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5G Update March 23, 2022

Introduction

Several important changes have happened in the cellular industry since my last update to this 5G article in October 2020.

First and foremost among them, an Aug 13, 2021 ruling in the United States Courts of Appeals, District of Columbia Circuit irrevocably changed the wireless world — see the full details here (https://wireamerica.org/update/). The DC Circuit rules on the constitutionality/legality (or lack of it) of Federal agencies' regulatory orders and laws passed by our elective representatives. DC Circuit rulings in such cases therefore apply to the entire country.

Specifically, in Aug 2021, the DC Circuit ruled *against* the FCC in a lawsuit that challenged the legality of FCC Order 19-126, which had been the standard of acceptable safety limits by the FCC for over twenty-five years. In August's case 20-1025, Environmental Health Trust (https://createhealthyhomes.com/education/5g/#Links_to_4G_LTE_and_5G_Maps_for_US_Cell_Carriers) and Children's Health Defense (https://childrenshealthdefense.org) et al. v FCC, the judges ruled, "The Commission [FCC] failed to provide a reasoned explanation for its determination that its guidelines protect against the harmful effects of exposure to radiofrequency radiation". The DC Circuit further ruled that the original FCC Order 19-126 was "arbitrary and capricious" and, therefore, unlawful. The order was remanded back to the FCC with very specific instructions of what to do, as one can read in full here (https://wireamerica.org/update/).

Read the judges' ruling on Case 20-1025 here (https://www.cadc.uscourts.gov/internet/opinions.nsf/FB976465BF00F8BD85258730004EFDF7/%24file/20-1025-1910111.pdf). Read a summary of the ruling by the CHD here (https://childrenshealthdefense.org/defender/chd-wins-case-fcc-safety-guidelines-5g-wireless/?itm_term=home), and a summary of the ruling from the EHT here (https://ehtrust.org/in-historic-decision-federal-court-finds-fcc-failed-to-explain-why-it-ignored-scientific-evidence-showing-harm-from-wireless-radiation/). Finally, read about important, immediate action steps you can take, based upon the ruling, at Wire America here (https://wireamerica.org/update/).

Turning to what has happened in the past eighteen months in the domestic cellular industry within the U.S., the following took place:

- First of all, remember that 5G comes in three flavors: low band (600 to 1,000 MHz), mid band (1,000 MHz, or 1 GHz, to 6 GHz), and high band, otherwise known as the millimeter Wave (mmWave) band starting at 20 GHz.
  Verizon, and to a much lesser degree initially, AT&T both launched new 5G mid-band cellular service in the C-band at 3.7 GHz in January 2022.

- AT&T has won new spectrum at auction, also in January 2022, for mid-band service at 3.45-3.55 GHz, which they will launch by the end of 2022 and into 2023. Meanwhile, T-Mobile has expanded its 5G mid-band service at 2.5 GHz that it inherited from Sprint when the companies merged in 2020.

- The mid band is the "holy grail" for cellular carriers because wavelengths are shorter than lower band 4G LTE service but cell signals still transmit far, and they pass through building walls and both old and new, Low-E, window glass, which mmWave 5G signals cannot easily pass through.
  All three cellular carriers are also expanding their mmWave presence. Verizon far and away leads the pack with mmWave deployment in the past two years in almost 90 U.S. cities, extending well into suburbs.
  Meanwhile, T-Mobile and AT&T are beginning to expand their mmWave service beyond a few convention centers, stadiums, arenas, airports and similar areas with concentrated foot traffic, spreading now into more downtown urban and nearby areas.

- All carriers are also expanding their mmWave antennas into buildings to reach customers when they are indoors in public places (shopping malls, office buildings). All three U.S. carriers now use repurposed 4G LTE frequencies for their low band "5G Nationwide" service. Verizon recently added a low band 5G service using repurposed 4G LTE frequencies, just as their competitors have done for the past two to three years.

- U.S. carriers also continue to expand and upgrade their 4G LTE networks in the low and mid bands by installing equipment on legacy cell and small cell antenna arrays that increase speed and lower latency. This is known collectively as LTE-Advanced and LTE-Advanced Pro.

- All of these steps affect particularly electrically hypersensitive people, as well as the rest of us and biological systems in nature.

It is important to understand that 4G and 5G are terms primarily used by the marketing departments of the world's cellular carriers. Industry groups such as the International

Telecommunication Union (ITU) also use 5G to define a relatively challenging set of criteria for cellular technologies based upon characteristics such as peak data rate and efficiency, the data download experience of users, latency of data transmission, reliability, mobility and bandwidth. These criteria are set out in the ITU's 2017 publication, Report IUT-R M.2410, "Minimum requirements related to technical performance for IMT (International Mobile Telecommunications)-2020 radio interface(s)," available here (https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2410-2017-PDF-E.pdf).

