

Contents of this informationsheet about the dangers of 5G radiation

- [Evidence for a connection between coronavirus disease-19 and exposure to radiofrequency radiation from wireless communications including 5G](#) – *Journal of Clinical and Translational Research*, Sept. 2021. [PDF]
“SARS-CoV-2, the virus that caused the COVID-19 pandemic, surfaced in Wuhan, China shortly after the implementation of city-wide (fifth generation [5G]) of wireless communications radiation [WCR]), and rapidly spread globally, initially demonstrating a statistical correlation to international communities with recently established 5G networks. In this study, we examined the peer-reviewed scientific literature on the detrimental bioeffects of WCR and identified several mechanisms by which WCR may have contributed to the COVID-19 pandemic as a toxic environmental cofactor.”
- [CORRELATION BETWEEN THE POTENTIAL ELECTROMAGNETIC POLLUTION LEVEL AND THE DANGER OF COVID-19](#) – Vladimir Mordachev, May, 2020. [PDF]
“The paper considers a hypothesis concerned the possible influence of electromagnetic pollution of the environment on the lethality rate of the population from coronavirus infection, along with other factors. The hypothesis is indirectly confirmed by the correlation between the degree of rigidity of hygienic regulations of radio frequency electromagnetic background levels for the population, which are mainly created by mobile (cellular) communication systems, and the lethality rate from COVID-19 in various countries.”
- [Dangers of 5G – Links – WordDoc](#) – CHI, Jan, 2022. [WordDoc]
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- [A Chinese Lab Has Claimed a Major Breakthrough in 6G: 206 Gigabits per Second](#) – *Interesting Engineering*, 07/Jan/2022. [Archived webpage]
“The world is yet to see the potential of 5G and how [it could change our world](#). Although the low latency and high transmission speeds are notable features of the technology, there does not appear to be a common world application that could put this technology to use en-masse. The high deployment costs of the technology have also put a dampener on its rollout, with operators opting for a slow pace until usage really picks up, [SCMP reported](#).”
- [CELL TOWERS ON THE OCEAN FLOOR](#) – Arthur Firstenberg, Jan, 2022. [PDF]
“In 2018, on land and in space, preparations to deploy millions of antennas were very publicly being made and advertised, for “5G,” “Smart Cities,” and the “Internet of Things.” At the same time, and without any publicity, governments, research laboratories, and commercial and military interests were collaborating on plans to create “Smart Oceans” and the “**Internet of Underwater Things**” (IoUT). They did not consult the fishes, whales, dolphins, octopuses, and other inhabitants of those depths.”
*[\[Video presentation\]](#)
- [Published Scientific Research on 5G, 4G Small Cells, Wireless Radiation and Health](#) – Environmental Health Trust, [Archived webpage]
“Published peer reviewed science already indicates that the current wireless technologies of 2G, 3G and 4G – in use today with our cell phones, computers and wearable tech – creates (create) radiofrequency exposures which poses (pose) a serious health risk to humans, animals and the environment. Scientists are cautioning

that before rolling out 5G, research on human health effects urgently needs to be done first to ensure the public and environment are protected.“

- [**1,670 Peer-Reviewed Scientific Papers on Electromagnetic Fields and Biology or Health**](#) – [Webpage]
- [**International Appeal: Scientists call for protection from non-ionizing electromagnetic field exposure**](#) – [PDF]

Abstract; “We are scientists engaged in the study of biological and health effects of non-ionizing electromagnetic fields (EMF). Based upon peer-reviewed, published research, we have serious concerns regarding the ubiquitous and increasing exposure to EMF generated by electric and wireless devices. These include—but are not limited to—radiofrequency radiation (RFR) emitting devices, such as cellular and cordless phones and their base stations, Wi-Fi, broadcast antennas, smart meters, and baby monitors as well as electric devices and infra-structures used in the delivery of electricity that generate extremely-low frequency electromagnetic field (ELF EMF).“

- [**Scientific Studies; 5G Exacerbated C19**](#) – CHI, Dec. 2021 [Article]
“Research conducted by Beverly Rubik from the college of Integrated sciences and medicine, California, and Robert Brown from the department of radiology at Hamot Medical Center, Pennsylvania, recently [published](#) online at NIH.gov, provides scientific evidence that 5G played a role in the C19 pandemic in their study titled; ‘Evidence for a connection between coronavirus disease-19 and exposure to radiofrequency radiation from wireless communications including 5G’. [[PDF](#)]“



REVIEW ARTICLE

Evidence for a connection between coronavirus disease-19 and exposure to radiofrequency radiation from wireless communications including 5G

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ABSTRACT

Background and Aim: Coronavirus disease (COVID-19) public health policy has focused on the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) virus and its effects on human health while environmental factors have been largely ignored. In considering the epidemiological triad (agent-host-environment) applicable to all disease, we investigated a possible environmental factor in the COVID-19 pandemic: ambient radiofrequency radiation from wireless communication systems including microwaves and millimeter waves. SARS-CoV-2, the virus that caused the COVID-19 pandemic, surfaced in Wuhan, China shortly after the implementation of city-wide (fifth generation [5G] of wireless communications radiation [WCR]), and rapidly spread globally, initially demonstrating a statistical correlation to international communities with recently established 5G networks. In this study, we examined the peer-reviewed scientific literature on the detrimental bioeffects of WCR and identified several mechanisms by which WCR may have contributed to the COVID-19 pandemic as a toxic environmental cofactor. By crossing boundaries between the disciplines of biophysics and pathophysiology, we present evidence that WCR may: (1) cause morphologic changes in erythrocytes including echinocyte and rouleaux formation that can contribute to hypercoagulation; (2) impair microcirculation and reduce erythrocyte and hemoglobin levels exacerbating hypoxia; (3) amplify immune system dysfunction, including immunosuppression, autoimmunity, and hyperinflammation; (4) increase cellular oxidative stress and the production of free radicals resulting in vascular injury and organ damage; (5) increase intracellular Ca^{2+} essential for viral entry, replication, and release, in addition to promoting pro-inflammatory pathways; and (6) worsen heart arrhythmias and cardiac disorders.

Relevance for Patients: In short, WCR has become a ubiquitous environmental stressor that we propose may have contributed to adverse health outcomes of patients infected with SARS-CoV-2 and increased the severity of the COVID-19 pandemic. Therefore, we recommend that all people, particularly those suffering from SARS-CoV-2 infection, reduce their exposure to WCR as much as reasonably achievable until further research better clarifies the systemic health effects associated with chronic WCR exposure.

1. Introduction

1.1. Background

Coronavirus disease 2019 (COVID-19) has been the focus of international public health policy since 2020. Despite unprecedented public health protocols to quell the pandemic, the number of COVID-19 cases continues to rise. We propose a reassessment of our public health strategies.

According to the Center for Disease Control and Prevention (CDC), the simplest model of disease causation is the epidemiological triad consisting of three interactive factors: the agent (pathogen), the environment, and the health status of the host [1]. Extensive research is being done on the agent, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Risk factors that make a host more likely to succumb to the disease have been elucidated. However, environmental factors have not been sufficiently explored. In this paper, we investigated the role of wireless communication radiation (WCR), a widespread environmental stressor.

We explore the scientific evidence suggesting a possible relationship between COVID-19 and radiofrequency radiation related to wireless communications technology including fifth generation (5G) of wireless communications technology, henceforth referred to as WCR. WCR has already been recognized as a form of environmental pollution and physiological stressor [2]. Assessing the potentially detrimental health effects of WCR may be crucial to develop an effective, rational public health policy that may help expedite eradication of the COVID-19 pandemic. In addition, because we are on the verge of worldwide 5G deployment, it is critical to consider the possible damaging health effects of WCR before the public is potentially harmed.

5G is a protocol that will use high frequency bands and extensive bandwidths of the electromagnetic spectrum in the vast radiofrequency range from 600 MHz to nearly 100 GHz, which includes millimeter waves (>20 GHz), in addition to the currently used third generation (3G) and fourth generation (4G) long-term evolution (LTE) microwave bands. 5G frequency spectrum allocations differ from country to country. Focused pulsed beams of radiation will emit from new base stations and phased array antennas placed close to buildings whenever persons access the 5G network. Because these high frequencies are strongly absorbed by the atmosphere and especially during rain, a transmitter's range is limited to 300 meters. Therefore, 5G requires base stations and antennas to be much more closely spaced than previous generations. Plus, satellites in space will emit 5G bands globally to create a wireless worldwide web. The new system therefore requires significant densification of 4G infrastructure as well as new 5G antennas that may dramatically increase the population's WCR exposure both inside structures and outdoors. Approximately 100,000 emitting satellites are planned to be launched into orbit. This infrastructure will significantly alter the world's electromagnetic environment to unprecedented levels and may cause unknown consequences to the entire biosphere, including humans. The new infrastructure will service the new 5G devices, including 5G mobile phones, routers, computers, tablets, self-driving vehicles, machine-to-machine communications, and the Internet of Things.

The global industry standard for 5G is set by the 3G Partnership Project (3GPP), which is an umbrella term for several organizations developing standard protocols for mobile telecommunications. The 5G standard specifies all key aspects of the technology, including frequency spectrum allocation, beam-forming, beam steering, multiplexing multiple in, multiple out schemes, as well as modulation schemes, among others. 5G will

utilize from 64 to 256 antennas at short distances to serve virtually simultaneously a large number of devices within a cell. The latest finalized 5G standard, Release 16, is codified in the 3GPP published Technical Report TR 21.916 and may be downloaded from the 3GPP server at <https://www.3gpp.org/specifications>. Engineers claim that 5G will offer performance up to 10 times that of current 4G networks [3].

COVID-19 began in Wuhan, China in December 2019, shortly after city-wide 5G had "gone live," that is, become an operational system, on October 31, 2019. COVID-19 outbreaks soon followed in other areas where 5G had also been at least partially implemented, including South Korea, Northern Italy, New York City, Seattle, and Southern California. In May 2020, Mordachev [4] reported a statistically significant correlation between the intensity of radiofrequency radiation and the mortality from SARS-CoV-2 in 31 countries throughout the world. During the first pandemic wave in the United States, COVID-19 attributed cases and deaths were statistically higher in states and major cities with 5G infrastructure as compared with states and cities that did not yet have this technology [5].

There is a large body of peer reviewed literature, since before World War II, on the biological effects of WCR that impact many aspects of our health. In examining this literature, we found intersections between the pathophysiology of SARS-CoV-2 and detrimental bioeffects of WCR exposure. Here, we present the evidence suggesting that WCR has been a possible contributing factor exacerbating COVID-19.

1.2. Overview on COVID-19

The clinical presentation of COVID-19 has proven to be highly variable, with a wide range of symptoms and variability from case to case. According to the CDC, early disease symptoms may include sore throat, headache, fever, cough, chills, among others. More severe symptoms including shortness of breath, high fever, and severe fatigue may occur in a later stage. The neurological sequela of taste and smell loss has also been described.

Ing *et al.* [6] determined 80% of those affected have mild symptoms or none, but older populations and those with comorbidities, such as hypertension, diabetes, and obesity, have a greater risk for severe disease [7]. Acute respiratory distress syndrome (ARDS) can rapidly occur [8] and cause severe shortness of breath as endothelial cells lining blood vessels and epithelial cells lining airways lose their integrity, and protein rich fluid leaks into adjacent air sacs. COVID-19 can cause insufficient oxygen levels (hypoxia) that have been seen in up to 80% of intensive care unit (ICU) patients [9] exhibiting respiratory distress. Decreased oxygenation and elevated carbon dioxide levels in patients' blood have been observed, although the etiology for these findings remains unclear.

Massive oxidative damage to the lungs has been observed in areas of airspace opacification documented on chest radiographs and computed tomography (CT) scans in patients with SARS-CoV-2 pneumonia [10]. This cellular stress may indicate a biochemical rather than a viral etiology [11].

Because disseminated virus can attach itself to cells containing an angiotensin-converting enzyme 2 (ACE2) receptor; it can spread and damage organs and soft tissues throughout the body, including the lungs, heart, intestines, kidneys, blood vessels, fat, testes, and ovaries, among others. The disease can increase systemic inflammation and induce a hypercoagulable state. Without anticoagulation, intravascular blood clots can be devastating [12].

In COVID-19 patients referred to as “long-haulers,” symptoms can wax and wane for months [13]. Shortness of breath, fatigue, joint pain, and chest pain can become persistent symptoms. Post-infectious brain fog, cardiac arrhythmia, and new onset hypertension have also been described. Long-term chronic complications of COVID-19 are being defined as epidemiological data are collected over time.

As our understanding of COVID-19 continues to evolve, environmental factors, particularly those of wireless communication electromagnetic fields, remain unexplored variables that may be contributing to the disease including its severity in some patients. Next, we summarize the bioeffects of WCR exposure from the peer reviewed scientific literature published over decades.

1.3. Overview on bioeffects of WCR exposure

Organisms are electrochemical beings. Low-level WCR from devices, including mobile telephony base antennas, wireless network protocols utilized for the local networking of devices and internet access, trademarked as Wi-Fi (officially IEEE 802.11b Direct Sequence protocol; IEEE, Institute of Electrical and Electronic Engineers) by the Wi-Fi alliance, and mobile phones, among others, may disrupt regulation of numerous physiological functions. Non-thermal bioeffects (below the power density that causes tissue heating) from very low-level WCR exposure have been reported in numerous peer-reviewed scientific publications at power densities below the International Commission on Non-Ionizing Radiation Protection (ICNIRP) exposure guidelines [14]. Low-level WCR has been found to impact the organism at all levels of organization, from the molecular to the cellular, physiological, behavioral, and psychological levels. Moreover, it has been shown to cause systemic detrimental health effects including increased cancer risk [15], endocrine changes [16], increased free radical production [17], deoxyribonucleic acid (DNA) damage [18], changes to the reproductive system [19], learning and memory defects [20], and neurological disorders [21]. Having evolved within Earth’s extremely low-level natural radiofrequency background, organisms lack the ability to adapt to heightened levels of unnatural radiation of wireless communications technology with digital modulation that includes short intense pulses (bursts).

The peer-reviewed world scientific literature has documented evidence for detrimental bioeffects from WCR exposure including 5G frequencies over several decades. The Soviet and Eastern European literature from 1960 to 1970s demonstrates significant biological effects, even at exposure levels more

than 1000 times below 1 mW/cm², the current guideline for maximum public exposure in the US. Eastern studies on animal and human subjects were performed at low exposure levels (<1 mW/cm²) for long durations (typically months). Adverse bioeffects from WCR exposure levels below 0.001 mW/cm² have also been documented in the Western literature. Damage to human sperm viability including DNA fragmentation by internet-connected laptop computers at power densities from 0.0005 to 0.001 mW/cm² has been reported [22]. Chronic human exposure to 0.000006 – 0.00001 mW/cm² produced significant changes in human stress hormones following a mobile phone base station installation [23]. Human exposures to cell phone radiation at 0.00001 – 0.00005 mW/cm² resulted in complaints of headache, neurological problems, sleep problems, and concentration problems, corresponding to “microwave sickness” [24,25]. The effects of WCR on prenatal development in mice placed near an “antenna park” exposed to power densities from 0.000168 to 0.001053 mW/cm² showed a progressive decrease in the number of newborns and ended in irreversible infertility [26]. Most US research has been performed over short durations of weeks or less. In recent years, there have been few long-term studies on animals or humans.

Illness from WCR exposure has been documented since the early use of radar. Prolonged exposure to microwaves and millimeter waves from radar was associated with various disorders termed “radio-wave sickness” decades ago by Russian scientists. A wide variety of bioeffects from nonthermal power densities of WCR were reported by Soviet research groups since the 1960s. A bibliography of over 3700 references on the reported biological effects in the world scientific literature was published in 1972 (revised 1976) by the US Naval Medical Research Institute [27,28]. Several relevant Russian studies are summarized as follows. Research on *Escherichia coli* bacteria cultures show power density windows for microwave resonance effects for 51.755 GHz stimulation of bacterial growth, observed at extremely low power densities of 10⁻¹³ mW/cm² [29], illustrating an extremely low level bioeffect. More recently Russian studies confirmed earlier results of Soviet research groups on the effects of 2.45 GHz at 0.5 mW/cm² on rats (30 days exposure for 7 h/day), demonstrating the formation of antibodies to the brain (autoimmune response) and stress reactions [30]. In a long-term (1 – 4 year) study comparing children who use mobile phones to a control group, functional changes, including greater fatigue, decreased voluntary attention, and weakening of semantic memory, among other adverse psychophysiological changes, were reported [31]. Key Russian research reports that underlie the scientific basis for Soviet and Russian WCR exposure guidelines to protect the public, which are much lower than the US guidelines, have been summarized [32].

By comparison to the exposure levels employed in these studies, we measured the ambient level of WCR from 100 MHz to 8 GHz in downtown San Francisco, California in December, 2020, and found an average power density of 0.0002 mW/cm². This level is from the superposition of multiple WCR devices. It is approximately 2×10^{10} times above the natural background.

Pulsed radio-frequency radiation such as WCR exhibits substantially different bioeffects, both qualitatively and quantitatively (generally more pronounced) compared to continuous waves at similar time-averaged power densities [33-36]. The specific interaction mechanisms are not well understood. All types of wireless communications employ extremely low frequency (ELFs) in the modulation of the radiofrequency carrier signals, typically pulses to increase the capacity of information transmitted. This combination of radiofrequency radiation with ELF modulation(s) is generally more bioactive, as it is surmised that organisms cannot readily adapt to such rapidly changing wave forms [37-40]. Therefore, the presence of ELF components of radiofrequency waves from pulsing or other modulations must be considered in studies on the bioeffects of WCR. Unfortunately, the reporting of such modulations has been unreliable, especially in older studies [41].

The BioInitiative Report [42], authored by 29 experts from ten countries, and updated in 2020, provides a scholarly contemporary summary of the literature on the bioeffects and health consequences from WCR exposure, including a compendium of supporting research. Recent reviews have been published [43-46]. Two comprehensive reviews on the bioeffects of millimeter waves report that even short-term exposures produce marked bioeffects [47,48].

2. Methods

An ongoing literature study of the unfolding pathophysiology of SARS-CoV-2 was performed. To investigate a possible connection

to bioeffects from WCR exposure, we examined over 250 peer-reviewed research reports from 1969 to 2021, including reviews and studies on cells, animals, and humans. We included the world literature in English and Russian reports translated to English, on radio frequencies from 600 MHz to 90 GHz, the carrier wave spectrum of WCR (2G to 5G inclusive), with particular emphasis on nonthermal, low power densities ($<1 \text{ mW/cm}^2$), and long-term exposures. The following search terms were used in queries in MEDLINE® and the Defense Technical Information Center (<https://discover.dtic.mil>) to find relevant study reports: radiofrequency radiation, microwave, millimeter wave, radar, MHz, GHz, blood, red blood cell, erythrocyte, hemoglobin, hemodynamic, oxygen, hypoxia, vascular, inflammation, pro-inflammatory, immune, lymphocyte, T cell, cytokine, intracellular calcium, sympathetic function, arrhythmia, heart, cardiovascular, oxidative stress, glutathione, reactive oxygen species (ROS), COVID-19, virus, and SARS-CoV-2. Occupational studies on WCR exposed workers were included in the study. Our approach is akin to Literature-Related Discovery, in which two concepts that have heretofore not been linked are explored in the literature searches to look for linkage(s) to produce novel, interesting, plausible, and intelligible knowledge, that is, potential discovery [49]. From analysis of these studies in comparison with new information unfolding on the pathophysiology of SARS-CoV-2, we identified several ways in which adverse bioeffects of WCR exposure intersect with COVID-19 manifestations and organized our findings into five categories.

Table 1. Bioeffects of Wireless Communication Radiation (WCR) exposure in relation to COVID-19 manifestations and their progression

Wireless communications radiation (WCR) exposure bioeffects	COVID-19 manifestations
Blood changes Short-term: rouleaux, echinocytes Long-term: reduced blood clotting time, reduced hemoglobin, hemodynamic disorders	Blood changes Rouleaux, echinocytes Hemoglobin effects; vascular effects → Reduced hemoglobin in severe disease; autoimmune hemolytic anemia; hypoxemia and hypoxia → Endothelial injury; impaired microcirculation; hypercoagulation; disseminated intravascular coagulopathy (DIC); pulmonary embolism; stroke
Oxidative stress Glutathione level decrease; free radicals and lipid peroxide increase; superoxide dismutase activity decrease; oxidative injury in tissues and organs	Oxidative stress Glutathione level decrease; free radical increase and damage; apoptosis → Oxidative injury; organ damage in severe disease
Immune system disruption and activation Immune suppression in some studies; immune hyperactivation in other studies Long-term: suppression of T-lymphocytes; inflammatory biomarkers increased; autoimmunity; organ injury	Immune system disruption and activation Decreased production of T-lymphocytes; elevated inflammatory biomarkers. → Immune hyperactivation and inflammation; cytokine storm in severe disease; cytokine-induced hypo-perfusion with resulting hypoxia; organ injury; organ failure
Increased intracellular calcium From activation of voltage-gated calcium channels on cell membranes, with numerous secondary effects	Increased intracellular calcium → Increased virus entry, replication, and release → Increased NF-κB, pro-inflammatory processes, coagulation, and thrombosis
Cardiac effects Up-regulation of sympathetic nervous system; palpitations and arrhythmias	Cardiac effects Arrhythmias → Myocarditis; myocardial ischemia; cardiac injury; cardiac failure

Supportive evidence including study details and citations are provided in the text under each subject heading, i.e., blood changes, oxidative stress, etc.

3. Results

Table 1 lists the manifestations common to COVID-19 including disease progression and the corresponding adverse bioeffects from WCR exposure. Although these effects are delineated into categories — blood changes, oxidative stress, immune system disruption and activation, increased intracellular calcium (Ca^{2+}), and cardiac effects — it must be emphasized that these effects are not independent of each other. For example, blood clotting and inflammation have overlapping mechanisms, and oxidative stress is implicated in erythrocyte morphological changes as well as in hypercoagulation, inflammation, and organ damage.

3.1. Blood changes

WCR exposure can cause morphologic changes in blood readily seen through phase contrast or dark-field microscopy of live peripheral blood samples. In 2013, Havas observed erythrocyte aggregation including rouleaux (rolls of stacked red blood cells) in live peripheral blood samples following 10 min human exposure to a 2.4 GHz cordless phone [50]. Although not peer reviewed, one of us (Rubik) investigated the effect of 4G LTE mobile phone radiation on the peripheral blood of ten human subjects, each of whom had been exposed to cell phone radiation for two consecutive 45-min intervals [51]. Two types of effects were observed: increased stickiness and clumping of red blood cells with rouleaux formation, and subsequent formation of echinocytes (spiky red blood cells). Red blood cell clumping and aggregation are known to be actively involved in blood clotting [52]. The prevalence of this phenomenon on exposure to WCR in the human population has not yet been determined. Larger controlled studies should be performed to further investigate this phenomenon.

