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A view from nano and space technologies: Can gigahertz waves destroy or spread viruses?

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1. Introduction

There is a set of natural frequencies for each physical system. Free vibration refers to natural frequencies at which the system vibrates naturally. Whereas, the forced vibration refers to the externally applied vibration to the system. Resonance might occur when the exciting frequency matches with any of the natural frequencies of the system and at resonance, it may cause severe mechanical damage to the system. Every cell in the human body has a natural tendency to vibrate at a frequency known as the natural frequency, and so the virus. Thus, the use of the right frequency may provide a new possibility to control the spread of the virus.

1.1. Bacteria and vibration

The frequency of the natural oscillations of bacteria is in the megahertz (MHz) range [1]. Resonance oscillations of the cells were observed by Miller who imaged standing wave (high-quality resonance oscillation) in the cell wall of algae in a 1 MHz ultrasonic wave [2]. As reported [3], natural oscillations for *E. coli, B. emersonii, B. yeast* (AFM)*, B. yeast* (micromanipulation) are 4.58, 2.24, 0.16, and 2.06 MHz, respectively.

In addition, millimeter-waves (30 - 60 GHz) based biosensor can detect the pathogenic bacteria in different food samples using bacteriophages [4]. In case of viruses (with smaller size, like coronaviruses of 80-200 nm [5]), THz wave could be used to detect them. In this direction, recently researchers at Ben-Gurion University of the Negev (Israel) developed a lab-on-a-chip sensors with a dense array of metamaterial to sense test coronavirus using breath test or throat/nose swaps [6]. The interation of electromagnetic (THz) waves in complex nanoparticles (airborne viruses) might cause their scattering or reflecting [7]. Similar to the use of radar waves (12-100 GHz) for detection of objects [8].

1.2. Virus and vibration

The genetic material (DNA/RNA) of a virus is enclosed within the capsid as the protective protein shell. The natural frequency of virus vibrations is very high compared to the healthy cells and depends on the molecular structure which differs from virus to virus. For example, the lowest natural frequency of HIV, Hepatitis, and Ebola is 18 GHz, 37 GHz, and 19 GHz, respectively [9]. The average diameters of coronaviruses are in the range of 80 to 200 nm with a molecular mass of about 40,000 kDa [5, 10]. HIV has a diameter of about 120 nm [11].

Ebolavirions are 80 nanometers (nm) width and may be as long as 14,000 nm [12]. The average size of the Hepatitis B virus is about 42 nm [13].

1.3. Vibration induced damage of spikes/ viral shell

There are two competing mechanisms in transient vibration of the lipid membrane (with resonant vibrations of individual spikes) and buckling/collapse of the entire shell. In both cases, large tensile strains are developed, potentially resulting in the formation of cracks and rupture. The release of RNA from the viral envelope could then disrupt the life cycle of a virus. Ultrasonic waves could be used to destroy the protective protein shell (capsid) of a virus. The protective protein shell (capsid) of viruses is influenced by mechanical excitations in the form of ultrasonic waves. For processing applications, ultrasound frequencies are in the range of 20-100 kHz, whereas, in diagnostic radiology, they are in the range of 2 MHz to 15 MHz. High-frequency ultrasound (> 30 MHz) could be achieved by using ultrasonic transducers. It was reported that new ultrasonic transducers can provide frequencies in the range of 100–300 MHz for applications in the optical resolution medical imagining [14]. The frequency of the ultrasonic waves can be tuned to match the natural frequency of the virus to destroy the capsid of the virus. At the resonance frequency, the system provides sufficient wave energy which causes the capsid to undergoes alternating compression and rarefaction. The induces mechanical stress can cause to shatter the virus shell. Therefore, the virus becomes inactive by the destruction of its protective shell. For example, to destroy the spike protein, Yao and Wang used an ultrasonic vibration exciter to disable the 2019-nCoV from infected human cells [15]. The ultrasonic vibration exciter was applied 360° rotating sweep excitation to the human body at the vibration frequencies of 1.9×10^8 Hz to 2.0×10^8 Hz with an amplitude of more than 1.041×10^{-5} mm.

1.4. Electromagnetic (radio) waves

Figure 1 presents the electromagnetic spectrum in which radio frequency (3 kHz-300 GHz) is considered as a possible frequency to use against the spread of many viruses including SARS-CoV2. Below, various types of radio frequency and their applications are discussed.