Engineers and developers working for these carriers, however, also focus on technological features that come from committee work done by members of the Third Generation Partnership Program, or 3GPP (https://www.3gpp.org), a consortium of the world's cell carriers that provides guidance on how carriers can implement technological innovations and upgrades into the world's cellular networks. The 3GPP publishes recommendations in what are known as "Releases," which are developed and published in a staggered format. The 3GPP and the world's cell carriers are currently working on Releases 16 through 18.

These releases include integration of advanced features, such as:

- Automation of radios at cellular sites for more "edge computing", thereby cutting down on the time it takes commands to be sent from mobile devices to antenna sites, which are then processed by servers and returned to end users' devices, providing what they call "Ultra Low Latency".

- Carrier aggregation, which allows signals to be processed by multiple antennas simultaneously, also markedly increasing download and upload speed.

- Network slicing, which allows networks to simultaneously allocate slices of its signal to different phones depending upon each customers' needs.

- Cell carriers converting from 4G LTE-supported non-standalone (NSA) technology to new, enhanced 5G-supported standalone (SA) technology. Standalone technology is more integrated and operates faster and more seamlessly than non-standalone technology.

- Standalone technology allows for network slicing. Dish network's new, fourth cellular network being deployed in the U.S. is built completely on SA technology. This is possible because they do not have a 4G LTE network that they need to integrate into their new 5G network like older, legacy cell carriers, including Verizon, T-Mobile and AT&T, do, which need to maintain 4G service for their existing customer bases.

- Incorporation of Dynamic Spectrum Sharing, or DSS, by Verizon and AT&T to allow their phones to use 5G technologies when the user's device is only near 4G LTE frequencies. Massive MIMO, which allows for many more customers to be connected to the same antenna simultaneously at the same frequency through a process known as "spatial multiplexing."

- Verizon uses massive MIMO for their mid-band C-band service, thereby bringing focused, beam-formed signals used primarily in the mmWave band down into their more geographically expanded mid-band coverage.

- T-Mobile has already been using massive MIMO for three years for their mid-band 2.5 GHz 5G service that they inherited from Sprint.

- Conversion by the industry from Non-Open Radio Access Networks to Open Radio Access Networks (O-RAN). O-RAN provides for more optimization of the flow of information on the network, using virtualized software and greater interoperability. See a summary here (https://connectlp.keysight.com/ORAN-Essentials-eBook-ThankYou).

- Moving the cellular industry's networks onto the Internet. The world's cell networks are now cloud-based, or "cloud-native".

- Expansion of fixed wireless Internet service by all three U.S. major cell carriers further into residential neighborhoods.

- Increase in energy/electricity consumption by cell carriers because of increased power density levels.

These upgrades are discussed in more detail below in this update, as well as in previous installments of this 5G article, seen further below.

What Are the Biological Effects of These Advanced Cell Technologies?

All of the technological upgrades listed above have biological implications for us. We need to know how *both* cellular signals broadcast from outdoor (and indoor) cell antennas *as well as* from wireless devices that we keep in our hands and pockets affect our physiologies. We have extensive knowledge of how wireless radio frequency (RF) signals affect us in general, but we do not know the full extent to which these numerous technological upgrades in the 5G era are specifically affecting us now and will affect us in the future.

Questions remain, such as: What are the biological effects from these more modulated wireless signals that come indoors from outside sources? Which frequencies reach us indoors and which do not? When we are indoors, what added harm do 5G technologies have on us at close range from our own portable wireless devices when they are in use versus when they are on standby? What are the biological effects of wireless technologies, particularly upgraded 4G and 5G, on wildlife, insects and vegetation, essentially, the earth's bio-sphere?

Just as importantly, we need to focus as much on the harmful effects from wireless devices within our homes as we do on outdoor 4G and 5G cell antennas. My colleagues and I say, every time we talk about stopping deployment of 5G antennas in residential areas, we need, in the same sentence and breath, to say, "And also pay attention to the wireless devices in your hands, lap and pocket and those of your children. Let us show you how to shift to hardwired connections when you are at home, in school and at the office".

We are also hearing about so-called "wearables," where cell technology is incorporated into the skin of one's arm or implanted elsewhere on the body or head, allowing for direct connection with cell networks. These and other developments are among the many reasons we need to pause and take a deep look at where all this is headed.