Similar red blood cell changes have been described in peripheral blood of COVID-19 patients [53]. Rouleaux formation has been observed in 1/3 of COVID-19 patients, whereas spherocytes and echinocyte formation is more variable. Spike protein engagement with ACE2 receptors on cells lining the blood vessels can lead to endothelial damage, even when isolated [54]. Rouleaux formation, particularly in the setting of underlying endothelial damage, can clog the microcirculation, impeding oxygen transport, contributing to hypoxia, and increasing the risk of thrombosis [52]. Thrombogenesis associated with SARS-CoV-2 infection may also be caused by direct viral binding to ACE2 receptors on platelets [55].

Additional blood effects have been observed in both humans and animals exposed to WCR. In 1977, a Russian study reported that rodents irradiated with 5 – 8 mm waves (60 – 37 GHz) at 1 mW/cm² for 15 min/day over 60 days developed hemodynamic disorders, suppressed red blood cell formation, reduced hemoglobin, and an inhibition of oxygen utilization (oxidative phosphorylation by the mitochondria) [56]. In 1978, a 3-year Russian study on 72 engineers exposed to millimeter wave generators emitting at 1 mW/cm² or less showed a decrease in their hemoglobin levels and red blood cell counts, and a tendency toward hypercoagulation, whereas a control group showed no changes [57]. Such deleterious hematologic effects from WCR

exposure may also contribute to the development of hypoxia and blood clotting observed in COVID-19 patients.

It has been proposed that the SARS-CoV-2 virus attacks erythrocytes and causes degradation of hemoglobin [11]. Viral proteins may attack the 1-beta chain of hemoglobin and capture the porphyrin, along with other proteins from the virus catalyzing the dissociation of iron from heme [58]. In principle this would reduce the number of functional erythrocytes and cause the release of free iron ions that could cause oxidative stress, tissue damage, and hypoxia. With hemoglobin partially destroyed and lung tissue damaged by inflammation, patients would be less able to exchange carbon dioxide (CO_2) and oxygen (O_2), and would become oxygen depleted. In fact, some COVID-19 patients show reduced hemoglobin levels, measuring 7.1 g/L and even as low as 5.9 g/L in severe cases [59]. Clinical studies of almost 100 patients from Wuhan revealed that the hemoglobin levels in the blood of most patients infected with SARS-CoV-2 are significantly lowered resulting in compromised delivery of oxygen to tissues and organs [60]. In a meta-analysis of four studies with a total of 1210 patients and 224 with severe disease, hemoglobin values were reduced in COVID-19 patients with severe disease compared to those with milder forms [59]. In another study on 601 COVID-19 patients, 14.7% of anemic COVID-19 ICU patients and 9% of non-ICU COVID-19 patients had autoimmune hemolytic anemia [61]. In patients with severe COVID-19 disease, decreased hemoglobin along with elevated erythrocyte sedimentation rate (ESR), C-reactive protein, lactate dehydrogenase, albumin [62], serum ferritin [63], and low oxygen saturation [64] provide additional support for this hypothesis. In addition, packed red blood cell transfusion may promote recovery of COVID-19 patients with acute respiratory failure [65].

In short, both WCR exposure and COVID-19 may cause deleterious effects on red blood cells and reduced hemoglobin levels contributing to hypoxia in COVID-19. Endothelial injury may further contribute to hypoxia and many of the vascular complications seen in COVID-19 [66] that are discussed in the next section.

3.2. Oxidative stress

Oxidative stress is a non-specific pathological condition reflecting an imbalance between an increased production of ROS and an inability of the organism to detoxify the ROS or to repair the damage they cause to biomolecules and tissues [67]. Oxidative stress can disrupt cell signaling, cause the formation of stress proteins, and generate highly reactive free radicals, which can cause DNA and cell membrane damage.

SARS-CoV-2 inhibits intrinsic pathways designed to reduce ROS levels, thereby increasing morbidity. Immune dysregulation, that is, the upregulation of interleukin (IL)-6 and tumor necrosis factor α (TNF- α) [68] and suppression of interferon (IFN) α and IFN β [69] have been identified in the cytokine storm accompanying severe COVID-19 infections and generates oxidative stress [10]. Oxidative stress and mitochondrial dysfunction may further perpetuate the cytokine storm, worsening tissue damage, and increasing the risk of severe illness and death.

Similarly low-level WCR generates ROS in cells that cause oxidative damage. In fact, oxidative stress is considered to be one of the primary mechanisms in which WCR exposure causes cellular damage. Among 100 currently available peer-reviewed studies investigating oxidative effects of low-intensity WCR, 93 of these studies confirmed that WCR induces oxidative effects in biological systems [17]. WCR is an oxidative agent with a high pathogenic potential especially when exposure is continuous [70].

Oxidative stress is also an accepted mechanism causing endothelial damage [71]. This may manifest in patients with severe COVID-19 in addition to increasing the risk for blood clot formation and worsening hypoxemia [10]. Low levels of glutathione, the master antioxidant, have been observed in a small group of COVID-19 patients, with the lowest level found in the most severe cases [72]. The finding of low glutathione levels in these patients further supports oxidative stress as a component of this disease [72]. In fact, glutathione, the major source of sulfhydryl-based antioxidant activity in the human body, may be pivotal in COVID-19 [73]. Glutathione deficiency has been proposed as the most likely cause of serious manifestations in COVID-19 [72]. The most common co-morbidities, hypertension [74]; obesity [75]; diabetes [76]; and chronic obstructive pulmonary disease [74] support the concept that pre-existing conditions causing low levels of glutathione may work synergistically to create the “perfect storm” for both the respiratory and vascular complications of severe infection. Another paper citing two cases of COVID-19 pneumonia treated successfully with intravenous glutathione also supports this hypothesis [77].

Many studies report oxidative stress in humans exposed to WCR. Peraica *et al.* [78] found diminished blood levels of glutathione in workers exposed to WCR from radar equipment (0.01 mW/cm² – 10 mW/cm²; 1.5 – 10.9 GHz). Garaj-Vrhovac *et al.* [79] studied bioeffects following exposure to non-thermal pulsed microwaves from marine radar (3 GHz, 5.5 GHz, and 9.4 GHz) and reported reduced glutathione levels and increased malondialdehyde (marker for oxidative stress) in an occupationally exposed group [79]. Blood plasma of individuals residing near mobile phone base stations showed significantly reduced glutathione, catalase, and superoxide dismutase levels over unexposed controls [80]. In a study on human exposure to WCR from mobile phones, increased blood levels of lipid peroxide were reported, while enzymatic activities of superoxide dismutase and glutathione peroxidase in the red blood cells decreased, indicating oxidative stress [81].

In a study on rats exposed to 2450 MHz (wireless router frequency), oxidative stress was implicated in causing red blood cell lysis (hemolysis) [82]. In another study, rats exposed to 945 MHz (base station frequency) at 0.367 mW/cm² for 7 h/day, over 8 days, demonstrated low glutathione levels and increased malondialdehyde and superoxide dismutase enzyme activity, hallmarks for oxidative stress [83]. In a long-term controlled study on rats exposed to 900 MHz (mobile phone frequency) at 0.0782 mW/cm² for 2 h/day for 10 months, there was a significant increase in malondialdehyde and total oxidant status over controls [84]. In another long-term controlled study on rats exposed to two mobile phone frequencies, 1800 MHz and 2100

MHz, at power densities 0.04 – 0.127 mW/cm² for 2 h/day over 7 months, significant alterations in oxidant-antioxidant parameters, DNA strand breaks, and oxidative DNA damage were found [85].

There is a correlation between oxidative stress and thrombogenesis [86]. ROS can cause endothelial dysfunction and cellular damage. The endothelial lining of the vascular system contains ACE2 receptors that are targeted by SARS-CoV-2. The resulting endotheilitis can cause luminal narrowing and result in diminished blood flow to downstream structures. Thrombi in arterial structures can further obstruct blood flow causing ischemia and/or infarcts in involved organs, including pulmonary emboli and strokes. Abnormal blood coagulation leading to micro-emboli was a recognized complication early in the history of COVID-19 [87]. Out of 184 ICU COVID-19 patients, 31% showed thrombotic complications [88]. Cardiovascular clotting events are a common cause of COVID-19 deaths [12]. Pulmonary embolism, disseminated intravascular coagulation (DIC), liver, cardiac, and renal failure have all been observed in COVID-19 patients [89].

Patients with the highest cardiovascular risk factors in COVID-19 include males, the elderly, diabetics, and obese and hypertensive patients. However, increased incidence of strokes in younger patients with COVID-19 has also been described [90].

Oxidative stress is caused by WCR exposure and is known to be implicated in cardiovascular disease. Ubiquitous environmental exposure to WCR may contribute to cardiovascular disease by creating a chronic state of oxidative stress [91]. This would lead to oxidative damage to cellular constituents and alter signal transduction pathways. In addition, pulse-modulated WCR can cause oxidative injury in liver, lung, testis, and heart tissues mediated by lipid peroxidation, increased levels of nitric oxides, and suppression of the antioxidant defense mechanism [92].

In summary, oxidative stress is a major component in the pathophysiology of COVID-19 as well as in cellular damage caused by WCR exposure.

3.3. Immune system disruption and activation

When SARS-CoV-2 first infects the human body, it attacks cells lining the nose, throat, and upper airway harboring ACE2 receptors. Once the virus gains access to a host cell through one of its spike proteins, which are the multiple protuberances projecting from the viral envelope that bind to ACE2 receptors, it converts the cell into a virus self-replicating entity.

In response to COVID-19 infection, both an immediate systemic innate immune response as well as a delayed adaptive response has been shown to occur [93]. The virus can also cause a dysregulation of the immune response, particularly in the decreased production of T-lymphocytes. [94]. Severe cases tend to have lower lymphocyte counts, higher leukocyte counts and neutrophil-lymphocyte ratios, as well as lower percentages of monocytes, eosinophils, and basophils [94]. Severe cases of COVID-19 show the greatest impairment in T-lymphocytes.

In comparison, low-level WCR studies on laboratory animals also show impaired immune function [95]. Findings

include physical alterations in immune cells, a degradation of immunological responses, inflammation, and tissue damage. Baranski [96] exposed guinea pigs and rabbits to continuous or pulse-modulated 3000 MHz microwaves at an average power density of 3.5 mW/cm² for 3 h/day over 3 months and found nonthermal changes in lymphocyte counts, abnormalities in nuclear structure, and mitosis in the erythroblastic cell series in the bone marrow and in lymphoid cells in lymph nodes and spleen. Other investigators have shown diminished T-lymphocytes or suppressed immune function in animals exposed to WCR. Rabbits exposed to 2.1 GHz at 5mW/cm² for 3 h/day, 6 days/week, for 3 months, showed suppression of T-lymphocytes [97]. Rats exposed to 2.45 GHz and 9.7 GHz for 2 h/day, 7 days/week, for 21 months showed a significant decrease in the levels of lymphocytes and an increase in mortality at 25 months in the irradiated group [98]. Lymphocytes harvested from rabbits irradiated with 2.45 GHz for 23 h/day for 6 months show a significant suppression in immune response to a mitogen [99].

In 2009, Johansson conducted a literature review, which included the 2007 Bioinitiative Report. He concluded that electromagnetic fields (EMF) exposure, including WCR, can disturb the immune system and cause allergic and inflammatory responses at exposure levels significantly less than current national and international safety limits and raise the risk for systemic disease [100]. A review conducted by Szmigielski in 2013 concluded that weak RF/microwave fields, such as those emitted by mobile phones, can affect various immune functions both *in vitro* and *in vivo* [101]. Although the effects are historically somewhat inconsistent, most research studies document alterations in the number and activity of immune cells from RF exposure. In general, short-term exposure to weak microwave radiation may temporarily stimulate an innate or adaptive immune response, but prolonged irradiation inhibits those same functions.

In the acute phase of COVID-19 infection, blood tests demonstrate elevated ESR, C-reactive protein, and other elevated inflammatory markers [102], typical of an innate immune response. Rapid viral replication can cause death of epithelial and endothelial cells and result in leaky blood vessels and pro-inflammatory cytokine release [103]. Cytokines, proteins, peptides, and proteoglycans that modulate the body's immune response, are modestly elevated in patients with mild-to-moderate disease severity [104]. In those with severe disease, an uncontrolled release of pro-inflammatory cytokines--a cytokine storm--can occur. Cytokine storms originate from an imbalance in T-cell activation with dysregulated release of IL-6, IL-17, and other cytokines. Programmed cell death (apoptosis), ARDS, DIC, and multi-organ system failure can all result from a cytokine storm and increase the risk of mortality.

By comparison, Soviet researchers found in the 1970s that radiofrequency radiation can damage the immune system of animals. Shandala [105] exposed rats to 0.5 mW/cm² microwaves for 1 month, 7 h/day, and found impaired immune competence and induction of autoimmune disease. Rats irradiated with 2.45 GHz at 0.5 mW/cm² for 7 h daily for 30 days produced autoimmune reactions, and 0.1 – 0.5 mW/cm² produced persistent pathological

immune reactions [106]. Exposure to microwave radiation, even at low levels (0.1 – 0.5 mW/cm²), can impair immune function, causing physical alterations in the essential cells of the immune system and a degradation of immunologic responses [107]. Szabo *et al.* [108] examined the effects of 61.2 GHz exposure on epidermal keratinocytes and found an increase in IL-1b, a pro-inflammatory cytokine. Makar *et al.* [109] found that immunosuppressed mice irradiated 30 min/day for 3 days by 42.2 GHz showed increased levels of TNF- α , a cytokine produced by macrophages.

In short, COVID-19 can lead to immune dysregulation as well as cytokine storms. By comparison, exposure to low-level WCR as observed in animal studies can also compromise the immune system, with chronic daily exposure producing immunosuppression or immune dysregulation including hyperactivation.

3.4. Increased intracellular calcium

In 1992, Walleczek first suggested that ELF electromagnetic fields (<3000 Hz) may be affecting membrane-mediated Ca²⁺ signaling and lead to increased intracellular Ca²⁺ [110]. The mechanism of irregular gating of voltage-gated ion channels in cell membranes by polarized and coherent, oscillating electric or magnetic fields was first presented in 2000 and 2002 [40,111]. Pall [112] in his review of WCR-induced bioeffects combined with use of calcium channel blockers (CCB) noted that voltage-gated calcium channels play a major role in WCR bioeffects. Increased intracellular Ca²⁺ results from the activation of voltage-gated calcium channels, and this may be one of the primary mechanisms of action of WCR on organisms.

Intracellular Ca²⁺ is essential for virus entry, replication, and release. It has been reported that some viruses can manipulate voltage-gated calcium channels to increase intracellular Ca²⁺ thereby facilitating viral entry and replication [113]. Research has shown that the interaction between a virus and voltage-gated calcium channels promote virus entry at the virus-host cell fusion step [113]. Thus, after the virus binds to its receptor on a host cell and enters the cell through endocytosis, the virus takes over the host cell to manufacture its components. Certain viral proteins then manipulate calcium channels, thereby increasing intracellular Ca²⁺, which facilitates further viral replication.

Even though direct evidence has not been reported, there is indirect evidence that increased intracellular Ca²⁺ may be involved in COVID-19. In a recent study, elderly hospitalized COVID-19 patients treated with CCBs, amlodipine or nifedipine, were more likely to survive and less likely to require intubation or mechanical ventilation than controls [114]. Furthermore, CCBs strongly limit SARS-CoV-2 entry and infection in cultured epithelial lung cells [115]. CCBs also block the increase of intracellular Ca²⁺ caused by WCR exposure as well as exposure to other electromagnetic fields [112].

Intracellular Ca²⁺ is a ubiquitous second messenger relaying signals received by cell surface receptors to effector proteins involved in numerous biochemical processes. Increased intracellular Ca²⁺ is a significant factor in upregulation of transcription nuclear factor KB (NF- κ B) [116], an important

regulator of pro-inflammatory cytokine production as well as coagulation and thrombotic cascades. NF- κ B is hypothesized to be a key factor underlying severe clinical manifestations of COVID-19 [117].

In short, WCR exposure, therefore, may enhance the infectivity of the virus by increasing intracellular Ca^{2+} that may also indirectly contribute to inflammatory processes and thrombosis.

3.5. Cardiac effects

Cardiac arrhythmias are more commonly encountered in critically ill patients with COVID-19 [118]. The cause for arrhythmia in COVID-19 patients is multifactorial and includes cardiac and extra-cardiac processes [119]. Direct infection of the heart muscle by SARS-CoV-19 causing myocarditis, myocardial ischemia caused by a variety of etiologies, and heart strain secondary to pulmonary or systemic hypertension can result in cardiac arrhythmia. Hypoxemia caused by diffuse pneumonia, ARDS, or extensive pulmonary emboli represent extra-cardiac causes of arrhythmia. Electrolyte imbalances, intravascular fluid imbalance, and side effects from pharmacologic regimens can also result in arrhythmias in COVID-19 patients. Patients admitted to ICUs have been shown to have a higher increase in cardiac arrhythmias, 16.5% in one study [120]. Although no correlation between EMFs and arrhythmia in COVID-19 patients has been described in the literature, many ICUs are equipped with wireless patient monitoring equipment and communication devices producing a wide range of EMF pollution [121].

COVID-19 patients commonly show increased levels of cardiac troponin, indicating damage to the heart muscle [122]. Cardiac damage has been associated with arrhythmias and increased mortality. Cardiac injury is thought to be more often secondary to pulmonary emboli and viral sepsis, but direct infection of the heart, that is, myocarditis, can occur through direct viral binding to ACE2 receptors on cardiac pericytes, affecting local, and regional cardiac blood flow [60].

Immune system activation along with alterations in the immune system may result in atherosclerotic plaque instability and vulnerability, that is, presenting an increased risk for thrombus formation, and contributing to development of acute coronary events and cardiovascular disease in COVID-19.

Regarding WCR exposure bioeffects, in 1969 Christopher Dodge of the Biosciences Division, U.S. Naval Observatory in Washington DC, reviewed 54 papers and reported that radiofrequency radiation can adversely affect all major systems of the body, including impeding blood circulation; altering blood pressure and heart rate; affecting electrocardiograph readings; and causing chest pain and heart palpitations [123]. In the 1970s Glaser reviewed more than 2000 publications on radiofrequency radiation exposure bioeffects and concluded that microwave radiation can alter the electrocardiogram, cause chest pain, hypercoagulation, thrombosis, and hypertension in addition to myocardial infarction [27,28]. Seizures, convulsions, and alteration of the autonomic nervous system response (increased sympathetic stress response) have also been observed.

Since then, many other researchers have concluded that WCR exposure can affect the cardiovascular system. Although the nature of the primary response to millimeter waves and consequent events are poorly understood, a possible role for receptor structures and neural pathways in the development of continuous millimeter wave-induced arrhythmia has been proposed [47]. In 1997, a review reported that some investigators discovered cardiovascular changes including arrhythmias in humans from long-term low-level exposure to WCR including microwaves [124]. However, the literature also shows some unconfirmed findings as well as some contradictory findings [125]. Havas *et al.* [126] reported that human subjects in a controlled, double-blinded study were hyper-reactive when exposed to 2.45 GHz, digitally pulsed (100 Hz) microwave radiation, developing either an arrhythmia or tachycardia and upregulation of the sympathetic nervous system, which is associated with the stress response. Saili *et al.* [127] found that exposure to Wi-Fi (2.45 GHz pulsed at 10 Hz) affects heart rhythm, blood pressure, and the efficacy of catecholamines on the cardiovascular system, indicating that WCR can act directly and/or indirectly on the cardiovascular system. Most recently, Bandara and Weller [91] present evidence that people who live near radar installations (millimeter waves: 5G frequencies) have a greater risk of developing cancer and experiencing heart attacks. Similarly, those occupationally exposed have a greater risk of coronary heart disease. Microwave radiation affects the heart, and some people are more vulnerable if they have an underlying heart abnormality [128]. More recent research suggests that millimeter waves may act directly on the pacemaker cells of the sinoatrial node of the heart to change the beat frequency, which may underlie arrhythmias and other cardiac issues [47].

In short, both COVID-19 and WCR exposure can affect the heart and cardiovascular system, directly and/or indirectly.

4. Discussion

Epidemiologists, including those at the CDC, consider multiple causal factors when evaluating the virulence of an agent and understanding its ability to spread and cause disease. Most importantly, these variables include environmental cofactors and the health status of the host. Evidence from the literature summarized here suggests a possible connection between several adverse health effects of WCR exposure and the clinical course of COVID-19 in that WCR may have worsened the COVID-19 pandemic by weakening the host and exacerbating COVID-19 disease. However, none of the observations discussed here prove this linkage. Specifically, the evidence does not confirm causation. Clearly COVID-19 occurs in regions with little wireless communication. Furthermore, the relative morbidity caused by WCR exposure in COVID-19 is unknown.

We recognize that many factors have influenced the pandemic's course. Before restrictions were imposed, travel patterns facilitated the seeding of the virus, causing early rapid global spread. Population density, higher mean population age, and socioeconomic factors certainly influenced early viral spread. Air pollution, especially particulate matter $\text{PM}_{2.5}$ (2.5

micro-particulates), likely increased symptoms in patients with COVID-19 lung disease [129].

We postulate that WCR possibly contributed to the early spread and severity of COVID-19. Once an agent becomes established in a community, its virulence increases [130]. This premise can be applied to the COVID-19 pandemic. We surmise that “hot spots” of the disease that initially spread around the world were perhaps seeded by air travel, which in some areas were associated with 5G implementation. However, once the disease became established in those communities, it was able to spread more easily to neighboring regions where populations were less exposed to WCR. Second and third waves of the pandemic disseminated widely throughout communities with and without WCR, as might be expected.

The COVID-19 pandemic has offered us an opportunity to delve further into the potential adverse effects of WCR exposure on human health. Human exposure to ambient WCR significantly increased in 2020 as a “side effect” to the pandemic. Stay-at-home measures designed to reduce the spread of COVID-19 inadvertently resulted in greater public exposure to WCR, as people conducted more business and school related activities through wireless communications. Telemedicine created another source of WCR exposure. Even hospital inpatients, particular ICU patients, experienced increased WCR exposure as new monitoring devices utilized wireless communication systems that may exacerbate health disorders. It would potentially provide valuable information to measure ambient WCR power densities in home and work environments when comparing disease severity in patient populations with similar risk factors.

The question of causation could be investigated in future studies. For example, a clinical study could be conducted in COVID-19 patient populations with similar risk factors, to measure the WCR daily dose in COVID-19 patients and look for a correlation with disease severity and progression over time. As wireless device carrier frequencies and modulations may differ, and the power densities of WCR fluctuate constantly at a given location, this study would require patients to wear personal microwave dosimeters (monitoring badges). In addition, controlled laboratory studies could be conducted on animals, for example, humanized mice infected with SARS-CoV-2, in which groups of animals exposed to minimal WCR (control group) as well as medium and high power densities of WCR could be compared for disease severity and progression.

