5G

THE NEXT GEN LTE

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1. INTRODUCTION :

I have been involved in the aviation industry for 30 years and the last 10 years I became a specialist on Business Aircraft Cabin Connectivity. The first item on VIP's, and operators list is solid cabin internet, to stay connected in all phases of flight. And yes they want back-up. That involves multiple internet sources: with GEO Satellites; Ka Band system, Ku Band, Air-to-Ground (ATG), Iridium Certus, and on LEO Satellites; ***Starlink and OneWeb***. All this represents installing Smart routers, access points, transceivers, Passive antennas, motorized dish Antenna, and other fuselage fixed antennas.

Business Aircraft like commercial are using advance smart routers and WiFi access points (WAP) to connect passengers. Those passengers browses on internet, TXT and make phone calls using WiFi calling mode or a SIP App. on their smart phones. Same as your home the WiFi radios are tuned at 2 popular WiFi bands: 2.4Ghz and 5.8Ghz. Aircraft cabin are certified to handle this to make sure these bands have no EMI effect on Aircraft navigation, systems , auto-pilot, FMS, and other primary flight systems.

An Aircraft cabin is a metal tube where we radiate 2.4 & 5.8Ghz for connectivity. This started my large list of questions. Would this contribute to air fatigue like it does with cabin pressure ?

But the real question that initiated this article:

Do we have to many of those antennas radiating around us ?

Starlink are planning 2300 satellites end of year 2023 above us at 550km altitude connecting us on the ground on the Ku band(18—21Ghz) and ***OneWeb*** planning 720 birds at 1200km altitude on the 10.7 Ghz to 18Ghz bands .

And now **5G** is deployed in cities with thousands of smart cells radiating on multiple bands from 900Mhz, up to 6Ghz and soon above 21Ghz.

I don't have a crystal ball, but let me provide the basics,

Let's dive-in :

2. What is 5G ?

5G is the fifth generation of cellular network . It delivers higher speeds, wider bandwidth, lower latency, and more advanced capabilities than previous 3G-4G –LTE Networks.

5G is a smart system and is using many Frequency bands and a technology called beam forming to zoom-in and focus on locations and devices and advanced algorithm to establish directional high speed connectivity.

5G networks are improving high-speed Internet connectivity around the globe and the beginning of a revolution in the **Internet of Things** (IoT). There are already billions of IoT devices, but the wider bandwidth and more efficient spectrum usage of 5G networks will allow far more devices to operate in proximity without interfering with one another.

It will be years before 5G reaches its full potential, and 4G LTE networks will still be used for a long time. See below difference between 4G and 5G). But for us the user's, it's helpful to understand what makes this technology different and how we can expect it to change the cellular connectivity going forward.

But that opens many questions: and I wonder if I opened a can of worms !

- Do we really need 5G ?
- What are the benefits ? and what are the drawbacks ?
- Where this will be implemented ?
- Are we forced to use it ?
- Any health concerns with so many cells radiating so many high Freq. Bands
- What are those conspiracy theories ?
- Will this improve our way of using internet, or its a Big tech. marketing scam ?
- Almost all articles points to better performance but none presents any risks !

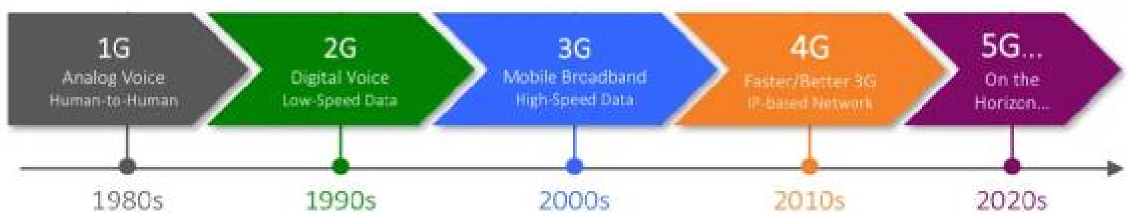
  Anything they don't tells us ?

- The IEE, FCC and WHO exposure levels, are they accurate ?
- People are diagnosed with hyper-electrosensitivity (EHS), is this real ?
- On the ground we have 5G and in the sky we now have StarLInk, do we need all this ?

3. How fast is 5G?

Lets look first at the Cellular Evolution:

- 1G: The original generation, just allowed for analog voice between callers
- 2G: the second generation, allowed data to be sent in text messages.
- 3G: Allowed for high-speed internet through faster data transfer
- 4G: Allowing for significantly faster data transfer.



The speeds that 4G support are also not keeping up with technologies demands. With Artificial Intelligence controlling more and more things, Internet of Things (IoT)and autonomous vehicles, our current network isn't cutting it. These types of devices not only require faster speeds and more bandwidth, but also lower latency.

- ## 5G The basics:

5G networks are designed to achieve a peak download speed of 20 Gbps and peak upload speed of 10 Gbps. The average rates are more like 100 Mbps for downloads and 50 Mbps for uploads.

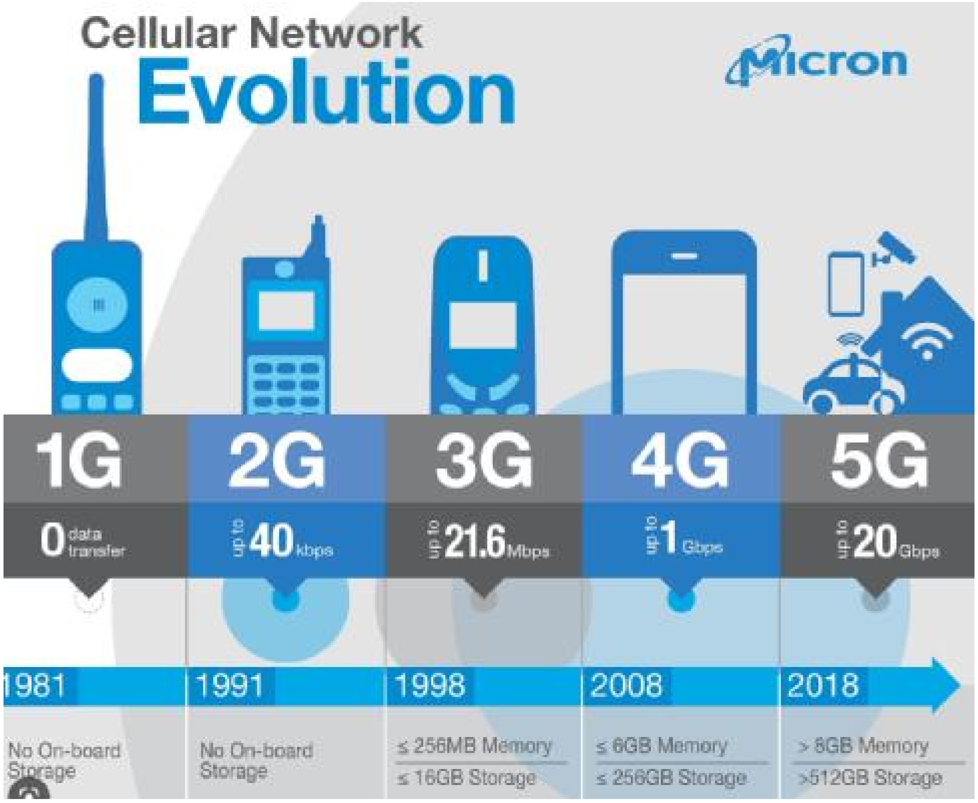
For comparison, the maximum theoretical data speeds for 4G LTE is 150 Mbps for downloads and 50 Mbps for uploads, with an average download speed of 20 Mbps and an average upload speed of about 10 Mbps.

In other words, 5G's average data speed is five times faster than 4G, in theory, it could reach speeds more than 100 times faster.

But 5G doesn't just boast faster downlink and uplink speeds. It has lower latency . Latency is the time it takes to relay requests and responses from one device to another through a network. In a 5G network, the average latency is 4 milliseconds, and it can be as low as one millisecond. With a 4G connection, latency is closer to 50 milliseconds—making 5G's latency more than 10 times lower than 4G.

Users can download full-length movies in high definition in seconds. And advanced IoT (Internet of Things) applications like no pilot self-driving cars, smart farming equipment, industrial automation, and remote healthcare will rely on 5Gs low latency and greater bandwidth.

In the past, faster speeds have come hand-in-hand with greater power consumption, but 5G systems incorporate power saving features of 4G to offer higher data throughput but lower power usage.



Cellular Network
Evolution
Micron
1G
0 data transfer
1981
No On-board Storage
2G
up to 40 kbps
1991
No On-board Storage
3G
up to 21.6 Mbps
1998
≤ 256MB Memory
≤ 16GB Storage
4G
up to 1 Gbps
2008
≤ 6GB Memory
≤ 256GB Storage
5G
up to 20 Gbps
2018
> 8GB Memory
>512GB Storage

4. What is the bandwidth of 5G?

Speed isn’t the only advantage of 5G networks. 5G systems offers much wider bandwidth and greater flexibility in regard to how bands get used. This means 5G networks can maintain stable connectivity for a much larger number of devices in a concentrated area. And it’s the primary way 5G is changing the Internet of Things.(IoT)

Every network operates within specific frequency bands, and the devices on that network have to share that bandwidth. Over the years, advances in wireless technology and new approaches to connectivity have allowed providers to do more with the bandwidth they have. But: every network still faces the same limitation: too many devices using the same frequency bands within the same “cell” of a cellular network creates interference and disrupts connectivity , lower speed.

5G networks can facilitate connectivity on low frequencies below 1 Gigahertz (GHz), mid frequencies from 1 GHz to 6 GHz, and high frequencies from 6 GHz up to 100 GHz. Also a 5G network can connect devices over both licensed and unlicensed spectrum, giving providers greater flexibility with how they use the radio frequency spectrum.

For comparison, commercial 4G networks can only use bands between 600 MHz and 3 GHz.

While the substantially higher frequencies allow for greater speeds, but this also creates new challenges for engineers that want to take advantage of 5G Network.

5. What is the Coverage

Higher radio frequencies have shorter wavelengths. And that means they can’t travel as far. This means that the “cells” of a 5G cellular network have to be smaller if a Network Operator (MNO) wants to provide access to those high-frequency bands. 5G networks require more infrastructure, and that infrastructure offers less coverage.

Additionally, higher frequencies have a harder time penetrating objects like buildings, which means they have poor indoor coverage. 5G can use bands in low and mid-range frequencies as well, but indoor applications will often not be able to use the higher bands.

5G connectivity is most useful in big cities where there’s a higher concentration of cellular devices (and greater demand for high-speed, low latency Internet). But it will take time for MNOs to build up the infrastructure needed to provide widespread 5G coverage.

6. What is Internet of Things: IoT

The Internet of Things (IoT) describes the network of physical objects—"things"—that are embedded with sensors, software, and other technologies for the purpose of inter-connecting and exchanging data with other devices and systems over the internet.

IoT :security risks ?

5G connectivity is making room for tens of billions of new connected devices and more advanced applications for cellular IoT. This massive increase in the volume and capabilities of Internet-enabled devices will continue to present IoT security challenges.

Every connected device creates opportunities for an application to serve as a gateway to an end -user's other connected devices, and botnets will likely grow in direct proportion to this increase, making them capable of introducing greater harm on a network through Distributed Denial-of-Service attacks. As IoT devices continue to collect and use more advanced data, the risk of unauthorized access increases also.

This has always been a challenge with IoT, and it will be greater by the continued growth in this sector, but it is also not a challenge that is *unique* to 5G . In fact, 5G networks introduce new security mechanisms that make this connectivity more secure than other network.

7. Any Satellite interference ?

5G's is accessing higher frequencies and has introduced a problem cellular carriers and manufacturers haven't encountered before: they're sharing bandwidth with satellites we use for weather forecasting. Scientists and engineer have warned that using these high-frequency bands could significantly interfere with our ability to accurately track, measure, record, and predict the weather.

Wireless carriers and the Federal Communications Commission (FCC) have concluded that keeping 5G networks concentrated in urban areas and using beamforming technology will make this potential disruption insignificant.

See below S-IoT: Satellite Internet of Things:

8. 5G, when ?

Major carriers have already deployed 5G networks, and they've sold millions of 5G compatible devices. But for now, 5G service is typically only available in larger cities. Some carriers already have 5G coverage in hundreds or thousands of cities, but on low frequency bands. Low-band 5G coverage will likely be widely available soon, but high-speed 5G connections will take more time to roll out.

5G is the **future of cellular connectivity** and –Things-. But for IoT, widespread 5G is still in the works. While 5G includes IoT-specific features, all of the relevant solutions are already present in LPWANs like LTE-M and NB-IoT. So unless you have a use case that requires very high data throughput and ultra low latency, there are existing cellular networks that might be better suited for your needs.

9. Some definitions:

- ### What is LPWAN:

A low-power wide-area network (**LPWAN** or LPWA network) is a type of wireless telecommunication wide area network designed to allow long-range communications

- ### What is LTE-M:

Long Term Evolution- Machine type Communication, a type of 4G Network designed for IoT

(CAT-M1, Cat-M2)

- ### What is NB-IoT:

NarrowBand-Internet of Things (NB-IoT) is **a standards-based low power wide area (LPWA) technology developed to enable a wide range of new IoT devices and services**. NB-IoT significantly improves the power consumption of user devices, system capacity and spectrum efficiency, especially in deep coverage

10. THE SPECTRUM

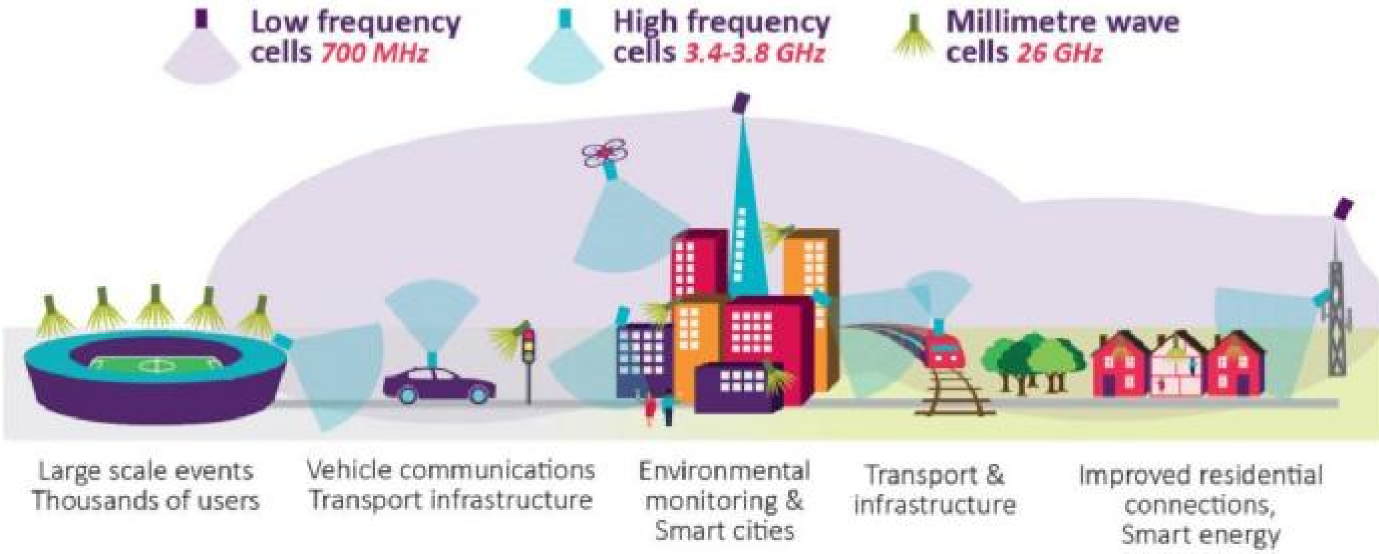
- 5th generation wireless systems,

Abbreviated **5G**, are improved networks deploying in 2018 and later and may use existing 4G or newly specified 5G Frequency Bands to operate. The primary technologies include: Millimeter wave bands (26, 28, 38, and 60 GHz) are 5G and offer performance as high as 20 gigabits per second; Massive MIMO (Multiple Input Multiple Output – 64-256 antennas) offers performance “up to ten times current 4G networks;” “Low-band 5G” and “Mid-band 5G” use frequencies from 600 MHz to 6 GHz, especially 3.5-4.2 GHz.