Finally, I give a list, at the end of this update, of links to articles and other sources of information that I used for this specific update, as well as what I consider to be useful websites from the cell industry that you can access yourself to stay informed. You can sign up for regular emails and to be notified of informative one-hour webinars from many sources that go into great detail about the technology involved with 5G.

If you are a 5G activist, you need to stay informed about what the industry is doing technologically so we can understand the basis for biological effects. In my opinion, that way can we come to conclusions and recommendations based upon correctly understanding the technology involved. I provide a link at the end of this update to my list of organizations that work as activists and advocates on the issue of 5G, also accessed here (https://createhealthyhomes.com/education/5g/#Resources_on_5G).

Learning the Cell Industry's Expanded Use of Marketing Terminology

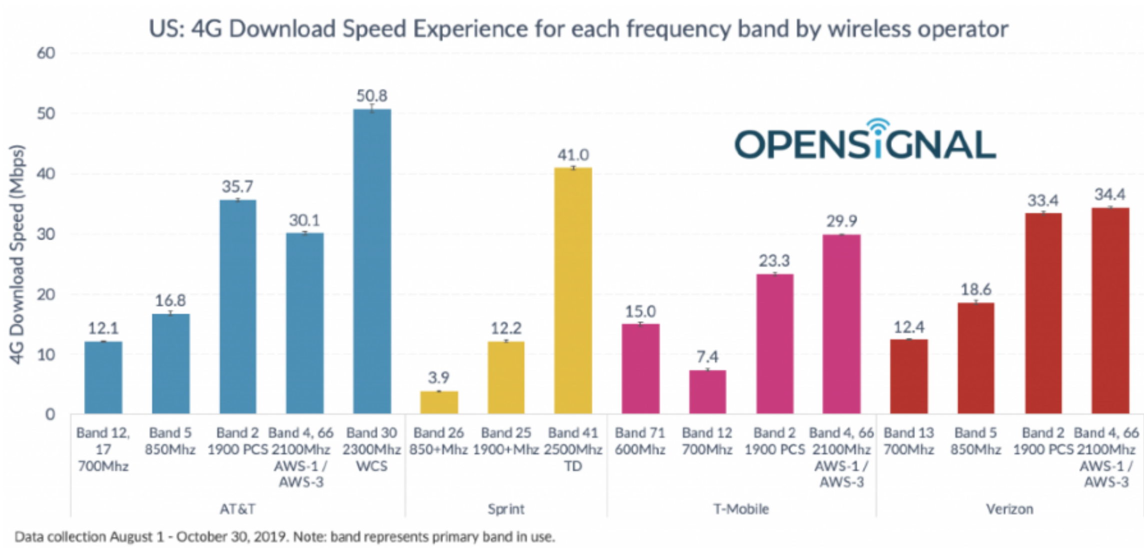
To begin with, let's learn the new terms used by cellular carriers here in the U.S. for their expanded 5G services. Remember, 5G operates differently in each of the three bands that broadcast 5G due to the physics of these different wavelengths and frequencies:

- T-Mobile now calls *both* their mid-band 2.5 GHz service as well as their more limited mmWave service, "Ultra Capacity 5G".
- Verizon now calls *both* their upper mid-band 3.7 GHz C-band service as well as their extensive mmWave high band service, "Ultra Wideband 5G".
- AT&T now calls their upper mid-band 3.7 GHz C-band and their more limited mmWave high-band service, "5G+". When they deploy their new mid-band 3.45-3.55 MHz service in late 2022 and 2023, they plan to also call that, "5G+".

These are in addition to the low band "5G Nationwide" services all three of these carriers provide using repurposed 4G LTE frequencies in the low band (and mid band for Verizon when their 850 MHz frequency is not available).

Here Are the Details

First of all, let's do a brief review. 5G is built upon the 4G LTE network. Here is a chart from Opensignal (https://www.opensignal.com/2020/02/20/how-att-sprint-t-mobile-and-verizon-differ-in-their-early-5g-approach) showing 4G frequencies by carrier, published in 2019 (before the merger of T- Mobile and Sprint):



Refer to the chart above to follow the frequencies used by the various U.S. cell carriers as they have begun to provide low and lower mid-band "5G Nationwide" service in the last three years:

- T-Mobile repurposes their 600 MHz 4G frequency (seen in purple in the chart above as Band 71) for their 5G Nationwide service.

- AT&T repurposes their 850 MHz 4G frequency (seen in blue as Band 5) for their 5G Nationwide service.