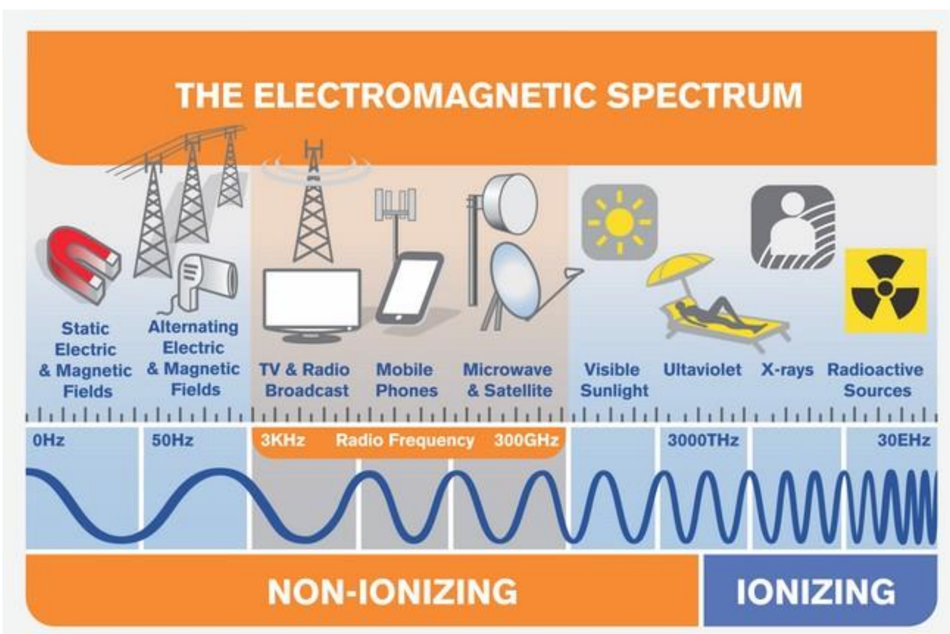

Figure 1: Electromagnetic spectrum [16]

1.4.1. Microwave band

The microwave band is just below the millimeter-wave band and is typically defined to cover the 3–30-GHz range.

1.4.2. Millimeter waves

Millimeter waves are electromagnetic (radio) waves typically defined to lie within the frequency range of 30–300 GHz.

1.4.3. Mobile phones

1G (frequency bands 150 MHz /900 MHz) from 1980 to 1990

2G (frequency bands 1.8 GHz/900 MHz) from 1991 to 2000

3G (frequency bands 1.6 GHz -2.0 GHz) from 2001 to 2010

4G (frequency bands 2 GHz -8 GHz) from 2010 to today

5G networks operate on up to three frequency bands – low, medium, and high. Low-band 5G uses a similar frequency range as 4G cellphones, 600–850 MHz, giving download speeds a little higher than 4G: 30–250 (Mbit/s). Low-band cell towers have a range and coverage area similar to 4G towers. Mid-band 5G uses microwaves of 2.5–3.7 GHz, allowing speeds of 100–900 Mbit/s, with each cell tower providing service up to several kilometers in radius. The first 5G deployments are taking place mainly in the 3.5 GHz frequency bandwidth, which is a bandwidth very close to current mobile networks (3G/4G and Wi-Fi) in terms of coverage. This means that many existing antennae sites may be reused for 5G, without adding new sites. High-band 5G uses frequencies of 25–39 GHz, near the bottom of the millimeter-wave band, although higher frequencies may be used in the future.

1.4.4. Wi-Fi bands

Most of the wireless routers utilizing 802.11ac now have dual-band technology, i.e. they have the ability to use both 2.4 and 5.0 GHz simultaneously (**Figure 2**). A 2.4 GHz wireless band is used for many things ranging from microwaves appliances to Bluetooth speakers. Whereas, 5.0 GHz is mostly used to transmit large amounts of data, like streaming live audio or video without interruption and at remarkable speeds. Both together make for a fantastic solution to network overload.