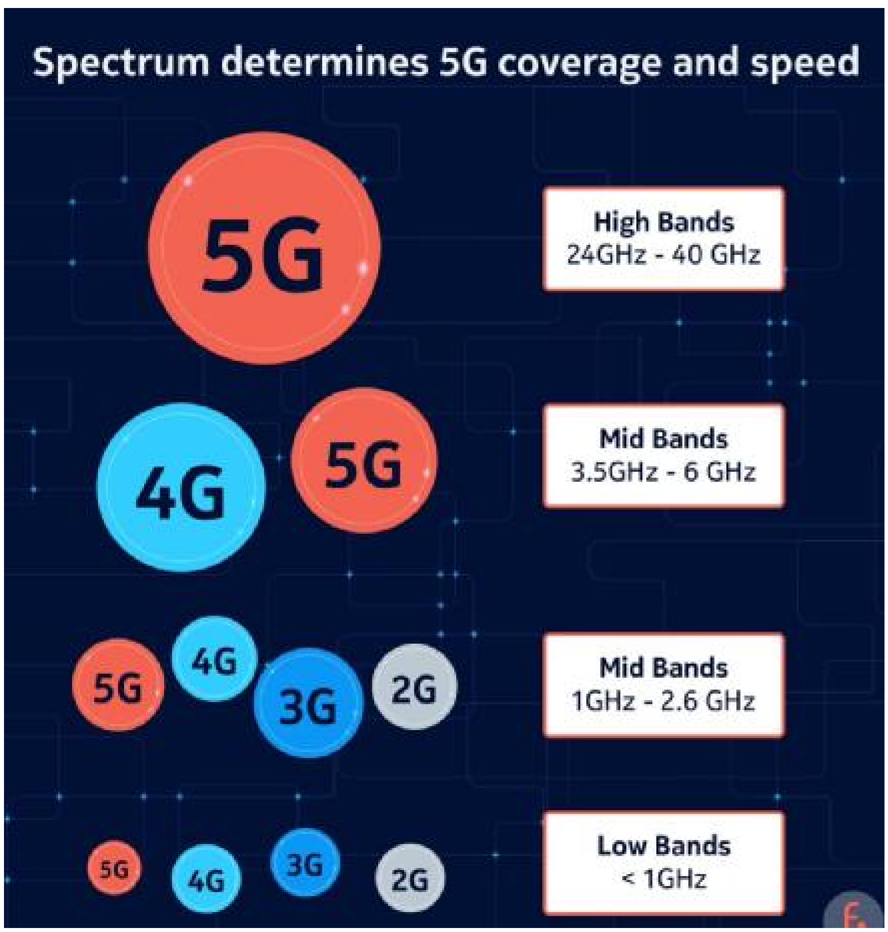
- **Lower 5G Frequency Bands**

The bands 600 MHz, 700 MHz, 800 MHz, 900 MHz, 1.5 GHz, 2.1 GHz, 2.3 GHz and 2.6 GHz are considered for traditional coverage applications and new specific usages such as Internet of Things (IoT), Industry Automation, and Business Critical use cases. However “refarming” will be required for most of these bands, hence the time required to have them allocated to 5G will be much longer than the higher bands.

See further below the Spectrum table:



5G SPECTRUM USAGE:



11. The difference 4G vs 5G:

4G / LTE networks are yet to have full global coverage, 5G technology is already going forward. The first 5G radio masts and Antenna group have been installed across multiple countries, ready to supply the world with a new high-speed network. But, what is the difference between 4G vs 5G and can the 5G standard meet its own requirements? To really understand 4G vs 5G we must take a look at the core of 5G and make a valid comparison with 4G.

<u>5G technology offers several improvements in terms of data rate</u>, coverage and reliability.

One of the main reasons for switching to 5G is the increasing number of end devices within the Internet of Things (IoT) and the resulting increasing hunger for data. But with Cellular providers forcing to upgrade our devices are we falling into a marketing saga ?

According to a study entitled "*A Playbook for accelerating 5G in Europe"*, existing 4G networks worldwide will only be able to cope with the increasing data traffic until 2021. Really ?

Especially in the big cities as the data traffic will probably accumulate . 5G will deliver the planed performance and sets new technical standards. For example, more radio antennas, wider frequency spectra (combinable ranges), lower latencies and higher transmission rates, and beam forming technology.

5G is significantly faster in direct comparison to its predecessor. You can find out how fast the network really is in the above section. But, , speed is only one of the advantages of the 5th generation mobile communications revolution. The focus is particularly on the possibility of connecting a large number of devices. The potential number of end devices in a 5G network is much higher than in a 4G network and high speed communication is possible in real time. Of course, 4G already supplies numerous end devices with sufficient performance and reliability. However, 4G will never be able to supply the mass of data and devices that 5G can. Well we will see about that ! Expert say the 4G network is simply not designed as such. OK but that depends how users are planning to use it.

The industry also has big plans with 5G. The focus is particularly on the network system of "smart" devices and sensors – the "Internet of Things" (IoT) comes up again here. Many studies assume that more than 50 billion devices will be networked worldwide, and the trend is rising. From the simplified search for a parking space to the "smart trash can", there are many concepts just coming up. Even more end devices should be networkable per square kilometer. All these facts and scenarios make a connection using 5G technology essential.

The question is : do we need 5G ? will this improve our lives ?

12. MORE SPEED BUT FOR WHAT ?

What would a new generation of mobile communications be without an extreme increase in performance? The jump from 3G to 4G was already a big step . Today's LTE networks provide 500-1000 Mbit (1 GBit), while 3G ends at a 42 Mb. 5G, on the other hand, will deliver a good 1-3 GB. in the first phase, later it will rise to 10 or 20 GB. That would correspond to an improvement by a factor of 10 to 20, .From today's perspective, data rates are crazy. Because even an Ultra-HD video stream in the best quality hardly requires more than 30 Mbit per second. (with compression)

The data rate factor should therefore become somewhat irrelevant for end customers in the medium term, as for now there are noticeable advantages between 2 and 5 GB. However, this does not mean that this will always be the case. In a few years, 2 GB. will most likely be able to be measured with the regular on-line speed test. On average, today's 4G networks are not as fast as they appear to be on paper. Network tests usually show an average speed of around 50-80 Mbs. But with 5G, the average data rate should increase further – initially to at least 100-100 Mbit.

The next fundamental innovation is the targeted latency rate, which is still in the range of 10-50 ms for LTE. Fiber optic customers sometimes can have values of 2-5 ms. 5G, however, should even enable latencies below 2 ms, which is the basic requirement for real-time applications such as autonomous vehicles or augmented reality.

Now ask yourself the question, will this really improve your on-line activities ?

13. 5G Works differently:

The most fundamental innovation is that besides new frequency ranges and a lot more antennas are used. In the comparison of 4G vs. 5G, 4G is mainly used with bands below 3 GHz. Whereas with 5G, you go much further up. In addition to ranges up to 6 GHz, completely new ones will soon be added. With much higher frequencies and thus shorter wavelengths but lower ranges. The aim is for bands between 24 and 100 GHz – this is often referred to as the "mmWave" range. Primarily, this means that much more bandwidth is available for the data transfer rate. With LTE, mobile operators have so far used a maximum of 100 MHz per carrier aggregation. With 5G, this value could multiply to over 1000 MHz.

The disadvantage: you need a lot more radio stations for good 5G coverage than with LTE.

5G will do much more than just accelerate videos on smartphones. Experts expect a small revolution, especially in the industrial sector. Autonomous vehicles, the Internet of Things, Industry 4.0, and Smart Farming are the most frequently mentioned terms. Thanks to the multi-layer approach, 5G can be designed for all needs equally, whereas LTE was primarily only optimized for performance.

Another feature will be that 5G masts can transmit much more precisely with focus capability (known as “beamforming”). Instead of broadcasting in all directions, one or more users can be targeted, which saves energy and improves the capacity of the radio station.

14. The 5 technologies of 5G:

14.1. Millimeter Wave (MMW)

Today's wireless networks have run into a problem: More people and devices are consuming more data than ever before, but it remains crammed on the same bands of the spectrum that mobile providers have always used. That means less bandwidth for everyone, causing slower service .

One way to get around that problem is to simply transmit signals on a whole new set of the spectrum, one that's never been used for mobile service before. That's why providers are now broadcasting on millimeter waves, which use higher frequencies than the radio waves that have long been used for mobile phones.

Millimeter waves are broadcast at frequencies between above 30 Ghz compared to the bands below 6 GHz that were used for mobile devices in the past. They are called millimeter waves because they vary in wavelength from1 to 10 mm, compared to the radio waves that serve today's smartphones.

Until now, only operators of satellites and radar systems used millimeter waves for real-world applications. Now, most cellular providers have begun to use them to send data between stationary points, such as two base stations. But using millimeter waves to connect mobile users with a nearby base station is an entirely new approach.

There is one major problem to millimeter waves, though—they can't easily travel through buildings or obstacles and they can be absorbed by foliage and rain. That's why 5G networks will likely augment traditional cellular towers with another new technology, called small cells.

14.2. Small Cell

Small cells are portable miniature base stations that require minimal power to operate and can be placed every 250 meters or so throughout cities. To prevent signals from being dropped, carriers could install thousands of these stations in a city to form a dense meshed network that acts like a relay team, receiving signals from other base stations and sending data to users at any location.

While traditional cell networks have also come to rely on an increasing number of base stations, achieving 5G performance will require an even greater infrastructure. Antennas on small cells can be much smaller than traditional antennas if they are transmitting millimeter waves. This size difference makes it even easier to stick cells on light poles and atop buildings.

This radically different network structure should provide more targeted and efficient use of spectrum. Having more stations means the frequencies that one station uses to connect with devices in one area can be reused by another station in a different area to serve another customer. There is a problem, though—the sheer number of small cells required to build a 5G network may make it hard to set up in rural areas.

14.3. Massive MIMO (multiple-input, multiple-output)

Today's 4G base stations have a dozen ports for antennas that handle all cellular traffic: eight for transmitters and four for receivers. But 5G base stations can support about a hundred ports, which means many more antennas can fit on a single array. That capability means a base station could send and receive signals from many more users at once, increasing the capacity of mobile networks by a factor of 22 or greater.

This technology is called massive MIMO. It all starts with MIMO, which stands for **multiple-input multiple-output**. MIMO describes wireless systems that use two or more transmitters and receivers to send and receive more data at once. Massive MIMO takes this concept to a new level by featuring dozens of antennas on a single array.

MIMO is already found on some 4G base stations. Massive MIMO looks very promising for the future of 5G. However, installing so many more antennas to handle cellular traffic also causes more interference if those signals cross. That's why 5G stations must incorporate beamforming.

14.4. Beamforming

Beamforming is a traffic-signaling system for cellular base stations that identifies the most efficient data-delivery route to a particular user, and it reduces interference for nearby users in the process. Depending on the situation and the technology, there are several ways for 5G networks to implement it.

Beamforming can help massive MIMO arrays make more efficient use of the spectrum around them. The primary challenge for massive MIMO is to reduce interference while transmitting more information from many more antennas at once. At massive MIMO base stations, signal-processing algorithms plot the best transmission route through the air to each user. Then they can send individual data packets in many different directions, bouncing them off buildings and other objects in a precisely coordinated pattern. By choreographing the packets' movements and arrival time, beamforming allows many users and antennas on a massive MIMO array to exchange much more information at once.

For millimeter waves, beamforming is primarily used to address a different set of problems: Cellular signals are easily blocked by objects and tend to weaken over long distances. In this case, beamforming can help by focusing a signal in a concentrated beam that points only in the direction of a user, rather than broadcasting in many directions at once. This approach can strengthen the signal's chances of arriving intact and reduce interference for everyone else.

Besides boosting data rates by broadcasting over millimeter waves and beefing up spectrum efficiency with massive MIMO, wireless engineers are also trying to achieve the high throughput and low latency required for 5G through a technology called full duplex, which modifies the way antennas deliver and receive data.

14.5. Full Duplex

Today's base stations and cellphones rely on transceivers that must take turns if transmitting and receiving information over the same frequency, or operate on different frequencies if a user wishes to transmit and receive information at the same time.

With 5G, a transceiver will be able to transmit and receive data at the same time, on the same frequency. This technology is known as full duplex, and it could double the capacity of wireless networks at their most fundamental physical layer: Picture two people talking at the same time but still able to understand one another—which means their conversation could take half as long and their next discussion could start sooner.

To achieve full duplex in personal devices, engineers must design a circuit that can route incoming and outgoing signals so they don’t collide while an antenna is transmitting and receiving data at the same time.

This is especially hard because of the tendency of radio waves to travel both forward and backward on the same frequency—a principle known as reciprocity. But recently, experts have assembled silicon transistors that act like high-speed switches to halt the backward roll of these waves, enabling them to transmit and receive signals on the same frequency at once.

One drawback to full duplex is that it also creates more signal interference, through a pesky echo. When a transmitter emits a signal, that signal is much closer to the device’s antenna and therefore more powerful than any signal it receives. Expecting an antenna to both speak and listen at the same time is possible only with special echo-canceling technology.

With these and other 5G technologies, engineers hope to build the wireless network that future smartphone users, autonomous cars will rely on every day. Already, researchers and companies have set high expectations for 5G by promising ultralow latency and record-breaking data speeds for consumers. If they can solve the remaining challenges, and figure out how to make all these systems work together, ultrafast 5G service could reach consumers soon.

Overview video: https://www.youtube.com/watch?v=GEx_d0SjvS0

15. Is LTE Obsolete ?:

No at all ! In a direct comparison of 4G vs. 5G, the 5G network will by not replace the 4G network, but will complement it in the near future. Similar as with the older 3G radio technology, 4G will likely phase out (by 2022) with the introduction of 5G. However, 4G still has a lot of potential. Even with 1000 MB. the development is not at all completed. We assume that LTE will be expanded even further in the first 5 years after the introduction of 5G. 4G plays an important role, particularly when it comes to supplying regions without fast cable internet .

One thing is clear - 5G is predestined and designed for the Internet of Things (IoT). The technology will prove of crucial importance to all realms of our future. It will uncover new application scenarios only possible with the larger data volume that 5G offers. The potential is there - it's up to business, society and communities and us everywhere to realize if this is a valid potential.

16. Satellite Internet of Things:

Satellite IoT uses satellite network for global connectivity and relies on LEO (Low Earth Orbit) satellies which offers high bandwidth and low latency. It requires a large number of satellites to keep coverage on the globe. This technology can complement on the ground Networks like Cellular.

The Internet of Things (IoT) is a world in and of itself with “smart” technology impacting nearly all facets of society. When the average person thinks about IoT, examples such as connected thermostats, home security systems and intelligent cars come to mind, but this is just the tip of the iceberg.