A major strength of this paper is that the evidence rests on a large body of scientific literature reported by many scientists worldwide and over several decades--experimental evidence of adverse bioeffects of WCR exposure at nonthermal levels on humans, animals, and cells. The Bioinitiative Report [42], updated in 2020, summarizes hundreds of peer-reviewed scientific papers documenting evidence of nonthermal effects from exposures ≤ 1 mW/cm². Even so, some laboratory studies on the adverse health effects of WCR have sometimes utilized power densities exceeding 1 mW/cm². In this paper, almost all of the studies that we reviewed included experimental data at power densities ≤ 1 mW/cm².

A potential criticism of this paper is that adverse bioeffects from nonthermal exposures are not yet universally accepted in

science. Moreover, they are not yet considered in establishing public health policy in many nations. Decades ago, Russians and Eastern Europeans compiled considerable data on nonthermal bioeffects, and subsequently set guidelines at lower radiofrequency radiation exposure limits than the US and Canada, that is, below levels where nonthermal effects are observed. However, the Federal Communications Commission (FCC, a US government entity) and ICNIRP guidelines operate on thermal limits based on outdated data from decades ago, allowing the public to be exposed to considerably higher radiofrequency radiation power densities. Regarding 5G, the telecommunication industry claims that it is safe because it complies with current radiofrequency radiation exposure guidelines of the FCC and ICNIRP. These guidelines were established in 1996 [131], are antiquated, and are not safety standards. Thus, there are no universally accepted safety standards for wireless communication radiation exposure. Recently international bodies, such as the EMF Working Group of the European Academy of Environmental Medicine, have proposed much lower guidelines, taking into account nonthermal bioeffects from WCR exposure in multiple sources [132].

Another weakness of this paper is that some of the bioeffects from WCR exposure are inconsistently reported in the literature. Replicated studies are often not true replications. Small differences in method, including unreported details, such as prior history of exposure of the organisms, non-uniform body exposure, and other variables can lead to inadvertent inconsistency. Moreover, not surprisingly, industry-sponsored studies tend to show less adverse bioeffects than studies conducted by independent researchers, suggesting industry bias [133]. Some experimental studies that are not industry-sponsored have also shown no evidence of harmful effects of WCR exposure. It is noteworthy, however, that studies employing real-life WCR exposures from commercially available devices have shown high consistency in revealing adverse effects [134].

WCR bioeffects depend on specific values of wave parameters including frequency, power density, polarization, exposure duration, modulation characteristics, as well as the cumulative history of exposure and background levels of electromagnetic, electric and magnetic fields. In laboratory studies, bioeffects observed also depend on genetic parameters and physiological parameters such as oxygen concentration [135]. The reproducibility of bioeffects of WCR exposure has sometimes been difficult due to failure to report and/or control all of these parameters. Similar to ionizing radiation, the bioeffects of WCR exposure can be subdivided into deterministic, that is, dose-dependent effects and stochastic effects that are seemingly random. Importantly, WCR bioeffects can also involve “response windows” of specific parameters whereby extremely low-level fields can have disproportionately detrimental effects [136]. This nonlinearity of WCR bioeffects can result in biphasic responses such as immune suppression from one range of parameters, and immune hyperactivation from another range of parameters, leading to variations that may appear inconsistent.

In gathering reports and examining existing data for this paper, we looked for outcomes providing evidence to support a proposed connection between the bioeffects of WCR exposure and

COVID-19. We did not make an attempt to weigh the evidence. The radiofrequency radiation exposure literature is extensive and currently contains over 30,000 research reports dating back several decades. Inconsistencies in nomenclature, reporting of details, and cataloging of keywords make it difficult to navigate this enormous literature.

Another shortcoming of this paper is that we do not have access to experimental data on 5G exposures. In fact, little is known about population exposure from real-world WCR, which includes exposure to WCR infrastructure and the plethora of WCR emitting devices. In relation to this, it is difficult to accurately quantify the average power density at a given location, which varies greatly, depending on the time, specific location, time-averaging interval, frequency, and modulation scheme. For a specific municipality it depends on the antenna density, which network protocols are used, as, for example, 2G, 3G, 4G, 5G, Wi-Fi, WiMAX (Worldwide Interoperability for Microwave Access), DECT (Digitally Enhanced Cordless Telecommunications), and RADAR (Radio Detection and Ranging). There is also WCR from ubiquitous radio wave transmitters, including antennas, base stations, smart meters, mobile phones, routers, satellites, and other wireless devices currently in use. All of these signals superimpose to yield the total average power density at a given location that typically fluctuates greatly over time. No experimental studies on adverse health effects or safety issues of 5G have been reported, and none are currently planned by the industry, although this is sorely needed.

Finally, there is an inherent complexity to WCR that makes it very difficult to fully characterize wireless signals in the real world that may be associated with adverse bioeffects. Real world digital communication signals, even from single wireless devices, have highly variable signals: variable power density, frequency, modulation, phase, and other parameters changing constantly and unpredictably each moment, as associated with the short, rapid pulsations used in digital wireless communication [137]. For example, in using a mobile phone during a typical phone conversation, the intensity of emitted radiation varies significantly each moment depending on signal reception, number of subscribers sharing the frequency band, location within the wireless infrastructure, presence of objects and metallic surfaces, and “speaking” versus “non-speaking” mode, among others. Such variations may reach 100% of the average signal intensity. The carrier radiofrequency constantly changes between different values within the available frequency band. The greater the amount of information (text, speech, internet, video, etc.), the more complex the communication signals become. Therefore, we cannot estimate accurately the values of these signal parameters including ELF components or predict their variability over time. Thus, studies on the bioeffects of WCR in the laboratory can only be representative of real-world exposures [137].

This paper points to the need for further research on nonthermal WCR exposure and its potential role in COVID-19. Moreover, some of the WCR exposure bioeffects that we discuss here — oxidative stress, inflammation, and immune system disruption — are common to many chronic diseases, including autoimmune disease

and diabetes. Thus, we hypothesize that WCR exposure may also be a potential contributing factor in many chronic diseases.

When a course of action raises threats of harm to human health, precautionary measures should be taken, even if clear causal relationships are not yet fully established. Therefore, we must apply the Precautionary Principle [138] regarding wireless 5G. The authors urge policymakers to execute an immediate worldwide moratorium on wireless 5G infrastructure until its safety can be assured.

Several unresolved safety issues should be addressed before wireless 5G is further implemented. Questions have been raised about 60 GHz, a key 5G frequency planned for extensive use, which is a resonant frequency of the oxygen molecule [139]. It is possible that adverse bioeffects might ensue from oxygen absorption of 60 GHz. In addition, water shows broad absorption in the GHz spectral region along with resonance peaks, for example, strong absorption at 2.45 GHz that is used in 4G Wi-Fi routers. This raises safety issues about GHz exposure of the biosphere, since organisms are comprised of mostly water, and changes in the structure of water due to GHz absorption have been reported that affect organisms [140]. Bioeffects from prolonged WCR exposure of the whole body need to be investigated in animal and human studies, and long-term exposure guidelines need to be considered. Independent scientists in particular should conduct concerted research to determine the biological effects of real-world exposure to WCR frequencies with digital modulation from the multiplicity of wireless communication devices. Testing could also include real-life exposures to multiple toxins (chemical and biological) [141], because multiple toxins may lead to synergistic effects. Environmental impact assessments are also needed. Once the long-term biological effects of wireless 5G are understood, we can set clear safety standards of public exposure limits and design an appropriate strategy for safe deployment.

5. Conclusion

There is a substantial overlap in pathobiology between COVID-19 and WCR exposure. The evidence presented here indicates that mechanisms involved in the clinical progression of COVID-19 could also be generated, according to experimental data, by WCR exposure. Therefore, we propose a link between adverse bioeffects of WCR exposure from wireless devices and COVID-19.

Specifically, evidence presented here supports a premise that WCR and, in particular, 5G, which involves densification of 4G, may have exacerbated the COVID-19 pandemic by weakening host immunity and increasing SARS-CoV-2 virulence by (1) causing morphologic changes in erythrocytes including echinocyte and rouleaux formation that may be contributing to hypercoagulation; (2) impairing microcirculation and reducing erythrocyte and hemoglobin levels exacerbating hypoxia; (3) amplifying immune dysfunction, including immunosuppression, autoimmunity, and hyperinflammation; (4) increasing cellular oxidative stress and the production of free radicals exacerbating vascular injury and organ damage; (5) increasing intracellular Ca^{2+} essential for viral entry, replication, and release, in addition to promoting pro-

inflammatory pathways; and (6) worsening heart arrhythmias and cardiac disorders.

WCR exposure is a widespread, yet often neglected, environmental stressor that can produce a wide range of adverse bioeffects. For decades, independent research scientists worldwide have emphasized the health risks and cumulative damage caused by WCR [42,45]. The evidence presented here is consistent with a large body of established research. Healthcare workers and policymakers should consider WCR a potentially toxic environmental stressor. Methods for reducing WCR exposure should be provided to all patients and the general population.

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Conflict of Interest

The authors declare that they have no conflicts of interest in preparing and publishing this manuscript. No competing financial interests exist.

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КОРРЕЛЯЦИЯ МЕЖДУ ПОТЕНЦИАЛЬНЫМ УРОВНЕМ ЭЛЕКТРОМАГНИТНОГО ЗАГРЯЗНЕНИЯ И ОПАСНОСТЬЮ COVID-19. 4G/5G/6G МОГУТ БЫТЬ БЕЗОПАСНЫМИ ДЛЯ ЛЮДЕЙ

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Аннотация. В работе рассматривается гипотеза о возможном, наряду с другими факторами, влиянии на уровень смертности населения от коронавирусной инфекции уровня электромагнитного загрязнения среды обитания. Гипотеза косвенно подтверждается наличием корреляции между степенью жесткости гигиенического нормирования уровней радиочастотного электромагнитного фона для населения, главным источником которого являются системы мобильной (сотовой) связи, и уровнем смертности от COVID-19 в различных странах. Обсуждаются специальные меры по обеспечению безопасного быстрого развития технологий, систем и услуг мобильной связи четвертого (4G), пятого (5G), а к 2030 году и шестого (6G) поколения, связанного с увеличением на несколько порядков числа излучающих устройств, скорости передачи данных по радиочастотным каналам и территориальной плотности трафика мобильной связи. Для количественного анализа этих процессов развита и верифицирована с использованием результатов многочисленных измерений электромагнитного фона в различных странах практическая методика пессимистической оценки уровня электромагнитного фона, создаваемого этими системами, основные положения которой излагаются в данной работе. Данная методика основана на использовании интегральных системных характеристик беспроводного информационного обслуживания общества и позволяет обосновать необходимые системные, технические и организационные решения, направленные на обеспечение необходимого уровня электромагнитной экологии населенных территорий и электромагнитной безопасности населения в условиях быстрого развития систем 4G/5G/6G без ущерба информационному обслуживанию населения и информационным технологиям в экономике, образовании, здравоохранении и других областях.

Ключевые слова: COVID-19, электромагнитное загрязнение, нормы, корреляция сотовая связь, 4G, 5G, 6G, электромагнитная экология, электромагнитная безопасность.

Конфликт интересов. Автор заявляет об отсутствии конфликта интересов.

Для цитирования. Мордачев В.И. Корреляция между потенциальным уровнем электромагнитного загрязнения и опасностью COVID-19. 4G/5G/6G могут быть безопасными для людей. Доклады БГУИР. 2020; 18(4): 96-112.

CORRELATION BETWEEN THE POTENTIAL ELECTROMAGNETIC POLLUTION LEVEL AND THE DANGER OF COVID-19. 4G/5G/6G CAN BE SAFE FOR PEOPLE

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Abstract. The paper considers a hypothesis concerned the possible influence of electromagnetic pollution of the environment on the lethality rate of the population from coronavirus infection, along with other factors. The hypothesis is indirectly confirmed by the correlation between the degree of rigidity of hygienic regulations of radio frequency electromagnetic background levels for the population, which are mainly created by mobile (cellular) communication systems, and the lethality rate from COVID-19 in various countries. A special measures to ensure the safety of rapid development of technologies, systems and services for mobile communications of the fourth (4G), fifth (5G), and, by 2030, the sixth (6G) generation, associated with an increase by several orders of magnitude in the number of radiating devices, the data transmission rates over radio frequency channels and the area capacity of mobile traffic, are discussed. For quantitative analysis of these processes, a practical method of worst-case estimation of electromagnetic background level generated by these systems has been developed, verified using the results of numerous measurements of the electromagnetic background in various countries, and described in this paper. This technique is based on the use of the integrated system characteristics of wireless information services and makes it possible to justify the necessary system, technical and managerial solutions aimed at ensuring the necessary level of electromagnetic ecology of populous areas and electromagnetic safety of people in conditions of rapid advancement of 4G/5G/6G systems without affecting the quality of informational support of the population and information technologies in economy, education, healthcare and other sectors.

Keywords: COVID-19, electromagnetic pollution, regulations, correlation, mobile communications, 4G, 5G, 6G, electromagnetic ecology, electromagnetic safety.

Conflict of interests. The author declares no conflict of interests.

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Relevance of the Problem

Due to the extremely intensive development of wireless technologies and systems of public information services and their deep penetration into all areas of human activity, the electromagnetic (EM) pollution associated with these processes is becoming an increasingly threatening anthropogenic factor. Its danger, as a rule, is underestimated, and in the coming years may turn out to be commensurate with the danger of the known processes of global warming and environmental degradation.

Numerous measurements of the levels of electromagnetic background (EMB) generated by cellular communications (CC) in places with different population density in 2005-2019 [1–11, etc.] indicate that CC radio networks of the second (GSM, IS-95) and the third (UMTS, CDMA2000) generations, which provided the bulk of mobile telephony services and a relatively small volume of mobile Internet services during measurement periods, as a whole, posed no danger for the population. In the places where these measurements were carried out, the area density of sources of radio frequency EM radiation did not exceed 10^3 – 10^4 devices/km², the area traffic capacity (ATC) did not exceed 0.1–1.0 kbit/s/m² at data rates on the radio channels of user's interface no higher than 0.032–2.0 Mbit/s. As a result, the intensity of EM background created by these sources was

no more than a few $\mu\text{W}/\text{cm}^2$ in the overwhelming majority of cases, not exceeding the level of $9.5\text{--}10 \mu\text{W}/\text{cm}^2$, defined in many countries (Azerbaijan, Belarus, Bulgaria (short-term), Canada (Toronto), Chile (sensitive), France (Paris), Hungary, Italy (general), Kazakhstan, Lithuania, Poland, Russia, Switzerland, Ukraine, etc.) [12] as the maximum permissible level (MPL) of EM background intensity for population.

In the early periods of CC development (first and second generations of CC), when the main type of service was mobile telephony, uplink and downlink traffic rates (the amount of information transmitted from mobile (MS) to the base (BS) station and vice-versa) were symmetrical, it was supposed that the main hazard to health is brought about by EM radiation of CC MS, since the mobile phone is located near the human body, and voluntary environmental risks during the CC operation are predominant.

However, as a result of the subsequent evolution of CC in the direction of intensive development of data transmission technologies and services (mobile Internet, interactive broadcasting, etc.), the situation has changed quite significantly, giving the room for the following to take place:

- a constant decrease in the average range of cellular radio-telephone communications with a corresponding decrease in the average power of MS EM radiation in this mode and an attendant decrease in voluntary environmental risks due to the fast development of the CC radio network infrastructure and the increasing use of indoor hotspots, urban micro-cells, etc. [13];
- a constantly increasing asymmetry of downlink and uplink traffic rates, the ratio of capacities of information transmitted from BS to MS and in the opposite direction reaches $10\text{--}100$ [14] with a corresponding change in the ratio of EM energy radiated by sets of BS and MS;
- as a result, the environmental risks caused by the increased intensity of EM background created by CC, come to the fore and become predominant.

The observed dynamic evolution of CC generations from 2G (GSM, IS-95) and 3G (UMTS, CDMA2000) to the 4G (LTE) [13–15], and then to the upcoming 5G [16–18] and 6G [19, 20] is an inevitable process, due to the highest efficiency of digital mobile communication systems in almost all areas of human activity and the extreme attractiveness of a wide range of wireless information services.

Let us consider the summary data of Table 1, characterizing the planned growth of six main system parameters of wireless information services in near future. An increase in the values of parameters No. 1, 2, 3, 4 is associated with a proportional increase in the power of EM radiations of BS and MS of CC, and an increase in the values of parameters No. 5, 6 provides a proportional decrease in this power. Moreover, the aforementioned parameters experience an increase for the following reasons:

- the expected cumulative increase in parameters No. 1, 2, 3, 4 is at least $\approx 10^4$ times for $4\text{G} \rightarrow 5\text{G}$ evolution, and the same $\approx 10^4$ times for $5\text{G} \rightarrow 6\text{G}$ evolution (in total about 8 orders of magnitude for $4\text{G} \rightarrow 6\text{G}$ evolution), and
- the expected total increase in parameters No. 5, 6 is only $\approx 30\text{--}300$ times for $4\text{G} \rightarrow 5\text{G}$ evolution, and $50\text{--}1000$ times for $5\text{G} \rightarrow 6\text{G}$ evolution (in total no more than 3–4 orders of magnitude for $4\text{G} \rightarrow 6\text{G}$ evolution taking into account the uncertainty of estimates [16–20]), the declared development of mobile communications from 4G to 5G and further to 6G using traditional approaches can cause a sharp (by several orders of magnitude!) increase in the intensity of EM background created by CC in places with a high population density, and a corresponding sharp degradation of the environmental EM ecology, and, in general, an unacceptable reduction of public EM safety.

On the one hand, such prospects are a cause of growing concern about the health and well-being of population, which may result in local government-level decisions that restrict the use of wireless services in critical places, such as decisions [21–23] adopted in Switzerland and France in order to limit the use of wireless solutions and services in buildings and in public transport.

Table 1. Summary data characterizing the planned evolution of the system parameters of mobile communication networks, according to [15–20]

Таблица 1. Сводные данные, характеризующие планируемую эволюцию системных параметров сетей мобильной связи, по данным [15–20]

System parameters Системные параметры	Generation of mobile (cellular) communications Поколение мобильной (сотовой) связи			Total increase in evolution 4G→6G Суммарный рост при эволюции 4G→6G
	4G	5G	6G	
1. Peak data rate	100 Mb/s	10–20 Gb/s	≥ 1 Tb/s	$\approx 10^4$ times
2. Experienced data rate	10 Mb/s	0.1 Gb/s	1–10 Gb/s	$\approx 10^2$ times
3. Area traffic capacity	0.1 Mb/s/m ²	10 Mb/s/m ²	1 Gb/s/m ²	$\approx 10^4$ times
4. Connectivity density (density of radiating MS)	0.1 Devices/m ²	1.0 Devices/m ²	10 Devices/m ²	$\approx 10^2$ times
5. Spectrum efficiency	1*	3* that of 4G	(5–10)* that of 5G	≈ 15 –30 times
6. Network energy efficiency	1 (relative base level)	10–100 times increase compared to 4G	10–100 times increase compared to 5G	$\approx 10^2$ – 10^4 times

On the other hand, there is a noticeable worry that such local government decisions, as well as growing radio phobia of population, can impede the CC development on a scale and pace [16–20]. Apparently, this was the reason for the emergence of the latest corporate recommendations ICNIRP [24], declaring the safety of 5G systems and services at levels of radio frequency EM background that 100 times or more higher than the MPL of EM background accepted in many countries.

It should be noted that these recommendations, taking into account only the thermal effect of radio frequency EM fields on human body, determining upper boundary of the range of their supposedly safe intensity at a level of 10 W/m² (1000 μ W/cm²) and above, and allowing them to heat the human upperparts to 2 degrees and some parts of the body up to 5 degrees in 6 minutes, are extremely optimistic from the point of view of EM safety of the population. They have a pronounced corporate character, do not take into account various non-thermal effects of exposure to radio-frequency EM fields [25–36, etc.] and, apparently, can only illustrate the boundaries between the non-fatal and fatal effects of radio-frequency EM fields on human body.

Such levels of EM exposure actually correspond to the modes of gentle defrosting of food products in a microwave oven and, in the author's deep assurance, cannot be considered as acceptable for the whole population.

The author is sure that MPL values of EM fields of the order of 2.5–10 μ W/cm² (0.025–0.1 W/m²), accepted in many countries as a result of in-depth scientific research and many years of analysis of the health of separate population groups subjected to forced or voluntary exposure to radio-frequency EM fields, and reflecting the real danger of non-thermal effects of exposure to these fields on the human body, are more adequate to the required degree of protection of the population from EM background created by modern and future CC systems.

These effects, in particular, are associated with impairing of nervous and mental activity [26–30], decreasing of reproductive function in both men and women [31, 32], and an appreciable increase in DNA damage [32], impairing of heart rhythm and peripheral arterial pressure [33, 34], suppression of the immune system [35, 36], when exposed to radio frequency EM fields with levels significantly lower than those recommended in [24]; finally, by a WHO decision [37], radio-frequency EM fields are classified as a potentially carcinogenic hazard.

Correlation between EM environmental pollution and harm to population by COVID-19

Quite numerous publications, such as [25–37], make us take a fresh look at the causes of a rather uneven harm to population by the COVID-19 in different countries. In conditions of complete “multilayer” area coverage (i. e. coverage by several radio networks of various operators) with mobile communications, the effect of the adopted restrictions on MPL of radio frequency EM fields on the population's exposure to infections like COVID-19 is apparently inevitable.

Although a large number of other factors (the degree of general environmental pollution, food quality, climate features, epidemic phase, timeliness and effectiveness of restrictive measures taken, etc.) affects public health and susceptibility of the population to infections, and also data of different countries on morbidity and lethality have a different degree of reliability and reflect the different effectiveness of national health systems in struggle with COVID-19, today one cannot fail to see the area correlation between the use of recommendations [24] and the distribution of lethality from COVID-19.

In particular, an analysis of WHO reports [38–40] indicates that in a group of countries where, according to data [12], hygienic restrictions on radio frequency EM fields of $1\text{--}10\text{ }\mu\text{W}/\text{cm}^2$ are accepted, the relative level of lethality from COVID-19 is (1–5) % of the number of the infected, and in a group of countries where the hygienic regulation of EMB is carried out in accordance with corporate recommendations [24], this level is (5–20) %.

Tables 2 and 3 shows the results of a correlation analysis of the relationship between the degree of severity of hygienic regulation of levels of radio frequency EM background for the population in different countries according to data [12] and the lethality rate from COVID-19 in relation to the number of people infected according to [38–40].

The data in Table 2 were obtained for the first version of definition of the relative lethality rate from COVID-19 as the ratio of the total number of deaths to the total number of the infected, and the data in Table 3 correspond to the second version of its definition as the ratio of the number of deaths to the country's population in millions of people.

In this analysis, the representativeness of the samples is ensured by quota sampling – ensuring approximately equal representation of data from countries of both groups; the limited sample size is caused by the lack of more complete data on hygienic regulation of EMF in the countries listed in [38–40].