- Verizon also repurposes Band 5 at 850 MHz (in brown above) for their new 5G Nationwide service, where available. Where 850 MHz is not available, Verizon uses their PCS (4G) frequency at 1,900 MHz (Band 2) and their AWS (4G) frequency at 2,100 MHz (in brown in Bands 4 and 66).

Verizon and AT&T both also use Dynamic Spectrum Sharing, or DSS, for their 5G Nationwide coverage. DSS provides some of the new 5G technologies when only 4G frequencies are available. This includes carrier aggregation, which combines up to eight channels or frequencies of spectrum to provide more efficiency in data transmission, resulting in data speeds of up to 4 Gbps (4,000 Mbps). DSS service is being deployed by Verizon at their existing 4G LTE cell antenna sites.

Cell carriers therefore all now have a smorgasbord of advanced services, including Advanced 4G LTE, 5G in the low and mid bands, and 5G in the mmWave, to provide faster, more stable and reliable data coverage to their customers with lower latency by integrating many new features into their networks, depending upon where the user's device is located (rural, suburban or urban). However, we must all remember that this comes at a price to our biological health.

There is a sequence that each carrier's phones are programmed to follow to access the fastest cellular data service, depending upon the features in the phone and what services are available in the place where the user's device is located.

For example, Verizon 5G-enabled phones are programmed to first pick up mmWave service where available (in the 28 and 39 GHz band), such as in urban areas with heavy foot traffic and close-in suburban neighborhoods. If mmWave service is not available, Verizon's phones are programmed to pick up DSS coverage at 4G frequencies of 850, 1,900 or 2,100 MHz. If neither mmWave service nor DSS is available, Verizon's phones will then use standard 4G LTE coverage at their 4G frequencies of 700, 850, 1,900 and 2,100 MHz. However, that standard 4G service is now upgraded with advanced technologies, which are even more biologically active to our physiologies than exposure to 4G LTE service was previously. All 5G technologies are highly biologically active.

How Much is Low-Band and Mid-Band 5G Really Different than 4G?

Analysts say that each carrier's "Nationwide 5G" service is really more like "4G+", meaning, that at 50-60 Mbps (Megabits per second), it is somewhat faster than standard 4G LTE's download speeds of 12-60 Mbps but not as fast as the 250-300 Mbps speeds provided by mid-band 5G (such as T- Mobile's 2.5 GHz, Verizon and AT&T's C-band service at 3.7 GHz, and AT&T's yet to be released 3.45 GHz service). Nor is "4G+" as fast as the 700 Mbps to 1 Gbps speeds possible from 5G mmWave service (mostly from Verizon at 28 and 39 GHz).

This Nationwide 5G "4G+" experience provided by the U.S.'s cell carrier's is possible due to small cell antenna densification in urban and suburban neighborhoods, deployment of a speedier fiber-based backhaul network, and more automation at cell tower radios, known as "edge computing" where the network manages itself "on the fly".

Analysts say most customers won't notice much difference in data speed increases when comparing between current 4G LTE and 5G Nationwide service that is broadcast in the low band (at T-Mobile's 600 MHz and AT&T's and Verizon's 850 MHz). Low band 5G service was initially expected to be perhaps only 10% faster, according to some estimates. See Opensignal (https://www.opensignal.com) for detailed surveys of actual speed comparisons between 4G and 5G service by carrier.

It is only when customers connect in the mid band, such as with T-Mobile's 2.5 GHz service, with Verizon's and AT&T's new C-band service at 3.7 GHz, and AT&T's yet to be deployed mid band service at 3.45 GHz, and when customers also connect with Verizon's mmWave service in the mmWave band that they will notice substantial data speed increases.

All customers will notice lower latency and more reliability of their data connection with all 5G services across the frequency spectrum (low band, mid-band and mmWave) compared to 4G LTE in the low and mid-bands.

What Are the Specifics of AT&T's New 3.45-3.55 GHz Mid Band Service?

The new spectrum auctioned off by the FCC to AT&T in January 2022 is called the "Andromeda" spectrum because it does not have its own numerical designation like other cellular bands do (for instance, 850 MHz is Band 5). As such, it also does not have regional limitations and can be deployed nationwide. AT&T's deployment of mid-band Andromeda spectrum will therefore be possible in parts of the country where their C-band service is not yet available because that city's C-band service is in the second tranche coming online in 2023 and 2024, as in Atlanta and Denver.

