, Jacinta H. Martin, Brett Nixon, Geoffry N. De Juiis

Abstract ^

The domain of reproductive biology underpins our understanding of human fertility and forms an important part of the debate on the safety of wireless communication (WC) electromagnetic fields (EMFs). While studies on the effects of anthropogenic EMFs on reproduction are of clear importance, recent evidence suggests that such studies are well placed to provide much-anticipated mechanistic insights on the health impacts of EMFs. Resolution of the biophysical mechanism(s) of action is one of the most important keys required to unlock scientific progression and enable accurate assessment of health risk. Growing recourse to assisted reproductive technologies (ART) across developed nations has justifiably given rise to concern about our decreasing collective fertility as a species. While this issue is certainly multi-factorial, the rise of anthropogenic EMF exposures and especially those of WC technology has aligned with a simultaneous global decline in male semen quality parameters. This well recognized link to reproductive health clearly underlines the unique sensitivity of our reproductive systems to environmental change and has prompted investigation of the impact of novel environmental insults such as WC EMFs. The current picture of how WC EMFs impact reproduction is not yet completely clear, but the field offers strong evidence of negative impacts on the cells, tissues, and processes that influence fertility. Accordingly, here we summarize the highest quality evidence outlining effects of WC EMFs on reproductive tissues and germ cells, and based on this, we propose a plausible mechanism for the molecular nature of the interaction of WC EMF with our biology. We also highlight some of the controversies in this field, including those pertaining to policy. Against this background, we contend that, in parallel with our advancing research, revising the safety limits of anthropogenic EMF exposures to our population is warranted.

Effects of Wireless Communication Electromagnetic Fields on Human and Animal Brain Activity

By *Haitham S. Mohammed*

Abstract ^

The wide and increasing use of telecommunication equipment has necessitated the study of its effects on biological systems and, in particular, on brain activity. Due to the electrical nature of communication between neuronal cells in the brain, the effects of anthropogenic electromagnetic fields (EMFs) and corresponding electromagnetic radiation (EMR) on the human and animal brain have become the focus of many studies. Electroencephalography (EEG) as a direct and sensitive tool for monitoring brain functional changes can be implemented to decipher these effects. Pulsation and modulation of the wireless communication (WC) electromagnetic signals at low frequencies produce complex radiation patterns with components in the Radio Frequency (RF)/microwave and the Extremely Low Frequency (ELF) bands. This mixed type of EMFs/EMR we call wireless communication EMFs/EMR (WC EMFs/EMR). Increasing experimental and theoretical evidence emphasizes the crucial role of the ELF signal pulsation/modulation in the effects of WC EMFs/EMR on human and animal EEG, even at intensities well below the officially accepted limits for human exposure. The duration of exposure is an additional important parameter for the induced effects. The vast majority of recorded effects of WC EMFs/EMR on the human/animal brain are not accompanied by any significant heating, and thus, they are categorized as non-thermal effects. This chapter highlights the concepts related to the human and animal EEG and its alterations induced by anthropogenic EMFs and especially WC EMFs/EMR. Effects on wake and sleep human and animal EEG are described. The importance of animal studies is discussed, and the need for methodological standardization in experimental studies is emphasized. Proposed mechanisms for the action of anthropogenic EMFs on brain activity are reviewed. More studies investigating the non-thermal effects of WC EMFs/EMR on the human and animal brain are needed in order to further explore the effects, the interaction mechanisms, and the consequences of anthropogenic EMFs on health and wellbeing.

Electro-hypersensitivity as a Worldwide, Man-made Electromagnetic Pathology:

