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The Covid-19 Pandemic and 5G Cellular Telecommunication Systems

Recently, there were several odd or unusual reports coming out of the UK about linking the coronavirus disease (COVID-19) pandemic to the rollout of 5G communication systems [1]. It sounded rather bizarre; even as a conspiracy theory, it did not make sense! While both 5G and COVID-19 are global phenomena happening at around the same time, it boggles the mind how the two got entangled. On second thought, it is not as shocking as it may seem upon first encounter!

By now (as I write this in early May 2020), the coronavirus has been established as a global pandemic with rapidly increasing case counts and fatalities worldwide [2]. The impact and interruptions of computer "viruses" on private citizen, commerce, corporation, and government operations and common lives have been widely publicized and recognized for quite some time, now. They have been slowly embedded into the public consciousness as an undesirable hi-tech affliction still in search of an effective remedy. Moreover, for a couple of years if not longer, various groups have been broadcasting and escalating politicized or overblown concerns about 5G security challenges and threats.

Aside from the array of socio-technical issues surrounding the 5G cellular mobile network and technology, the palpable politicization of 5G has caused bewilderment and consternation in its deployment. It has certainly impacted the pace with which investment decisions are being made: namely, to engage5G as a hare or tortoise.

The onset of coronavirus COVID-19, a complex and devastating global pandemic, on top of a public already jittery about computer viruses and 5G wireless cellular technology perhaps conjures up horrors in some people's minds of being attacked by pandemic viruses or malevolent cells, even the type associated with 5G cell phones. The script is not neoteric. Scapegoating has been a cultural norm in some quarters for no less than 2000 years.

The fact is that there is no link between the COVID-19 virus and 5G cell-phone technology or 5G communication base-station towers. These are totally different constructs: they are not even close. None of the conspiracy theories that try to link 5G and the coronavirus scientifically make any sense. The electromagnetic radiation from 5G devices and systems is not carrying the COVID-19 virus or any other microbial virus into which humans can come into contact, nor can infect anyone.

Proponents of 5G mobile technology hail 5G as a faster and more secure technology than its predecessors, 3G and 4G systems, which incidentally are not necessarily entirely secure, either. They can be just as vulnerable to attempts such as real-time location tracking and surveillance practices. However, there are 5G security concerns and issues that can be somewhat more complicated. A central vulnerability or key threat is that it may allow spying on users: not new, either. Nevertheless, this is a system architecture and technology or regulatory issue, but not a biological or health effect matter or challenge.

5G cellular mobile technology is a telecommunication platform that is multifaceted in radio-frequency (RF) engagement and varied in operational scope and performance. It includes an extremely wide range of multiple

RF bands. Its frequency coverage may be roughly separated into two ranges: the sub-6 GHz bands, and 24 GHz to 60 GHz frequencies that reach well into the millimeter-wave region. The frequency ranges have often been further divided into low-band 5G, mid-band 5G, and high-band 5G. Low-band 5G begins at about 400 MHz and often uses existing or previous 3G or 4G frequencies or newly opened frequencies to operate, which, for example, may overlap with the current 4G band. The mid-band 5G especially includes the frequencies around 3 GHz and 4 GHz. However, the primary 5G technological advances are associated with the high-band 5G, promising performance bandwidths as high as 20 GHz and multiple-input and multiple-output (MIMO), using 64 to 256 antennas at short distances, and offering performance up to 10 times that of the current 4G networks.

From the perspective of frequency allocation, 5G encompasses an enormous range, from 3 GHz to 60 GHz and beyond, in one giant skip from 4G. Even with current technological advances, the demand and performance challenges clearly vary immensely from the low to high bands. The anticipated performance bandwidth of 20 GHz obviously is not viable or supportable at low band. By design default or spectrum necessity, the bandwidth performance will only be accomplished by leapfrogging to the high-band 5G. For biological matters, it is not obvious whether the biological responses to high-band 5G radiations would be akin to earlier generations or low-band 5G radiations, given the distinctive characteristics of mm-wave and its interaction with the complex structure and composition of pertinent biological tissues.