Modern-day businesses and organizations rely on IoT to enable millions of intelligent data communication, helping them track, monitor and manage devices; ensure the safety of their workers, and improve remote operations. To many people, it may come as a surprise that because of IoT technology, critical elements of our economy, such as the global supply chain, can be managed remotely. For instance, trucks carrying perishable goods can be monitored in real time, and merchant ships can be piloted from the safety of the shore, and it’s all made possible by some form of connectivity. But since cellular coverage only reaches approximately 15 percent of the planet, technology developers have had to find ways to extend their reach beyond the limits of terrestrial infrastructure. This need led more and more companies to look to satellite communications to create coverage continuity, and as a result, a new IoT category emerged – satellite IoT.

The number of satellite IoT subscribers will increase at a compound annual growth rate (CAGR) of 40.3 percent to reach 21.2 million units in 2026. Only about 10 percent of the Earth's surface has access to terrestrial connectivity services which leaves a massive opportunity for satellite IoT communications.

According to some estimates, more than 6,000 satellites orbit the earth right now—around 3,000 of which are in LEO. Many of these satellites are owned by the same entities, like Iridium, StarLINK and OneWeb, enabling corporations and government agencies to network them together. While most people are familiar with satellite applications like GPS tracking, and Iridium telephony this technology has only recently been leveraged for other networking applications like Internet access.

Some have touted satellite IoT as a better global solution than cellular IoT since businesses can use a single provider... but you can already do that with cellular IoT, too. So while this can be g a single global solution isn’t an inherent advantage of satellite IoT, there are some good reasons to consider it for your application. But before we get into those, let’s talk about the types of Non-Terrestrial Networks (NTN) that make satellite IoT possible.

A satellite constellation is a group of artificial satellites working together as a system. These constellations can provide permanent or nearly global coverage depending on how many satellites there are and their position in relation to the earth. The bigger and denser the constellation, the closer it gets to providing real-time data.

Generally, there are three main types of satellite networks that can be used for IoT connectivity: Low Earth Orbit (LEO), Medium Earth Orbit (MEO), and high altitude Geostationary (GEO). They're characterized by orbital height, where they're deployed, and ground coverage area. Some of these constellations are "stationary" (moving in sync with Earth's equator), while others are spinning across the globe.

The **3rd Generation Partnership Project** (**3GPP**) Release 17 has specified the use of GEO and LEO satellites for Non-Terrestrial Network (NTN) IoT connectivity.

LEO satellites have a smaller coverage area and circle Earth every 90 to 100 minutes , which means they're available at the same location 16 times in every 24 hour . This may only suffice for some IoT applications. For more frequent IoT service availability, providers have been creating constellations of numerous LEO satellites that work together with various ground stations.

Due to the lower orbital height, the latency of LEO satellites is about 10 to 20 milliseconds—more than 20-times lower than that of a GEO satellite.

16.1. Benefits :

Satellite IoT offers a unique connectivity solution—it’s the only option where the infrastructure is in space, orbiting the earth. Depending on the orbit, the satellites may change position over time while maintaining the same general coverage on the surface, or stay in the same position relative to the earth.

The three main reasons to consider satellite IoT are that it works in remote locations where there’s no other coverage, it can work as a backup when another solution has gaps in coverage, and it can extend the coverage of certain networks.

It keeps devices connected in locations with no terrestrial infrastructure:

In remote environments, your connectivity options become very limited. While cellular networks are available worldwide, some deployments may be too isolated for even cellular coverage. In these cases, the alternative has traditionally been to build your own infrastructure on site—an expensive process that also requires you to maintain and secure the network yourself.

Satellite IoT is an excellent solution for these unique scenarios.

16.2. Some applications:

- Marine telematics

There’s little network infrastructure available on the ocean. And the further you get from the coastline, the less accessible connectivity solutions become. For telematics applications where you may, for example, track shipping containers as they cross the oceans, need to recover lost or stolen vehicles, or warn vessels of emergency situations, satellite IoT may be the most viable choice. Telematics devices are often designed to be low power and don’t require a constant network connection, which further makes satellite IoT a good option.

- Smart agriculture

Agriculture increasingly relies on IoT to automate routine processes and make more data-informed decisions. But remote environments can also create challenges for traditional connectivity solutions. In environments where cellular coverage is unavailable or spotty, satellite IoT could close coverage gaps for tech-enabled farming operations.

- Remote oil rigs

Oil rigs need to operate wherever the oil is—and that's often not where the network infrastructure is. Some oil operations need to set up on the ocean, too far from cellular towers and other traditional connectivity solutions. With satellite IoT, it doesn't matter if you apply on land or sea—the connectivity is the same, so long as the provider has an acceptable number of satellites.

- Mining

In remote mining areas there is either no public cellular network coverage, or only intermittent coverage available due to geographical conditions. This is exactly where non-terrestrial network connectivity solution via satellite is needed. When cellular land reception drops, or is not available, the IoT device uses the satellite network connection. Heavy equipment used in mining locations can stay connected for tracking location, remote maintenance, monitoring and emergency alerts.

16.3. The future is cellular IoT + satellite IoT

Satellites are already proving to be an excellent solution for extending cellular coverage. With the right technology, they can essentially function as cellular towers in space, creating a global grid of cellular coverage for particular network technologies.

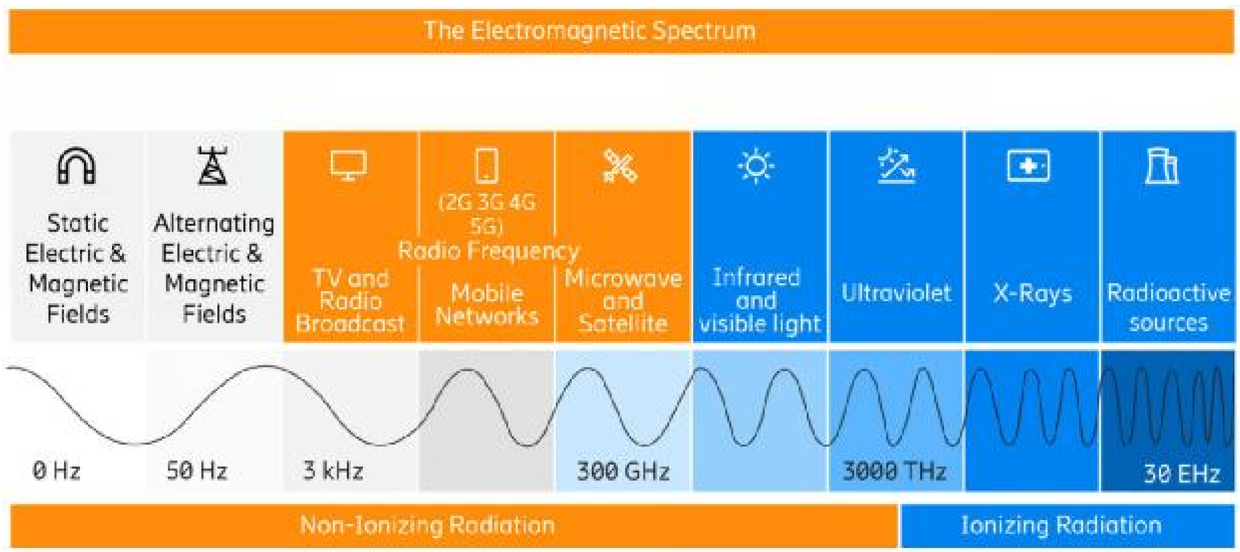
In the near future, if we combine satellite IoT with our global cellular IoT coverage, giving us the best of both worlds. **And it won't require additional hardware to access our satellite connectivity.**

17. ENVIRONMENTAL AND HEALTH EFFECT:

Now that you are a 5G expert lets jump into the serious stuff:

The dark side of the story:

We are bombarded from wireless 3G, 4G and 5G networks producing radio-frequency electromagnetic fields using many Freq. bands and RF levels simultaneously . Yes they say Electromagnetic fields have been around in different forms since the birth of the universe but are in no comparison to this new technology in frequency and radiation levels. They differ from each other by frequency and visible light is its most familiar form. The Spectrum can be divided in 2 major sections: the non-ionizing radiation and the Ionizing radiation. Most agencies are considering the effect of tissue temperature by radiation in the non-Ionizing type, and assumes no other harm to the body. But many experts are showing a different story. A Conspiracy ?



Today's RF exposure originate from many sources:

- Home WiFi access point, and public WiFi acces points,(2.4 & 5Ghz)
- Microwave oven (leakage)
- Our own Cellular (900Mhz , 1.9Ghz, 2.4Ghz, 5Ghz)
- GEO Satellite radiation in the Ka Band (21 – 31Ghz)
- LEO (Starlink, and OneWeb and others Ku Band, (12—18Ghz)
- Multiple industry microwave towers (4Gh—10Ghz)
- Your Hydro smart meter (902 Mhz & 2.4Ghz),
- Smart appliances and security systems using the 2.4Ghz band
- Bluetooth Heaphones (2.4Ghz)
- 4G-LTE- and now 5G Cellular towers emitting many frequency bands across cities and highways.

For all radio frequencies (0 to 300 GHz), Agencies produced international maximum levels designed to avoid any adverse health effects. (FCC, Canada Health) are they ?

But is this sufficient and does it represent the real picture ? specially that MMW in the 5G spectrum (above 21Ghz) is new technology and very few studies have been conducted showing the biological effect on humans and animals and clear evidence of what shall be the safe time/radiation levels. Most studies are considering only the tissue heating effect and ignore other effect including the possible damage at the cellular level.

MMWs are weaker than microwaves, they are predominantly absorbed by the skin, meaning their distribution is quite focused on the body surface. Since skin contains capillaries and nerve endings, MMW bio-effects may be transmitted through molecular mechanisms by the skin or through the nervous system.

But we also forget to consider Hypersensitivity.

Some studies at the *National Library of Medicine* are looking at this and are showing evidence that INVALIDATES FCC exposure limit.

The limits were also based on two major assumptions: any biological effects were due to excessive tissue heating and no effects would occur below the putative threshold SAR, as well as twelve assumptions that were not specified by either the FCC or ICNIRP.

Articles show how the past 25 years of extensive research on RFR demonstrates that the assumptions underlying the FCC's and ICNIRP's exposure limits are **invalid** and continue to present a public health harm. Adverse effects observed at exposures below the assumed threshold SAR include non-thermal induction of reactive oxygen species, DNA damage, cardiomyopathy, carcinogenicity, sperm damage, and neurological effects, including electromagnetic **hypersensitivity**.

Consequently, these exposure limits, which are based on **false suppositions**, do not adequately protect workers, children, hypersensitive individuals, and the general population from short-term or long-term RFR exposures. Thus, urgently needed are health protective exposure limits for humans and the environment. These limits must be based on scientific evidence rather than on erroneous assumptions, especially given the increasing worldwide exposures of people and the environment to RFR, including novel forms of radiation from 5G telecommunications for which there are no adequate health effects studies.

The industry, Cell companies, the market , have you noticed that all websites, the entire purpose is to advocate for the immediate rollout of 5G. The pictures, articles, and information, are only focused on the positives.

Some Health issues articles:

- **Scientific evidence invalidates health assumptions underlying the FCC and ICNIRP exposure limit determinations for radiofrequency radiation: implications for 5G**

  https://pubmed.ncbi.nlm.nih.gov/36253855/

- **Low-level exposure to radiofrequency electromagnetic fields: health effects and research needs**

  https://pubmed.ncbi.nlm.nih.gov/9453702/

- **The Ramazzini Institute Study:**

  https://www.sciencedirect.com/science/article/abs/pii/S0013935118300367?via%3Dihub

- **ENVIRONMENTAL HEALTH TRUST: Resource**

  https://ehtrust.org/key-issues/cell-phoneswireless/5g-internet-everything/20-quick-facts-what-you-need-to-know-about-5g-wireless-and-small-cells/

17.1 AGENCIES RF EXPOSURE GUIDELINES:

Radiofrequency (RF) electromagnetic fields (EMF) are a type of non-ionizing radiation with several technological applications. For decades, RF has been used for purposes such as telecommunication signals and microwave heating.

Health Canada's guidelines, referred to as Safety Code 6, regulates exposure to RF. Safety Code 6, which is based on peer-reviewed scientific literature, is intended to protect all members of the public from potential adverse effects to RF exposure.

Two international bodies produce exposure guidelines on electromagnetic fields. Many countries currently adhere to the guidelines recommended by:

The International Commission on Non-Ionizing Radiation Protection and,

The Institute of Electrical and Electronics Engineers, through the International Committee on Electromagnetic Safety

These guidelines are not technology-specific. They cover radiofrequencies up to 300 GHz, including the frequencies under discussion for 5G.

Human Exposure to Radiofrequency Electromagnetic Energy Frequency Range from 3 kHz to 300 GHz

https://www.canada.ca/en/health-canada/services/publications/health-risks-safety/limits-human-exposure-radiofrequency-electromagnetic-energy-range-3-300.html

17.2 Cellular Telephone Specific Absorption Rate (SAR)

The SAR is a value that corresponds to the relative amount of RF energy absorbed in the head of a user of a wireless handset. The FCC limit for public exposure from cellular telephones is an SAR level of 1.6 watts per kilogram (1.6 W/kg). Specific Absorption Rate (SAR) for Wireless Phones and Devices Available at FCC Web Site.

17.3 FCC- RF exposure limits;

This is a measure of the rate at which the body absorbs RF energy. The FCC limit is **1.6 watts per kilogram (W/kg)**. All wireless devices sold in the United States are certified by the FCC that they don't exceed FCC exposure limits.

The FCC is required by the National Environmental Policy Act of 1969, among other things, to evaluate the effect of emissions from FCC-regulated transmitters on the quality of the human environment.   Several organizations, such as the American National Standards Institute (ANSI), the Institute of Electrical and Electronics Engineers, Inc. (IEEE),and the National Council on Radiation Protection and Measurements (NCRP) have issued recommendations for human exposure to RF electromagnetic fields.

18. Adverse Health Impacts: by dr. Paul Heroux Phd:

Professor of Toxicology and Health Effects of Electromagnetism, McGill University Medicine, Department of Surgery, McGill University Health Center.

Dr. Heroux has experience in Physics (BSc. MSc. Phd) , engineering(15y) and health science (30y) Dr. Heroux performed many experiences related to EMF radiation on cells.