When determining the relative lethality rate as the ratio of the number of deaths to the total number of the infected, the Pearson's correlation coefficient for the three different correlated samples turned out to be 0.551–0.552. When determining the relative lethality rate as the ratio of the number of deaths to the total country population, the Pearson's correlation coefficient for these samples was even higher, i.e 0.577–0.6. This convincingly confirms the existence of a correlation between the factors under consideration.

The detected correlation is quite stable - its multivariate analysis when varying MPL values for countries where MPL value pairs are used (for Bulgaria (“long-term”/“short-term”) and Chile (“sensitive”/“others”), which differ by 10 times), as well as when trying correction of lethality for some countries suspected of distorting medical statistics, indicates that in all cases the resulting Pearson's correlation coefficient turned out to be no lower than 0.45–0.55.

Of course, the hygienic regulation of MPL radio frequency EMB in accordance with [24], or the absence of such regulation in a number of countries does not mean the mandatory presence of high levels of environmental EM pollution by CC systems.

However, taking into account the extremely high cost of the existence of a relation between the degree of environmental EM pollution and the degree of population susceptibility to similar viral infections, the presence of a relationship between the average levels of radio frequency EM background created by CC systems and the lethality rate from COVID-19 requires the most serious further research and verification.

And if the correlation between the average levels of EM background created by CC systems and the injury of population by COVID-19 will be confirmed by further in-depth studies (which is quite probable, taking into account a very large difference between the “thermal” and “non-thermal” MPL of radio frequency EM fields), this may serve as an objective motivation for the following:

- for much closer attention to the problem of EM pollution of populous areas and, in particular, a more objective critical attitude to corporate declarations like [24], and
- for making decisions similar to [21–23] at the national or regional levels, as well as for searching for reasonable system and technological alternatives to a number of declared directions for the extremely rapid development of 4G/5G/6G systems and for the upcoming extremely deep penetration of wireless technologies and services in all areas of human activities, without prejudice to progress in the field of information technology and public, industrial, educational and other information services.

The fundamental difficulties in justification of such decisions, system and technological alternatives are caused by the lack of adequate practical methods for predicting and evaluating the expected levels of EM background at different stages of the development and implementation of 4G/5G/6G systems and services, since the direct calculation of the total background intensity created by a huge number of stationary (BS) and mobile (MS) sources of EM radiation, is impossible both because of the extreme complexity of this mission, and due to significant a priori uncertainty and confidentiality of the source data.

Table 2. Results of the analysis of a correlation between the degree of severity of hygienic regulations of levels of radio frequency EM background for the population in different countries according to data [12], and the relative lethality rate from COVID-19, defined as the ratio of the number of deaths to the total number of the infected, according to [38–40]

Таблица 2. Результаты анализа корреляции между степенью жесткости гигиенического нормирования уровней радиочастотного электромагнитного фона для населения в различных странах, по данным [12], и относительным уровнем смертности от COVID-19, определяемым как отношение числа умерших к общему числу заразившихся, по данным [38–40]

Country	MPL, W/m ²	The ratio of the total number of deaths to the total number of infected					
		04.05.2020 WHO Rep. 105	%	11.05.2020 WHO Rep. 112	%	18.05.2020 WHO Rep. 119	%
Страна	ПДУ, Вт/м ²	Отношение числа умерших к общему числу заразившихся					
		04.05.2020 WHO Rep. 105	%	11.05.2020 WHO Rep. 112	%	18.05.2020 WHO Rep. 119	%
1. Azerbaijan	0.1	25/1932	1.29	32/2519	1.27	39/3274	1.19
2. Belarus	0.1	103/17489	0.59	135/23906	0.56	165/29650	0.56
3. Belgium	10	7844/49906	15.72	8656/53081	16.31	9052/55280	16.37
4. Bulgaria ¹⁾	0.01	73/1618	4.51	91/1965	4.63	110/2235	4.92
5. Canada	4	3681/59365	6.20	4728/67996	6.95	5702/76204	7.48
6. Chile ¹⁾	0.1	260/19663	1.32	312/28866	1.08	450/43781	1.03
7. China	0.4	4643/84400	5.50	4643/84450	5.50	4645/84494	5.50
8. Denmark	10	484/9523	5.08	529/10429	5.07	547/10927	5.01
9. France	10	24859/129708	19.17	26338/137073	19.21	28059/140036	20.04
10. Germany	10	6692/163175	4.10	7417/169575	4.37	7935/174697	4.54
11. UK	10	28446/186603	15.24	31855/219187	14.53	34636/243699	14.21
12. Hungary	0.1	351/3035	11.57	421/3284	12.82	462/3535	13.07
13. India	0.9	1373/42533	3.23	2206/67152	3.29	3029/96169	3.15
14. Ireland	10	1303/21506	6.06	1458/22996	6.34	1543/24112	6.40
15. Israel	0.9	227/16152	1.41	254/16492	1.54	271/16607	1.63
16. Italy	0.1	28884/210717	13.71	30560/219070	13.95	31908/225435	14.15
17. Japan	10	510/15057	3.39	621/15798	3.93	749/16305	4.59
18. Kazakhstan	0.1	27/3988	0.68	31/5138	0.60	34/6440	0.53
19. Lithuania;	0.1	46/1410	3.26	50/1479	3.38	56/1541	3.63
20. Luxembourg	0.45	96/3824	2.51	101/3886	2.60	107/3945	2.71
21. Netherlands	10	5056/40571	12.46	5440/42627	12.76	5680/43995	12.91
22. Poland	0.1	678/13693	4.95	800/15996	5.00	925/18529	5.00
23. Portugal	10	1043/25282	4.13	1135/27581	4.12	1218/29036	4.19
24. Russia;	0.1	1356/145268	0.93	2009/221344	0.91	2722/290678	0.94
25. Spain	10	25264/217466	11.62	26621/224390	11.86	27650/231350	11.95
26. Sweden;	10	2679/22317	12.00	3225/26322	12.25	3679/30143	12.21
27. Switzerland	0.1	1472/29822	4.94	1537/30222	5.09	1602/30504	5.25
28. Turkey	0.56	3397/126045	2.70	3786/138657	2.73	4140/149435	2.77
29. Ukraine	0.1	303/12331	2.48	408/15648	2.61	535/18616	2.87
30. USA	10	60710/1125719	5.39	76916/1271645	6.05	87180/1432265	6.09
31. Uzbekistan	0.025	10/2160	0.46	10/2411	0.41	12/2762	0.43
Pearson's correlation coefficient:			0.551		0.552		0.551

¹⁾ The lower limit of the range of normalized values.

Table 3. Results of the analysis of a correlation between the degree of severity of hygienic regulations of levels of radio frequency EM background for the population in different countries according to data [12], and the relative lethality rate from COVID-19, defined as the ratio of the number of deaths according to [38–40], to the total country population in millions of people ¹⁾

Таблица 3. Результаты анализа корреляции между степенью жесткости гигиенического нормирования уровней радиочастотного электромагнитного фона для населения в различных странах, по данным [12], и относительным уровнем смертности от COVID-19, определяемым как отношение числа умерших, по данным [38–40], к общей численности населения в миллионах чел. ¹⁾

Country	MPL, W/m ²	The ratio of the total number of deaths to the country population					
		04.05.2020 WHO Rep. 105	Total	11.05.2020 WHO Rep. 112	Total	18.05.2020 WHO Rep. 119	Total
Страна	ПДУ, Вт/м ²	Отношение числа умерших к общей численности населения					
		04.05.2020 WHO Rep. 105	Всего	11.05.2020 WHO Rep. 112	Всего	18.05.2020 WHO Rep. 119	Всего
1. Azerbaijan	0.1	25/10.139	2.47	32/10.139	3.16	39/10.139	3.85
2. Belarus	0.1	103/9.449	10.9	135/9.449	14.3	165/9.449	17.5
3. Belgium	10	7844/11.590	677	8656/11.590	747	9052/11.590	781
4. Bulgaria ²⁾	0.01	73/6.948	10.5	91/6.948	13.1	110/6.948	15.8
5. Canada	4	3681/37.742	97.5	4728/37.742	125	5702/37.742	151
6. Chile ²⁾	0.1	260/19.116	13.6	312/19.116	16.3	450/19.116	23.5
7. China	0.4	4643/1439.324	3.23	4643/1439.324	3.23	4645/1439.324	3.23
8. Denmark	10	484/5.792	83.6	529/5.792	91.3	547/5.792	94.4
9. France	10	24859/65.274	381	26338/65.274	403	28059/65.274	430
10. Germany	10	6692/83.784	79.9	7417/83.784	88.5	7935/83.784	94.7
11. UK	10	28446/67.886	419	31855/67.886	469	34636/67.886	510
12. Hungary	0.1	351/9.660	36.3	421/9.660	43.6	462/9.660	47.8
13. India	0.9	1373/1380.004	0.995	2206/1380.004	1.60	3029/1380.004	2.19
14. Ireland	10	1303/4.938	264	1458/4.938	295	1543/4.938	312
15. Israel	0.9	227/8.656	26.2	254/8.656	29.3	271/8.656	31.3
16. Italy	0.1	28884/60.462	478	30560/60.462	505	31908/60.462	528
17. Japan	10	510/126.76	4.03	621/126.476	4.91	749/126.476	5.92
18. Kazakhstan	0.1	27/18.777	1.44	31/18.777	1.65	34/18.777	1.81
19. Lithuania	0.1	46/2.722	16.9	50/2.722	18.4	56/2.722	20.6
20. Luxemburg	0.45	96/0.626	153	101/0.626	161	107/0.626	171
21. Netherlands	10	5056/17.135	295	5440/17.135	317	5680/17.135	331
22. Poland	0.1	678/37.847	17.9	800/37.847	21.1	925/37.847	24.4
23. Portugal	10	1043/10.197	102	1135/10.197	111	1218/10.197	119
24. Russia;	0.1	1356/146.796	9.24	2009/146.796	13.7	2722/146.796	18.5
25. Spain	10	25264/46.755	540	26621/46.755	569	27650/46.755	591
26. Sweden;	10	2679/10.099	265	3225/10.099	319	3679/10.099	364
27. Switzerland	0.1	1472/8.655	170	1537/8.655	178	1602/8.655	185
28. Turkey	0.56	3397/84.339	40.3	3786/84.339	44.9	4140/84.339	49.1
29. Ukraine	0.1	303/42.156	7.19	408/42.156	9.68	535/42.156	12.7
30. USA	10	60710/331.003	183	76916/331.003	232	87180/331.003	263
31. Uzbekistan	0.025	10/33.469	0.299	10/33.469	0.299	12/33.469	0.359
Pearson's correlation coefficient:			0.577		0.593		0.60

¹⁾ Country population is given according to <https://www.worldometers.info/world-population/>
²⁾ The lower limit of the range of normalized values.

These difficulties can be effectively overcome by using my technique [41–51] of worst-case system analysis of EM background created by CC, which allows to perform the pessimistic estimation of EM background average intensity near the ground surface with the use of integral system CC parameters, given in Table 1.

The adequacy of this technique is confirmed by its verification [49, 52] using a numerous results [1–11] of measurements of EM background created by 2G/3G CC in many countries.

Technique of worst-case system analysis of EM background created by CC

This technique offers a number of useful expressions and procedures for worst-case estimation of the average level of EMB created by radio frequency EM fields that are generated by sets of BS and/or MS of CC at the observation point (OP) at a height of $H_{OP} = 1 \dots 2$ m near the earth's surface (Fig. 1, 2).

In accordance with this technique, the total EM background intensity Z_{Σ} [W/m²] in OP means the scalar sum of values of power flux densities Z_n of EM fields created by N sources of these fields located in an area of radio visibility of these sources from the OP:

$$Z_{\Sigma} = \sum_{n=1}^N Z_n. \quad (1)$$

EM background Intensity created by BS of CC

The average total intensity $Z_{\Sigma BS}$ [W/m²] of EM background created in OP near the ground surface by a set of BS located randomly uniformly (with respect to the OP position) in the area of BS radio visibility from the OP, is determined by the following expression [44, 46, 47]:

$$Z_{\Sigma BS} = Z_{\Sigma BS1} + Z_{\Sigma BS2} = \frac{B_{BS}}{2} \ln \left(\frac{4H_{OP}\sqrt{e}}{\lambda} \right) \approx \frac{B_{BS}}{2} \ln \left(\frac{6.6 \cdot H_{OP}}{\lambda} \right), \quad H_{OP} \geq \frac{\lambda}{4}, \quad (2)$$

$$Z_{\Sigma BS1} = \frac{B_{BS}}{2} \ln \left(\frac{4H_{OP}}{\lambda} \right), \quad Z_{\Sigma BS2} = \frac{B_{BS}}{4}, \quad (3)$$

where λ is the wavelength of BS radiation, B_{BS} [W/m²] is the average specific electromagnetic loading on area (SEMLA) created by BS in the considered area.

The SEMLA B_{BS} [W/m²] created by the set of K BS which are EMR sources, distributed over the area S , is defined as a sum of covering total radiated powers P_{ek} of these BS per unit area:

$$B_{BS} = \frac{\sum_{k=1}^K P_{ek}}{S}, \quad P_{ek} \approx Q_k P_{EIRPk}, \quad (4)$$

where P_{EIRPk} is the equivalent isotropic radiated power (EIRP) of k -th BS in the main lobe of its antenna; $Q_k = P_{ARK}/P_{EIRPk} \leq 1$ is the system parameter of EMR directivity of k -th BS; in this ratio P_{ARK} and P_{EIRPk} are the values of this BS average total radiating power which reaches an observation area by the real BS antenna with horizontal and vertical selectivity, and by the ideal isotropic antenna with the same antenna gain, correspondingly. In particular, if CC radio network is regular with N_S sectors on each BS, then for worst-case estimations $Q_k \approx 1/N_S$ can be used. For separate k -th BS with a sector antenna with $\Delta\alpha_k$ [rad] of main beam width that is usually inclined 5–10 degrees to the earth's surface, it is possible to use $Q_k \approx \Delta\alpha_k/2\pi$.

The average EMB intensity (2) created by BS consists of two components (3): frequency dependent component $Z_{\Sigma BS1}$ corresponds to the contribution of BS located in the OP vicinity of free-space radio waves propagation (RWP) between BS and OP (breakpoint vicinity [53]), and frequency independent component $Z_{\Sigma BS2}$ corresponds to the contribution of BS located outside the breakpoint vicinity in the area of interference (multipath) RWP.

In cases when sources with the same EIRP P_e [W] of non-directional EM radiation are distributed over the area uniformly with average density ρ , the average SEMLA created by these sources, will be $B = \rho P_e$. The latter, in particular, can be used when evaluating the SEMLA created by MS, and also by BS in CC networks of a regular cellular structure.

Estimates (2) significantly depend on the wavelength λ . Taking into account the relative narrowness of the frequency bands allocated for EM radiation of BS of CC (the ratio of the width of the allocated frequency band to the value of its left border is 2.7 % for GSM-900, 4.2 % for GSM-1800, 2.8 % for UMTS, less than 5 % for each of the LTE frequency bands [15]), these estimates using (2) for each frequency band, can be performed for a fixed value of λ corresponding

to its middle. As a result, the total average intensity $Z_{\Sigma BS}$ of EM background generated by the set of BS of all J frequency bands allocated for the BS EM radiation, can be determined in an obvious way:

$$Z_{\Sigma BS} = \sum_{j=1}^J Z_{\Sigma BSj} = \sum_{j=1}^J \frac{B_{BSj}}{2} \ln \left(\frac{4H_{OP}\sqrt{e}}{\lambda_j} \right), \quad H_{OP} \geq \max \left\{ \frac{\lambda_1}{4}, \frac{\lambda_2}{4}, \dots, \frac{\lambda_J}{4} \right\}, \quad (5)$$

where $Z_{\Sigma BSj}$ is the total average EM background intensity, created in OP at a height H_{OP} above the Earth's surface by the set of BS radiating in the relatively narrow j -th frequency band, for which the wavelength of BS radiation is taken equal to λ_j .

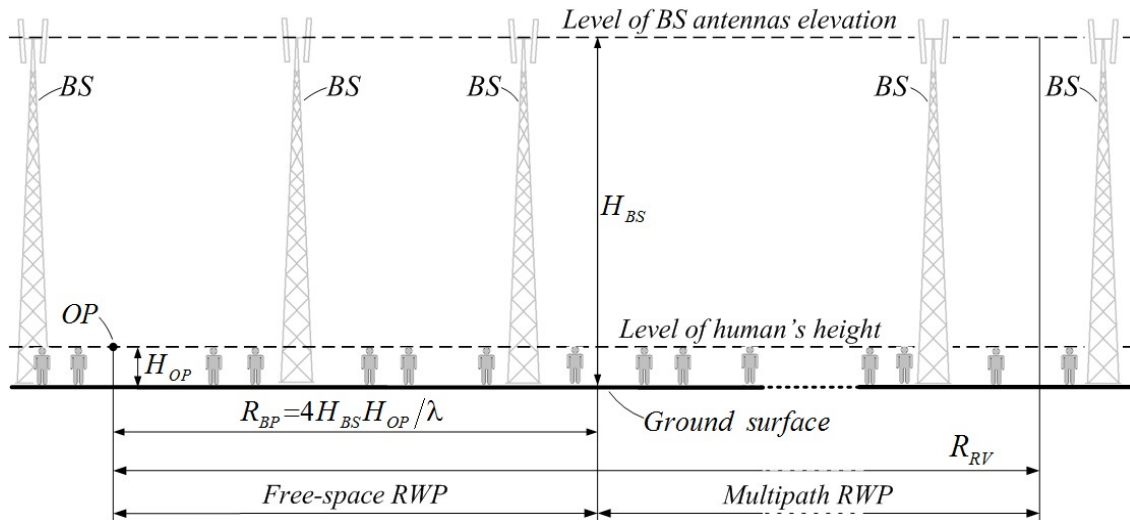


Fig. 1. Mutual terrestrial distribution of observation point (OP) and BS. Height of BS antennas above the surface $H_{BS} \geq 10$ m is significantly higher than the height $H_{OP} = 1 \dots 2$ m of the OP above the Earth's surface. Boundary between regions of free and of interference RWP corresponds to the radius of the OP "breakpoint" vicinity $R_{BP} = 4H_{BS}H_{OP}/\lambda$

Рис. 1. Взаимное территориальное размещение точки наблюдения (OP) и базовых станций (BS). Высота антенн BS над поверхностью $H_{BS} \geq 10$ м значительно превышает высоту $H_{OP} = 1 \dots 2$ м OP над земной поверхностью. Граница между областями свободного и интерференционного распространения радиоволн (RWP) соответствует радиусу «брейкпойнт»-окрестности OP $R_{BP} = 4H_{BS}H_{OP}/\lambda$

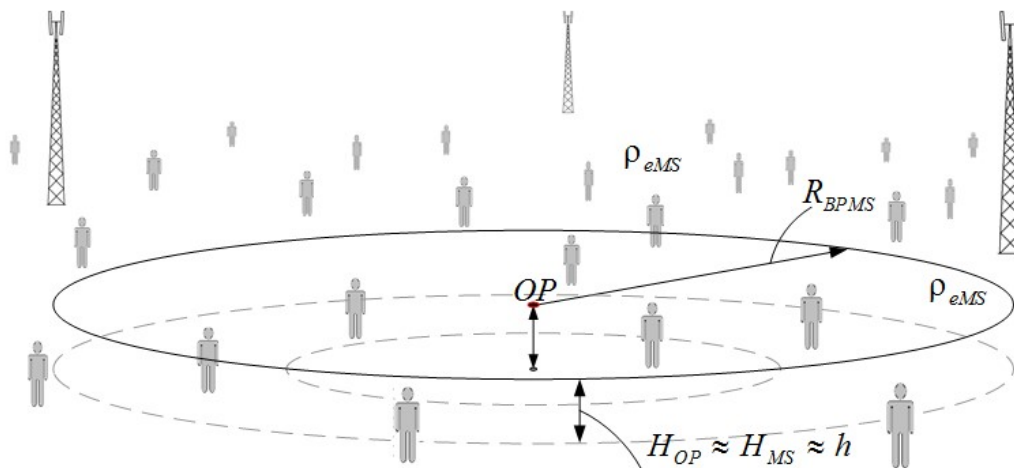


Fig. 2. Mutual terrestrial distribution of OP and subscribers with radiating MS. Elevation H_{MS} of MS and elevation of OP H_{OP} above the Earth's surface is assumed to be equal roughly: $H_{OP} \approx H_{MS} \approx h$. In this figure $R_{BPMS} = 4h^2/\lambda$ is the radius of region of free-space RWP between MS and OP

Рис. 2. Взаимное территориальное размещение OP и пользователей с излучающими мобильными станциями (MS). Высоты MS H_{MS} и OP H_{OP} над земной поверхностью приняты примерно одинаковыми: $H_{OP} \approx H_{MS} \approx h$. На этом рисунке $R_{BPMS} = 4h^2/\lambda$ – радиус области свободного RWP между MS и OP

EM background Intensity created by MS of CC

The average total intensity of EM background $Z_{\Sigma MS}$ [W/m²] created in OP by a set of radiating MS located at a height $H_{MS} \approx H_{OP} \approx h$ above the Earth's surface randomly uniformly in area of MS radio visibility from the OP, is determined by the following expression [45, 48]:

$$Z_{\Sigma MS} = Z_{\Sigma MS1} + Z_{\Sigma MS2} \approx B_{MS} \ln \left(\frac{6.44 \cdot h}{\lambda} \right), \quad h \geq \frac{\lambda}{2\sqrt{2}\pi}, \quad (6)$$

$$Z_{\Sigma MS1} = \frac{B_{MS}}{2} \ln \left(\frac{8\pi h^2}{\lambda^2} \right), \quad Z_{\Sigma MS2} = \frac{B_{MS}}{4}, \quad (7)$$

where λ is the wavelength of MS radiation, B_{MS} [W/m²] is the average SEMLA created by radiating MS in the area of MS radio visibility (at least, in the OP vicinity). In (6), (7) the presence of a MS reactive near-field zone (absence of radiation at distances $R \leq \lambda/2\pi$) was taken into account.

The average SEMLA B_{MS} created by MS is defined by the average terrestrial density ρ_{eMS} [devices/m²] of radiating MS in the considered area, and by the average EIRP P_{eMS} [W] of these MS: $B_{MS} = \rho_{eMS} P_{eMS}$. The ρ_{eMS} value is determined by the total area density of MS (radiating and non-radiating) ρ_{MS} and by the specific traffic intensity G_{MS} [Erl] (the probability of the MS being in the radiation mode): $\rho_{eMS} = \rho_{MS} G_{MS}$. For CC phones, $G_{MS} = 0.08$ – 0.1 Erl can be reached during business-hours [14, 10, 54]. The P_{eMS} value can be taken equal to 30–50 % of the maximum power P_{MSmax} of MS radiation [43, 55]. Depending on the CC standard and MS type $P_{MSmax} = 0.1 \dots 0.25$ W; EM radiation of MS is considered to be isotropic with an antenna gain of 1.