In 2011, the World Health Organization's (WHO's) International Agency for Research on Cancer (IARC) classified exposure to RF radiation as a possible carcinogen to humans. The IARC had then evaluated available scientific studies and concluded that while evidence was incomplete and limited, especially regarding results from animal experiments, epidemiological studies of humans reported that increased risks for gliomas (a type of malignant brain cancer) and acoustic neuromas (or acoustic schwannomas – a non-malignant tumor of Schwann-cell-sheathed auditory nerves on the side of the brain) among heavy or long-term users of cellular mobile telephones are sufficiently strong to support a classification of being possibly cancer causing in humans for exposure to RF radiation [3, 4].

The classification of RF radiation as possibly carcinogenic to humans is third on the IARC groupings of carcinogenic risk to humans. The highest category is Group 1, which is reserved for agents that are found to be carcinogenic to humans. It is followed by Group 2A: probably carcinogenic to humans; 2B: possibly carcinogenic to humans; then Group 3: not classifiable as to its carcinogenicity to humans; and lastly, Group 4: probably not carcinogenic to humans.

Recently, the National Toxicology Program (NTP) of the US National Institute of Environmental Health Science (NIEHS) reported observations of two types of cancers in laboratory rats given life-long exposure to RF radiation used for 2G and 3G wireless cellular mobile telephone operations [5]. This was the largest health effect study ever undertaken by NIEHS/NTP. It concluded, among other observations, that there was statistically significant and "clear evidence" that the RF radiation had led to the development of malignant schwannoma (a rare form of tumor) in the heart of male rats. Further, there was "equivocal evidence" for the same schwannoma risk among female rats. NTP also noted that there were unusual patterns of cardiomyopathy, or damage to heart tissue, in both RF-exposed male and female rats when compared with concurrent control animals. In addition, based on statistical significance, the pathology findings showed indications of "some evidence" for RF-dependent carcinogenic activity in the brain of male rats, specifically glioma. However, the findings for female rats were deemed as providing only "equivocal evidence" for malignant gliomas when compared with concurrent controls [6, 7].

Note that the NTP uses five categories of evidence for carcinogenic activity to classify the strength of evidence observed in their reports: "clear evidence" and "some evidence" for positive findings; "equivocal evidence" for uncertain results; "no evidence" for no observable effects; and "inadequate study" for results that cannot be evaluated because of major experimental flaws.

Shortly after the NTP report, the Cesare Maltoni Cancer Research Center at the Ramazzini Institute in Bologna, Italy, published the final results from its comprehensive study on carcinogenicity in rats exposed (either lifelong or prenatal until death) to 2G/3G, 1800 MHz RF radiation [8]. The study involved whole-body exposure of male and female rats under plane-wave equivalent or far-zone exposure conditions. The authors estimated that the whole-body SARs were roughly 0.001 W/kg, 0.03 W/kg, and 0.1 W/kg during exposures of 19 h/day for approximately two years. A statistically significant increase in the rate of schwannomas in the hearts of male rats was detected for the highest RF exposure. Furthermore, an increase in the rate of heart Schwann cell hyperplasia was observed in exposed male and female rats at the highest RF exposure, although this was not statistically significant. An increase in the rate of gliomas was observed in exposed female rats at the highest exposure level, but it was not deemed statistically significant [9]. It is important to note that the recent NTP and Ramazzini RF exposure studies presented similar findings in heart schwannomas and brain gliomas. Two relatively well-conducted RF exposure studies employing the same strain of rats thus showed consistent results in significantly increased cancer risks.

More recently, an Advisory Group for IARC has recommended including re-evaluation of carcinogenicity of human exposure to RF radiation, with high priority, in their Monograph series [10].

As mentioned above, the 5G frequency domain is divided into low, mid, and high bands. The operating frequencies at low and mid bands can overlap with the current 4G band at 6 GHz or below. The biological effects of RF radiations at these lower-frequency bands are thus likely to be comparable to 2G, 3G or 4G. However, the scenarios of high band 5G, especially for 24 GHz to 60 GHz in the mm-wave region for high-capacity, short-range wireless data communications, are relatively recent new arrivals, and pose considerable challenge to health-risk assessment.