He also demonstrated many different opinions about appropriate level of Electromagnetic radiation. (uMW/m2)

FCC (USA), Code 6 (Canada), Western Europe	10,000,000
Inhibition of DNA Repair in Stem Cells	920,000
Russia, China, Italy, Switzerland, Eastern Europe	100,000
Karyotype Changes in Cancer Cells	24,000
Permeability Loss Blood-Brain Barrier	4,000
Bioinitiative, Salzburg Resolution	1,000
European Union Resolution 1815	106
Building Biology Recommendation	0.1
Cell Phone Minimum Limit	0.001
Natural Radiation	0.000,001

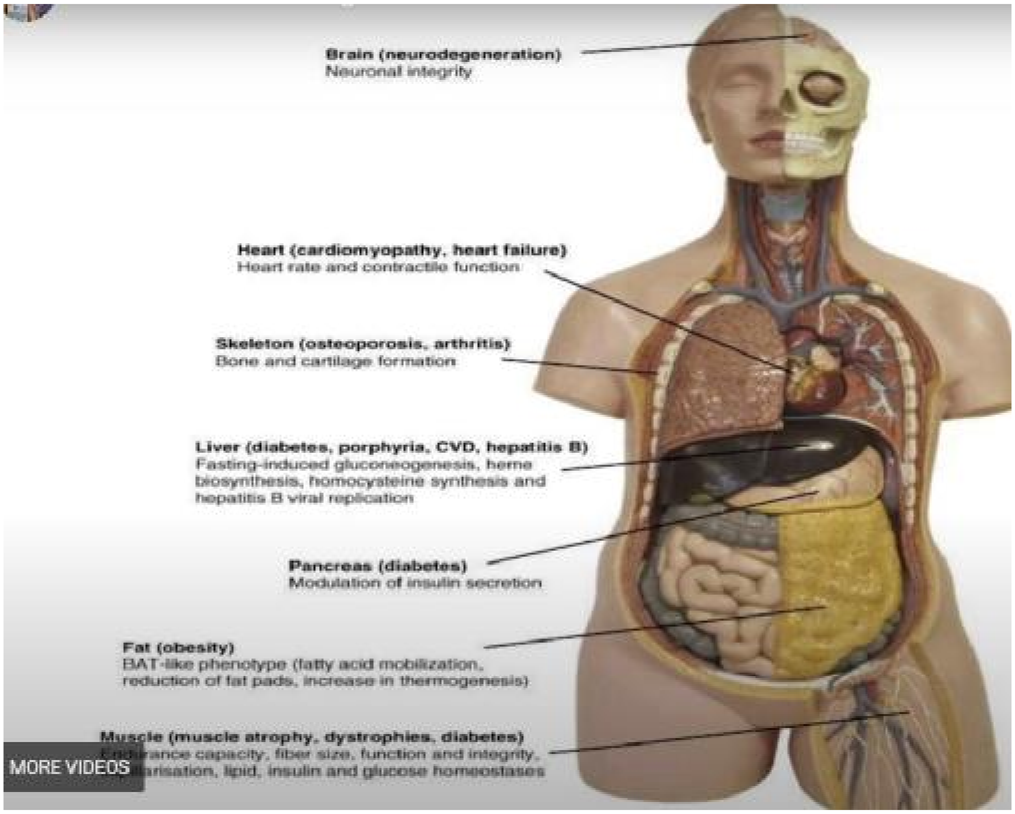
He also reported many effects from those radiations, and observed drastic effects on cancer cells 500 times below FCC limits. His test where performed on Cells that never had any exposure to LF magnetic field (that represent well RF communications), no RF radiation to demonstrate the effect with time. One observed effect is an increase in nycrosis (cells that dies)

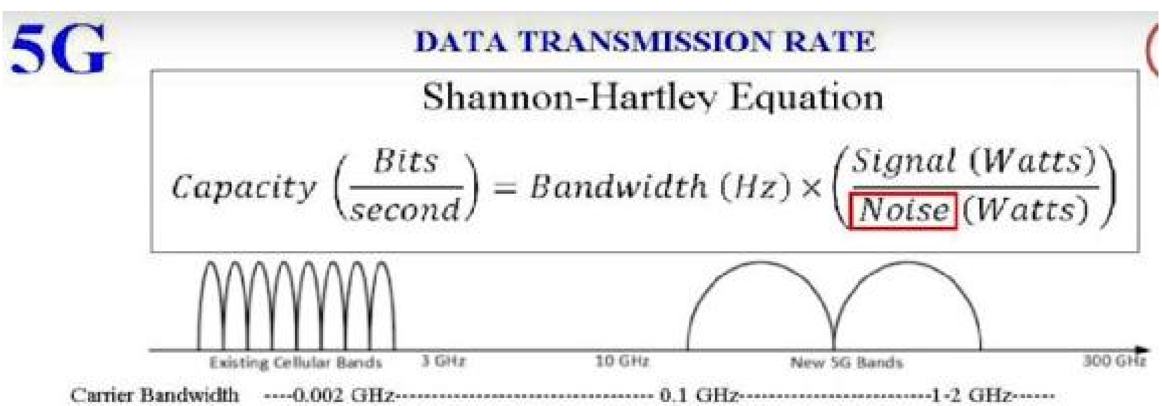
He presented a 1992 study showing an increase of cancer by 4 times on 2180 mouses and 4288 rats when exposed to radiation at the FCC radiation limit. Now that standard becomes the question ! There is also evidence that cancer is increasing in the US population. His concerns relates to childrens in schools exposed to constant WiFI radiation specially that they have developing tissues being more vulnerable. Microwaves penetrates much more effectively a child brains than an adult.

Radiation effects:

Altered Enzyme Activity	363
Biochemical Changes	342
Oxidative Stress (ROS)	240
Pathologic Cell Changes	193
Neuro-Behavioral Effects	192
DNA Damage	145
Altered Gene Expression	144
Brain Wave Changes	105

Location of possible damage to human body:

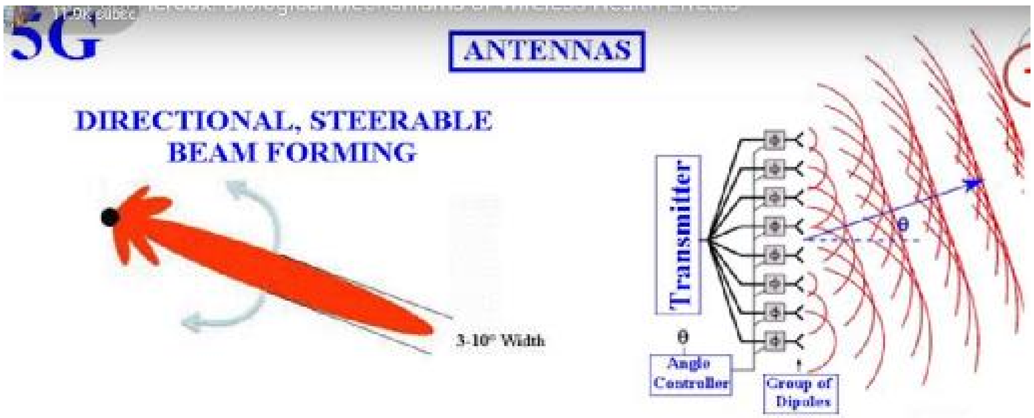




18.1 Radiation penetration Depth:

At 10Ghz penetration depth is 5mm, and at 50Ghz is 1mm. Energy is concentrated in this region. Within the first mm of skin , Cells are dividing and the nervous system extends in the human skin. Ultraviolet light known to cause cancer has a penetration depth less than 0.1mm.

5G emission in a spherical pattern requires more power since the wavelength is much smaller, and you get less energy. This is why beamforming is used to focus and steered on devices. Dipole Antennas are used to achieve this pattern.



19. IEEE GUIDELINE:

19.1. IEEE ; Technical Information Statement: Health and Safety Issues Concerning Exposure of the General Public to Electromagnetic Energy from 5G Wireless Communications Networks

This Technical Information Statement (TIS) addresses health and safety issues concerning exposure of the general public to radiofrequency (RF) fields from 5G wireless communications networks, the expansion of which started on a large scale in 2018 to 2019.

5G technology can transmit much greater amounts of data at much higher speeds for a vastly expanded array of applications compared with preceding 2-4G systems; this is due, in part, to using the greater bandwidth available at much higher frequencies than those used by most existing networks. Although the 5G engineering standard may be deployed for operating networks currently using frequencies extending from 100s to 1,000s of MHz, it can also operate in the 10s of GHz where the wavelengths are 10 mm or less, the so-called millimeter wave (MMW) band. Until now, such fields were found in a limited number of applications (e.g., airport scanners, automotive collision avoidance systems, perimeter surveillance radar), but the rapid expansion of 5G will produce an increase of MMW in the environment.

While some 5G signals will originate from small antennas placed on existing base stations, most will be deployed with some key differences relative to typical transmissions from 2-4G base stations. Because MMW do not penetrate foliage and building materials as well as signals at lower frequencies, the networks will require “densification,” the installation of many lower power transmitters/antennas (often called “small cells” located mainly on buildings and utility poles) to provide for effective indoor coverage. Also, “beamforming” antennas on some 5G systems will transmit one or more signals directed to individual users as they move around, thus limiting exposures to non-users.

5G has significantly greater data transfer rates (bandwidth) and much shorter delays (latency) at the base station in responding to incoming signals. 5G will also be needed to manage the data traffic on present wireless networks, which is increasing by 90% per year. As of early 2019, data traffic stood at about 29 exabytes (29×10^{18} bytes) per month. For perspective, one exabyte of data could store 100,000 times the information in all printed material in the U.S. Library of Congress.

Real-time 5G communications will enable humans and machines to control or operate remote equipment and devices to accomplish tasks such as remote surgery, repair of equipment in hostile environments, and remote control of aircraft and other vehicles. Other advanced applications might include control of medical devices on the surface of the body or implanted within it (e.g., insulin pumps or cardiac devices) or augmented reality applications on cell phones.

5G wireless networks, and their predecessors (2-4G), are sometimes called “cellular” networks because of the way the network base stations create “cells” of coverage to mobile subscribers. As subscribers move through the cells, the network “hands off” the connection with the subscriber to the next cell. This enables the same frequency bands to be used repeatedly across a large geographic area with minimal interference. As these networks continue to mature, they are often referred to as mobile-wireless or simply wireless networks, which is the term used here.

19.2. Technical background

5G is not specific to frequency and will operate across the RF spectrum: a “low band” below 1 GHz for voice and support of many IoT (Internet of Things)[4] applications; a “middle band” in the 1-6 GHz range—already in use and in many cases nearing capacity—in which the 5G protocols will enable faster data transfer compared to 2-4G; and a new “**high band**” of ~30-300 GHz in the millimeter wave (MMW) portion of the spectrum corresponding to wavelengths from 10 mm to 1 mm that can support extremely high data transfer rates. MMWs are not entirely novel to the environment, as they are found in applications such as airport scanners, automotive collision avoidance systems, and perimeter surveillance radar security systems. The specific band used for 5G will vary by country; for example, in several nations in Europe, 5G was principally introduced in the 3.6 GHz band.

To provide adequate spectrum for 5G, the US Federal Communications Commission (US FCC) has already auctioned spectrum at 24 and 28 GHz and continues to auction frequencies in the 37 GHz, 39 GHz, and 47 GHz bands, with other countries taking similar measures. While the use of MMW allows transmissions across very large bandwidths at higher frequencies, they are readily absorbed outdoors by flora (e.g., wet trees and their foliage) and by building materials, such that a receiving/transmitting device deployed on the building exterior is necessary to receive and transmit the signal to the intended recipient within. Although 5G will operate across a wide spectrum (see below table), discussions among the public concerning health and safety issues focus generally on 5G’s MMW transmissions.

19.3. Sources of RF exposure from cellular telephone networks:

Exposure to RF fields from a cellular network originates from two possible sources: one is the “downlink” signal from the base station, while the other is the “uplink” signal from one’s own or a nearby person’s handset. Handsets can transmit at power levels of up to about 1 watt, but their actual output is set by the network to the lowest level that communicates effectively with the base station, in some cases as low as a few milliwatts.

The power[5] transmitted by a base station varies with the area it serves, ranging from several hundred watts in a “microcell” base station mounted on a tower or on the top of a building, to typically less than 10 W for a “small cell” mounted on a 10-m utility pole, to mW for ‘microcells, picocells or femtocells’[6] commonly mounted in the celling or on the inside wall of a building and to serve very limited areas. The signal’s frequency depends on the wireless provider and on which of several different services (voice vs. data) the provider supports in a particular region.

19.4. Influence of small cells on population exposure to RF signals:

Adding small cells to a network has mixed results on overall RF exposures. Their addition will increase the downlink signal levels intended to improve quality of service. Secondarily, these higher signal strengths will cause the network to reduce the power output of handsets (the uplink). Since in most cases the stronger exposure to cellphone users is from uplink signals from their own devices, the presence of small cells will generally reduce overall RF exposure to a user or a bystander. However, many variables determine personal exposure to RF fields, and simple generalizations of this sort do not always apply.

19.5. RF exposure limits

In most countries, RF exposure limits are based generally on either the International Commission on Nonionizing Radiation Protection (ICNIRP) guidelines ([ICNIRP 1998, 2020]) or the Institute of Electrical and Electronics Engineers (IEEE) Standard C95.1-2019 ([IEEE 2019]). In the US, RF exposures are regulated by the Federal Communications Commission (FCC). IEEE and ICNIRP limits were last updated in 2019 and 2020, respectively. The current version of the FCC limit was approved in 1996 ([FCC 1997]), but in August of 2019, the FCC issued a press release stating that it intends to maintain its current RF exposure safety standards, citing a statement from the Director of the US Food and Drug Administration Center for Devices and Radiological Health that "**the available scientific evidence to date does not support adverse health effects in humans due to exposures at or under the current limits**.

While most countries have adopted limits based on ICNIRP or IEEE, several cities (and even a few countries) have established their own "precautionary" limits based on a philosophy of minimizing exposure to avoid as-yet unproven hazards and are motivated in part by social concerns about RF technology.

19.6. Exposure from base stations

A key difference between 2G/3G/4G and 5G systems is that RF signals from present and older-generation systems remain in a fixed (or static) spatial pattern, whereas 5G antennas can be configured to transmit multiple beams that are steered toward individual users as they move about within a base station's coverage area. Such antennas are often referred to as beamforming or "smart" antennas. Importantly, the term 5G may encompass either static antenna beams or beamforming antennas.

Thus, even if a 5G base station that uses beamforming technology were to transmit more total power than a comparable 4G station, that power could be divided among multiple narrowly focused beams, each propagating in a different direction. The net effect is that 5G beamforming systems will have the capacity to provide high-quality communications through the more efficient use of transmitter power that can steer signals toward specific users. Field levels within other (off-beam) areas having no users would be sharply lower than those from a typical 4G base station; and since the 5G beam will exist only while communicating with a user, the long-term time-averaged exposure levels will also be lower.

So far, no comprehensive surveys of environmental 5G signals have been conducted; few 5G networks are presently in operation, and those are largely demonstration projects transmitting at less than full capacity. Nevertheless, the designs of 5G networks are constrained by the same requirements that apply to previous generations of cellular systems: to provide a signal that is strong enough to be useful within a given cell but not so strong as to cause interference to users in nearby cells. Consequently, on this basis alone, one can expect that exposures from 5G networks will not differ greatly from those associated with present generation networks. In fact, most 5G systems transmitting millimeter waves will operate with only a few watts of power.

While many bioeffects studies have been performed using RF fields in cellular bands currently in use, comparatively **only a few studies have been done in the millimeter wave band**.

19.7. Effect on the body:

First, unlike lower frequency fields, MMW do not penetrate beyond the outer skin layers and thus do not expose inner tissues to MMW. Second, current research indicates that overall levels of exposure to RF are unlikely to be significantly altered by 5G, and exposure will continue to originate mostly from the "uplink" signals from one's own device (as they do now). Third, exposure levels in publicly accessible spaces will remain well below exposure limits established by international guideline and standard setting organizations, including ICNIRP and IEEE

While it is acknowledged that the scientific literature on MMW biological effect research is more **limited than that for lower frequencies**, we also note that it is of mixed quality and stress that future research should use appropriate precautions to enhance validity.

19.8. Health: Lack of studies

There is a **little number of well-done studies** on health-related effects of millimeter waves. The results of most studies in the literature are of uncertain relevance to health. Many have small samples of subjects, and many lack elementary precautions to ensure reliability. Well-done studies to identify biological effects of millimeter waves of potential health significance are warranted. For example, since some future 5G systems will transmit at millimeter wave frequencies, which until now have not been prevalent in the public domain (with limited exceptions), research should examine whether skin heating from such exposures at sufficiently high levels results in adverse biological effects that differ from those due to infrared heating.