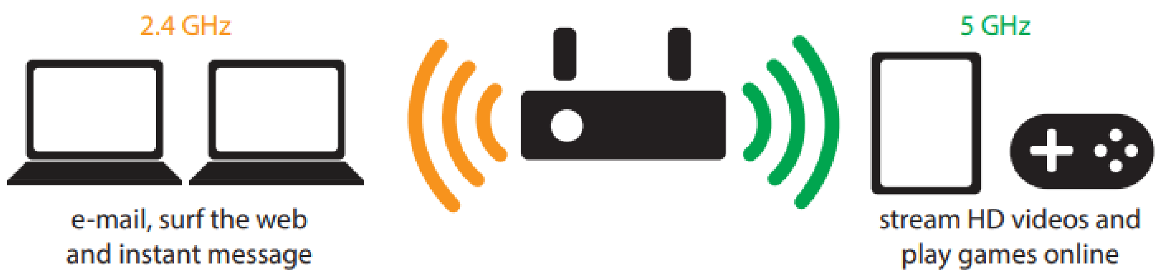

Figure 2: Wi-Fi dual-band technology [17]

1.4.5. Satellite frequency

Figure 3 shows the range of satellite frequency [18]. Its L, S, C, X, Ku, and Ka bands are used for various applications and their frequency ranges are given below:

-L-band (1-2 GHz): Global Positioning System (GPS) carriers and satellite mobile phones

-S-band (2–4 GHz): Weather radar, surface ship radar, and some communications satellites

-C-band (4–8 GHz): Primarily used for satellite communications, full-time satellite TV networks or raw satellite feeds.

-X-band (8–12 GHz): Primarily used by the military.

-Ku-band (12–18 GHz): Used for satellite communications. In Europe, Ku-band downlink is used from 10.7 GHz to 12.75 GHz for direct broadcast satellite services such as Astra.

-Ka-band (26–40 GHz): Communications satellites, uplink in either 27.5 GHz and 31 GHz bands, and high-resolution, close-range targeting radars on military aircraft.

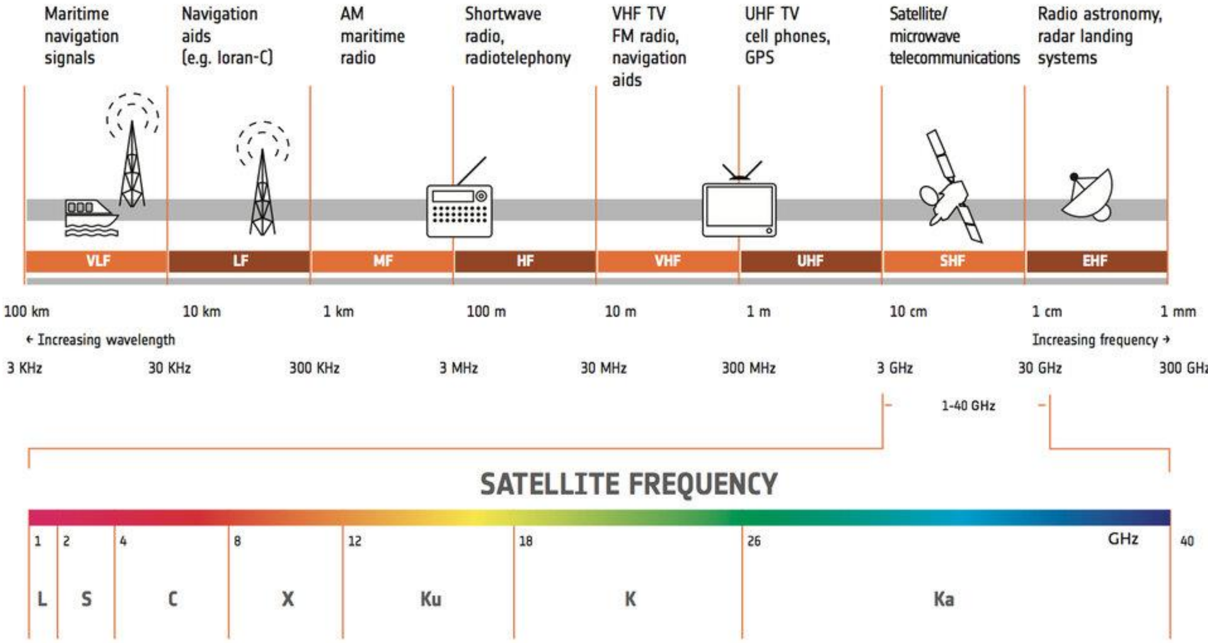

Figure 3: Satellite frequency [18]