A Review of the Medical Evidence

By *Dominique Belpomme, Philippe Irigaray*

Abstract ^

Much of the controversy over the causes of electro-hypersensitivity (EHS) and multiple chemical sensitivity (MCS) lies in the absence of both recognized clinical criteria and objective biomarkers for widely accepted diagnosis. However, there are, presently, sufficient clinical, biological, and radiological data for EHS to be acknowledged as a distinctly well-defined, objectively identified, and characterized neurologic pathological disorder. Therefore, patients who self-report suffering from EHS should be diagnosed and treated on the basis of currently available biological tests and 299the use of suitable cerebral imaging. Because we have shown that EHS is frequently associated with MCS in EHS patients and that both those individualized clinical entities share a common pathophysiological mechanism for symptom occurrence, it appears that EHS and MCS can be identified as a unique neurologic pathological syndrome, whatever their precise causal origin is. In this review, we distinguish the etiology of EHS itself from the environmental causes that trigger symptoms and subsequent pathophysiological changes after EHS occurrence. Contrary to present scientifically unfounded claims, we indubitably refute the hypothesis of a nocebo effect to account for the genesis of EHS and its presentation in EHS self-reported patients. We also refute the erroneous concept that EHS could be reduced to a vague “functional impairment”. The hypersensitivity that characterizes EHS appears to be a persistent and most often irreversible pathological state, as is also the case for sensitivity to chemicals in MCS-bearing patients. Taken into consideration the WHO-proposed causality criteria, we argue that EHS may, in fact, be causally related to increased exposure to man-made electromagnetic fields (EMFs) and, in a limited number of cases, to marketed environmental chemicals. We, therefore, appeal to all governments and international health institutions and, more particularly, the WHO to urgently consider this growing EHS-associated pandemic plague and to acknowledge EHS as a new real disorder.

**Carcinogenic Effects of Non-thermal Exposure to Wireless Communication
Electromagnetic Fields**

By Igor Yakymenko, Oleksandr Tsybulin

Abstract ^

In this chapter, we discuss alarming epidemiological and experimental data on carcinogenic effects of long-term non-thermal exposure to man-made electromagnetic fields (EMFs) and corresponding electromagnetic radiation (EMR), mainly from wireless communication (WC) systems, termed as WC EMFs and WC EMR, respectively. Moreover, since all WC EMFs/EMR include Extremely Low Frequency (ELF) components in the form of pulsations and modulation, the chapter also examines corresponding data from purely ELF man-made EMFs. During the past two decades, a number of scientific reports have revealed that, under certain conditions, non-thermal exposure to WC EMFs/EMR or modulated microwaves (MMWs) can substantially induce cancer progression in humans and animals. The carcinogenic effect of WC EMFs is typically manifested after long-term (usually ≥ 10 years) exposure, e.g., in mobile phone users. Nevertheless, even a year of operation of a powerful base station for mobile telephony (MT) reportedly resulted in a dramatic increase of cancer incidence among the population living nearby. In addition, studies in rodents unveiled a significant increase in carcinogenesis after 17–24 months of MMW exposure both in tumor-prone and intact animals. Data on widely accepted molecular markers of carcinogenesis confirm that exposure to non-thermal levels of MMWs or ELF man-made EMFs can induce tumorigenesis. It is becoming increasingly evident that assessment of biological effects of man-made EMFs/EMR based solely on thermal approach used in recommendations by certain international regulatory agencies, including the International Commission on Non-Ionizing Radiation Protection (ICNIRP), requires urgent and significant re-evaluation. We conclude that available scientific data strongly point to the need for re-elaboration of the current safety limits for man-made EMF exposures. We also emphasize that the everyday exposure of the population to WC EMFs/EMR should be regulated based on the Precautionary Principle, which implies maximum restriction of the risk factor till new, more unambiguous conclusions can be drawn regarding its safety.

Chapter 10 | 54 pages

[Effects of Man-made and Especially Wireless Communication Electromagnetic Fields on Wildlife](#)

By Alfonso Balmori

[Abstract ^](#)

During the past few decades, millions of mobile telephony (MT) base antennas and antennas of other types of wireless communications (WC) have been installed around the world, in cities and in nature, including protected natural areas, in addition to pre-existing antennas (e.g., for television, radio broadcasting, radars, etc.) and high-voltage power lines. Only the aesthetic aspects or urban regulations have been generally considered in this deployment by the responsible authorities, while the biological and environmental impacts of the associated electromagnetic fields (EMFs) and corresponding non-ionizing electromagnetic radiation (EMR) emissions have not been assessed so far. Therefore, the effects on animals (including humans) and plants living around the anthropogenic EMF sources have not been considered. This deficit is particularly concerning because these EMFs/EMR are very different from natural EMFs/EMR, such as light, geomagnetic and geoelectric fields, atmospheric (Schumann) oscillations, or cosmic microwaves, which not only are not dangerous at normal intensities, but, on the contrary, they are vital to the environment and to all forms of life. This chapter reviews the available research on the effects of anthropogenic and especially WC EMFs on wildlife and the natural environment, published mainly during the past 30 years. It includes studies conducted both in the nature and in the laboratory, with vertebrates (mammals, birds, fish, amphibians, and reptiles), invertebrates (mostly insects), plants, and trees. Most of these studies have shown significant detrimental effects of the anthropogenic EMFs on wildlife, at intensities comparable to the current ambient exposure levels, suggesting that we are facing a new environmental pollutant which threatens the health and existence of these species. It is worrying that, despite the accumulating evidence, the people, governments, and even nature conservation organizations are uninformed and unaware of the risks that anthropogenic, and especially WC EMFs pose to the welfare of biodiversity and ultimately to humans.