The thermal response of the body to millimeter wave exposures for extended times (10s of minutes or longer) **needs further study**. Above 6 GHz, present IEEE and ICNIRP exposure limits rely on theoretical/numerical models to predict transient and steady-state increases in tissue temperature. Better experimental validation of these models is needed, as well as an assessment of inter- and intra-subject variability in responses. This is particularly needed for occupational exposure limits, where extended high-level exposures of several 10s of minutes or more might result in unacceptable temperature increases in the skin under worst-case conditions

20. WHO STATEMENT:

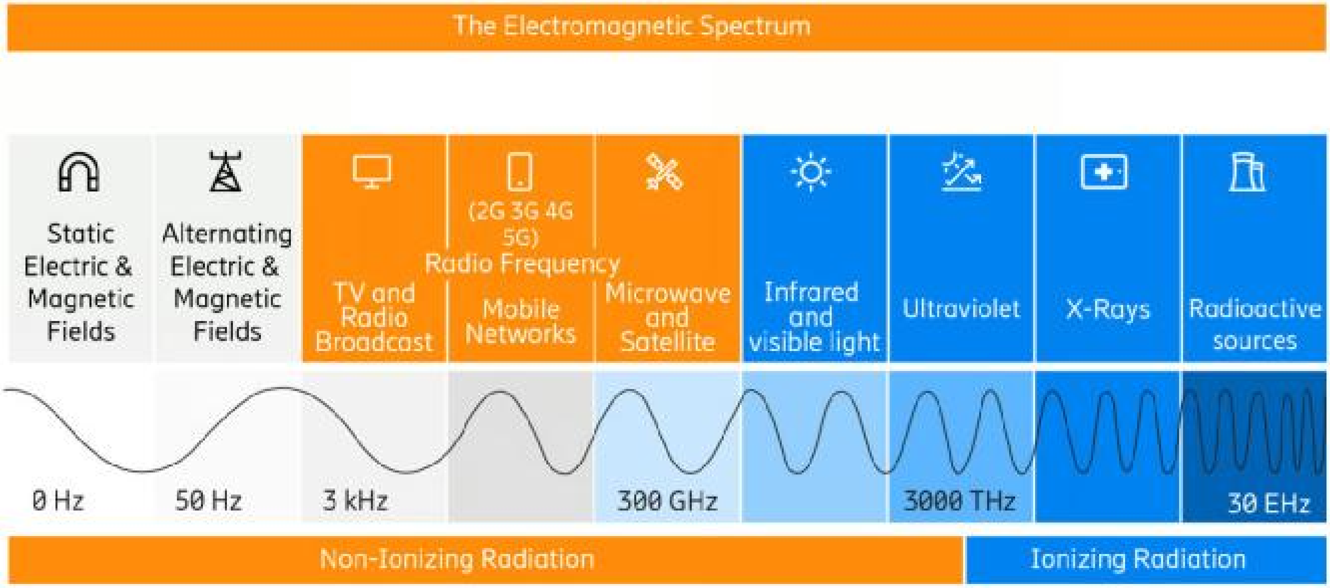
To date, and after much research performed, no adverse health effect has been causally linked with exposure to wireless technologies. Health-related conclusions are drawn from studies performed across the entire radio spectrum but, so far, **only a few studies have been carried** out at the frequencies to be used by 5G.

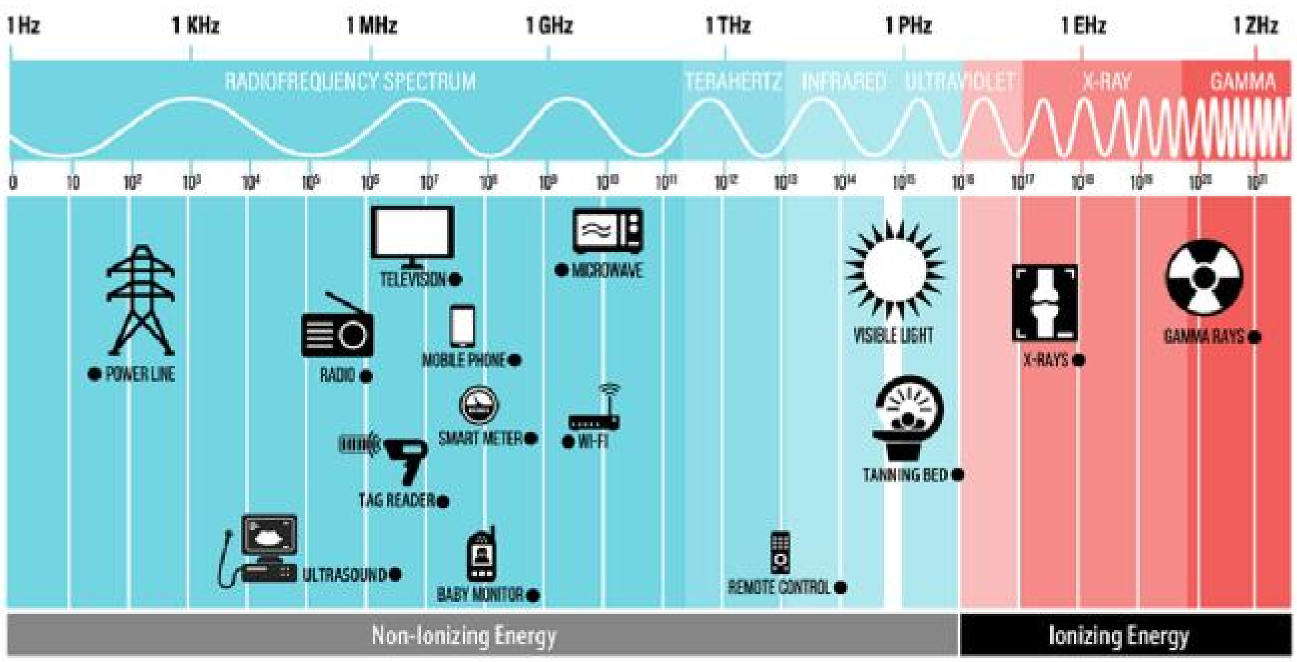
Tissue heating is the main mechanism of interaction between radiofrequency fields and the human body. Radiofrequency exposure levels from current technologies result in negligible temperature rise in the human body.

As the frequency increases, there is less penetration into the body tissues and absorption of the energy becomes more confined to the surface of the body (skin and eye). Provided that the overall exposure remains below international guidelines, no consequences for public health are anticipated.

21. AGENCIES PUBLISHED EXPOSURE LIMITS:

WHO		Radiofrequer	Radiofrequency	Radiofrequency	Radiofrequency	Radiofrequency	Radiofrequency	Radiofrequency
		Electric field (V/m) 900 MHz	Electric field (V/m) 1800 MHz	Power density (W/m^2) 900 MHz	Power density (W/m^2) 1800 MHz	Specific absorption rate (SAR) (W/kg)	Specific absorption rate (SAR) (W/kg)	Specific absorption rate (SAR) (W/kg)
Country	Year					Whole body	Head and trunl	Limbs
Argentina	2017	41.25	58.36	4.5	9	0.08	2	4
Australia	2017	41.1	58.1	4.5	9	0.08	2	4
Austria	2017	41.25	58.34	4.5	9	0.08	2	4
Bahrain	2017	41	58	4.5	9	0.08	2	4
Belgium	2017							
Brazil	2017	41.25	58.34	4.5	9	0.08	2	4
Bulgaria	2017	5.14	6.14	0.1	0.1			
Canada	2017	32.1	40.07	2.74	4.4	0.08	1.6	4
Chile	2017			0.1/1.0	0.1/1.0	1.6/2	1.6/2	1.6/2
Cuba	2017						0.8/1.6	
Cyprus	2017	41	58	4.5	9	[0.08]	[2]	[4]
Finland	2017	41.4	58.55	4.5	9	0.08	2	4
France	2017	41	58	4.5	9	0.08	2	4
Germany	2017	41.25	58	4.5	9	0.08	2	4
Greece	2017	31.9/34.5	45.1/48.8	2.7/3.15	5.4/6.3	0.048/0.056/0.0	1.2/1.4/2.0	2.4/2.8/4.0
Iran (Islamic Republic of)	2017	41.25	58.34	4.5	9			
Israel	2017	[13.0]	[18.0]	[0.45]	[0.9]	[0.08]	[2]	[4]
Italy	2017	20-Jun	20-Jun	0.1/1.0	0.1/1.0	0.08	2	4
Japan	2017	47.55	61.4	6	10	0.08	2	4
Malaysia	2017	41.25	58.34	4.5	9		2	
Netherlands	2017	41.25	58.34	4.5	9	0.08	2	4
New Zealand	2017	41.25	58.34	4.5	9	0.08	2	4
Norway	2017	41.25	58.34	4.5	9	0.08	2	4
Peru	2017	41.25	58.34	4.5	9	0.08	2	4
Philippines	2017	41.25	58.34	4.5	9	0.08	2	4
Republic of Korea	2017	41.25	58.34	4.5	9	0.08	2	4
Russian Federation	2017			1	1			
Saudi Arabia	2017	41.25	58.34	4.5	9	0.08	2	4
South Africa	2017	[41.0]	[58.0]	[4.5]	[9.0]	[0.08]	[2]	[4]
Sweden	2017	[41.25]	[58.33]	[4.5]	[9]	[0.08]	[2]	[4]
Switzerland	2017	4/41.25	6/58.34					
Tunisia	2017	41	58	4.5	9	0.08	2	4
TÃ¼rkiye	2017	3/10.23/41.0	3/14.5/58	0.27	0.55		2	
United Kingdom of Great Britain and Nor	2017	[41.25]	[58.34]	[4.5]	[9.0]	[0.08]	[2]	[4]
United States of America	2017	47.6	61.4	6	10	0.08	1.6	4
Zambia	2017	41	58	4.5	9	0.08	2	4


The Electromagnetic Spectrum
Static Electric & Magnetic Fields
Alternating Electric & Magnetic Fields
TV and Radio Broadcast
(2G 3G 4G 5G)
Radio Frequency
Mobile Networks
Microwave and Satellite
Infrared and visible light
Ultraviolet
X-Rays
Radioactive sources
0 Hz
50 Hz
3 kHz
300 GHz
3000 THz
30 EHz
Non-Ionizing Radiation
Ionizing Radiation


1 Hz
1 KHz
1 MHz
1 GHz
1 THz
1 PHz
1 EHz
1 ZHz
RADIOFREQUENCY SPECTRUM
TERAHERTZ
INFRARED
ULTRAVIOLET
X-RAY
GAMMA
POWER LINE
RADIO
TELEVISION
MOBILE PHONE
SMART METER
TAG READER
ULTRASOUND
BABY MONITOR
MICROWAVE
WI-FI
REMOTE CONTROL
VISIBLE LIGHT
TANNING BED
X-RAYS
GAMMA RAYS
Non-Ionizing Energy
Ionizing Energy

22. HOW TO LIMIT YOUR EXPOSURE:

- Turn OFF your WiFi router at night, (before sleep) (2.4 & 5Ghz bands)

- Replace your Hydro Smart Meter with a non-communicating meter. (X-type)

  They operate at: 902—928 Mhz and 2.4Ghz bands

- Do not use your Cell phone near your head, use wired headphones, or activate Speaker-Phone.

- Limit Cell phone usage, or Turn ON *Airplane* mode when not using.

  Airplane Mode turns OFF the 4 RF radios: GPS, Cell, WiFi, Bluetooth.

- For your next house consider to be away from Cell towers.

  Cell tower contains transmitters that operate on many Frequency bands from 950Mhz , 1.9Ghz (4G-LTE) up to 6Ghz (5G) Freq. bands and soon up to >21Ghz bands with beamforming, and MIMO technology.

- When possible connect your PC with an Ethernet cable to your router, (not via WiFi)

  Many new houses are pre-wired with CAT-6 cables.

Note: Remember the inverse square law of physics. This law essentially states that as we double our distance from a source of EMF radiation, we quarter(1/4) our exposure to it. This concept means that distance gives us exponential protection.

- Check your Cell phone SAR: (FCC level is 1.6 W/Kg)

  Dial *#07# , go down to RF Exposure, click the link to show the SAR of your phone.

  You can verify your Phone SAR here: https://emfacademy.com/sar-value-searchable-chart/

- Above all , stay educated, do your own research !

23. AIRCRAFT RADIO ALTIMETER:

5G Networks (C-band) Could Pose a 'Major Risk' to Airplane Rad-Alt.

In November 2020 a white paper by the RTCA, a private-public aviation partnership that advises the Federal Aviation Administration, warns that 5G technologies in the 3.7 –3.98 Ghz band could pose a "major risk…of harmful interference" to radar altimeter on business jets and other civilian aircraft.

If 5G telecommunications systems are permitted to use that frequency band, said the report, "the risk is widespread and has the potential for broad impacts to aviation operations in the US, including the possibility of catastrophic failures leading to multiple fatalities, in the absence of appropriate mitigations.

Radar altimeters are deployed on thousands of civil and military aircraft in the United States and worldwide and support several critical safety-of-life aircraft functions by providing a direct measurement of the clearance height of the aircraft over the terrain or other obstacles.

A Radio altimeter/radar altimeter — is an Airborne electronic devices capable of measuring the height of the aircraft above the terrain immediately below the aircraft. They operate in the **4.2–4.4 GHz** band.

Radio altimeters provide highly accurate information about an aircraft's height above the ground. Data from these radio altimeters informs other safety equipment on the plane, including navigation instruments, terrain awareness, and collision-avoidance systems.

Used on thousands of civilian aircraft around the world, radar altimeters are the only aircraft sensors that measure the height of the aircraft above the terrain and other obstacles. According to the Flight Safety Foundation, altimeters provide critical information to terrain awareness and warning systems (TAWS), traffic-alert and collision avoidance systems (TCAS), wind shear detection systems, flight control systems and autoland systems. The measurements from radar altimeters are also used by electronic centralized aircraft monitoring (ECAM) systems and engine-indicating and crew alerting systems (EICAS).

FAA Statement: on 5G: C-Band Mobile Telecommunication:
https://www.faa.gov/newsroom/faa-statements-5g

The FAA is working to ensure that radio signals from newly activated wireless telecommunications systems can coexist safely with flight operations in the United States, with input from the aviation sector and telecommunications industry.

Restrictions by FAA:
FAA imposes restrictions on flight operations using certain types of radio altimeter equipment close to antennas in 5G networks.

RTCA White paper:
https://www.rtca.org/wp-content/uploads/2020/10/SC-239-5G-Interference-Assessment-Report_274-20-PMC-2073_accepted_changes.pdf

24. HOW TO MEASURE EMF:

Most EMF meters are limited to measurements up to 5 and 8Ghz. With the 5G much larger frequency spectrum we need to consider bands up to the 30Ghz region.

Meter manuals provide guidance in ref. to the FCC limit, but use your own judgement to determine YOUR SAFE level !

- The LATNEX AF- 5000 5G EMF Meter is a device that can measure electromagnetic field (3-axis), electric field, and RF strength. The AF-5000 measures high-frequency electromagnetic fields (RF) in a frequency range of 50MHz - 10GHz and low frequency electric and magnetic fields (EMF) at 50-60Hz.

- The FM5 5G meter will measure radiofrequency radiation, or RF waves, in a specific area.

  Much of the mobile networks offered in America at the moment as 5G are in fact better described as 4.5G, and will be detectable on standard EMF meters that can measure RF signals up to 10GHz. However, future 5G signals will be between the frequency range above 24GHz and 32Ghz and will require a specialist 5G meter to detect.