Recently, Starlink Satellites Constellation has been developed. Starlink satellites are over 60 times closer to Earth than traditional satellites, resulting in lower latency and the ability to support services that are typically not possible with traditional satellite internet. The constellation consists of over 1600 satellites in mid-2021, and will eventually consist of many thousands of mass-produced small satellites in low Earth orbit (LEO), which communicate with designated ground transceivers. Their equipment includes the Ku-, Ka-, and E-band phased array antennas [19]. The U.S. Federal Communications Commission (FCC) has currently approved SpaceX to launch 4,425 of these communications satellites into low Earth orbit (LEO, 550/1110 km altitude) and 7,518 more in very low Earth orbit (VLEO, 340 km altitude). According to filings with the FCC, the LEO satellites will broadcast in the Ku (12 to 18 GHz) and Ka (26.5 to 40 GHz) spectral bands, which are typical bands for communications satellites. The VLEO satellites, however, will make use of the V band, a higher frequency band ranging from 40 to 75 GHz [20]. The V band has been used for short, line-of-sight terrestrial applications, due to the ability of these frequencies to penetrate walls and the high absorbance of signals in moisture over longer distances [21].

2. Can gigahertz waves cause/spread viruses?

2.1. Rumors about COVID/5G

There was the gradual spread of information about the pandemic around the world, the implementation of increasingly severe quarantine and lockdown measures in most nations, and the attacks on mobile phone towers in the United Kingdom and elsewhere in early April 2020. There were rumors about the connection between pandemic outbreaks and 5G mobile telephony technology in Wuhan and around the world [22]. The COVID/5G conspiracy theory could be a product of the collision of non-scientific beliefs about the supposed health dangers of 5G and vaccines. From early 2020, many posts in social media claimed that 5G radiation can reduce the ability of the human body to absorb oxygen and COVID-19 is a cover story for this. As reported by many researchers and authors, there was an illogical belief that 5G technology could cause or exacerbate the symptoms of severe viral infection [22]. Suspicions about the installation of new 5G base stations during the time of the COVID-19 lockdown eventually appear to have initiated the most visible and violent phase in the timeframe. There were several attacks at 5G masts and towers during early 2020. By April 20, 2020, ZDNet counts 61 “suspected arson attacks” in the United Kingdom alone, with several more attacks on 5G towers in the Netherlands, Belgium, Italy, Cyprus, and Sweden [23].

2.2. COVID/5G: A view from nanotechnology

There have been many speculations regarding the origin and spread of SARS-CoV-2 coronavirus such as lab fabricated virus, etc. there are many other questions such as (a) can the virus and its spread be controlled using nanotechnology? (b) can it be controlled from a distance? and many more. Nanotechnology might provide answers to these questions [24-30].

Gao et al. [24] reported the use of electromagnetic-field-responsive polypyrrole nanowires as a high-capacity drug reservoir. The impregnated drug (dexamethasone, DEX) was found to be released on demand by the application of high-frequency pulsed electromagnetic fields (EMF). They used 3.2 MHz and 65 MHz of the frequency of the magnetic and electric fields, respectively. Kuo and Yu [25] reported an expression of human ornithine decarboxylase and transport of saquinavir across the blood–brain barrier by using composite polymeric nanocarriers under an electromagnetic field. In their work, two EMFs were applied. The first EMF was frequency modulation (FM) with a square wave, power of 5 mW, modulation of 20 MHz, deviation of 400 kHz, and a frequency of 915 MHz. The second EMF was amplitude modulation with a square wave, power of 5 mW, modulation of 20 MHz, depth of 100%, and frequency of 915 MHz. Similarly, Do et al. [26] used the electromagnetic/targeted drug-delivery actuator for Treating Alzheimer's Disease (using a pulsed 0.25-1 Hz and constant magnetic fields). Vinhas et al. [27] used magnetic responsive materials with the pulsed electromagnetic field of 5 Hz in the immunomodulatory response of macrophages. In other directions, ultrasound-responsive nanocarriers also can be used in cancer treatment [28]. At low ultrasound frequencies (< 20 KHz), it could be applied for imaging, while it could be applied for disrupting nanocarriers to release cargos or enhancing the permeability of cancer cell membrane at high ultrasound frequencies too (> 20 KHz) [29].