The average EM background intensity (6) created by MS also consists of two components: the frequency dependent component $Z_{\Sigma MS1}$ corresponds to the contribution of MS located in OP vicinity of free-space RWP between MS and OP, and the frequency independent component $Z_{\Sigma MS2}$ corresponds to the contribution of MS located outside this vicinity in the area of interference RWP.

As for EM background created by BS, estimates (6) also depend on the wavelength λ . Therefore, taking into account that frequency bandwidths of the BS and MS radiation are usually the same, to determine the total average EM background intensity $Z_{\Sigma \Sigma MS}$ created by radiations of MS of all J CC frequency bands, an obvious procedure similar to (5) can be proposed:

$$Z_{\Sigma \Sigma MS} = \sum_{j=1}^J Z_{\Sigma MSj} = \sum_{j=1}^J B_{MSj} \ln \left(\frac{6.44 \cdot h}{\lambda_j} \right), \quad h \geq \max \left\{ \frac{\lambda_1}{5}, \frac{\lambda_2}{5}, \dots, \frac{\lambda_J}{5} \right\}, \quad (8)$$

where $Z_{\Sigma MSj}$ is the total average EM background intensity, created in OP at a height h above the Earth's surface by the set of randomly distributed MS radiating in the relatively narrow j -th frequency band, for which the wavelength of MS radiation is taken equal to λ_j .

Ideally, if we neglect the presence of a MS near-field reactive zone where the MS EM radiation is absent, then the frequency dependence of levels of MS fields in OP can also be neglected. In this case the level Z_{MSp} of EM background in OP caused by MS radiations, which is not exceeded with probability p , is determined by the level of prevailing EM field of the nearest MS, which is also related to the average SEMLA B_{MS} created by MS set in the OP vicinity [41–43]:

$$Z_{MSp} \approx \frac{B_{MS}}{4(1-p)}, \quad B_{MS} \approx \rho_{eMS} P_{eMS}; \quad p > 0.9. \quad (9)$$

For UHF CC systems (0.3–3 GHz), the level of EM background created by MS radiations, not exceeded with probability $p \approx 0.99$, is approximately equal to $Z_{p \approx 0.99} \approx 25 B_{MS}$ [48].

Comparative estimates using (2) and (6), allow us to conclude that at uniform MS terrestrial distribution, the contribution of their EM fields to the total background intensity created by CC is less by an order of magnitude or more than the contribution of BS EM fields, due to the significantly different EIRP of BS and MS at the radio link between them. However, in places of mass gathering of MS, where their area density can exceed the average density a hundred times or more (shopping and business centers, stadiums, airports, etc.), contribution of MS radiations to the total EM background intensity created by CC, turns out to be dominating.

SEMLA Estimation in 4G/5G/6G Networks

Due to the extremely intensive increase in the quantity and spatial density of sources of EM radiations, as well as the significant expansion of wireless information services at CC evolution to 5G/6G, direct SEMLA calculation based on (4) to predict total average background intensity using (2), (5), is rather difficult due to a significant complication of CC radio network infrastructure. Alternatively, the technique [50, 51] of estimation of average SEMLA and average EM background intensity created by the set of CC BS, in terms of prediction of the average ATC, can be proposed.

The average total ATC S_{tr} [bit/s/m²] of CC wireless information services (one of the key 4G/5G/6G system parameters, presented in Table 1) is defined as the volume of downlink traffic over the set M of BS radio frequency channels (RFC) per unit area:

$$S_{tr} = \frac{\sum_{m=1}^M V_{tr RFC m}}{S}, \quad M = \sum_{l=1}^L k_l, \quad (10)$$

where S is the area, the wireless information services of which are provided by the total set of M downlink RFC of all of L BS located in area S ; $V_{tr RFC m}$ [bit/s] is the traffic volume of the m -th servicing downlink RFC (can be equal to its capacity or data rate).

The proposed technique is based on the following relations obtained on the basis of the well-known Shannon-Hartley theorem under the assumption that properties of the intranet interference in RFC are close to the properties of their internal thermal noise:

$$B_{\Sigma BS} = \frac{8\pi^2 mkT_0 K_N D_{\Sigma} (2^{W_{EP}} - 1) R_{\max}^2 S_{tr} Q}{\lambda^2 W_{EP}} = \frac{8\pi^2 mkT_0 K_N D_{\Sigma} CNIR \cdot R_{\max}^2 S_{tr} Q}{\lambda^2 \log_2(1 + CNIR)}, \quad (11)$$

$$\left. \begin{aligned} C_{PR} &\approx \Delta F_R \cdot \log_2(1 + CNIR), \quad CNIR = P_R / N_{\Sigma} \\ W_{EP} &= C_{PR} / \Delta F_R = m W_{ER} \approx \log_2(1 + CNIR) \\ D_{\Sigma} &= (K_{CC} + 1) L_m L_C K_H \end{aligned} \right\}, \quad (12)$$

where C_{PR} [bit/s] is the potential RFC capacity; ΔF_R is the RFC bandwidth, [Hz]; P_R is the RFC useful signal power, [W]; N_{Σ} is the RFC total noise power which is a sum of RFC internal thermal noise power N_0 and intrasystem interference power N_{INT} , [W]; $CNIR$ is the "carrier-to-(noise plus intrasystem interference)" ratio; $k=1.38 \cdot 10^{-23}$ W/K is Boltzmann's constant, K_N is radio receiver noise factor, T_0 is an ambient temperature ($T_0=290$ K); W_{EP} [bit/s/Hz] is the RFC potential spectral efficiency which is m times greater than the real RFC spectral efficiency W_{ER} ; D_{Σ} is a total necessary reserve in BS radiating power which take into account the losses L_m at RWP into buildings ($L_m \leq 100$ [56–58]), the losses L_C at RWP in street canyons (which are caused by multipath phenomenon due to the reflection from buildings and Earth's surface, and also by diffraction; $L_C \leq 100$ [53]), the necessary margin K_H in levels of receiving signals for the handover implementation ($K_H \leq 10$), and the factor $K_{CC} = N_{INT}/N_0$ which characterizes the excess of the internal thermal noise level by the intrasystem interference level. K_{CC} value is determined by the quality of the frequency-spatial planning (FSP) of CC radio network and can take values in a wide range from 0 (without intrasystem interference) to 100...1000 (20–30 dB) and even more at low FSP quality (at poor intrasystem electromagnetic compatibility (EMC)); $R_{\max}$ is a radius of service area (cell radius of CC network), on the border of which the required level of useful signal on MS receiver's input needs the maximum BS radiated power; Q characterizes the average level of spatial selectivity of BS EM radiation of data bits in the direction of the Earth's surface; it is taken into account above when considering the expression (4).

Total necessary reserve D_{Σ} in transmitting power is different for BS of different hierarchical levels of CC radio network structure: for internal pico-BS (access points in rooms, hotspots, etc.) $D_{\Sigma} \leq 10$ –30 dB, for external micro- and macro-BS with $R_{\max} \geq 200$ m in dense urban areas [13] it can reach 70–80 dB in radio networks with poor intrasystem EMC (at high K_{CC} levels). Thus, under the requirements for RFC data rates of 4G/5G/6G CC (Table 1), it is the value of the parameter D_{Σ} that actually determines the total average SEMLA (11) and the total background intensity (2), (5) created by BS of CC. In some cases, when determining the D_{Σ} value, it is advisable to take into account some correlation between its components in (12).

Factor m in (11), (12) reflects both the ratio of potential and real RFC spectral efficiency, and the contribution of MIMO technology in its improvement. In cellular RFC without the use of MIMO technology $m \approx 2 \dots 10$. Thus, the expected increase in CC RFC spectral efficiency due to MIMO technology by 2–8 times [15] actually allows one only to compensate approximately for the imperfectness of real modulation/demodulation and coding-decoding processes. Therefore, in today's practice, predictable analysis of EM background in 4G/5G networks can be performed for $m = 1$ under the assumption that CC RFC capacity is close to the potential (use $m \approx 1$).

How to make 4G/5G/6G safe for people?

To illustrate the possibilities of using the proposed technique for the analysis of EM background generated by CC, the calculated dependences $Z_{\Sigma BS}(D_{\Sigma})$ of the average intensity of EM background created by BS of CC urban micro-cells ($R_{\max} = 200$ m) in the 2 GHz band ($\lambda = 0.15$ m) near the Earth's surface at a height of $H_{OP} = 1.5$ m, on the level of total necessary reserve D_{Σ} in BS radiating power, are given in Fig. 3.

These dependencies are obtained using expressions (2), (11) for various ATC levels created by CC networks: curve No. 1 is obtained for $S_{tr} = 10^3$ bit/s/m², which corresponds to the estimated ATC in 2G/3G networks; curve No. 2 is calculated for $S_{tr} = 10^5$ bit/s/m², which corresponds to the declared ATC level in 4G networks [13, 16], curve No. 3 is calculated for $S_{tr} = 10^7$ bit/s/m² which corresponds to the declared maximum ATC level in 5G networks [16, 17], the curve No. 4 corresponds to the predicted ATC limit $S_{tr} = 10^9$ bit/s/m² in 6G networks [19, 20]; the red horizontal line corresponds to MPL 0.1 W/m², accepted in many countries, taking into account the danger of non-thermal effects of radio frequency EM fields on the human body.

Curve 1 in Figure 3 is in full agreement with measurement results [1–11]: at the ATC levels created by 2G/3G networks, the average level of EM Background is below 0.1 W/m² at network energy reserve $D_{\Sigma} \leq 10^7$ (70 dB), which is more than enough to compensate for all RWP losses in urban area and for presence of intrasystem interference due to the limited radio frequency resource used in CC radio network.

Dependence 2 allows us to conclude that the average ATC level expected in 4G networks requires the CC operation with an energy reserve of $D_{\Sigma} \leq 10^5$ (50 dB). This can be reached at the high FSP quality and the widespread use of indoor hotspots, urban micro-cells to reduce RWP losses in urban areas.

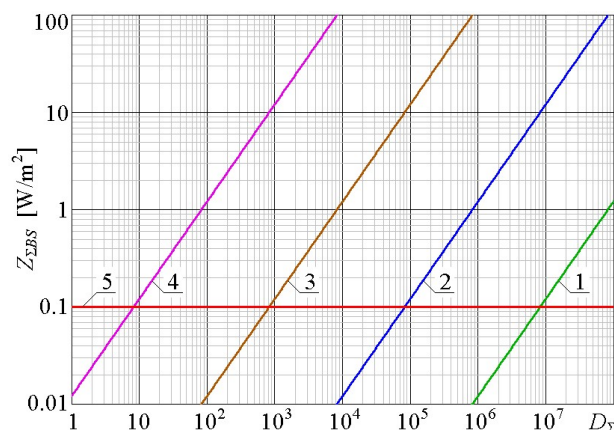


Fig. 3. The calculated dependences of the average EMB intensity created by CC urban micro-cells of UHF frequency range ($\lambda = 0.15$ m) near the Earth's surface at a height of $H_{OP} = 1.5$ m, on the total necessary reserve D_{Σ} in BS EMR power to compensate for RWP losses in street canyons and buildings, for handover implementation and for overcoming intra-network interference, at different levels of CC area traffic capacity (ATC)

Рис. 3. Расчетные зависимости средней интенсивности ЭМ фона, создаваемого городскими микро-сайтами в диапазоне УВЧ ($\lambda = 0.15$ м) вблизи земной поверхности на высоте $H_{OP} = 1.5$ м, от суммарного запаса D_{Σ} по мощности ЭМ излучения BS, необходимого для компенсации затухания радиоволн в городских «каньонах», при их проникновении в здания, для реализации хэндовера и для преодоления внутрисетевых помех, при различной территориальной плотности беспроводного трафика (ATC)

As for the total ATC levels predicted for 5G/6G radio networks, these levels of wireless information services in all areas of human activities can only be safe at CC networks energy reserves $D_{\Sigma} \leq 10^3$ in 5G systems and $D_{\Sigma} \leq 10$ in 6G systems (which requires a significant reduction in the radio communication range up to a few tens of meters or less, exclusion of the effect of any obstacles on urban RWP and also exclusion or reduction to the minimum level of intra-network interference, as well as introduction of the necessary restrictions on the volume and options of wireless public information services and various technological information processes).

Thus, the use of (2) – (11) provides the possibility of a proximate system analysis and forecast of environmental EM pollution by both operating and designed CC networks, as well as the possibility of quantitative substantiation of the requirements for possible options for ensuring their safety and environmental friendliness.

The SEMLA value in definition (4) is an integral parameter characterizing the specific average EM loading on area created by terrestrially distributed radio transmitters. Therefore, expressions (2), (3), (5) – (9) can also be used to analyze the intensity of EM background created by any other radio systems and radio services – broadcasting, fixed, navigation, etc.

In definition (11), the SEMLA value is directly and unambiguously related to the general system parameters of 4G/5G/6G networks presented in Table 1, in particular,

- with ATC (10), which defines the integral level of wireless information services and is used in (11);
- with “Connectivity density” (density ρ_{eMS} of radiating MS), which determines the average SEMLA value created by EM radiations of MS used in (6) – (9); ρ_{eMS} definition also provides the possibility of indirect estimation of ATC for subsequent use of model (11) to estimate the background level created by BS radiations;
- with “RFC spectrum efficiency” and $CNIR$ which are used in (11), (12) and determine the CC network energy efficiency;
- with RFC “Peak data rate” and “Experienced data rate” associated with ATC and along with cell’s radius R_{max} determining the average SEMLA created by BS [50, 59], as well as
- with wavelength λ describing the radio frequency resource used by the CC system.

The planned widespread use of quasi-optical and optical (terahertz and laser) technologies and subsystems for ultra-fast wireless data transmission (up to 1 Tbps) at various infrastructure levels of the 5G/6G networks, as well as at the implementation of various technological information processes in industry, transportation, education and other areas, provides a significant reduction in radio-frequency ATC (10), and a corresponding decrease in radio-frequency SEMLA and in the intensity of radio-frequency EM background created by CC.

The planned increasingly widespread use of adaptive active phased-array antennas as the BS antenna systems of an adaptive multibeam operation with adaptability of directivity and power of BS radiation for each of serving MS will also reduce SEMLA levels (4), (11) and the EM background created by these systems by reducing the parameter Q of BS radiation directivity, at least, by an order of magnitude.

The influence of the planned widespread use of MIMO technology on the intensity of EM background created by 4G/5G/6G networks, is also taken into account by the presence in (11), (12) of the WEP and m parameters that determine the real spectral efficiency of RFC of CC.

Finally, a very significant expansion of the radio-frequency spectrum allocated to these networks, including allocation of numerous frequency bands in SHF and EHF ranges, which greatly simplify the solving of intra-network EMC problem and increase the spatial selectivity of BS EM radiation with a significant (by 1–2 orders of magnitude or more) decrease in the level of intra-network interference and an increase in the real sensitivity of radio reception means the corresponding increase in 4G/5G/6G network energy efficiency, and is also taken into account by the presence of parameters λ , K_{CC} and Q in expressions (2), (11) and (12).

Since the analysis of all referred CC parameters and characteristics can be performed without the use of confidential commercial information of CC operator companies, the use of this technique can provide a high degree of independence and objectivity of estimations of EM background intensity created by CC systems. Its application to estimate the expected levels of EM background at various implementation alternatives and different structure and volumes of wireless information services can

provide a justification and assessment of the effectiveness of system, technical and managerial solutions aimed at ensuring the required levels of safety and environmental friendliness of 4G/5G/6G systems in various conditions.

Conclusion

1. The validity of the hypothesis about the possible impact of the EM background created by the public wireless information systems, first of all by systems of cellular (mobile) communications, on the relative lethality rate from COVID-19 is indirectly confirmed by the results of the analysis of correlation between the degree of severity of hygienic regulation of levels of radio frequency EM background for the population in different countries according to data [12] and the lethality rate from COVID-19 in relation to the number of people infected according to [38–40].

Taking into account the extremely high cost of error in this conclusion, this hypothesis certainly requires further verification, both in terms of analyzing the reliability of data [38–40, etc.], which are the basis of the correlation analysis, and in analyzing the actual levels of EM background in places with different levels of the lethality rate from COVID-19, and in terms of accounting for the impact on the lethality rate from COVID-19 of other factors (the effectiveness of national health systems, the effectiveness of government measures against the spread of COVID-19, etc.).

2. Detected correlation between the degree of severity of hygienic regulation of levels of radio frequency EM background for the population and the lethality rate from COVID-19 in various countries requires a critical attitude to corporate declarations [24, etc.] about the harmlessness of 4G/5G/6G technologies and systems for the population, as well as possibly revising plans [15–20] for the development of these technologies and systems towards a wider, if possible, use of non-radiating wire (fiber-optic, cable, etc.) technologies and systems without any damage to the quality of public information services and to the technological level in industry, services, education, healthcare and in other sectors.

3. The calculated data contained in [41–51], as well as preliminary quantitative estimates using (2), (3), (5) – (9), (11), (12), indicate that the fulfillment of severe hygiene restrictions on the MPL of EM background $1\text{--}10\text{ }\mu\text{W}/\text{cm}^2$, which take into account the danger of non-thermal effects of radio frequency EM fields on public health, in 4G/5G/6G networks, and the safe development of these networks to the levels indicated in Table 1, are quite possible under the following conditions:

a) reducing the distances of high-speed wireless data transmission up to a few tens of meters or less in conditions of direct visibility and lack of multipath RWP [50, 51] so that the achieved SEMLA level created by CC BS in UHF bands will be no more than half of the accepted MPL value [44];

b) using the external micro- and macro-BS of CC substantially for mobile telephony and technological low data rate services, including such wireless servicing of mobile objects, with a restriction to safe levels of data transfer rates over the RFC of these BS;

c) fast developing of 4G/5G/6G technologies and systems towards the implementation of system and technical solutions related to increasing spectral and network energy efficiency and ensuring decrease in EM background levels created by 4G/5G/6G radio networks, ensuring in them the maximum possible level of adaptation of power and directivity of EM radiation, optimization of the volume of wireless information services;

d) following the example of [21–23], introduction of reasonable restrictions on the use of wireless services in places requiring special attention – in places where children stay (kindergartens, schools, etc.), in hospitals, in vehicles, etc., providing the necessary level of public EM safety.

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A close-up photograph of a honeybee on a bright yellow flower, likely a rapeseed flower. The bee is positioned on the right side of the image, facing left, with its head buried in the flower's center. The background is a soft, out-of-focus blue and yellow gradient.

INTERNATIONAL APPEAL

Stop 5G on Earth and in Space

Sign the Appeal: www.5gSpaceAppeal.org

CELL TOWERS ON THE OCEAN FLOOR

One blue sky above us,
One ocean lapping all our shores,
One earth so green and round,
Who could ask for more?

- Pete Seeger

In 2018, on land and in space, preparations to deploy millions of antennas were very publicly being made and advertised, for “5G,” “Smart Cities,” and the “Internet of Things.” At the same time, and without any publicity, governments, research laboratories, and commercial and military interests were collaborating on plans to create “Smart Oceans” and the “Internet of Underwater Things” (IoUT). They did not consult the fishes, whales, dolphins, octopuses, and other inhabitants of those depths.

In the United States, the National Science Foundation funded what it called the SEANet Project. The goal was to enable broadband wireless communication from any point on or in the oceans to anywhere else on the planet or in space. The Internet of Underwater Things is being designed to enable all the same communication capabilities that are being provided on land, including “real-time video streaming from underwater.”

In the last three years, a flood of papers have been published by scientists and engineers in the U.S., China, Pakistan, Qatar, South Korea, Spain, Australia, Greece,

Italy, France, Morocco, Saudi Arabia, and elsewhere. In 2020, the *IEEE Internet of Things Journal* published a Special Issue on *Internet of Things for Smart Ocean*. In 2019, the journal *Sensors* published a Special Issue on *Smart Ocean: Emerging Research Advances, Prospects and Challenges*, and the same journal is now publishing another Special Issue on *Internet of Underwater Things*.

Some of the activities that supposedly “need” this technology in the oceans are:

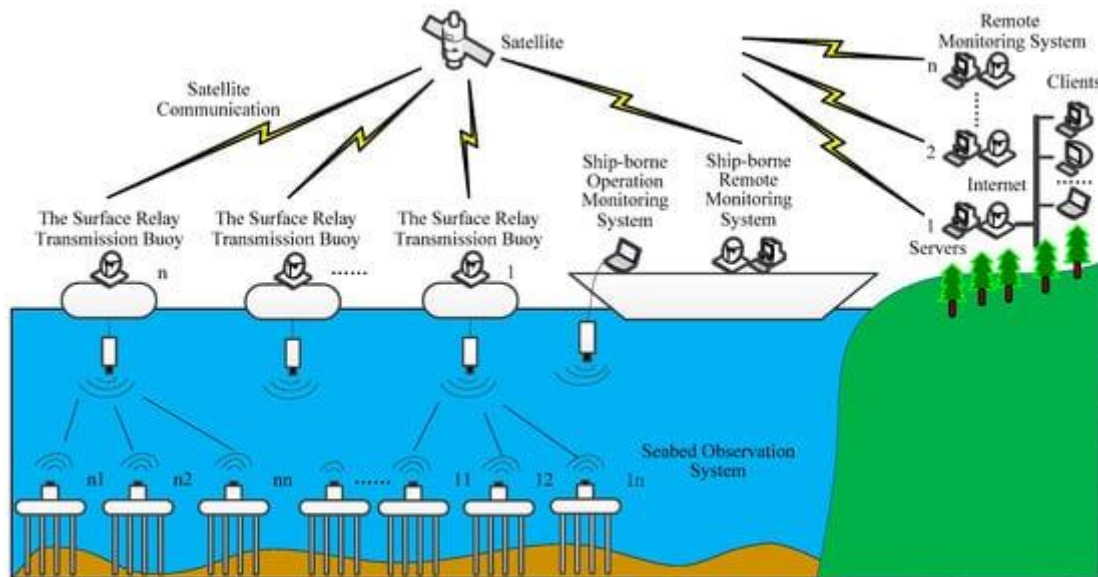
- climate change monitoring
- pollution control and tracking
- disaster prevention including tsunami warning systems
- ocean exploration
- fishing and aquaculture
- coral reef harvesting
- tectonic plate monitoring
- navigation
- global oceanic trade
- oil and gas exploration and production
- military communication and surveillance

The infrastructure that is beginning to be deployed, throughout the oceans, includes:

- sensors and antennas (“nodes”) on the ocean floor
- nodes at different depths
- surface nodes
- relay antennas at different depths to transmit data vertically from the ocean floor to the ocean surface, and horizontally between nodes
- Autonomous Underwater Vehicles (AUVs)
- Autonomous Surface Vehicles (ASVs)
- underwater robots
- wireless surface buoys
- smart boats and ships
- smart submarines
- smart shores²

Communication being more difficult to accomplish underwater than through the air, and more subject to interference, several different types of communication media are being used in the oceans to send data at different speeds and over different distances. Acoustic waves, radio waves, lasers, LED light, and magnetic induction are

all being used to flood the oceans with data. An underwater GPS system is being developed. Most of these media work only for short- to medium-range communication. Long-range communication relies on acoustic waves, and is similar to the technology used in ocean sonar.