  While the health risks of 5G networks are yet to be determined, non-ionising EMF radiation has been linked to numerous adverse health effects over the years, such as insomnia and migraines, alongside more serious issues. Once true 5G has rolled out the only method to detect it will be with a monitor that specifically covers the higher frequencies.

  See video: https://www.youtube.com/watch?v=IaBmiBb6E0w

LATNEX-AF-5000

FM5

25. LOCATING CELL TOWERS:

Locating Cell towers is now common and can be done using an on-line Cell Mapper.

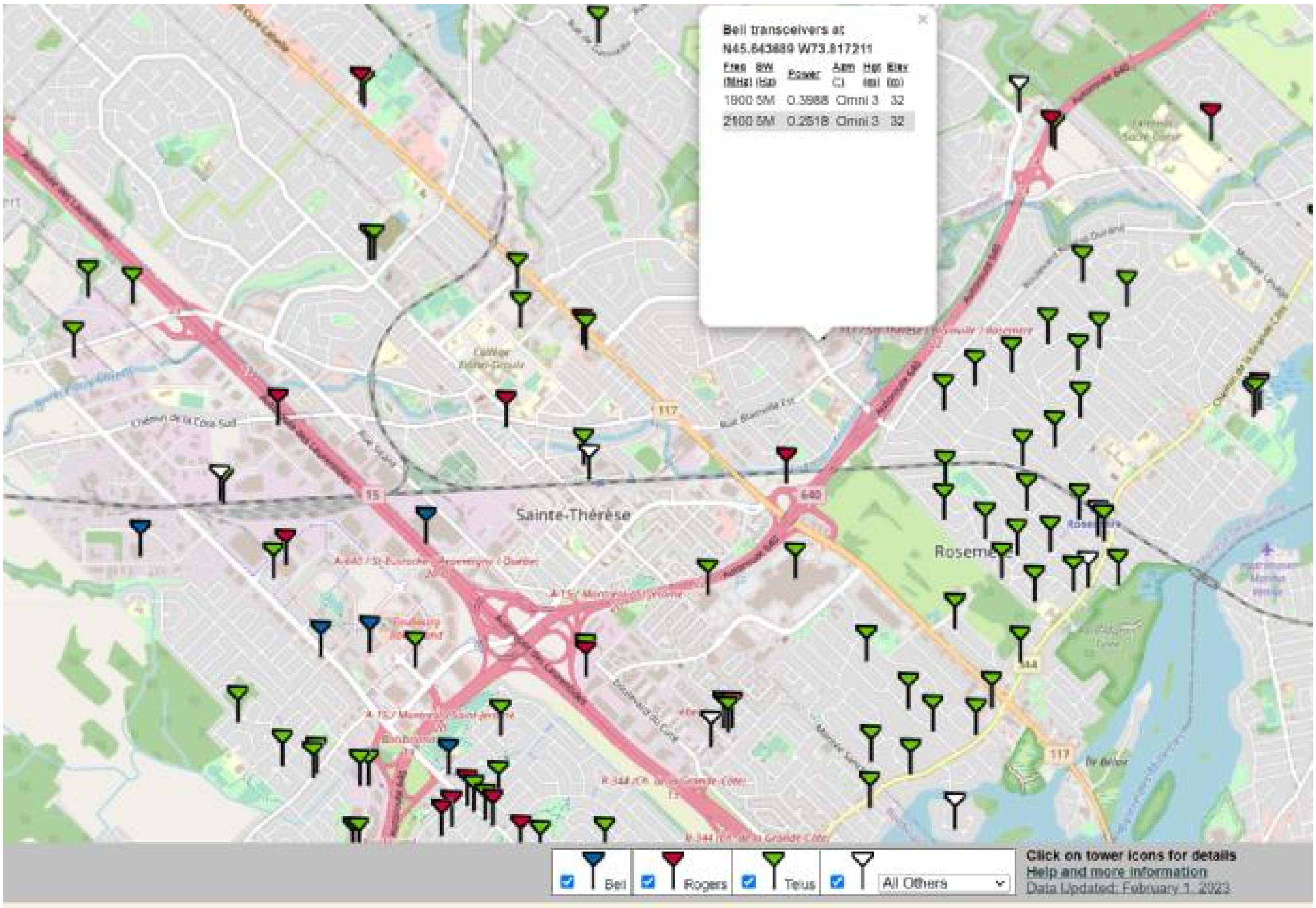
Most will provide Cell info, location, and the service provider.

The cellular map **allows users to quickly view all Cell Tower locations across America**. Zooming into the map will reveal an icon identifying the tower's provider. Clicking on the map will reveal the tower's location as well as all the radio information associated with the tower.

Typical Cell mapper:

https://www.scadacore.com/tools/rf-path/cell-tower-map-canada/

https://www.ertyu.org/steven_nikkel/cancellsites.html



26. CONCLUSION:

5G, the next evolution in communications, smarter, faster, larger bandwidth, more coverage, low latency, with Internet of Things, automation, AI, smart cities, real time gaming, Autonomous vehicles, remote monitoring and many more applications.

5G deployment is ongoing, the effect of 5G networks on population exposures to RF signals has **not been as thoroughly researched** as have RF exposures at lower frequencies. Most technical journalist will snap you being in conspiracy theories ! without any solid arguments.

This is where you need to educate yourself and make your own assessment. Right here I am providing the references and the technical background, now do your homework.

Many scientists do have a concern, are they all on the wrong track ?

https://ehtrust.org/wp-content/uploads/Scientist-5G-appeal-2017.pdf

Agencies are declaring that in all cases, exposure levels will remain well below major international exposure limits and that network operators will be aware of their obligation to maintain their systems within compliant operating parameters. When exposure levels are maintained below current exposure limits, neither health agencies nor guideline/standards setting organizations have identified hazards from exposure to millimeter waves or RF signals in lower frequency bands used in previous generation technologies.

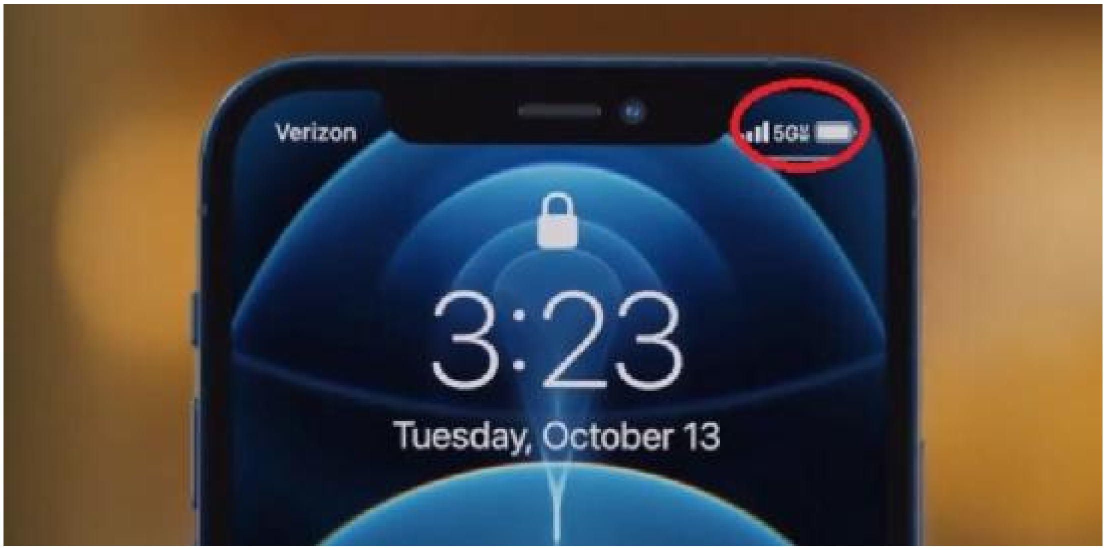
Given the limited bio-effects literature on millimeter wave exposure, however, IEEE COMAR **recommends more high-quality research on MMW**, together with ongoing surveillance by health agencies of relevant scientific developments.

From the reports shown by Paul Heroux Phd-EMF, Pierre Dubochet Ing. Radio toxicologist (and others) the question remain, are those limits adequate to represent real scenarios and long term effect of MMW ? are those limits valid for children's ?

The WHO statement is very vague and does confirm the lack of serious studies and they limit the concerns to body tissue heating effect when we know this can produce damage at the cellular level and possibly others.

5G Connectivity is here to stay, but above all the next step is yours,

Be safe, Be healthy !



Verizon
5G
3:23
Tuesday, October 13

27. DISCLAIMER:

The content Is for educational purpose only, it is not intended to provide design practice, system solution, marketing of any form, diagnosis or medical advice. The Resources provided are references only. Any claims in this article have not been evaluated by the FCC and are provided as-is for information only. The reader shall perform his own research regarding the correct usage of any wireless equipment and possible EMF health effect.

28. RESOURCES:

EMF ACADEMY

- https://emfacademy.com/5g-radiation/#need

Science Direct:

https://www.sciencedirect.com/science/article/pii/S016041201830196X

ENVIRONMENTAL HEALTH TRUST

- https://ehtrust.org/about/

IEEE SPECTRUM

- https://spectrum.ieee.org/everything-you-need-to-know-about-5g

SAR SEARCH

- https://emfacademy.com/sar-value-searchable-chart/

- PHYSICIANS FOR SAFE TECHNOLOGY:

  https://mdsafetech.org/conversion-and-exposure-limits-emr-emf/

- RTCA- 5G and RAD-ALT

  https://www.rtca.org/news/potential-5g-interference-to-radar-altimeters-frequently-asked-questions/

- FAA 5G and Aviation safety:

  https://www.faa.gov/5g

- The General Frequency Bands: © CopyRight Pierre Dubochet:

  https://www.pierredubochet.ch/tableau-de-plages-de-frequences.html?fbclid=IwAR2iwBOVxXgKblvx4FvS6ZH4qesbB0JK6sAzfQGyc1Br92J6_XOpyitXyG8

- RF TOXICOLOGY with Pierre Dubochet :

  https://www.pierredubochet.ch/home.html

29. EMF CONVERSION CHART:

PHYSICIANS FOR SAFE TECHNOLOGY

www.MDSafeTech.org

Conversion Chart EMR = EMF

Power equivalents--- 1 µW/cm2 = 10,000 µW/m2 = 0.01 W/m2

*** Low concern- Building Biologists benchmark**
**** BioinInitiative- No observable effect on humans**
***** Extreme concern for long term exposure- Building Biologists benchmark**
$\mu W/m^2$ = Yellow highlights are Current limits in U.S.

Watts/ Square Meter (W/m^2)	microWatts/Square Meter ($\mu W/m^2$)	microWatts/Square Centimeter ($\mu W/cm^2$)
0.000,000,000,000,1 W/m^2	0.000,000,1 $\mu W/m^2$	0.000,000,000,01 $\mu W/cm^2$
0.000,000,000,001 W/m^2	0.000,001 $\mu W/m^2$	0.000,000,000,1 $\mu W/cm^2$
0.000,000,000,01 W/m^2	0.000,01 $\mu W/m^2$	0.000,000,001 $\mu W/cm^2$
0.000,000,000,1 W/m^2	0.000,1 $\mu W/m^2$	0.000,000,01 $\mu W/cm^2$
0.000,000,001 W/m^2	0.001 $\mu W/m^2$	0.000,000,1 $\mu W/cm^2$
0.000,000,01 W/m^2	0.01 $\mu W/m^2$	0.000,001 $\mu W/cm^2$
0.000,000,1 W/m^2 *	0.1 $\mu W/m^2$ *	0.000,01 $\mu W/cm^2$ *
0.000,001 W/m^2 **	1 $\mu W/m^2$ **	0.000,1 $\mu W/cm^2$ **
0.000,01 W/m^2	10 $\mu W/m^2$	0.001 $\mu W/cm^2$
0.000,1 W/m^2	100 $\mu W/m^2$	0.01 $\mu W/cm^2$
0.001 W/m^2 ***	1,000 $\mu W/m^2$ ***	0.1 $\mu W/cm^2$ ***
0.01 W/m^2	10,000 $\mu W/m^2$	1 $\mu W/cm^2$
0.1 W/m^2	100,000 $\mu W/m^2$	10 $\mu W/cm^2$
1 W/m^2	1,000,000 $\mu W/m^2$	100 $\mu W/cm^2$
10 W/m^2	10,000,000 $\mu W/m^2$	1,000 $\mu W/cm^2$
100 W/m^2	100,000,000 $\mu W/m^2$	10,000 $\mu W/cm^2$
1000 W/m^2	1,000,000,000 $\mu W/m^2$	100,000 $\mu W/cm^2$

Wireless Exposure Limits in Different Countries

From 300Mhz-300GHz in microwatts/cm2

Guidelines in U.S. are from 200 uW/cm^2 to 1000 uW/cm^2 (2 W/m^2 to 10 W/m2) for RF radiation depending on frequency.

US.	**200 microwatts/cm^2 - 1,000 microwatts/cm^2 – depending on frequency**
Canada	**1,000 microwatts/cm^2**
China	10 microwatts/cm^2
Russia	10 microwatts/cm^2
Italy	10 microwatts/cm^2
France	10 microwatts/cm^2
Poland	10 microwatts/cm^2
Hungary	10 microwatts/cm^2
Switzerland General	9.5 microwatts/cm^2
Switzerland- Schools and Hospitals	4.25 microwatts/cm^2
Belgium	2.4 microwatts/cm^2
Bulgaria	2.4 microwatts/cm^2
Luxembourg	2.4 microwatts/cm^2
Ukraine	2.4 microwatts/cm^2
Lichtenstein	0.1 microwatts/cm^2
Austria Outdoor	0.001 microwatts/cm^2
Austria Indoor	0.0001 microwatts/cm^2
Cosmic Background we evolved from	**<0.00000000001**

BioInitiative Report recommendation - 'No Observable Effect' with factor of 10 added for safety = 0.0003 microwatts/cm2. http://www.bioinitiative.org/conclusions/

High-frequency electromagnetic radiation (as power flow density)

0.1 μW/cm^2 (≥1000 μW/m2) (≥1 mW/m2)—**Very far above normal**
0.001 μW/cm^2 to **0.1 μW/cm^2** (10-1000 μW/m2) (0.01-1 mW/m2)- **Far above normal**

0.000,1 μW/cm^2 to **0.001 μW/cm^2** (1-10 μW/m2) (0.001-0.01 mW/m2)- **Slightly above normal**

Less than 0.000,1 μW/cm^2 (≤1 μW/m2) (≤0.001 mW/m2) – **Within normal limits**

"The benchmarks listed are intended to be applied to individual types of radiation, e.g. GSM, UMTS, WiMAX, TETRA, radio, TV, DECT or WLAN, and refer to peak levels. The benchmarks do not apply to radar, which must be evaluated separately. Highly critical types of radiation, such as periodic signals (mobile telephony, DECT, WLAN, digital broadcasting...), should be critically evaluated, especially if levels are far above normal, while less critical types, such as non-pulsed or non-periodic signals (USW, shortwave, medium and long wave, analogue broadcasting), may be considered more leniently." AMA

Low-frequency alternating electric fields

≥10 V/m Very far above normal

1.5-10 V/m -Far above normal

0.3-1.5 V/m- Slightly above normal

≤0.3 V/m – Within normal limits

The benchmarks (potential-free measurement) are intended to be applied to the range up to and around 50 Hz; higher frequencies and distinct harmonics should be more critically evaluated.

Exposure Limits for Radio Frequency Energy: Three Models

Ken Foster, University of Pennsylvania, Philadelphia

This **article** points out that different long term exposure limits in different countries is due to different models of reasoning.

