Health Matters

5G Communication Technology and Coronavirus Disease

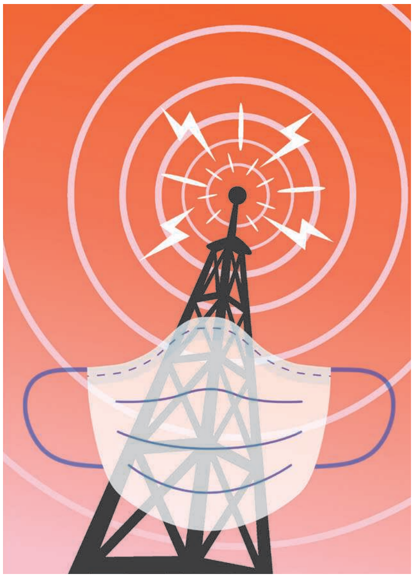
■ **James C. Lin**

In April, there were several odd reports coming out of the United Kingdom about 5G cellular communication towers being set on fire—allegedly linking the coronavirus (COVID-19) pandemic to the rollout of 5G communication technology [1]. It sounds 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 became entangled. However, on second thought, it is not as shocking as it might seem upon first encounter.

By now (as I write this in early May 2020), COVID-19 has been established as a global pandemic, with rapidly increasing case counts and fatalities worldwide [2]. For quite some time now, the impacts of computer "viruses" on the operation of commerce, corporations, and governments—and on the ordinary lives of private citizens—have been widely publicized and recognized. They have been slowly ingrained 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 threats and challenges. Aside from the range of sociotechnical issues surrounding the 5G cellular mobile network and associated technology, the palpable politicization of 5G has caused bewilderment in its deployment. It has certainly impacted the pace with which investment decisions are being made: namely, to engage 5G as a hare or as a tortoise.



TOWER—©ISTOCKPHOTO.COM/ARTPUPPY
MASK—©ISTOCKPHOTO.COM/GHRZUZUDU

For a public that is already jittery about computer viruses and 5G wireless cellular technology, the advent of COVID-19, a complex and devastating global pandemic, perhaps conjures up horror 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 during crises has been a convenient cultural norm for no less than 2,000 years.

The fact is that there is no link between the COVID-19 virus and 5G cell phone technology or 5G base-station communication towers. These are totally different constructs; they are not even close. None of the conspiracy theories that try to link 5G and the coronavirus make any sense scientifically.

James C. Lin (lin@uic.edu) is with the University of Illinois, Chicago, United States.

Digital Object Identifier 10.1109/MMM.2020.2999236
Date of current version: 3 August 2020

The electromagnetic radiation from 5G devices and systems is not carrying the COVID-19 virus or any other microbe that humans can come into contact with or that infects anyone.

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

5G cellular mobile is a telecommunication technology that is multifaceted in frequency 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 24–60-GHz frequencies that reach well into the millimeter-wave (mm-wave) region. The frequency ranges have often been further divided into low-band, midband, 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; these latter for example, may overlap with the current 4G band. Midband 5G includes the frequencies around 3 and 4 GHz. However, the primary 5G technological advances are associated with high-band 5G, promising performance bandwidth as high as 20 GHz and multiple input, multiple output using 64 to 256 antennas at short distances and offering performance up to 10 times that of current 4G networks.