3. Can gigahertz waves destroy viruses?

3.1. Effect of electromagnetic radiation on the proliferation of cells

Electromagnetic radiation (EMR) can modify the energy level and spin orientation of electrons. Thus, EMR can increase the activity, concentration, and lifetime of reactive oxygen species (ROS) [31]. However, the harmful effects of ROS can be neutralized by different antioxidant mechanisms in cells [31]. In fact, the loss of efficiency of antioxidant mechanisms and alterations in the mitochondrial electron transfer chain under EMR exposure could finally increase ROS [32, 33]. Çiğ and Nazıroğlu [34[reported the effects of distance from sources (mobile phones: 900/1800/2450 MHz, and Wi-Fi) on apoptosis, oxidative stress and cytosolic calcium accumulation via TRPV1 channels in breast cancer cells. The authors demonstrated that Wi-Fi and mobile phone EMR placed within 10 cm of the cells induced excessive oxidative responses and apoptosis in the cancer cells, while placing the source farther away than 10 cm may provide useful protection against oxidative stress and apoptosis. Lee et al. [35] studied (in vitro) the influence of smartphone Wi-Fi signals on adipose-derived stem cells of 30-70 μm in diameter. It was observed that the cell proliferation rate was higher in Wi-Fi-exposed cells as compared with the control cells. The increased proliferation might be attributed to the thermal effect. In addition, they could not find any harmful effects of Wi-Fi signals.

3.2. Effect of electromagnetic radiation on virus

Robach et al. [36] and Cerf [37] demonstrated that ultrasonic energy can be absorbed by viruses. In 2000, Babincová et al. [38] hypothesized that viruses can be inactivated by generating the corresponding resonance ultrasound vibrations of viruses, which is in the GHz region. They suggested that the HIV virus can be attacked with 10 GHz high frequency ultrasound or hypersound excitation. Based on this hypothesis, several groups started investigating the vibrational modes of viruses in this frequency range [39-42].

Since the light emission of laser device is the process of optical amplification based on the stimulated emission of electromagnetic radiation, laser pulses may kill virus [43]. For inactivation of viruses, Tsen et al. [44] proposed using impulsive stimulated Raman scattering (ISRS) with visible light. Experimental proofs showed that laser pulses when tuned to the right frequency can kill certain viruses [45]. In 2008, Dykeman and Sankey [39] modeled the vibrational motion of every atom in a STNV virus shell (satellite tobacco necrosis virus, diameter of ~18 nm [46]). The author found STNV virus could resonate around 70 GHz (Figure 4).

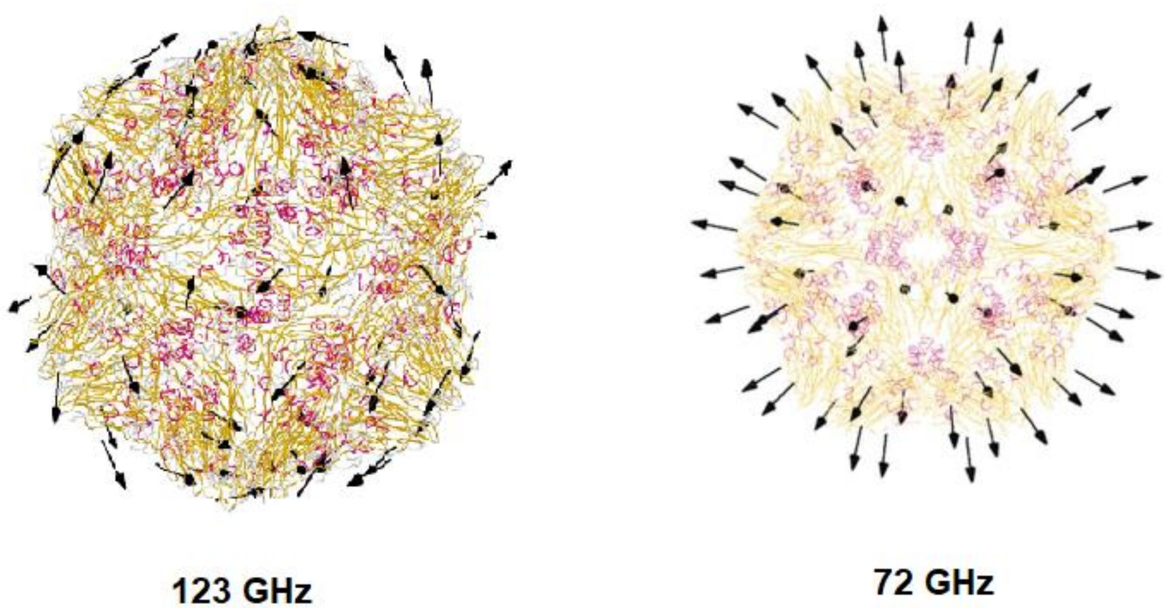

Figure 4: Displacement of the center of mass of each peptide in the full STNV virus at different frequency vibrational modes [39]