30. THE 5G SPECTRUM

5G Frequency bands and channel bandwidths

FR1 FREQ RANGE-1

Band	Duplex mode	f (MHz)	Common name	Subset of band	Uplink (MHz)	Downlink (MHz)	Duplex spacing (MHz)	Channel bandwidths (MHz)
n1	FDD	2100	IMT	n65	1920 – 1980	2110 – 2170	190	5, 10, 15, 20
n2	FDD	1900	PCS	n25	1850 – 1910	1930 – 1990	80	5, 10, 15, 20
n3	FDD	1800	DCS		1710 – 1785	1805 – 1880	95	5, 10, 15, 20, 25, 30
n5	FDD	850	CLR		824 – 849	869 – 894	45	5, 10, 15, 20
n7	FDD	2600	IMT-E		2500 – 2570	2620 – 2690	120	5, 10, 15, 20, 25, 30, 40, 50
n8	FDD	900	Extended GSM		880 – 915	925 – 960	45	5, 10, 15, 20
n12	FDD	700	Lower SMH		699 – 716	729 – 746	30	5, 10, 15
n14	FDD	700	Upper SMH		788 – 798	758 – 768	−30	5, 10
n18	FDD	850	Lower 800 (Japan)		815 – 830	860 – 875	45	5, 10, 15
n20	FDD	800	Digital Dividend (EU)		832 – 862	791 – 821	−41	5, 10, 15, 20
n25	FDD	1900	Extended PCS		1850 – 1915	1930 – 1995	80	5, 10, 15, 20
n28	FDD	700	APT		703 – 748	758 – 803	55	5, 10, 15, 20
n29	SDL	700	Lower SMH		N/A	717 – 728	N/A	5, 10
n30	FDD	2300	WCS		2305 – 2315	2350 – 2360	45	5, 10

FR1 FREQ RANGE-1

Band	Duplex mode	f (MHz)	Common name	Subset of band	Uplink (MHz)	Downlink (MHz)	Duplex spacing (MHz)	Channel bandwidths (MHz)
n34	TDD	2100	IMT		2010 – 2025	N/A	5, 10, 15	
n38	TDD	2600	IMT-E		2570 – 2620	N/A	5, 10, 15, 20	
n39	TDD	1900	DCS–IMT Gap		1880 – 1920	N/A	5, 10, 15, 20, 25, 30, 40	
n40	TDD	2300	S-Band		2300 – 2400	N/A	5, 10, 15, 20, 25, 30, 40, 50, 60, 80	
n41	TDD	2500	BRS	n90	2496 – 2690	N/A	10, 15, 20, 30, 40, 50, 60, 80, 90, 100	
n48	TDD	3500	CBRS (US)		3550 – 3700	N/A	5, 10, 15, 20, 40, 50, 60, 80, 90, 100	
n50	TDD	1500	L-Band		1432 – 1517	N/A	5, 10, 15, 20, 30, 40, 50, 60, 80	
n51	TDD	1500	L-Band Extension		1427 – 1432	N/A	5	
n65	FDD	2100	Extended IMT		1920 – 2010	2110 – 2200	190	5, 10, 15, 20
n66	FDD	1700	Extended AWS		1710 – 1780	2110 – 2200[6]	400	5, 10, 15, 20, 40
n70	FDD	2000	AWS-4		1695 – 1710	1995 – 2020	300	5, 10, 15, 20, 25
n71	FDD	600	Digital Dividend (US)		663 – 698	617 – 652	−46	5, 10, 15, 20
n74	FDD	1500	Lower L-Band (Japan)		1427 – 1470	1475 – 1518	48	5, 10, 15, 20
n75	SDL	1500	L-Band		N/A	1432 – 1517	N/A	5, 10, 15, 20
n76	SDL	1500	Extended L-Band		N/A	1427 – 1432	N/A	5

FR1 FREQ RANGE-1

Band	Duplex mode	f (MHz)	Common name	Subset of band	Uplink (MHz)	Downlink (MHz)	Duplex spacing (MHz)	Channel bandwidths (MHz)
n77	TDD	3700	C-Band		3300 – 4200	N/A	10, 15, 20, 40, 50, 60, 80, 90, 100	
n78	TDD	3500	C-Band	n77	3300 – 3800	N/A	10, 15, 20, 40, 50, 60, 80, 90, 100	
n79	TDD	4700	C-Band		4400 – 5000	N/A	40, 50, 60, 80, 100	
n80	SUL	1800	DCS		1710 – 1785	N/A	N/A	5, 10, 15, 20, 25, 30
n81	SUL	900	Extended GSM		880 – 915	N/A	N/A	5, 10, 15, 20
n82	SUL	800	Digital Dividend (EU)		832 – 862	N/A	N/A	5, 10, 15, 20
n83	SUL	700	APT		703 – 748	N/A	N/A	5, 10, 15, 20
n84	SUL	2100	IMT		1920 – 1980	N/A	N/A	5, 10, 15, 20
n86	SUL	1700	Extended AWS		1710 – 1780	N/A	N/A	5, 10, 15, 20, 40
n89	SUL	850	CLR		824 – 849	N/A	N/A	5, 10, 15, 20
n90	TDD	2500	BRS		2496 – 2690	N/A	10, 15, 20, 30, 40, 50, 60, 80, 90, 100	
Band	Duplex mode	f (MHz)	Common name	Subset of band	Uplink (MHz)	Downlink (MHz)	Duplex spacing (MHz)	Channel ba

FR2 FREQ RANGE-2

Band	f (GHz)	Common name	Subset of band	Uplink / Downlink (GHz)	Channel bandwidths (MHz)
n257	28	LMDS		26.50 – 29.50	50, 100, 200, 400
n258	26	K-band		24.25 – 27.50	50, 100, 200, 400
n260	39	Ka-band		37.00 – 40.00	50, 100, 200, 400
n261	28	Ka-band	n257	27.50 – 28.35	50, 100, 200, 400
Band	f (GHz)	Common name	Subset of band	Uplink / Downlink (GHz)	Channel bandwidths (MHz)

High 5G Frequency Bands

These bands are usually available and can be quickly cleared for 5G use.

Geographical Area	5G Frequency Band
Europe	3400 – 3800 MHz (awarding trial licenses)
China	3300 – 3600 MHz (ongoing trial)
China	4400 – 4500 MHz
China	4800 – 4990 MHz
Japan	3600 – 4200 MHz
Japan	4400 – 4900 MHz
Korea	3400 – 3700 MHz
USA	3100 – 3550 MHz
USA	3700 – 4200 MHz

Very High 5G Frequency Bands (MMW)

These bands will allow the deployment of hotspots providing very high throughput thanks to the large bandwidth available for operators:

Geographical Area	5G Frequency Band
Europe	24.25 – 27.5 GHz for commercial deployments from 2020
China	Focusing on 24.25 – 27.5 GHz and 37 – 43.5 GHz studies
Japan	27.5 – 28.28 GHz trials planned from 2017 and potentially commercial deployments in 2020
Korea	26.5 – 29.5 GHz trials in 2018 and commercial deployments in 2019
USA	27.5 – 28.35 GHz and 37 – 40 GHz pre-commercial deployments in 2018

Ref:

https://www.cablefree.net/wirelesstechnology/4glte/5g-frequency-bands-lte/

31. THE 4G SPECTRUM

LTE FREQ BANDS

Band	Name	Mode	Downlink (MHz)			Bandwidth DL/UL (MHz)	Uplink (MHz)			Duplex spacing (MHz)	Geographical area	3GPP release	Channel bandwidth (MHz)					
			Low Earfcn	Middle	High		Low Earfcn	Middle	High				1.4	3	5	10	15	20
1	2100	FDD	2110 0	2140 300	2170 599	60	1920 18000	1950 18300	1980 18599	190	Global	8			5	10	15	20
2	1900 PCS	FDD	1930 600	1960 900	1990 1199	60	1850 18600	1880 18900	1910 19199	80	NAR	8	1.4	3	5	10	15	20
3	1800+	FDD	1805 1200	1842.5 1575	1880 1949	75	1710 19200	1747.5 19575	1785 19949	95	Global	8	1.4	3	5	10	15	20
4	AWS-1	FDD	2110 1950	2132.5 2175	2155 2399	45	1710 19950	1732.5 20175	1755 20399	400	NAR	8	1.4	3	5	10	15	20
5	850	FDD	869 2400	881.5 2525	894 [illegible]	25	824 20400	836.5 20525	849 20649	45	NAR	8	1.4	3	5	10		
7	2600	FDD	2620 2750	2655 3100	2690 [illegible]	70	2500 20750	2535 21100	2570 21449	120	EMEA	8			5	10	15	20
8	900 GSM	FDD	925 3450	942.5 3625	960 3799	35	880 21450	897.5 21625	915 21799	45	Global	8	1.4	3	5	10		
9	1800	FDD	1844.9 3800	1862.5 [illegible]	1879.9 [illegible]	35	1749.9 21800	1767.5 [illegible]	1784.9 22149	95	APAC	8			5	10	15	20
10	AWS-3	FDD	2110 4150	2140 4450	2170 4749	60	1710 22150	1740 22450	1770 22749	400	NAR	8			5	10	15	20
11	1500 Lower	FDD	1475.9 4750	1486 4850	1495.9 4949	20	1427.9 22750	1438 22850	1447.9 22949	48	Japan	8			5	10		
12	700 a	FDD	729 5010	737.5 [illegible]	746 [illegible]	17	699 23010	707.5 23095	716 23179	30	NAR	8.4	1.4	3	5	10		
13	700 c	FDD	746 5180	751 5230	756 5279	10	777 23180	782 23230	787 23279	-31	NAR	8			5	10		
14	700 PS	FDD	758 5280	763 5330	768 5379	10	788 23280	793 23330	798 23379	-30	NAR	8			5	10		
17	700 b	FDD	734 5730	740 5790	746 5849	12	704 23730	710 23790	716 23849	30	NAR	8.3			5	10		
18	800 Lower	FDD	860 5850	867.5 5925	875 5999	15	815 23850	822.5 23925	830 23999	45	Japan	9			5	10	15	
19	800 Upper	FDD	875 6000	882.5 6075	890 6149	15	830 24000	837.5 24075	845 24149	45	Japan	9			5	10	15	
20	800 DD	FDD	791 6150	806 6300	821 6449	30	832 24150	847 24300	862 24449	-41	EMEA	9			5	10	15	20

Band	Name	Mode	Downlink (MHz) Low	Middle	High	Bandwidth DL/UL (MHz)	Uplink (MHz) Low	Middle	High	Duplex spacing (MHz)	Geographical area	3GPP release	Channel bandwidth (MHz) 1.4	3	5	10	15	20
			Earfcn				Earfcn											
21	1500 Upper	FDD	1495.9 6450	1503.5 6525	1510.9 6599	15	1447.9 24450	1455.5 24525	1462.9 24599	48	Japan	9			5	10	15	
22	3500	FDD	3510 6600	3550 7000	3590 7399	80	3410 24600	3450 25000	3490 25399	100	EMEA	10.4			5	10	15	20
24	1600 L-band	FDD	1525 7700	1542 7870	1559 8039	34	1626.5 25700	1643.5 25870	1660.5 26039	-101.5	NAR	10.1			5	10		
25	1900+	FDD	1930 8040	1962.5 8365	1995 8689	65	1850 26040	1882.5 26365	1915 26689	80	NAR	10	1.4	3	5	10	15	20
26	850+	FDD	859 8690	876.5 8865	894 9039	35	814 26690	831.5 26865	849 27039	45	NAR	11	1.4	3	5	10	15	
27	800 SMR	FDD	852 9040	860.5 9125	869 9209	17	807 27040	815.5 27125	824 27209	45	NAR	11.1	1.4	3	5	10		
28	700 APT	FDD	758 9210	780.5 9435	803 9659	45	703 27210	725.5 27435	748 27659	55	APAC,EU	11.1		3	5	10	15	20
29	700 d	SDL	717 9660	722.5 9715	728 9769	11	Downlink only				NAR	11.3		3	5	10		
30	2300 WCS	FDD	2350 9770	2355 9820	2360 9869	10	2305 27660	2310 27710	2315 27759	45	NAR	12			5	10		
31	450	FDD	462.5 9870	465 9895	467.5 9919	5	452.5 27760	455 27785	457.5 27809	10	Global	12	1.4	3	5			
32	1500 L band	SDL	1452 9920	1474 10140	1496 10359	44	Downlink only				EMEA	12.4			5	10	15	20
33	TD 1900	TDD	1900 36000	1910 36100	1920 36199	20					EMEA	8			5	10	15	20
34	TD 2000	TDD	2010 36200	2017.5 36275	2025 36349	15					EMEA	8			5	10	15	
35	TD PCS Lower	TDD	1850 36350	1880 36650	1910 36949	60					NAR	8	1.4	3	5	10	15	20
36	TD PCS Upper	TDD	1930 36950	1960 37250	1990 37549	60					NAR	8	1.4	3	5	10	15	20
37	TD PCS Center gap	TDD	1910 37550	1920 37650	1930 37749	20					NAR	8			5	10	15	20
38	TD 2600	TDD	2570 37750	2595 38000	2620 38249	50					EMEA	8			5	10	15	20
39	TD 1900+	TDD	1880 38250	1900 38450	1920 38649	40					China	8			5	10	15	20
40	TD 2300	TDD	2300 38650	2350 39150	2400 39649	100					China	8			5	10	15	20
41	TD 2600+	TDD	2496 39650	2593 40620	2690 41589	194					Global	10			5	10	15	20
42	TD 3500	TDD	3400 41590	3500 42590	3600 43589	200						10			5	10	15	20

Band	Name	Mode	Downlink (MHz) Low Earfcn	Middle	High	Bandwidth DL/UL (MHz)	Uplink (MHz) Low Earfcn	Middle	High	Duplex spacing (MHz)	Geographical area	3GPP release	Channel bandwidth (MHz) 1.4	3	5	10	15	20
43	TD 3700	TDD	3600 43590	3700 44590	3800 45589	200						10			5	10	15	20
44	TD 700	TDD	703 45590	753 46090	803 46589	100					APAC	11.1		3	5	10	15	20
45	TD 1500	TDD	1447 46590	1457 46690	1467 46789	20					China	13.2			5	10	15	20
46	TD Unlicensed	TDD	5150 46790	5537.5 50665	5925 54539	775					Global	13.2				10		20
47	TD V2X	TDD	5855 54540	5890 54890	5925 55239	70					Global	14.1				10		20
48	TD 3600	TDD	3550 [illegible]	3625 [illegible]	3700 [illegible]	150					Global	14.2			5	10	15	20
49	TD 3600r	TDD	3550 56740	3625 57490	3700 58239	150					Global	15.1				10		20
50	TD 1500+	TDD	1432 [illegible]	1474.5 [illegible]	1517 [illegible]	85					EU	15		3	5	10	15	20
51	TD 1500	TDD	1427 [illegible]	1429.5 [illegible]	1432 [illegible]	5					EU	15		3	5			
52	TD 3300	TDD	3300 [illegible]	3350 [illegible]	3400 [illegible]	100						15.2			5	10	15	20
53	TD 2500	TDD	2483.5 [illegible]	2489.5 [illegible]	2495 [illegible]	11.5						16	1.4	3	5	10		
65	2100+	FDD	2110 [illegible]	2155 [illegible]	2200 [illegible]	90	1920 [illegible]	1965 [illegible]	2010 [illegible]	190	Global	13.2	1.4	3	5	10	15	20
66	AWS	FDD	2110 66436	2155 66886	2200 67335	90 / 70	1710 131972	1745 132322	1780 132671	400	NAR	13.2	1.4	3	5	10	15	20
67	700 EU	SDL	738 [illegible]	748 [illegible]	758 [illegible]	20	Downlink only				EMEA	13.2			5	10	15	20
68	700 ME	FDD	753 67536	768 67686	783 67835	30	698 132672	713 132822	728 132971	55	EMEA	13.3			5	10	15	
69	DL B38	SDL	2570 [illegible]	2595 [illegible]	2620 [illegible]	50	Downlink only					14			5	10	15	20
70	AWS 4	FDD	1995 [illegible]	2007.5 [illegible]	2020 [illegible]	25 / 15	1695 [illegible]	1702.5 [illegible]	1710 [illegible]	300	NAR	14			5	10	15	20
71	600	FDD	617 68586	634.5 68761	652 68935	35	663 133122	680.5 133297	698 133471	-46	NAR	15			5	10	15	20
72	450 PMR/PAMR	FDD	461 [illegible]	463.5 [illegible]	466 [illegible]	5	451 [illegible]	453.5 [illegible]	456 [illegible]	10	EMEA	15	1.4	3	5			
73	450 APAC	FDD	460 [illegible]	462.5 [illegible]	465 [illegible]	5	450 [illegible]	452.5 [illegible]	455 [illegible]	10	APAC	15	1.4	3	5			
74	L-band	FDD	1475 69036	1496.5 69251	1518 69465	43	1427 133372	1448.5 133787	1470 134001	48	NAR	15	1.4	3	5	10	15	20