There is a paucity of data on permittivity and coupling such as reflection, transmission, and induced energy deposition in biological tissues in the mm-wave frequency band.

In principle, at mm-wave frequencies, the induced fields and energy deposition in biological medium can be determined in much the same manner as for RF if the permittivity of the relevant biological tissues at these frequencies is known. Although there were some earlier extrapolations based on Debye formulas and using complex dielectric permittivity of the skin at lower frequencies, some measurements for skin within the mm-wave range are available for humans [11] and rodents [12]. Note that skin tissue is not homogeneous but consists of multiple layers of stratum corneum, epidermis, and dermis. Moreover, it is differentiated according to body location: for example, forearm and palm skins have thin and thick stratum corneum, respectively.

It has been shown that the mm-wave permittivity of different skin layers may be described by the Debye equation with a single relaxation time [13]. Measured data for human skin in the frequency range of 37 GHz to 74 GHz showed that the measured results tended to be lower compared to earlier extrapolations. More importantly, at mm-wave frequencies, the permittivity of skin is governed by cutaneous free water content. Available information for 30 GHz to 90 GHz thus indicates that the behavior of relative permittivity follows that of the lower RF frequencies. Specifically, the real and imaginary parts of permittivity for skin decrease from 20 to 6 and 20 to 12, respectively.

The power reflection coefficients for frequencies from 37 GHz to 74 GHz decreased from 60% to 45% and 40% to 20% for skin on the forearm and palm, respectively. The power transmission coefficient for skin on the forearm showed an increase from 55% to 65%, respectively, between 30 GHz and 90 GHz. It is noteworthy that a thick stratum corneum in the palm causes an increase in transmission because of the layer-matching phenomenon at higher mm-wave frequencies. The penetration depth of a plane wave field decreases from 0.8 mm to 0.4 mm and 1.2 mm to 0.7 mm for skin on the forearm and palm, respectively, between 30 GHz and 90 GHz. Induced energy deposition increases with mm-W frequency. However, at the highest frequencies the energy deposition in the deeper regions inside the skin is lower because of the reduced penetration depth at these frequencies [14].

Studies on mm-wave interactions aimed both toward biological effects and medical applications began nearly 50 years ago, most notably in the former Soviet Union. A comprehensive review of research on biological effects of mm-waves from the former Soviet Union showed that at intensities of 100 W/m^2 or less, mm-wave can affect cell growth and proliferation, enzyme activity, genetic status, function of excitable membranes, peripheral receptors, and other biological systems [15].

A recently published review included 45 in vivo studies conducted using laboratory animals and other biological preparations, and 53 in vitro studies involving primary cells and cultured cell lines [16]. The review was based on published data from scientific papers written in English available through the end of 2018 using 6 GHz to 100 GHz as the RF source. However, because fewer studies were reported at 30 GHz or below and at frequencies higher than 90 GHz, the review mainly covered published studies conducted in the mm-wave frequency range from about 30 GHz to 65 GHz.

This industry-supported review noted that aside from the wide frequency ranges, the studies were diverse both in subjects and end points investigated. Biological effects were observed to occur both in vivo and in vitro for different biological endpoints studied. Indeed, the percentage of positive responses at non-thermal levels in most frequency groups was as high as 70%. (Higher mm-wave intensities, up to 200 W/m^2, did not seem to cause any greater responses.) For example, in the 53 in vitro studies involving primary cells ($n = 24$) or cell lines ($n = 29$), approximately 70% of the primary cell studies and 40% of the cell line investigations showed effects that were related to mm-wave exposure. However, the protocol applied for control of biological target or culture medium temperature during mm-wave exposure was unclear in a large fraction of these studies.

While many of these investigations with mm-wave exposures reported biological responses, there is inconsistency in the dependence of biological effects and mm-wave intensity used for exposure. The number of reported in vitro and in vivo laboratory investigations were also modest and diverse, considering the wide 5G mm-wave frequency domain. The jury on biological effects or health impact is still out on 5G. Moreover, there is a lack of ongoing controlled laboratory investigations. Simply put, the existing scientific data is inadequate for any reliable assessment or conclusion with confidence.

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