These technologies are already being marketed commercially and installed in the world's oceans today. At the 2022 Oceanology International conference, which will be held in London from March 15 to 17, dozens of these companies will be exhibiting their products.

WaterLinked sells underwater sensor technology through distributors around the world for use in aquaculture, and in underwater navigation. "Our Wireless Sense™ technology enables reliable wireless communication and innovative subsea sensor solutions," says their website.

EvoLogics sells underwater acoustic modems, both mid-range and long-range, that "provide full-duplex digital communication."

SonarDyne International sells underwater acoustic modems to the oil and gas industry and to governments and navies.

Voyis sells short- and long-range underwater laser scanners.

GeoSpectrum sells "integrated, end-to-end acoustic systems" for oil and gas exploration and for military purposes.

Dynautics sells autonomous underwater vehicles (AUVs).
Seaber sells “off-the-shelf micro-AUVs.”

Hydromea markets “the first ever tether-less underwater drone.”

Mediterraneo Señales Maritimas sells “data buoys that integrate sensors through our datalogger so the data can be transmitted to a remote station and displayed on our software.”

3D at Depth, Inc. “provides advanced subsea LIDAR laser systems.”

Teledyne Marine sells Autonomous Underwater Gliders, Autonomous Underwater Vehicles (“unmanned robot submarines”) and “laser systems for both shallow and deep-sea submerged diving.”

“Underwater robots swarm the ocean,” says a page on the website of the Woods Hole Oceanographic Institute. The Institute has developed an acoustic-based navigation system that is enabling large numbers of underwater robots to work together. “Instead of using just a single, larger and more expensive underwater robot to cover an area of the ocean, we want to have hundreds or even thousands of smaller, lower-cost robots that can all work in sync,” says their webpage.

Ocean protection organizations have long been campaigning against noise pollution in the oceans, but they are only beginning to be aware of this new type of assault, which has the potential to dwarf all previous noise assaults in its scope and magnitude. For example, one of the campaigns of the environmental organization, Sea Shepherd, is “Silencing the Deafening Roar of Ocean Noise Pollution.” They write:

“In 1953, Jacques Cousteau published a classic memoir on his early days of underwater exploration. He titled this book *The Silent World*. Today, human activities make a mockery of that title. Over the past several decades, marine noise pollution has grown at an exponential rate. Noise from vessel traffic is doubling every decade. Pile-driving, dredging, sonar, and seismic exploration for oil and gas add to the cacophony. For marine wildlife, and especially for acoustically-sensitive cetaceans, this anthropogenic racket poses a grave and growing threat. Ocean noise pollution causes severe stress, behavioral changes, masking (i.e., difficulty perceiving important natural sounds), strandings, and noise-induced loss of hearing sensitivity.”

To this mix is now being added the Internet of Underwater Things, which is beginning to flood the oceans with sound in order to connect them to the Internet. And this sound will be pulse-modulated with the same harmful frequencies as radio waves in order to carry the same data. And to communicate over large distances, some of the underwater acoustic modems that are being marketed are capable of producing sound as loud as 202 decibels. That is equivalent to 139 decibels in air. It is as loud as a jet engine at a distance of 100 feet, and is above the threshold for pain in humans. These modems blast modulated sound at frequencies ranging from 7 kHz to 170 kHz, encompassing almost the entire hearing range of dolphins, which use sound for hunting and navigating.

The effects of sonar on whales and dolphins have been widely publicized. But the effects of noise pollution on fish and other denizens of the deep are just as devastating, as Lindy Weilgart details in her [36-page report for OceanCare](#). She reviews 115 research studies on the effects of noise on 66 species of fish and 36 species of invertebrates.

“Most fish and invertebrates use sound for vital life functions,” she writes. “Noise impacts on development include body malformations, higher egg or immature mortality, developmental delays, delays in metamorphosing and settling, and slower growth rates... Anatomical impacts from noise involve massive internal injuries, cellular damage to statocysts and neurons, causing disorientation and even death, and hearing loss... Behaviorally, animals showed alarm responses, increased aggression, hiding, and flight reactions; and decreased anti-predator defense, nest digging, nest care, courtship calls, spawning, egg clutches, and feeding... Some commercial catches dropped by up to 80% due to noise, with larger fish leaving the area.”

If the new assault continues, it will provide the last nails in the coffins of our oceans, and -- since the oceans are the source of all life -- of our planet. Already in 1970, just 17 years after he published *The Silent World*, Jacques Cousteau, returning from 3½ years of exploration in which he traveled 155,000 miles, told the world: “The oceans are dying. The pollution is general.”

“People don’t realize that all pollution goes to the seas,” said Cousteau. “The earth is less polluted. It is washed by the rain which carries everything into the oceans where life has diminished by 40 per cent in 20 years. Fish disappear. Flora too.” And what was not being poisoned was being mined for food as though ocean life was an

inexhaustible resource. “The oceans are being scraped,” he said. “Eggs and larvae are disappearing. In the past, the sea renewed itself. It was a complete cycle. But this balance was upset with the appearance of industrial civilization. Shrimps are being chased from their holes by electric shocks. Lobsters are being sought in impossible places. Coral itself is disappearing. Even in the Indian Ocean, which is little traveled.”

Life in the oceans today is hanging by a thread. If the rate of population declines continues, there will be no almost fish left in the oceans by 2048.¹ The oceans are absorbing 24 million tons of carbon dioxide every day, are 26% more acidic than before we began burning fossil fuels,² and have absorbed 93% of the heat generated by greenhouse gases since the 1970s.³ The damage already done to coral reefs by acidification, rising temperatures, and bottom trawling would take 100,000 years for nature to repair.⁴ Diatoms -- a type of algae at the base of the ocean's food chain that is also the source of a third of the world's oxygen production -- have been declining by more than 1% per year for two decades.⁵ Populations of krill -- the small shrimplike crustaceans that make up a large portion of the diet of many species of whales, penguins and seals -- have declined by 80% since the 1970s.⁶ And the deepest layers of the oceans are severely depleted of oxygen -- so much so that deep-diving fish no longer dive deep but remain near the surface in order to breathe. And populations of fishes that live in the deep sea are drastically declining. Warming oceans can no longer hold as much oxygen, and it is the deepest waters that are depleted of oxygen first.^{7,8,9,10} Large numbers of bottom-dwelling crabs have suffocated off the coast of Oregon.¹¹ More than a thousand manatees died of starvation in 2021 off the coast of Florida because the seagrass they eat has been killed by pollution.¹² And there is so much plastic throughout the oceans¹³ that sardines sold in an Australian fish market contain 3 milligrams of plastic in every gram of their tissue.¹⁴

Although many are the assaults on the oceans, and on the Earth, the single most urgent assault, which is destroying the planet the quickest, is wireless technology. It is the most destructive itself, and it speeds up and coordinates all the other assaults. And driving all of wireless technology, including wireless technology on land, in space, and in the oceans, is the cell phone. All of wireless technology, from 2G to 5G to the Internet of Things to the Internet of Underwater Things, requires everyone to be holding a cell phone in their hands. It is the director, it is the target, and without it, the present rate of destruction could not continue.

As Hillel said two thousand years ago, “If not now, when? If not me, who?”

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- ⁵ Cecile S. Rousseaux and Watson W. Gregg. [Recent decadal trends in global phytoplankton composition](#). *Global Biogeochemical Cycles* 29: 1674-1688 (2015).
- ⁶ Matthew Taylor. [Decline in krill threatens Antarctic wildlife, from whales to penguins](#). *The Guardian*, Feb. 14, 2018.
- ⁷ Craig Welch. [Oceans Are Losing Oxygen—and Becoming More Hostile to Life](#). *National Geographic*, March 12, 2015.
- ⁸ Laura Poppick. [The Ocean Is Running out of Breath, Scientists Warn](#). *Scientific American*, Feb. 25, 2019.
- ⁹ Kirsten Isensee. [The Ocean Is Losing Its Breath](#). Ocean and Climate Platform, 2018.
- ¹⁰ International Union for the Conservation of Nature. [Ocean Deoxygenation](#).
- ¹¹ Bradley W. Parks. [Low oxygen levels off Northwest coast raise fears of marine “dead zones.”](#) Oregon Public Broadcasting, July 22, 2021.
- ¹² Corryn Wetzel. [Florida Wildlife Officials Move to Feed Starving Manatees in Experimental Conservation Approach](#). *Smithsonian*, Dec. 8, 2021.
- ¹³ Captain Charles Moore. *Plastic Ocean*. Avery, NY 2011.
- ¹⁴ Francisca Ribeiro et al. [Quantitative Analysis of Selected Plastics in High-Commercial-Value Australian Seafood by Pyrolysis Gas Chromatography Mass Spectrometry](#). *Environmental Science and Technology* 54: 9408-9417 (2020).

Arthur Firstenberg

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Administrator, [International Appeal to Stop 5G on Earth and in Space](#)

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Thielens et al., Exposure of Insects to Radio-Frequency Electromagnetic Fields from 2 to 120 GHz, Scientific Reports (2018)

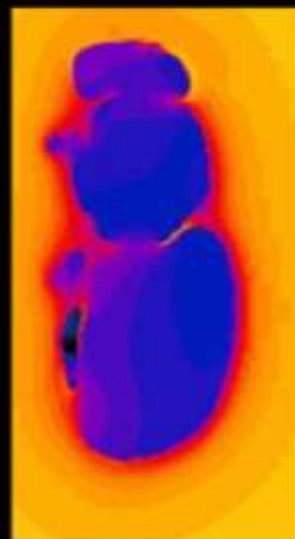


Apis mellifera
Photo Credit: Charles J Sharp

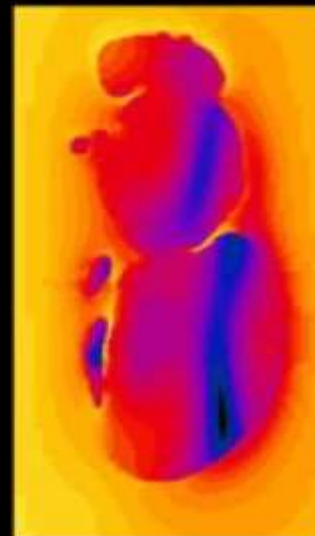
Figure 4. Normalized Electric field strength (dB) in a mid-transverse cross section of the Western Honey Bee as a function of frequency for a single plane wave incident.

"This is the first paper that investigates the exposure of electric fields with RF frequencies associated with 5 G wireless communication."

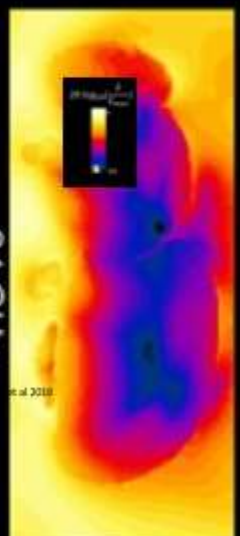
"This could lead to changes in insect behavior, physiology, and morphology over time due to an increase in body temperatures, from dielectric heating."



2 GHz



24 GHz



120 GHz

Published Scientific Research on 5G, 4G Small Cells, Wireless Radiation and Health

Published peer reviewed science already indicates that the current wireless technologies of 2G, 3G and 4G – in use today with our cell phones, computers and wearable tech – creates (create) radiofrequency exposures which poses (pose) a serious health risk to humans, animals and the environment. Scientists are cautioning that before rolling out 5G, research on human health effects urgently needs to be done first to ensure the public and environment are protected.

"Small cells" are microwave antennas (basically shorter cell towers) rapidly being installed in public areas on utility poles and street lights in front of homes, parks and

schools. Just like cell towers, these wireless antennas generate and emit microwave radiofrequency (RF) radiation to transmit 2G, 3G and 4G network signals. Companies soon plan to add a new technology called 5G which will use current 4G technology plus even higher frequencies. The higher frequencies include millimeter-wave emissions that were not previously released into public areas.

Companies state that these [4G](#) and [5G](#) antennas will [increase](#) the wireless radiation levels in the area so much that they are working to loosen several governments' radiation limits in order to roll it out. A 2021 [research study](#) found people who are exposed to higher radiation values present more severe headaches, dizziness and nightmares. Moreover, they sleep fewer hours.“

More than 240 scientists [published](#) an appeal to the United Nations to reduce public exposure and called for a [moratorium on 5G](#) citing “established” adverse biological effects of RF radiation. Peer-reviewed research has linked a myriad of adverse effects to wireless radiofrequency radiation including [brain cancer](#), [breast cancer](#), [DNA damage](#), [thyroid cancer](#), [memory damage](#), [sperm damage](#), [brain damage](#), [headaches](#), [diabetes](#), [hyperactivity](#), [liver damage](#), [oxidative stress](#), [behavior problems](#), [synergistic effects](#), [altered brain activity](#), [tumor promotion](#), [impaired growth](#) and more.

5G will utilize not only the frequencies currently in use, but also higher millimeter wave and sub-millimeter wave frequencies. Small cells being installed in cities are usually 4G technology with a wide variety of frequencies. Thus, when we consider the health impacts of 5G and small cells we are looking at research on current technologies and frequencies in use in addition to research on sub-millimeter and millimeter waves. The 5G standard is new there are no studies that have looked at long term human exposure to 5G. However the current body of research finding effects from current wireless technology provides enough data for scientists to call for a moratorium.

Published Reviews on 5G

“[5G Wireless Expansion: Public Health and Environmental Implications](#)” published in *Environmental Research* is a research review that documents the range of reported adverse effects of RF and millimeter waves—effects range from cancer to bacteria growth changes to DNA damage. The study concludes that “a moratorium on the deployment of 5G is warranted” and “the addition of this added high frequency 5G radiation to an already complex mix of lower frequencies, will contribute to a negative public health outcome ... from both physical and mental health perspectives” ([Russell, 2018](#)).

“[Adverse Health Effects of 5G Mobile Networking Technology Under Real Life Conditions](#)” published in *Toxicology Letters* identifies the wide-spectrum of adverse

health effects of non-ionizing non-visible radiation and concludes that 5 G mobile networking technology will affect not only the skin and eyes, but will have adverse systemic effects as well. They state that 5G will increase the cell tower densities by an order of magnitude. The researchers conclude that in aggregate, for the high frequency (radiofrequency-RF) part of the spectrum, currently published reviews show that RF radiation below the FCC guidelines can result in: carcinogenicity (brain tumors/glioma, breast cancer, acoustic neuromas, leukemia, parotid gland tumors), genotoxicity (DNA damage, DNA repair inhibition, chromatin structure), mutagenicity, teratogenicity, neurodegenerative diseases (Alzheimer's Disease, Amyotrophic Lateral Sclerosis), neurobehavioral problems, autism, reproductive problems, pregnancy outcomes, excessive reactive oxygen species/oxidative stress, inflammation, apoptosis, blood-brain barrier disruption, pineal gland/melatonin production, sleep disturbance, headache, irritability, fatigue, concentration difficulties, depression, dizziness, tinnitus, burning and flushed skin, digestive disturbance, tremor, cardiac irregularities, adverse impacts on the neural, circulatory, immune, endocrine, and skeletal systems" and "from this perspective, RF is a highly pervasive cause of disease" ([Kostoff et al., 2020](#)).

"[Towards 5G communication systems: Are there health implications?](#)" published in the *International Journal of Hygiene and Environmental Health* is a research review detailing research findings that millimeter waves can alter gene expression, promote cellular proliferation and synthesis of proteins linked with oxidative stress, inflammatory and metabolic processes." The researchers conclude, "available findings seem sufficient to demonstrate the existence of biomedical effects, to invoke the precautionary principle" ([Di Ciaula, 2018](#)).

The paper "[A New Look at Three Potential Mechanisms Proposed for the Carcinogenesis of 5G Radiation](#)" puts forward three mechanisms. One is that "absorption of 5G radiation in skin can lead to the generation of high levels of free radicals, which in turn increases the risk of skin cancer. Yakymenko et al., have reported that among 100 peer-reviewed publications on oxidative effects of low-intensity radiofrequency radiation included in their review, 93 studies showed that radiofrequency radiation induced oxidative effects in biological systems."

"[Systematic Derivation of Safety Limits for Time-Varying 5G Radiofrequency Exposure Based on Analytical Models and Thermal Dose](#)" published in *Health Physics* documents how significant tissue heating can be generated by 5G technology's rapid short bursts of energy. "The results also show that the peak-to-average ratio of 1,000 tolerated by the International Council on Non-Ionizing Radiation Protection guidelines may lead to permanent tissue damage after even short exposures, highlighting the importance of revisiting existing exposure guidelines" ([Neufeld and Kuster, 2018](#)).

A review of studies on 6 to 100 GHz ([Simkó and Mattsson 2019](#)) funded by Deutsche Telekom of Germany found that “the available studies do not provide adequate and sufficient information for a meaningful safety assessment, or for the question about non-thermal effects.” The review stated, “here is a need for research regarding local heat developments on small surfaces, e.g., skin or the eye, and on any environmental impact.” This study cited research that found “the presence of sweat glands [[120,121](#)] and also capillaries in the dermis can cause locally elevated SAR levels [[122](#)]. The latter study showed that SAR levels in vessels could be up to 30 times higher than in the surrounding skin, depending on the diameter of the vessels.”

[Simkó and Mattsson 2019](#) analyzed the quality of the selected studies according to specific criteria. The studies were categorized by the presence of sham/ control, dosimetry, positive control, temperature control, and whether the study was blinded. Of the 45 in vivo studies, 78% (35) demonstrated biological responses after exposure to MMW. However when analyzed for quality criteria, “only three publications were identified that met all five criteria [[26,51,53](#)].” (EHT note: These three publications found an effect.) Similarly, 31 of the 53 in vitro studies found an effect. However only 13 studies had 3 of the 5 criteria satisfied and the authors conclude that “the number of examinations and the quality criteria are insufficient for a statistical analysis. It should be stressed that this quality analysis covers all publications dealing with the responses/effects of exposure to 6 to 100 GHz MMW, irrespective of the endpoints tested. To perform a correlation analysis, a larger number of comparable studies (e.g., identical endpoints in a frequency group) would be required.”

The study “Physiological effects of millimeter-waves on skin and skin cells: An overview of the to-date published studies” published in Reviews on Environmental Health by Dariusz Leszczynski reviewed 99 studies and concluded that the “scientific evidence concerning the possible effects of millimeter-waves on humans is insufficient to devise science-based exposure limits and to develop science-based human health policies. The sufficient research has not been done and, therefore, precautionary measures should be considered for the deployment of the 5G, before the sufficient number of quality research studies will be executed and health risk, or lack of it, scientifically established.” “In conclusion, there is an urgent need for research on the biological and health effects of mm-waves because, using the currently available evidence on skineffects, the claims that “we know skin and human health will not be affected” as well as the claims that “we know skin and human health will be affected” are premature assumptions that lack sufficient scientific basis.” ([PDF of Accepted Manuscript](#))

[Chemical polarization effects of electromagnetic field radiation from the novel 5G network deployment at ultra high frequency](#) published in the journal Health and Technology([Ugochukwu et al., 2021](#)) concludes that “caution must be applied not to deploy 5G network under ultra-high frequency above 20 GHz due to its adverse health effects.” “On the several findings of the research, deploying 5G network technology under the ultra-high baseband above 20 GHz will produce effects such as heating up of the body tissues due to electromagnetic field inducement on the account that human

body is dipolar in nature. The effects will extend to produce dielectric polarization, ionic polarization, interfacial polarization and orientational polarization.”

5G, Wireless and Wildlife

FCC and ICNIRP limits were not developed to protect our flora or fauna. Wireless radiation “safety” limits for trees, plants, birds and bees simply do not exist. No US agency nor international authority with expertise in science, biology or safety has ever acted to review research and set safety limits for birds, bees, trees and wildlife.

A 2021 review ([Balmori 2021](#)) found “sufficient evidence on the damage caused by electromagnetic radiation” to insects to state that “electromagnetic radiation should be considered seriously as a complementary driver for the dramatic decline in insects, acting in synergy with agricultural intensification, pesticides, invasive species and climate change.” The paper concludes that “the precautionary principle should be applied before any new deployment (such 5G) is considered.”

A [2021 comprehensive research review](#) by Levitt, Lai and Manville (2021) entitled “Effects of non-ionizing electromagnetic fields on flora and fauna, part 1. Rising ambient EMF levels in the environment” published in Reviews of Environmental Health found “exponential increases in nearly all environments. ” The abstract states “biological effects have been seen broadly across all taxa and frequencies at vanishingly low intensities comparable to today’s ambient exposures. Broad wildlife effects have been seen on orientation and migration, food finding, reproduction, mating, nest and den building, territorial maintenance and defense, and longevity and survivorship. Cyto- and geno-toxic effects have been observed... It is time to recognize ambient EMF as a novel form of pollution and develop rules at regulatory agencies that designate air as ‘habitat’ so EMF can be regulated like other pollutants. Wildlife loss is often unseen and undocumented until tipping points are reached. Long-term chronic low-level EMF exposure standards, which do not now exist, should be set accordingly for wildlife, and environmental laws should be strictly enforced.”

This [paper](#), which is one of a three part series that addresses wireless frequencies now in use as well as the complex signals that will be deployed for 5G stating “serious concerns regarding phasing because it interacts with living cells in extremely complex ways that have nothing to do with traditional thermal thresholds. The wave form itself is the biologically active component” and “The reason that phasing may have a unique biological impact is because very fast peak radiation pulses generate bursts of energy that can give rise to what are called Sommerfeld and Brillouin precursors in living cells that can in turn penetrate and disperse much deeper than traditional models predict. Sommerfeld/Brillouin precursors most notably form with ultra wideband exposures as proposed with 5G.”

A 2020 report of the “biological effects of electromagnetic fields on insects” by high voltage, mobile communications and WLAN came to the conclusion that, in addition to pesticides and the loss of habitats, mobile communications radiation also has negative effects on insects and is therefore another factor in weakening the insect world. [Read “Biological effects of electromagnetic fields on insects” by Alain Thill.](#)

Several literature reviews warn that non-ionizing EMFs are an “emerging threat” to wildlife ([Balmori 2015](#), [Curachi 2013](#), [Sivani 2012](#)) and impacts to pollinators are documented in published studies ([Favre 2011](#), [Kumar et.al., 2011](#), [Lazaro et al., 2016](#)).

Field research has found years of exposure to cell tower radiation damages trees ([Waldmann-Selsam, C., et al. 2016](#), [Helmut 2016](#), [Haggerty 2010](#)) and plants ([Halgamuge 2017](#), [Pall 2016](#), [Halgamuge and Davis 2019](#)). Radiofrequency radiation has been found to affect the magnetic sense of invertebrates (including insects) ([Tomanová and Vácha, 2016](#); [Vácha et al., 2009](#)) birds ([Engels et al., 2014](#)) and mammals ([Malkemper et al., 2015](#)). Furthermore [research](#) shows bees and pollinators could suffer serious impacts from the higher frequencies to be used in 5G as the higher frequencies resonate with their bodies resulting in up to 370% higher absorbed power.