Chapter 11 | 32 pages

Mechanism of Ion Forced-Oscillation and Voltage-Gated Ion Channel Dysfunction by Polarized and Coherent Electromagnetic Fields

By Dimitris J. Panagopoulos

Abstract ^

Exposure of living organisms to man-made electromagnetic fields (EMFs) causes a variety of adverse biological and health effects including oxidative stress (OS), genetic damage, cell death, and cancer, as is today documented by a great number of indisputable scientific studies. How does this happen? Key signaling molecules in all cells are the mobile ions, the concentrations of which control all cellular functions. The mobile ions move in and out of the cells through ion channels. A most important class of ion channels are the voltage-gated ion channels (VGICs) which open or close by polarized forces on the electric charges of their voltage-sensors generated by changes ≥ 30 mV in the membrane voltage. Polarization, coherence, and existence of Extremely Low Frequencies (ELFs) are common features of all man-made EMFs. Polarized and coherent oscillating EMFs force mobile ions to oscillate in parallel and in phase with them. This coordinated oscillation generates electrical forces on neighboring charges. The forces increase with increasing EMF intensity and decreasing EMF frequency. The oscillating ions close to the voltage-sensors of VGICs generate similar forces on them as those generated by 30 mV changes in the membrane voltage, causing irregular opening and closing of the VGICs. Continuance of such a dysfunction disrupts intra-cellular ionic concentrations, which determine the cell's electrochemical balance and homeostasis. Impairment of this balance triggers overproduction of reactive oxygen species (ROS) in cells which create OS and can damage DNA and other critical biomolecules. Since no convincing corresponding non-thermal mechanism exists for Radio Frequency (RF) EMFs, and because all RF EMFs employed in wireless communications (WC) and other applications are necessarily combined with ELF pulsation, modulation, and random variability, it seems that all non-thermal biological effects of man-made EMFs attributed, until now, to RF EMFs are actually due to their ELF components and can be explained by this mechanism.

Electromagnetic Field-induced Dysfunction of Voltage-Gated Ion Channels, Oxidative Stress, DNA Damage, and Related Pathologies

By *Dimitris J. Panagopoulos, Igor Yakymenko, George P. Chrousos*

Abstract ^

A plethora of studies show that exposure of living organisms to man-made polarized and coherent electromagnetic fields (EMFs), especially in the Extremely Low Frequency (ELF) and the microwave/Radio Frequency (RF) bands, may lead to oxidative stress (OS) and DNA damage. DNA damage is associated with mutations, cell senescence, cell death, infertility, and other pathologies, including cancer. ELF EMF exposures from high-voltage power lines and complex "RF" EMF exposures from wireless communication (WC) antennas/devices have been associated with increased cancer risk. Almost all man-made microwave/RF EMFs, and especially those employed in WC, are combined with ELF components in the form of modulation, pulsation, and random variability. Thus, in addition to polarization/coherence, the existence of ELFs is a common feature of almost all man-made EMFs. Polarized/coherent ELF EMFs are predicted to induce dysfunction of voltage-gated ion channels (VGICs) in cell membranes through the ion forced oscillation mechanism, and this has been verified by many experimental studies. Dysfunction of VGICs disrupts intracellular concentrations of critical ions, such as calcium, sodium, potassium, etc. This condition initiates biochemical processes leading to OS by reactive oxygen species (ROS) overproduction. Such processes include a) increased calcium signaling, leading to nitric oxide (NO•) overproduction by the nitric oxide synthases (NOS) in various locations in the cell, and superoxide anion ($O_2^{\bullet-}$) overproduction in the mitochondria; b) activation of NADPH/NADH oxidase in the plasma membrane, leading to increased production of $O_2^{\bullet-}$; and c) dysfunction of the Na^+/K^+ pump (ATPase) in the plasma and internal cell membranes, triggering mitochondrial ROS production. At least these processes may result in excessive OS, leading to DNA damage and related diseases, including infertility and cancer. Thus, it seems that there is a plausible explanation for the genetic damage and related effects found to be induced by man-made EMF exposures as reported by many experimental and epidemiological studies.