Liu et al. [47] demonstrated that the dipolar mode of the confined acoustic vibrations (CAVs) inside viruses can be resonantly excited by microwaves of the same frequency with a resonant microwave absorption effect. The authors proposed the possible structure-resonant energy transfer (SRET) effect from electromagnetic waves (EM waves) to CAVs of viruses. In this direction, Yang et al. [48] observed a strong resonant effect on the H3N2 virus inactivation ratio at the dipolar oscillation frequency of 8.4 GHz. With a low resonator quality factor, the authors also observed H3N2 virus inactivation in off-resonant frequencies (6-12 GHz). Please note that the size of H3N2 virus is in range of 80–120 nm [49].

Recently, Wierzbicki et al. [50] suggested that coronaviruses may be vulnerable to ultrasound vibrations. The authors modeled the virus's response to the mechanical vibration across a range of ultrasound frequencies using computer simulations. They found that vibration between 25 and 910 MHz causes the shell of the virus to collapse and rupture in microseconds (0.35 μs at 110 MHz, 0.13 μs at 50 MHz, and 0.1 μs at 25 MHz). The authors also indicated the effect of harmonic frequency. A single pike vibrates with respect to the stationary shell at 110 MHz. The resonant vibration of spikes in the entire shell was 107 MHz. The resonant frequencies of the spike-free shell in the bouncing mode was 340 MHz and in the shell with spikes, it reduces to 312 MHz (Figure 5).

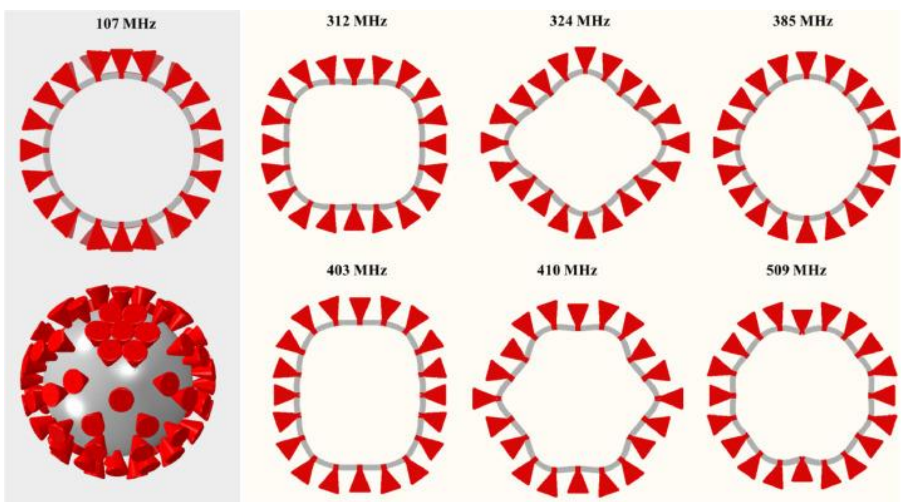

Figure 5: Vibration modes and the associated frequencies of the virus with spikes. The spike can move radially or swing to the left and right when increased the vibrating frequency [50].

4. Future perspectives

Currently, there are no reports on the effect of internet/mobile phone coverages on the vulnerability to Coronavirus infection. Huang et al [51] reported interesting data while studying the urban-rural differences in COVID-19 exposures and outcomes in South Carolina, USA. It was found that urban areas have a higher total number of COVID-19 confirmed cases, but lower case rates. The case rate of COVID-19 from March 1st to September 5th, 2020 was higher in rural counties (2,757 per

100,000 population) than in urban counties (2,373 per 100,000 population). As the predicted natural frequency of Coronavirus would be around 20 GHz, gigahertz waves from high-band 5G technology and LEO/VLEO satellites (Ku, Ki, V band) can be used to disrupt the reproductive cycle of SARS CoV-2 as the action/weapon from distance. Besides, 5 GHz Wi-Fi home networks could protect users from the attack of SARS-CoV2. Although the Wi-Fi frequency of 5 GHz is slightly far from the natural frequency of Coronavirus, it could inhibit (partly) the binding process of the virus to the human ACE2 receptor.

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