Currently there is no U.S. Government-funded research program into the non-thermal biological effects of RF emissions to the environment. The EPA, which formerly conducted such research, lost all of its research funding in 1996, and has done nothing since. In July 2020 the Director of the Radiation Protection Division of the EPA Lee Ann B. Veal wrote Theodora Scarato Executive Director of EHT that the EPA had no funded mandate to regarding wireless radiofrequency matters and that they are not aware of any developed safety limits or research reviews related to impacts of wireless on birds bees and the environment. [Read the letter](#). The EPA stated their last research review was their [1984 Report](#). The FCC confirmed in a [USTTI webinar October 15, 2020](#) that their limits were for humans only.

A [Petition for Writ of Certiorari to the United States Court of Appeals for the Second Circuit from September 8, 2000](#). It clarifies how decades ago, when FCC limits were set, the EPA was defunded from properly reviewing the science on harm from electromagnetic fields.

“The Court’s reliance on the EPA was technically correct but substantively naive. What the Court did not realize was that Congress terminated funding for radiation research by EPA in 1996, and no staff has been available at EPA to conduct such research for the past five years.”

5G Millimeter Waves and Human Skin

Some carriers will incorporate millimeter and submillimeter waves into 5G wireless networks.

The study “[Human Electromagnetic Field Exposure in 5G at 28 GHz](#)” published in *IEEE Consumer Electronics Magazine* evaluated human exposure to radiofrequency for three wireless systems -5G, 4G, and 3.9G and found that 5G’s higher frequencies penetrate into the skin very intensely despite the fact that the depth of penetration is more shallow. “The SAR is inversely proportional to the penetration depth, and hence, a shallower penetration occurring in 5G **yields a higher absorption.**” The authors conclude that “*the fact that a high-frequency EMF cannot penetrate deep into human skin does not mean that it is not dangerous.*”

“[The Human Skin as a Sub-THz Receiver – Does 5G Pose a Danger to It or Not?](#)”, published in *Environmental Research*, and “[The Modeling of the Absorbance of Sub-THz Radiation by Human Skin](#)”, published in *IEEE Transactions on Terahertz Science and Technology*, are two papers by physicists presenting research that found higher 5G frequencies are intensely absorbed into human sweat ducts (in skin), at a much higher absorption levels than other parts of our skin’s tissues ([Betzalet et al., 2017](#), [Betzalet et al., 2018](#)). In an article published in *Environmental Research*, researchers [conclude](#), “We are raising a warning flag against the unrestricted use of sub-THz technologies

for communication, before the possible consequences for public health are explored” ([Betzalel, et al., 2018](#)).

A [2020 study](#) published in the journal *Environmental Research and Public Health* investigated the combined exposure of 3 G mobile systems at 1950 MHz RF and UV found a 24-h RF exposure significantly reduced the MMP-1 enzyme concentration, caused by prior UV exposure. Although they did not find changes in cytokines due to exposure to RF alone or enhancement of the effects of UV radiation, their findings indicate changes after exposure and point to the importance of investigating this and other effects on skin. The authors conclude that, “the investigation of the possible adverse effects on the skin due to the high frequency electromagnetic fields become more and more important before the deployment of 5G mobile systems. Using this new technology, the absorption of exposure to RF in the skin will be enhanced. The skin will be the most important target organ of the RF exposure to 5G. Therefore, our approach of combined (i.e., consecutive) exposure to UV and RF might be important in future research related to 5G and skin.”

A 2021 paper “[Millimeter \(MM\) wave and microwave frequency radiation produce deeply penetrating effects: the biology and the physics](#)” by Martin L Pall PHD reviews the science on how MM waves can have highly penetrating effects stating that “in humans, MM-waves have penetrating effects including impacts on the brain, producing EEG changes and other neurological/neuropsychiatric changes, increases in apparent electromagnetic hypersensitivity and produce changes on ulcers and cardiac activity... Specifically, MM-wave electrical fields are almost completely absorbed in the outer 1 mm of the body due to the high dielectric constant of biological aqueous phases. However, the magnetic fields are very highly penetrating. 3. Time-varying magnetic fields have central roles in producing highly penetrating effects. The primary mechanism of EMF action is voltage-gated calcium channel (VGCC) activation with the EMFs acting via their forces on the voltage sensor, rather than by depolarization of the plasma membrane... There are three very important findings here which are rarely recognized in the EMF scientific literature: coherence of electronically generated EMFs; the key role of time-varying magnetic fields in generating highly penetrating effects; the key role of both modulating and pure EMF pulses in greatly increasing very short term high level time-variation of magnetic and electric fields. It is probable that genuine safety guidelines must keep nanosecond timescale-variation of coherent electric and magnetic fields below some maximum level in order to produce genuine safety. These findings have important implications with regard to 5G radiation.”

5G's Higher Frequencies Will Impact Insects

“[Exposure of Insects to Radio-Frequency Electromagnetic Fields from 2 to 120 GHz](#)” published in *Scientific Reports* is the first study to investigate how insects (including the Western honeybee) absorb the higher frequencies (2 GHz to 120 GHz) to be used in the 4G/5G rollout. The scientific simulations showed increases in absorbed power between 3% to 370% when the insects were exposed to the frequencies. Researchers concluded, “This could lead to changes in insect behaviour, physiology, and morphology over time...” ([Thielens et al., 2018](#))

According to [Belyaev 2019](#), “the health effects of chronic MMW exposures may be more significant than for any other frequency range.” The abstract states that, “Various responses to non-thermal microwaves (MW) from mobile communication including adverse health effects related to electrohypersensitivity, cancer risks, neurological effects, and reproductive impacts have been reported while some studies reported no such effects. This presentation provides an overview of the complex dependence of the MW effects on various physical and biological variables, which account for, at least partially, an apparent inconsistency in the published data. Among other variables, dependencies on carrier frequency, polarization, modulation, intermittence, electromagnetic stray fields, genotype, physiological traits, and cell density during exposure were reported. Nowadays, biological and health effects of 5G communication, which will use microwaves of extremely high frequencies (millimeter waves MMW, wavelength 1- 10 mm), are of significant public concern. It follows from available studies that MMW, under specific conditions of exposure at very low intensities below the ICNIRP guidelines, can affect biological systems and human health. Both positive and negative effects were observed in dependence on exposure parameters. In particular, MMW inhibited repair of DNA damage induced by ionizing radiation at specific frequencies and polarizations. To what extent the 5G technology and the Internet of Things will affect the biota and human health is definitely not known. However, based on possible fundamental role of MMW in regulation of homeostasis and almost complete absence of MMW in atmosphere due to effective absorption, which suggests the lack of adaptation to this type of radiation, the health effects of chronic MMW exposures may be more significant than for any other frequency range.”

The Bioeffects of Millimeter Waves Documented Years Ago

“[Biological Effect of Millimeter Waves](#)”, a Russian review on millimeter waves declassified by the CIA in 2012, reported multiple research findings and concluded that, “Morphological, functional and biochemical studies conducted in humans and animals revealed that millimeter wave 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 process of tissue respiration and nucleic metabolism” ([Zalyubovskaya, 1977](#)).

“[Current State And Implications Of Research On Biological Effects Of Millimeter Waves: A Review Of The Literature](#)” published in *BioElectroMagnetics* reviewed dozens of research findings on low-intensity millimeter waves and determined that the reported, “MMW effects could not be readily explained by temperature changes during irradiation.” The review concludes by questioning the adequacy of regulatory limits stating that, “Safety limits for these types of exposure 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](#)).

[“Skin Heating and Injury by Prolonged Millimeter-Wave Exposure: Theory Based on a Skin Model Coupled to a Whole Body Model and Local Biochemical Release From Cells at Supraphysiologic Temperatures”](#), published in *IEEE Transactions On Plasma Science* concludes that a consequence of MMW heating is the alteration of cell-membrane permeability. Nearby skin layers are affected by the biophysical mechanism of biochemical release through cell membranes. “The released molecules are delivered to other skin regions by diffusion and into the bloodstream by perfusion, where according to our hypothesis, the molecules interact with susceptible cells. This raises the possibility of additional indirect injury at nearby deeper skin regions that experience insignificant heating. Biochemical release may also lead to injury at distant sites within the body by perfusion clearance that transfers molecules into the systemic circulation to reach other susceptible cells” ([Stewart et al., 2006](#)).

[Siegel et al, 2010](#) published in [Electronics Records](#) reviewed a series of experiments “which show changes in cell membrane potential and the action potential firing rate of cortical neurons under short (1 min) exposures to continuous-wave 60 GHz radiation at mW/cm² power levels, more than 1000 times below the US government maximum permissible exposure.” “At power levels of approximately 300 nW/cm² and above, we observed strong inhibition of the action potential firing rate in some of the neurons, and increased firing in others, perhaps indicating the functional heterogeneity in the studied neuronal population. ... These results are believed to be the first positive correlative measurements of real-time changes in neuronal activity with ultra-low-power millimetre-wave exposures. The experiments point to changes in membrane channel opening....”

Yes, Adding More Cell Antennas Will Increase Exposures in Communities

A [2018 study](#) published in *Annals of Telecommunications* found increased RF-EMF exposure from small cell LTE networks in two urban cities in France and the Netherlands. Researchers measured the RF-EMF from LTE (Long-Term Evolution) MC (macro cells meaning large cell towers) and SC networks (low-powered small cell base stations) and found that the small cell networks increased the radio emissions from base stations (called downlink) by a factor of 7–46 while decreasing the radio emissions from user equipment exposure (called) by a factor of 5–17. So while the devices themselves could emit less radiation, the cell antennas will increase the levels from cell antennas ([Mazloun et al., 2019](#)). This study shows the increased exposures would be involuntary. We can turn our phones off, but we cannot turn off the antennas in the neighborhood.

A 2020 paper [“Radiation Analysis in a Gradual 5G Network Deployment Strategy,”](#) presented at the IEEE 3rd 5G World Forum documents how engineers found significant increases in levels of radio frequency radiation would result if a mmWave-based 5G network was fully deployed in Austin Texas. The researchers first mapped the pre-existing LTE antennas and then laid out the real world design for the

densification of cell towers and signal repeaters which would be needed in the City in order to fully build out a mmWave-based 5G network. The engineers then simulated the RF power densities that would be experienced in the outdoor environments should the 5G mmWave antennas be installed. They found the fully deployed 5G mmWave network would result in significant increases in outdoor RF levels for the City. The researchers conclude that, “This suggests that 5G mobile networks can not yet be classified as safe for the public, and demands serious considerations before using mmWave communications for 5G networks, given the potential harms it could afflict on the public.” The engineers created a heat map to show the increased radiation levels should 5G be fully deployed in Austin Texas.

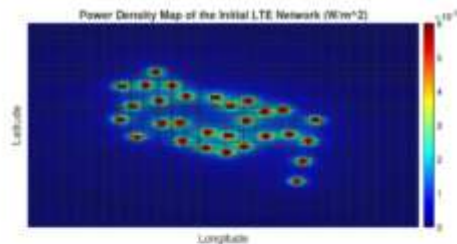


Fig. 9: Power Density Map of the Initial LTE Network

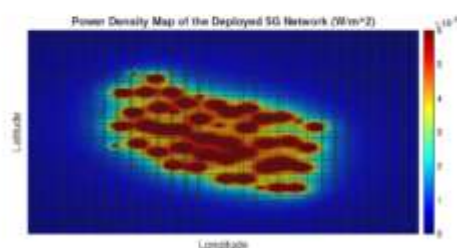


Fig. 10: Power Density Map of the Deployed 5G Network

An [Australian study](#) published in the *Journal of Exposure Science & Environmental Epidemiology* also found that children in kindergartens with nearby antenna installations had nearly three-and-a-half times higher RF exposures than children with installations further away by more than 300 meters ([Bhatt et al., 2016](#)).

A [2018 multi-country study](#) published in *Environment International* measured RF in several countries. It found that cell phone tower radiation is the dominant contributor to RF exposure in most outdoor areas; exposure in urban areas was higher and that exposure has drastically increased. As an example, the measurements the researchers took in Los Angeles, USA were 70 times higher than the US EPA estimate 40 years ago ([Sagar et al., 2018](#)).

As an example of how rapidly RF is increasing from wireless antennas, a [2014 published study](#) from *Environmental Research* looked at RF in three European cities and found in just one year (between April 2011 and March 2012) that the total RF-EMF exposure levels in all outdoor areas in combination increased by 57.1% in Basel, by 20.1% in Ghent and by 38.2% in Brussels. “Exposure increase was most consistently observed in outdoor areas due to emissions from mobile phone base stations” ([Urbiniello et al., 2014](#)).

[Another study](#), published in *Environment International*, looked at 529 children in Denmark, the Netherlands, Slovenia, Switzerland and Spain who wore meters around the waist or carried in a backpack during the day and placed close to the bed at night. Researchers found “the largest contributors to total personal environmental RF-EMF exposure were downlink (meaning from cell tower base stations) and broadcast” ([Birks et al., 2018](#)).

Cell tower radiation is a significant contribution to our daily exposure to RF. [A study recently](#) published in the *International Journal of Environmental Research and Public Health* equipped Australian adults with an RF measuring device in a small hip bag for approximately 24 consecutive hours. The study found “downlink and broadcast are the main contributors to total RF-EMF personal exposure.” Downlink (RF from mobile phone base station) contributed 40.4% of the total RF-EMF exposure ([Zeleeke et al., 2018](#)).

[Another published study](#) in the *Science of The Total Environment* journal, gave 50 Korean parents and their child a measuring device for 48 hours found that “the contribution of base-station exposure to total RF-EMF exposure was the highest both in parents and children” ([Choi et al., 2018](#)).

The study [Exposure of South Korean Population to 5G Mobile Phone Networks \(3.4–3.8 GHz\)](#) measured exposure to electromagnetic fields in South Korea to evaluate the relative contribution of 5G as compared with other frequencies such as 2G, 3G, and 4G. Results show that the emission of 5G contributes about 15% to total telecommunications emissions. Although levels were below ICNIRP, highest levels were observed in the vicinity of 5G antennas ([Selmaoui 2021](#)).

Several countries measure the levels of radiofrequency and post these measurements online- France, Greece, Turkey, India, Israel, French Polynesia, Croatia, Bulgaria, Tunisia, Switzerland, Bahrain, Iceland and Australia. If you look at the measurements by these governments as well as by industry itself the increase from 5G is evident. For example, in Australia the telecom companies report on the levels at this link <https://www.rfnsa.com.au/?first=1> The values are maximum theoretically calculated numbers and they show large changes with the introduction of 5G. Take the 2021 example [found here](#) of the level increasing from 6.44% of the limit to 14.22% of the limit when the 5G network antenna is added. As another example [on Queen Street in Melbourne Australia](#) the addition of 5G antennas increased the levels from 1.67% to 3.39% of the limit. 5G antennas near [a Melbourne powerpole at Elizabeth and Collins Street](#) increased the 2021 levels from .11% to .42% of the limit and the power density increased from 7.70 mW/m² to 42.26 mW/m² from 0 to 50 meters from the site. A [Russel Street Melbourne 5G](#) network (2021) increased the level from .09% to .75% of the limit and the power density increased from 6.77 mW/m² to 75.20 mW/m² from 0 to 50 meters from the site.

Experts Warn that Measurement Techniques Do Not Adequately Measure 5G Exposures

A 2019 Report for the European Parliament Committee on Industry, Research and Energy published for the Policy Department for Economic, Scientific and Quality of Life Policies, entitled “[5G Deployment: State of Play in Europe, USA, and Asia](#)” explained that “5G radio emission fields are quite different to those of previous generations because of their complex beamformed transmissions in both directions – from base station to handset and for the return. Although fields are highly focused by beams, they vary rapidly with time and movement and so are unpredictable, as the signal levels and patterns interact as a closed loop system. This has yet to be mapped reliably for real situations, outside the laboratory.” “While the International Commission on Non-Ionizing Radiation Protection (ICNIRP) issues guidelines for limiting exposure to electric, magnetic and electromagnetic fields (EMF), and EU member states are subject to Council Recommendation 1999/519/EC which follows ICNIRP guidelines, the problem is that currently it is not possible to accurately simulate or measure 5G emissions in the real world” ([Blackman & Forge, 2019](#)).

A 2020 European Parliament Briefing on the “[Effects of 5G wireless communication on human health](#)” reiterates the issues with measurements and also comments on how radiation limits are outdated stating in [this summary](#), “The EU’s current provisions on exposure to wireless signals, the Council Recommendation on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz), is now 20 years old, and thus does not take the specific technical characteristics of 5G into account” ([Karaboytcheva, 2020](#)).

“[Human Exposure to RF Fields in 5G Downlink](#)” in IEEE International Communications Conference found “that 5G downlink RF fields generate significantly higher power density (PD) and specific absorption rate (SAR) than a current cellular system. This paper also shows that SAR should also be taken into account for determining human RF exposure in the mmW downlink” ([Nasim & Kim, 2017](#)).

The study “[Human EMF Exposure in Wearable Networks for Internet of Battlefield Things](#)” published in [MILCOM 2019 – 2019 IEEE Military Communications Conference \(MILCOM\)](#) is the first work that explicitly compares the human EMF exposure at different operating frequencies for on-body wearable communications. The study investigates the exposure effects of the human electromagnetic field (EMF) from on-body wearable devices and compares the results to illustrate how the technology evolution to higher frequencies can impact one’s health. It concludes that

the results suggest the average specific absorption rate (SAR) at 60 GHz can exceed the regulatory guidelines within a certain separation distance between a wearable device and the human skin surface ([Nasim & Kim, 2019](#)).

Review Publications on Electromagnetic Radiation and RF

A 2019 literature review “[Oxidative mechanisms of biological activity of low-intensity radiofrequency radiation](#)” published in *Electromagnetic Biology and Medicine* found that 93 of the 100 peer-reviewed studies dealing with oxidative effects of low-intensity RFR, confirmed that RFR induces oxidative effects in biological systems ([Yakymenko et al., 2016](#)).

“[Planetary Electromagnetic Pollution: It Is Time to Assess Its Impact](#)” published in *The Lancet Planetary Health* documents the significant increase in environmental levels of radio-frequency (RF) electromagnetic wireless radiation over the past two decades. The study cites an evaluation that found 68.2% of 2,266 studies in humans, animals, and plants demonstrated significant biological or health effects associated with exposure to electromagnetic fields. 89% of experimental studies that investigated oxidative stress endpoints showed significant effects and “radiofrequency electromagnetic radiation causes DNA damage apparently through oxidative stress.” The paper also highlights research that has associated RF exposure with altered neurodevelopment and behavioural disorders, structural and functional changes in the brain and the sensitivity of pollinators. “These findings deserve urgent attention. This weight of scientific evidence refutes the prominent claim that the deployment of wireless technologies poses no health risks at the currently permitted non-thermal radiofrequency exposure levels” ([Bandara & Carpenter, 2018](#)).

The review “[Thermal and non-thermal health effects of low intensity non-ionizing radiation: An international perspective](#)” published in *Environmental Pollution* by researchers of the European Cancer Environment Research Institute in Brussels, Belgium and the Institute for Health and the Environment, University at Albany, NY, USA reviews current research findings and states that, “the mechanism(s) responsible include induction of reactive oxygen species, gene expression alteration and DNA damage through both epigenetic and genetic processes.” The paper affirms that “exposure to low frequency and radiofrequency electromagnetic fields at low intensities poses a significant health hazard that has not been adequately addressed by national and international organizations such as the World Health Organization” ([Belpomme et al., 2018](#)).

The literature review [“Effect of radiofrequency radiation on reproductive health”](#) published by the Division of Reproductive Biology & Maternal Health, Child Health, Indian Council of Medical Research documents research that has found a link between radiofrequency radiation and oxidative stress and changes to the reproductive system including sperm count, motility, normal morphology and viability. The review concludes that the “available data indicate that exposure to EMF can cause adverse health effects. It is also reported that biological effects may occur at very low levels of exposure” ([Singh et al., 2018](#)).

Environmental Review published a 2010 landmark [review study](#) on 56 studies that reported biological effects found at very low intensities, including impacts on reproduction, permeability of the blood-brain barrier, behavior, cellular and metabolic changes, and increases in cancer risk ([Lai & Levitt, 2010](#)).

Cancer

[“Cancer epidemiology update, following the 2011 IARC evaluation of radiofrequency electromagnetic fields”](#) published in *Environmental Research* is a comprehensive research review of RF effects in human and animal research. The review concludes that scientific evidence is now adequate to conclude radiofrequency radiation is carcinogenic to humans ([Miller, 2018](#)). Several previously published studies also concluded that RF causes various types of cancer, for example, [Carlberg & Hardell, 2017](#) published in *BioMed Research International*; [Atzman et al., 2016](#) published in the *International Journal Cancer Clinical Research*; and [Peleg et al., 2018](#) published in *Environmental Research*.

The US National Toxicology Program (NTP) is a federal, interagency program that conducted a \$30-million study designed to test the basis for federal safety limits. The study on, [“Cell Phone Radio Frequency Radiation”](#) found “clear evidence” of cancer, heart damage and DNA damage ([NIEHS, 2018](#)). The heart and brain cancers found in the NTP rats are the same cell type as tumors that researchers have found to be [increasing in](#) humans who have used cell phones for over 10 years as published in *BioMed Research* ([Carlberg & Hardell, 2017](#)). Thus, researchers assert in the *International Journal of Oncology* that the [animal evidence from the NTP study](#) confirms the human evidence associating radio frequency radiation exposure to cancer occurrences/developments ([Carlberg & Hardell, 2019](#)).

The 2018 report of final brain and heart tumor results from the [The Ramazzini Institute \(RI\) Study on Base Station RF](#), published in *Environmental Research* was another large scale rat study that also found increases in the same heart cancers that the US

National Toxicology Program (NTP) study found—yet the Ramazzini rats were exposed to much lower levels of RF than the NTP rats. In fact, all the RI radiation exposures were below FCC limits, as the study was specifically designed to test the safety of RF limits for cell tower/base stations ([Falconi et al., 2018](#).) Thus, the Ramazzini study corroborates the [NTP findings](#) as published on the National Institutes of Health website.

[“Tumor promotion by exposure to radiofrequency electromagnetic fields below exposure limits for humans”](#) published in *Biochemical and Biophysical Research Communications* is a replication study that used very, very low RF exposures (lower than the Ramazzini and NTP study) and combined the RF with a known carcinogen. Researchers found elevated lymphoma and significantly higher numbers of tumors in the lungs and livers in animals exposed to both RF and the carcinogen, leading researchers to state that previous research published in the *International Journal of Radiation Biology* ([Tillman et al., 2010](#)) was confirmed and that “our results show that electromagnetic fields obviously enhance the growth of tumors” ([Lerchl et al., 2015](#)).