Band	Name	Mode	Downlink (MHz) Low Earfcn	Middle	High	Bandwidth DL/UL (MHz)	Uplink (MHz) Low Earfcn	Middle	High	Duplex spacing (MHz)	Geographical area	3GPP release	Channel bandwidth (MHz) 1.4	3	5	10	15	20
75	DL B50	SDL	1432 69466	1474.5 69891	1517 70315	85	Downlink only				EU	15			5	10	15	20
76	DL B51	SDL	1427 70316	1429.5 70341	1432 70365	5	Downlink only				EU	15			5	10	15	20
85	700 a+	FDD	728 70366	737 70456	746 70545	18	698 134002	707 134092	716 134181	30	NAR	15.2			5	10		
87	410	FDD	420 70546	422.5 70571	425 70595	5	410 134182	412.5 134207	415 134231	10	EMEA	16.2	1.4	3	5			
88	410+	FDD	422 70596	424.5 70621	427 70645	5	412 134232	414.5 134257	417 134281	10	EMEA	16.2	1.4	3	5			

32. THE GENERAL RF SPECTRUM: © CopyRight Pierre Dubochet

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Nom de la bande	Fréquences	Longueurs d'onde	Usage
TLF	0 Hz à 3 Hz	100 000 km à ∞	Champ magnétique terrestre, ondes et bruits électromagnétiques naturels, ondes delta du cerveau (de 0,5 à 4 Hz, celles du sommeil profond, sans rêve).
ELF	3 Hz à 30 Hz	10 000 km à 100 000 km	Ondes électromagnétiques naturelles, résonance terrestre de Schumann (7,8 Hz), onde du cerveau humain (ondes thêta de 4 à 7 Hz en relaxation profonde, ondes alpha de 8 à 13 Hz en éveil calme, ondes bêta de 14 à 30 Hz en activités courantes), ondes physiologiques humaines sur les ions calcium cellulaires (9–17 Hz), recherches en géophysique, raies spectrales moléculaires.
SLF	30 Hz à 300 Hz	1 000 km à 10 000 km	Ondes électromagnétiques naturelles (provenant p. ex. des éclairs), ondes du cerveau humain (ondes gamma au-dessus de 30 Hz durant une forte activité cérébrale), ondes physiologiques humaines, ondes des lignes électriques, usages inductifs industriels, harmoniques des ondes électriques.
ULF	300 Hz à 3 kHz	100 km à 1 000 km	Ondes électromagnétiques naturelles notamment des orages solaires, ondes physiologiques humaines, ondes électriques des réseaux téléphoniques, harmoniques ondes électriques, signalisation des trains. 697-1633 Hz: DTMF (Dual Tone Multi Frequency), pour la téléphonie. jusqu'à 8,3 kHz: applications inductives.
VLF	3 kHz à 30 kHz	10 km à 100 km	9 kHz–59,750 kHz: applications inductives. 9 kHz–315 kHz: implants médicaux. 9–14 kHz: télégraphie maritime côtière, radionavigation. 20 kHz: signaux horaires. Ondes électromagnétiques naturelles, radiocommunications submaritimes militaires, transmissions par CPL (courant porteur en ligne à bas débit, de 9 à 150 kHz), systèmes de radionavigation.
LF	30 kHz à 300 kHz	1 km à 10 km	9 kHz–59,750 kHz: applications inductives. 9 kHz–315 kHz: implants médicaux. 9 à 150 kHz: transmissions par CPL (courant porteur en ligne à bas débit). 70-135,7 kHz: radionavigation. 135,7–137,8 kHz: radio amateur, transmissions continentales et intercontinentales. Ondes électromagnétiques naturelles des orages terrestres, radiocommunications maritimes et submaritimes, , radiodiffusion en ondes longues (OL), émetteurs de signaux horaires, systèmes de radionavigation GPS.

MF	300 kHz à 3 MHz	100 m à 1 km	400–600 kHz: applications inductives (RFID et EAS) 442,2–450 kHz: équipements de détection de personnes et équipements anticollision 456,9–457,1 kHz: équipements de recherche en cas d'urgence 516–8516 kHz: applications ferroviaires (Euroloop) 984–7484 kHz: applications ferroviaires (Eurobalise) 7'300–23'000 kHz: applications ferroviaires (Euroloop) 1,6 à 30 MHz: transmissions par CPL (courant porteur en ligne à haut débit. Systèmes de radionavigation, radiodiffusion en ondes moyennes (OM), radiocommunications maritimes et aéronautiques, radioamateurs, signaux horaires et ADSL (transmission numérique sur une ligne téléphonique conventionnelle).
HF	3-30 MHz	10-100 m	0,516–8,516 MHz: applications ferroviaires (Euroloop). 0,984–7,484 MHz: applications ferroviaires (Eurobalise). 1,6 à 30 MHz: transmissions par CPL (courant porteur en ligne à haut débit. 6,78 MHz (±15,0 kHz): chargeurs à induction pour les appareils sans fil. 10,36875–10,3688 MHz: balises locales. 13,553–13,567 MHz: applications inductives (RFID et EAS). 13,56 MHz: paiement mobile par NFC. 14,3 MHz: communications d'urgences mondiales. 18,16 MHz: communications d'urgences mondiales. 7,3–23 MHz: applications ferroviaires (Euroloop). 24,89–24,94 MHz: radiotélégraphie amateur. 24,94–24,99 MHz: radiotéléphonie amateur. 26,55–26,91 MHz: recherche de personnes sur site. 26,96–27,41 MHz: radiocommunication «CB». 26,96–27,2 MHz: télécommandes de modèles réduits. 26,99–27,76 MHz: télécommandes, télémétrie et transmission de données. 27,09–27,1 MHz: applications ferroviaires (Eurobalise). 27,42–27,91 MHz: équipement radio à usage professionnel (PMR). 27,45–27,46 MHz: équipement radio pour les services de sauvetage (PMR). 27,8–27,89 MHz: équipement radio pour les services de police (PMR). 27,81–27,88 MHz: applications audio sans fil (surveillance de bébés). 27,84–27,93 MHz: équipement radio pour les services du feu (PMR). Radiodiffusion internationale, radioamateurs, radiocommunications maritimes, aéronautiques, militaires et d'ambassades, applications inductives autorisées, signaux horaires, radars côtiers et radars «au-delà de l'horizon».

VHF	30 à 300 MHz	1 m à 10 m	30–88 MHz: applications militaires au sol à courte distance. 76–95 MHz: radio FM commerciale au Japon. 87,5–108 MHz: radio FM commerciale (arrêt le 31 décembre 2024 en Suisse). 144,037 MHz: communications d'urgence 145,45–145,4750 MHz: communications d'urgence RASEC France (radioamateur au service de la sécurité civile). 156,025–156,275 MHz: communication entre navires d'Europe et le sol. 156,8 MHz: fréquence internationale de détresse maritime. 161,3 MHz: fréquence de détresse en Suisse. 174,928–239,2 MHz: DAB+ (Digital Audio Broadcasting), radio commerciale numérique terrestre, radio numérique terrestre (RNT) en France. Télédiffusion, radiocommunications professionnelles, transmissions militaires, liaisons des secours publics, radionavigation (VOR et ILS), radiocommunications aéronautiques radioamateurs, satellites météo, radioastronomie, recherches spatiales, radars à très longue portée et à pénétration de sol.
UHF	300 -1000 MHz	0,3-1 m	401,600–401,650 MHz: recherche depuis l'espace de radiobalises et radiosondes (y compris suivi animal). 433,075–434,775 MHz: bande de fréquence sans licence dédiée aux télécommandes, télécontrôle, télémesure, transmission d'alarmes, de données pour équipements Low Power Device (LPD, appareil à faible puissance). Des talkies-walkies et des babyphone exploitent aussi cette bande. Portée quelques dizaines de mètres. 433,5 MHz - FM: fréquence d'appel pour radioamateurs. 446,0–446,2 MHz: radio exclusivement mobile professionnelle, sans licence, au chiffrement interdit. Portée jusqu'à 15-20 km en situation dégagée. 446,115625 MHz: canal urgence et entraide. 446,950–446,9875 MHz: anciennes fréquences de radiocommunication professionnelle. 700 MHz: téléphonie mobile 5G 800 MHz: téléphonie mobile 4G 900 MHz: téléphonie mobile, 3G un peu pour la 2G (897,6 MHz) 915 MHz: radars profileurs de vents Télédiffusion, radiodiffusion numérique, radioamateurs, radiocommunications professionnelles, transmissions militaires y compris aéronautiques, liaisons gouvernementales, liaisons satellites, radiolocalisation et radionavigation, usages spatiaux, satellites météo, radars à très longue portée et à pénétration de sol.
L	1-2 GHz	15-30 cm	1'227,6 MHz: GPS 1'400 MHz: téléphonie mobile 5G 1'575,42 MHz: GPS 1'675-1'680 MHz: informations météorologiques en temps réel par transmissions satellite NOAA's. 1'800 MHz: téléphonie mobile, un peu pour la 2G, 4G (1'747 MHz) 1'900 MHz: téléphonie DECT pour l'intérieur 1'950 MHz: 3G Contrôle aérien à longue portée et surveillance aérienne.

S	2-4 GHz	7,5-15 cm	2,1 GHz: téléphonie mobile 3G, parfois uniquement 5G 2,402–2,483 GHz: Bluetooth 2,412–2,472 GHz: Wi-Fi bande basse 2,450 GHz: four à microonde* 2'600 MHz: téléphonie mobile 4G 3,5–3,8 GHz: téléphonie mobile NR 5G Radars de trafic aérien local, radars météorologiques et navals. * Il n'existe pas de «fréquence de résonance de l'eau» qui aurait déterminé la fréquence des fours à microonde. Dans les bandes de fréquences, la règlementation ne laisse que quelques espaces qui peuvent être exploités sans licence, dont un entre 2,4 et 2,5 GHz.
C	4-8 GHz	3,75-7,5 cm	Wi-Fi bande haute: 5,15–5,25 GHz: utilisation à l'intérieur, 200 mW; 5,25–5,35 GHz: utilisation à l'intérieur, 200 mW si régulation de puissance, 100 mW sans régulation, système dynamique de sélection de fréquences obligatoire; 5,47–5,725 GHz: utilisation à l'intérieur + à l'extérieur, 1 W si régulation de puissance, 0,5 W sans régulation, système dynamique de sélection de fréquences obligatoire. 5,875-5,935 GHz: dédié aux systèmes de transports 5,925–6,425 GHz: Wi-Fi à haut débit en Europe grâce aux canaux larges sur 320 MHz introduits par le Wi-Fi 7 (802.11be). Radars météorologiques. Transpondeurs satellitaires.
X	8-12 GHz	2,5-3,75 cm	Radars météorologiques, autodirecteurs de missiles, radars de navigation, radars à résolution moyenne de cartographie, surveillance au sol des aéroports.
Ku	12-18 GHz	1,67-2,5 cm	14–14,5, GHz: Communications spatiales. vers 17 GHz: communications à très haut débit HiperLink. Radars de cartographie à haute résolution et altimétrie satellitaire.
K	18-27 GHz	1,11-1,67 cm	21,1-23,8 GHz: détection des gouttelettes de nuages, radioastronomie. 23,6-24 GHz: écoute par satellite (émission interdite) 24–24,25 GHz: radars, applications industrielles, scientifiques, médicales, domestiques Entre 24,25 et 27,5 GHz: téléphonie mobile 5G en Europe. Potentielle bande pour la téléphonie mobile 5G NR suisse. Entre 24,5 et 43,5 GHz: communications HiperACCESS. Radars routiers portatifs.
	30-300 GHz	1 cm -1 mm	Ondes millimétriques. Les ondes millimétriques subissent un fort affaiblissement en propagation, proportionnel à la fréquence.
Ka	27-40 GHz	0,75-1,11 cm	Entre 24,5 et 43,5 GHz: communications HiperACCESS. 23,4–36 GHz: radars. 34,3 GHz: radars routiers automatisés. Radars de cartographie, de courte portée, surveillance au sol des aéroports, radars anticollision automobile, radars de nébulosité.

			[illegible]
Q	40-60 GHz	5 mm - 7,5 mm	HiperACCESS (communications entre 24,5 et 43,5 GHz). Communications militaires. 37-43,5 GHz: potentielle bande pour la téléphonie mobile 5G NR en Europe. 40,5-43,5 GHz: potentielle bande pour la téléphonie mobile 5G NR suisse. 45,5-47 GHz: potentielle bande pour la téléphonie mobile 5G NR en Europe. 47,2-48,2 GHz: potentielle bande pour la téléphonie mobile 5G NR en Europe.
	50-75 GHz	6,0 - 4 mm	Fréquences peu utilisées car fortement absorbées par les molécules d'oxygène O2 (une goutte de pluie mesure de 0,5 à 5 mm). 57-64 GHz: détecteurs de mouvement de proximité, par exemple radar Soli dans les appareils portables Google. Entre 66 et 71 GHz: potentielle bande de radiocommunication mobile pour l'Europe. Bande pertinentes pour la Suisse. 57–71 GHz: systèmes de transmissions de données à large bande pour installations fixes à l'extérieur des bâtiments. Il pourrait aussi servir à la projection de contenu numérique haute résolution à l'intérieur, en WirelessHD ou WiGig.
W	75-110 GHz	2,7 - 4,0 mm	75-76 GHz: radar automobile pour le stationnement, la couverture des angles morts, l'anticollision 76–77 GHz: radars de détection de drones 76–81 GHz: télématique des transports et du trafic 94 GHz: armes à énergie dirigée, contrôle des foules Observation météorologique à haute résolution à courte portée, expérimentation et recherche scientifique, satellites.
D & G	110 - 300 GHz	2.7 - 1 mm	122–123 GHz: applications non spécifiques à courte portée 134 à 141 GHz: connexions personnelles par satellite 244–246 GHz: applications non spécifiques à courte portée 241 à 250 GHz: connexions personnelles par satellite 250 à 252 GHz: écoute, émission interdite. 265 à 275 GHz: Radioastronomie, recherche spatiale 275 à 300 GHz: non alloué.
	300 GHz à 384 THz	0,78 µm à 1 mm	Ondes infrarouges. [© pierredubochet.ch]

5G the Next Gen LTE