From the perspective of frequency allocation, 5G encompasses an enormous range from 3 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 be accomplished only by leapfrogging to the high-band 5G. For biological matters, it is not obvious whether the biological responses to high-band 5G radiation will 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 International Agency for Research on Cancer (IARC) classified exposure to RF radiation as a possible carcinogen to humans. The IARC had evaluated then-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 nonmalignant 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 high 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 U.S. National Institute of Environmental Health Science (NIEHS) reported observations of two types of cancers in laboratory rats exposed to lifelong RF radiation used for 2G and 3G wireless cellular mobile telephone operations [5]. This is the largest health effect study ever undertaken by the NIEHS/NTP. It concluded, among other observations, that there was statistically significant and "clear evidence" that RF radiation had led to the development of malignant schwannoma (a rare form of tumor) in the hearts 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 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 brains 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. Note that the NTP uses five categories of evidence for carcinogenic activity to classify the strength 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, 1,800-MHz RF radiation [6]. 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 specific absorption rates were roughly 0.001, 0.03, 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 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. It is important to note that the recent NTP and Ramazzini RF exposure studies presented similar findings in terms of heart schwannomas and brain gliomas. Thus, two relatively well-conducted RF exposure studies employing the same strain of rats showed consistent results in significantly increased cancer risks. More recently, an advisory group for the IARC has recommended including reevaluation of the carcinogenicity of human exposure to RF radiation, with high priority, in their monograph series [7].

As mentioned previously, 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. Thus, the biological effects of RF radiation at these lower-frequency bands are likely to be comparable to 2, 3, or 4G. However, the scenarios of high-band 5G—especially for 24–60 GHz in the mm-wave region for high-capacity, short-range wireless data communications—are relatively recent 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 media can be determined in much the same manner as for RF if the permittivity of the relevant biological tissues at these frequencies is known. In addition to some early extrapolations based on Debye formulas and using complex dielectric permittivity of the skin at lower frequencies, a few actual measurements for skin within the mm-wave range are available for humans [8] and rodents [9]. 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, the skin of the forearm has a thin stratum corneum, while the skin of the palm has a thick stratum corneum.

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 [10]. Measured data for human skin in the frequency range of 37 to 74 GHz showed that the measured results tend to be lower compared to earlier extrapolations. More importantly, at mm-wave frequencies, the permittivity of skin is governed by cutaneous-free water content. Thus, available information for 30–90 GHz 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 six and 20 to 12, respectively.

The power reflection coefficients for frequencies from 37 to 74 GHz decrease from 60 to 45% and from 40 to 20% for skin on the forearm and palm, respectively. Power transmission coefficients for skin on the forearm showed an increase from 55 to 65%, respectively, between 30 and 90 GHz. It is noteworthy that the 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 to 0.4 mm and from 1.2 to 0.7 mm for skin on the forearm and palm, respectively, between 30 and 90 GHz. Induced energy deposition increases with mm-wave 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 [11].

Studies on mm-wave interactions aimed at both biological effects and medical applications began nearly 50 years ago, most notably in the former Soviet Union. A comprehensive review of research from the former Soviet Union on biological effects of mm-wave showed that, at intensities of 100 W/m^2 or fewer, mm-waves can affect cell growth and proliferation, enzyme activity, genetic status, function of excitable membranes, peripheral receptors, and other biological systems [12].

A recently published review [13] 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. The review was based on published data from scientific papers written in English available through the end of 2018 using 6–100 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 to 65 GHz.

This industry-supported review noted that, aside from the wide frequency ranges, the studies were diverse both in subjects and in the 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 nonthermal 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. Also, the reported in vitro and in vivo laboratory investigations are modest in number and diverse in subject matter, considering the wide 5G/mm-wave frequency domain. The jury on the biological effect or health impact is still out on 5G. Moreover, there is a lack of ongoing controlled laboratory investigations. Simply put, the existing scientific data are too limited for any reliable assessment or conclusion with certainty.

References

[1] "Mast fire probe amid 5G coronavirus claims," *BBC News*, Apr. 4, 2020. [Online]. Available: https://www.bbc.com/news/uk-england-52164358

[2] A. Schuchat, "Public health response to the initiation and spread of pandemic COVID-19 in the United States, February 24–April 21, 2020," *MMWR Morb. Mortal Wkly. Rep. 2020*, vol. 69, no. 18, pp. 551–556, May 1, 2020. doi: 10.15585/mmwr.mm6918e2.

[3] R. Baan et al., "Carcinogenicity of radiofrequency electromagnetic fields," *Lancet Oncol.*, vol. 12, no. 7, pp. 624–626, 2011. doi: 10.1016/S1470-2045(11)70147-4.