Environment

[“A review of the ecological effects of radiofrequency electromagnetic fields \(RF-EMF\)”](#) published in *Environment International* reviewed 113 studies finding RF-EMF had a significant effect on birds, insects, other vertebrates, other organisms and plants in 70% of the studies ([Cucurachi et al., 2013](#)). Development and reproduction in birds and insects were the most strongly affected. As an example of the several studies on wildlife impacts, a study published in the *Bulletin of Environmental Contamination and Toxicology* focused on RF emissions from antennas found increased sperm abnormalities in mice exposed to RF from GSM antennas ([Otitoloju et al., 2009](#)).

Published studies, in *Toxicology International* and *Apidologie*, on bees have found behavioral effects ([Kumar et al., 2011](#); [Favre 2011](#)), while other studies from the *International Journal of Environmental Sciences* and the *IIAS-InterSymp Conference* attest to disrupted navigation ([Goldsworthy, 2009](#); [Sainudeen, 2011](#); [Kimmel et al., 2007](#)). Decreasing egg laying rate and reduced colony strength are documented in *Science Direct* and the *Acta Systemica-IIAS International Journal* ([Sharma & Kumar, 2010](#); [Harst et al., 2006](#)).

Research has also found high levels of damage to trees from cell antenna radiation. For example, a field monitoring study, [“Radiofrequency radiation injures trees around mobile phone base stations”](#) published in the *Science of The Total Environment*—spanning 9 years, involving over 100 trees—found trees sustained more damage on the side of the tree facing the antenna ([Waldmann-Selsam et al., 2016](#)).

Expanded 4G, 5G and the Internet of Things (IoT) will increase overall use of all types of wireless frequencies.

A published review, in *Environmental Research*, of effects of Wi-Fi radiation entitled, “[Wi-Fi is an important threat to human health](#)” found that “repeated Wi-Fi studies show that Wi-Fi causes oxidative stress, sperm/testicular damage, neuropsychiatric effects including EEG changes, apoptosis, cellular DNA damage, endocrine changes, and calcium overload ([Pall, 2018](#)).

“[The Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base station](#)” is a research study that compared people living close (within 80 meters) and far (more than 300 meters away) from cellular antennas found that the people living closer had several significant changes in their blood predictive of cancer development ([Zothansanga et al., 2017](#)). An earlier 2016 study, [on genetic damage in humans populations exposed to radiation from mobile towers](#) published in *Archives of Environmental Contamination and Toxicology*, evaluated 116 persons exposed to radiation from mobile towers and 106 control subjects, found DNA damage in peripheral blood lymphocytes ([Gulati et al., 2016](#)).

“[Mortality by neoplasia and cellular telephone base stations](#)”, published in *Science of The Total Environment*, is a 10 year study by the Belo Horizonte, Brazil Health Department and several universities in Brazil that found an elevated relative risk of cancer mortality at residential distances of 500 meters or less from cell installations ([Dode et al., 2011](#)). Shortly after this study was published, the city prosecutor sued several cell phone companies and requested that almost half of the city’s antennas be removed. Many antennas were dismantled.

The 2018 study, “[Mobile Phone Base Station Tower Settings Adjacent to School Buildings: Impact on Students’ Cognitive Health](#)” published in the *American Journal of Men’s Health*, investigated male students in schools near cell towers. The researchers concluded that exposure to higher RF levels is associated with negative impacts on motor skills, memory and attention ([Meo et al., 2019](#)). Examples of other effects linked to cell towers in research studies include [neuropsychiatric problems](#), published in *NeuroToxicology*; [elevated diabetes](#), published in the *International Journal of Environmental Research and Public Health*; [headaches](#), published in *Occupational and Environmental Medicine*; [sleep problems and genetic damage](#) published in the French journal *Pathologie Biologie*.

A study published in 2018 *International Conference on Power Energy, Environment and Intelligent Control (PEEIC)* by IEEE entitled, “[Effect of Mobile Tower Radiation on Microbial Diversity in Soil and Antibiotic Resistance](#)” took soil samples from four different base stations located in Dausa city, India and control samples from soil far from stations and then isolated and evaluated the microorganisms in the soil. The

researchers found greater antibiotic resistance in microbes present in soil near base stations compared to the control. The study concludes, “our findings suggest that mobile tower radiation can significantly alter the vital systems in microbes and turn them multidrug resistant (MDR) which is the most important current threat to public health” ([Sharma et al., 2018](#)).

Research on 3G and 4G

3G and 4G technology is still very much in use around the world. In addition, 5G devices will also have 4G emissions and 5G will utilize the frequencies currently used in 2G, 3G and 4G.

Published in *General Physiology and Biophysics*, a 2019 study titled, “[Chromosome damage in human cells induced by UMTS mobile telephony radiation](#)” examined human blood from healthy donors. The study found that 3G) EMF/microwave radiation emissions from mobile telephones, within the current exposure limits, has significant genotoxic effects on human cells and advises that “human exposure to this EMF/radiation should be kept at levels as low as possible” ([Panagopoulos, 2019](#)). A series of landmark studies found that effects from microwaves on human lymphocytes can be dependant on carrier frequency ([Markova et al., 2005](#)), that Universal Mobile Telecommunications System (UMTS) 3G microwaves can affect chromatin and inhibit formation of DNA double-strand breaks ([Belyaev et al., 2009](#)), and that stem cells are most sensitive to microwave exposure ([Markova et al., 2010](#)) published in *Environmental Health Perspectives*, *Bio Electro Magnetism*, and *Environmental Health Perspectives* respectively. Children have more active stem cells.

4G LTE

The fourth generation (4G) of cellular technology called Long Term Evolution (LTE) was launched without premarket safety testing for long term exposure. Published research has found behavioral changes in mice ([Broom et al., 2019](#)), damage to the testes and reproductive potential in mice ([Yu et al., 2019](#)), reduction to EEG alpha power ([Vecsei et al., 2018](#)), modulation to resting state EEG on alpha and beta bands ([Yang et al., 2017](#)), and the ; alteration of spontaneous low frequency fluctuations induced by the acute LTE RF-EMF exposure ([Lv et al., 2014](#)); published in *Bio Electro Magnetism*, *Science of the Total Environment*, *Scientific Reports*, *Clinical EEG and Neuroscience*, and *Clinical Neurophysiology* respectively.

Published in *Bio Electro Magnetism*, a 2018 double-blind, crossover, randomized, and counterbalanced design study about the [modulation of brain functional connectivity by exposure to 4G LTE cell phone radiation found](#) that acute LTE-EMF exposure did modulate connectivity in some brain regions. The authors conclude that, “Our results

may indicate that approaches relying on network-level inferences can provide deeper insights into the acute effects of LTE-EMF exposure with intensities below the current safety limits on human functional connectivity. In the future, we need to investigate the evolution of the effect over time” ([Wei et al., 2018](#)).

A [2021 study](#) found that exposure to 4.5G (LTE Advanced-Pro network) mobile phone radiation for two hours per day over a six week period caused significant damage to the optic nerve in rats. The authors concluded:

“The optic nerve transmits all visual information to the visual cortex, and any damage in this nerve can cause permanent and serious vision loss. This study demonstrated that RF exposure may be an environmental risk factor for eye toxicity and potential eye disorders. Further studies are needed to reveal the potentiality of the risk in this area.”

The Building Industry

Published in *Building and Environment* the article, “[Building Science and Radiofrequency Radiation: What Makes Smart and Healthy Buildings](#)” with a long list of authors, including former Microsoft Canada President Frank Clegg as well as Anthony Miller MD former Director of the Epidemiology Unit of the National Cancer Institute of Canada, review research studies finding adverse health effects below regulatory limits. The authors recommend reducing radiofrequency radiation in buildings by installing wired rather than wireless internet connections and corded rather than cordless phones ([Clegg et al., 2019](#)).

The Collaborative for High Performance Schools (CHPS) has developed “Best Practices for LOW EMF Classrooms” that details how schools can replace wireless networks with wired networks. See [CHPS Low EMF Criteria](#)

Cell Towers and Health

“[Mobile Phone Infrastructure Regulation in Europe: Scientific Challenges and Human Rights Protection](#)”, a 2014 publication in *Environmental Science & Policy* by human rights experts argue that cell tower placement is a human rights issue for children because “the protection of children is a high threshold norm in Human Right law and the binding language of the Convention on the Rights of the Child obliges States Parties to provide a higher standard of protection for children than adults” and “any widespread or systematic form of environmental pollution that poses a long-term threat to a child’s rights to life, development or health may constitute an international human rights violation.” The article concludes that the “dearth of legislation to

regulate the installation of base stations (cell towers) in close proximity to children's facilities and schools clearly constitutes a human rights concern..." ([Roda & Perry, 2014](#)).

"[Safety Zone Determination for Wireless Cellular Tower – A Case Study from Tanzania](#)" published in the *International Journal of Research in Engineering and Technology* evaluated the radiation levels and concluded that "respective authorities should ensure that people reside far from the tower by 120m or more depending on the power transmitted to avoid severe health effect" ([Nyakyi et al., 2013](#)).

"[Long-term Exposure to Microwave Radiation Provokes Cancer Growth: Evidences from Radars and Mobile Communication Systems](#)", published in *Experimental Oncology* reviews research findings on RF-EMF and states that it is "becoming increasingly evident that [the] assessment of biological effects of non-ionizing radiation based on physical (thermal) approach used in recommendations of current regulatory bodies, including the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines, requires urgent reevaluation." The paper concluded that "everyday exposure of both occupational and general public to MW radiation should be regulated based on a precautionary principles which imply maximum restriction of excessive exposure" ([Yakymenko et al., 2011](#)).

Published in *Electromagnetic Biology and Medicine*, [a cross-sectional case control study on genetic damage in individuals living near cell towers](#) found genetic damage parameters of DNA were significantly elevated. "The genetic damage evident in the participants of this study needs to be addressed against future disease-risk, which in addition to neurodegenerative disorders, may lead to cancer" ([Gandhi et al., 2015](#)).

"[Neurobehavioral Effects Among Inhabitants Around Mobile Phone Base Stations](#)" published in *NeuroToxicology*, concludes that, "Inhabitants living nearby mobile phone base stations are at risk for developing neuropsychiatric problems and some changes in the performance of neurobehavioral functions either by facilitation or inhibition" and called for the revision of standard guidelines for public exposure to RER from mobile phone base station antennas" ([Abdel-Rassoul et al., 2006](#)).

"[Epidemiological Evidence for a Health Risk from Mobile Phone Base Stations](#)" published in the *International Journal of Occupational Environmental Health* reviewed ten epidemiological studies that assessed for health effects of mobile phone base stations and found that 8 of the 10 studies reported increased prevalence of adverse neurobehavioral symptoms or cancer in populations living at distances less

than 500 meters from base stations. The review concludes that "current guidelines may be inadequate in protecting the health of human populations" ([Khurana et al., 2010](#)).

["How Does Long Term Exposure To Base Stations And Mobile Phones Affect Human Hormone Profiles?"](#) published in *Clinical Biochemistry* followed volunteers for six years and found that high radio frequency radiation had effects on pituitary–adrenal axis represented in the reduction of ACTH, cortisol, thyroid hormones, prolactin in young females, and testosterone levels ([Eskander et al., 2012](#)).

Published in the French journal, *Pathologie Biologie* a [study of 530 people](#) living near mobile phone masts reported more symptoms of headache, sleep disturbance, discomfort, irritability, depression, memory loss and concentration problems the closer they lived to the cellular antennas ([Santini et al., 2002](#)).

A study, ["The Microwave Syndrome: A Preliminary Study in Spain"](#) published in *Electromagnetic Biology and Medicine* found statistically significant associations between field intensity and the symptoms of fatigue, irritability, headaches, nausea, loss of appetite, sleeping disorder, depressive tendency, feeling of discomfort, difficulty in concentration, loss of memory, visual disorder, dizziness and cardiovascular problems ([Navarro et al., 2003](#)). ["Subjective Symptoms, Sleeping Problems, And Cognitive Performance In Subjects Living Near Mobile Phone Base Stations"](#) published in *Occupational and Environmental Medicine* found a significant correlation between measured power density and headaches, fatigue, and difficulty in concentration in 365 subjects ([Hutter et al., 2006](#)). Published in *NeuroToxicology*, [Abdel-Rassoul et al., 2007](#) found residents living beneath and opposite a long established mobile phone mast reported significantly higher occurrences of headaches, memory changes, dizziness, tremors, depressive symptoms and sleep disturbance than a control group.

["Increased Incidence of Cancer Near a Cell-Phone Transmitter Station"](#) published in the *International Journal of Cancer Prevention* found a four-fold increase in the incidence of cancer among residents living within a 300 meter radius of a mobile phone mast after three and seven years of exposure ([Wolf & Wolf, 2004](#)).

["The Influence of Being Physically Near to a Cell Phone Transmission Mast on the Incidence of Cancer"](#) published in *Umwelt Medizin Gesellschaft*, found a three-fold increase in the incidence of malignant tumours after five years of exposure in people living within a 400 meter radius of a mobile phone mast ([Eger et al., 2004](#)).

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Research on People Near Cell Towers Links Exposure to Adverse Effects

Published in the *Electromagnetic Biology and Medicine* journal, “The Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base station” is a research study that compared people living close (within 80 meters) and far (more than 300 meters away) from cellular antennas and found that the people living closer had several significant changes in their blood predictive of cancer development. The researchers controlled for various demographics, including the use of microwaves and wireless in the homes ([Zothansiama et al., 2017](#)).

“Mortality by neoplasia and cellular telephone base stations” is a 10 year study by the Belo Horizonte Brazil Health Department and several universities in Brazil that found an elevated relative risk of cancer mortality at residential distances of 500 meters or

less from cell installations ([Dode 2011](#)). Shortly after this study was published, the city prosecutor sued several cell phone companies and requested that almost half of the city's antennas be removed. Many antennas were dismantled.

A 2019 [study](#) of students in schools near cell towers found their higher RF exposure was associated with impacts on motor skills, memory and attention ([Meo 2019](#)). Examples of other effects linked to cell towers in research studies include [neuropsychiatric problems](#), [elevated diabetes](#), [headaches](#), [sleep problems](#) and [genetic damage](#). Such research continues to accumulate after the 2010 landmark [review study](#) on 56 studies that reported biological effects found at very low intensities, including impacts on reproduction, permeability of the blood-brain barrier, behavior, cellular and metabolic changes, and increases in cancer risk ([Lai and Levitt, 2010](#)).

A published study entitled, "[Effect of Mobile Tower Radiation on Microbial Diversity in Soil and Antibiotic Resistance](#)" took soil samples from four different base stations located in Dausa city, and control samples from soil far from stations and then isolated and evaluated the microorganisms in the soil. The researchers found greater antibiotic resistance in microbes present in soil near base stations compared to the control and a statistical significant difference in pattern of antibiotic resistance was found with Nalidixic acid, and cefixime when used as antimicrobial agents. The study concludes, "our findings suggest that mobile tower radiation can significantly alter the vital systems in microbes and turn them multidrug resistant (MDR) which is most important current threat to public health."

Cellular Antennas Create Measurable Increases in Radiation in the Area

A [2018 article published](#) in The Lancet Planetary Health points to unprecedented increasing RF exposures ([Bandara and Carpenter 2018](#)). Another key finding from [Zothansiam 2017](#) was that homes closer to antennas had measurably higher radiation levels—adding to the documentation that antennas increase RF levels. An [Australian study also](#) found that children in kindergartens with nearby antenna installations had nearly three-and-a-half times higher RF exposures than children with installations further away (more than 300 meters) ([Bhatt 2016](#)).

Research Finds that Cell Tower Base Station Radiation is the Dominant Contributor to Overall Environmental Radiation Exposures

A 2018 multi-country [study that](#) measured RF in several countries found that cell phone tower radiation is the dominant contributor to RF exposure in most outdoor areas exposure in urban areas was higher and that exposure has drastically increased. As an example, the measurements the researchers took in Los Angeles, USA were 70 times higher than the US EPA estimate 40 years ago ([Sagar 2018](#)).

As an example of how rapidly RF is increasing from wireless antennas, a [2014 published study looked](#) at RF in three European cities and found in just one year (between April 2011 and March 2012) that the total RF-EMF exposure levels in all outdoor areas in combination increased by 57.1% in Basel by 20.1% in Ghent and by 38.2% in Brussels ([Urbiniello 2014](#)). “Exposure increase was most consistently observed in outdoor areas due to emissions from mobile phone base stations.”

Another study, [Birks 2018](#), looked at 529 children in Denmark, the Netherlands, Slovenia, Switzerland and Spain who wore meters around the waist or carried in a backpack during the day and placed close to the bed at night. Researchers found “the largest contributors to total personal environmental RF-EMF exposure were downlink (meaning from cell tower base stations) and broadcast.”

A study on Australian adults where participants carried a measuring device in a small hip bag for approximately 24 consecutive hours also found “downlink and broadcast are the main contributors to total RF-EMF personal exposure.” Downlink (RF from mobile phone base station) contributed 40.4% of the total RF-EMF exposure ([Zeleeke 2018](#)).

Another published study ([Choi 2018](#)) that gave 50 Korean adult child pairs a special radiation measuring device for 48 hours evaluated the types of radiation the participants were exposed to and found that “the contribution of base-station exposure to total RF-EMF exposure was the highest both in parents and children.” These two studies are an important example of the research that shows that radiation from base stations is the dominant contributor to a person’s cumulative exposure. Therefore we cannot only focus on a person’s cell phone use as the way people are exposed to this radiation. People are exposed to wireless radiation even when they are not using a mobile device due to cell towers, antennas and hotspots and they have no control over this.

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PowerWatch: 1,670 Peer-Reviewed Scientific Papers on Electromagnetic Fields and Biology or Health

[Electromagnetic Radiation Safety](#), October 22, 2018

This list is a compilation of citations for 1,670 peer-reviewed scientific papers about electromagnetic fields (EMF) published in scientific journals from 1979 through 2018. The list includes all papers that PowerWatch published on its [website](#) as of October 11, 2018.

This is not a comprehensive list of studies. PowerWatch selected these studies from their internal database of 15,000 (approx.) scientific papers, most of which address EMF.

Powerwatch has been researching the links between EMF and health risks for more than 25 years. The organization, which is completely independent of government and industry, gathers information to help the lay person understand this issue. Powerwatch recently added a [search engine](#) to its website which enables the user to search specific fields in their database for specified time periods. For more information about PowerWatch go to: <https://www.powerwatch.org.uk/docs/aboutus.asp>.

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Study Effect Codes:

P This study reported effects from the exposure or radiation category (effects can be either positive or negative and may be primary or secondary outcomes)

N This study reported no effects from the exposure or radiation category

- This study offered important insights or findings but is neither evidence of an effect or a null finding

Mobile and Cordless Phones

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Scientific Studies; 5G Exacerbated C19



Date: [11/12/2021](#) Author: [CHI 3 Comments](#)

Updated; 31/Dec.

Research conducted by Beverly Rubik from the college of Integrated sciences and medicine, California, and Robert Brown from the department of radiology at Hamot Medical Center, Pennsylvania, recently [published](#) online at *NIH.gov*, provides scientific evidence that 5G played a role in the C19 pandemic in their study titled; ‘*Evidence for a connection between coronavirus disease-19 and exposure to radiofrequency radiation from wireless communications including 5G*’. [[PDF](#)]

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Evidence for a connection between coronavirus disease-19 and exposure to radiofrequency radiation from wireless communications including 5G

Beverly Rubik^{1, 2, *} and Robert B. Brown³

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The authors began their research based on the correlation between C19, and international communities that recently established 5G networks. The abstract [states](#) C19 began in Wuhan China, as early as November, 2019, shortly after 5G [had gone live](#) on October 31st. Outbreaks soon followed globally in areas where 5G had been implemented, such as [New York](#), and [Italy](#).

In May of 2020 Vladimir Mordachev also [reported](#) a statistically significant correlation between the intensity of RF radiation and the mortality of SARS-CoV-2 in 31 countries throughout the world [[PDF](#)];

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**CORRELATION BETWEEN THE POTENTIAL ELECTROMAGNETIC
POLLUTION LEVEL AND THE DANGER OF COVID-19.
4G/5G/6G CAN BE SAFE FOR PEOPLE**

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Submitted 15 June 2020

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Cases and deaths were [statistically higher](#) in states and major cities with 5G infrastructure. What the authors of this study found was that both 5G and C19 cause deleterious effects on red blood cells, and reduced haemoglobin levels, and both cause similar oxidative stress, cellular damage, and organ damage. Low levels of 5G can [compromise](#) the immune system, and daily exposure induces immunosuppression, or immune dysregulation, including hyperactivation.

5G exposure enhances the infectivity of C19, and contributes to it's inflammatory processes, as well as thrombosis. Both 5G and C19 can cause and complicate cardiac disorders. The authors present their work as evidence that 5G may have exacerbated the C19 pandemic by weakening host immunity, and increasing SARS-CoV2 virulence.

Table 1

Bioeffects of Wireless Communication Radiation (WCR) exposure in relation to COVID-19 manifestations and their progression

Wireless communications radiation (WCR) exposure bioeffects	COVID-19 manifestations
Blood changes Short-term: rouleaux, echinocytes Long-term: reduced blood clotting time, reduced hemoglobin, hemodynamic disorders	Blood changes Rouleaux, echinocytes Hemoglobin effects; vascular effects →Reduced hemoglobin in severe disease, autoimmune hemolytic anemia, hypoxemia and hypoxia →Endothelial injury; impaired microcirculation, hypercoagulation, disseminated intravascular coagulopathy (DIC); pulmonary embolism; stroke
Oxidative stress Glutathione level decrease; free radicals and lipid peroxide increase; superoxide dismutase activity decrease; oxidative injury in tissues and organs	Oxidative stress Glutathione level decrease; free radical increase and damage, apoptosis→Oxidative injury; organ damage in severe disease
Immune system disruption and activation Immune suppression in some studies; immune hyperactivation in other studies Long-term: suppression of T-lymphocytes; inflammatory biomarkers increased; autoimmunity; organ injury	Immune system disruption and activation Decreased production of T-lymphocytes; elevated inflammatory biomarkers. →Immune hyperactivation and inflammation; cytokine storm in severe disease; cytokine-induced hypo-perfusion with resulting hypoxia; organ injury; organ failure
Increased intracellular calcium From activation of voltage-gated calcium channels on cell membranes, with numerous secondary effects	Increased intracellular calcium →Increased virus entry, replication, and release →Increased NF- κ B, pro-inflammatory processes, coagulation, and thrombosis
Cardiac effects Up-regulation of sympathetic nervous system; palpitations and arrhythmias	Cardiac effects Arrhythmias →Myocarditis; myocardial ischemia; cardiac injury; cardiac failure

Supportive evidence including study details and citations are provided in the text under each subject heading, i.e., blood changes, oxidative stress, etc.

Bioeffects of Wireless Communication Radiation (WCR) exposure in relation to COVID-19 manifestations and their progression [click to enlarge]

Many of us reported on this over a year ago, and were silenced as ‘conspiracy theorists’.

Officially we are told that 5G is necessary for the Internet of things (IoT), a world run by artificial intelligence in which humanity no longer matters, but why should we trust anything from these globalist criminal parasites? Pass me my tin-foil hat.