[4] IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, "Non-ionizing radiation, part 2: Radiofrequency electromagnetic fields," *IARC Monogr. Eval. Carcinog. Risks Hum.*, vol. 102, no. 2, pp. 1–460, 2013.

[5] "Technical report on the toxicology and carcinogenesis studies in HSD: Sprague-Dawley SD rats exposed to whole-body radio frequency radiation at a frequency (900 MHz) and modulations (GSM and CDMA) used by cell phones," NTP, Raleigh, NC, Tech. Rep. 595, 2018.

[6] L. Falcioni et al., "Report of final results regarding brain and heart tumors in Sprague-Dawley rats exposed from prenatal life until natural death to mobile phone radiofrequency field representative of a 1.8 GHz GSM base station environmental emission," *Environ. Res.*, vol. 165, pp. 496–503, Aug. 2018. doi: 10.1016/j.envres.2018.01.037.

[7] H. Vainio, E. Heseltine, and J. Wilbourn, "Priorities for future IARC monographs on the evaluation of carcinogenic risks to humans," *Environ. Health Perspect.*, vol. 102, nos. 6–7, pp. 590–591, 1994. doi: 10.1289/ehp.94102590.

[8] S. I. Alekseev and M. C. Ziskin, "Human skin permittivity determined by millimeter wave reflection measurements," *Bioelectromagnetics*, vol. 28, no. 5, pp. 331–339, 2007. doi: 10.1002/bem.20308.

[9] S. I. Alekseev, A. A. Radzievsky, M. K. Logani, and M. C. Ziskin, "Millimeter wave dosimetry of human skin," *Bioelectromagnetics*, vol. 29, no. 1, pp. 65–70, 2008. doi: 10.1002/bem.20363.

[10] S. I. Alekseev, O. C. Gordiienko, and M. C. Ziskin, "Reflection and penetration depth of millimeter waves in murine skin," *Bioelectromagnetics*, vol. 29, no. 5, pp. 340–344, 2008. doi: 10.1002/bem.20401.

[11] J. C. Lin, *Electromagnetic Fields in Biological Systems*. Boca Raton, FL: CRC Taylor/Francis, Sept. 2011, pp. 1–69.

[12] A. G. Pakhomov, Y. Akyel, O. N. Pakhomova, B. E. Stuck, and M. R. Murphy, "Current state and implications of research on biological effects of millimeter waves: A review of the literature," *Bioelectromagnetics*, vol. 19, no. 7, pp. 393–413, 1998. doi: 10.1002/(SICI)1521-186X(1998)19:7<393::AID-BEM1>3.0.CO;2-X.

[13] M. Simkó and M. O. Mattsson, "5G Wireless communication and health effects—A pragmatic review based on available studies regarding 6 to 100 GHz," *Int. J. Environ. Res. Public Health*, vol. 16, no. 18, p. 3406, Sept. 2019. doi: 10.3390/ijerph16183406.

---

15 October 2020 Deadline for MTT-S Sponsored General Category and Medical Applications Fellowships

The deadline for the General Category Graduate Fellowships and Medical Applications Fellowships is 15 October 2020. Graduate awards include a $6,000 scholarship and up to $1,000 to travel to next year's IMS. Don't miss the great opportunity to be the next recipient. Please consult the detailed instructions for the graduate fellowship program at https://www.mtt.org/students.

15 October 2020 Deadline for MTT-S Sponsored Undergraduate/Pre-graduate Scholarships

The deadline for the Undergraduate/Pre-graduate Scholarships is 15 October 2020. Undergraduate awards include a $1,500 scholarship to be used for realizing the proposed project or as a stipend, and a travel supplement to attend the IMS following the award, or a regional MTT-S sponsored conference. Don't miss the great opportunity to be the next recipient. Please consult the detailed instructions for the program at https://www.mtt.org/students.

Digital Object Identifier 10.1109/MMM.2020.3011271