AT&T will call their Andromeda deployment "5G+", just as they already call their limited, but growing, mmWave presence, which has only been available in arenas, stadiums, airports and convention centers in urban areas. AT&T originally only offered their 5G+ service to business customers, but they recently opened it to all customers in spring 2021. AT&T's Andromeda service will be available on Samsung and Motorola phones, but not the new iPhone SE. Andromeda and mmWave service will, however, be supported for AT&T customers on the new iPhone 14 coming out in autumn 2022.

Are 5G Signals in the Low Band Beam-formed? Does Use of Massive MIMO for C-Band Service Bring More Beam-forming Down into the Mid Band?

None of the repurposed 5G signals in the low band are beam-formed, however Verizon is using massive MIMO technology, known as Multiple Input, Multiple Output, to provide beam-formed signals for its C-band service in the mid band, particularly on the uplink side when sending data from phones to cell antennas.

Standard legacy, macro 4G LTE cell antennas in the low and lower mid band use two transmitting antennas and two receiving antennas per array, known as 2T2R. Many 4G LTE antennas have now been upgraded to "Advanced 4G LTE," thereby doubling their transmitting capacity to four transmitting and receiving antennas, or 4T4R, as well as incorporating other features. However, 4G LTE signals at 600, 700 and 850 MHz and repurposed low-band 5G signals at 600 and 850 MHz are not beam-formed, as noted above. The photo at right shows a typical 4G LTE cell antenna array, noted by the slender antennas. A few rectangular 5G antennas are also present on the brackets. You will see newer mid- and high-band mmWave antennas on legacy 4G cell arrays.

High band mmWave antennas, on the other hand, use antenna arrays with eight antenna elements across and eight down for a total of sixty-four antennas, or 64T64R, as seen at right. These 64 antennas are housed in a rectangular box, compared to the older, but more plentiful tall, slender 4G antennas with 2X2 or 4X4 antennas seen above.

Beam-forming is needed to focus these 64 antennas into a beam-steered signal sent to multiple cell phones simultaneously (that are enabled for mmWave 5G service).

Verizon's use of 64T64R massive MIMO arrays for their C-band antennas provides a beam- formed, focused signal to multiple customers' phones, simultaneously in the mid-band. This increases speeds by up to 180% for C-band customers compared to 4G LTE service. Massive MIMO and carrier aggregation, which combines C-band's 3.7 GHz with other frequencies, provide Verizon customers with 900-1,000 Mbps (1 Gbps) of download speed, similar to their mmWave service. These C-band features also provide faster coverage for Verizon's customers at distances that stretch as far as their 4G AWS service at 2,100 MHz.

When the rest of the C-band becomes available as the second tranche of that spectrum is released to Verizon and AT&T in 2023, both carriers expect to increase their data speeds and the reliability of their networks even further. These are the selling points of these two cell carriers to their customers, and the reasons why customers are choosing to purchase these new phones.

It is also important for us to know these technical details because they allow us to better understand how these updates can affect the health of electrically sensitive people and the general public.

Then there is T-Mobile's 5G service that broadcasts in the mid-band at 2.5 GHz, which, again, T-Mobile inherited when they took over

Sprint in April 2020. T-Mobile's 5G signals provide download speeds of around 250-300 Mbps. They are also beam-formed using massive MIMO technology, just as Verizon now uses for their new C-band coverage, and which Verizon, T-Mobile and AT&T all use for their mmWave service. T-Mobile's beam-formed 2.5 GHz mid-band service has been present for three years. It is modulated and people do react to it. A 2.5 GHz 64T64R (64Transmit, 64 Receive) Massive MIMO Unit antenna, manufactured by Samsung for Sprint (now T-Mobile) on display in 2019 at the Mobile World Congress America 5G Conference in Los Angeles is shown at right.

Meanwhile, T-Mobile and AT&T were able to triple the download speed of their re-purposed 4G LTE coverage, which they call "Nationwide 5G" service, at lower frequencies of 600 MHz and 850 MHz, respectively. Download speeds increased from 12-15 Mbps up to roughly 50-60 Mbps.

This, however, is also the same speed as the 4G service you get if you happen to be near T- Mobile's 1900, 2100 and 2500 MHz (1.9, 2.1 and 2.5 GHz) 4G LTE transmitters. 4G LTE download speeds vary between 12 and 50 Mbps depending upon the frequency used by the 4G LTE cell tower that you are near. All three companies use four or five different frequencies for their 4G LTE service, from 600-700 MHz to 2,100-2,500 MHz, as shown in the first chart above.

Verizon Joins T-Mobile and AT&T in Providing 5G Nationwide Service Using Low (and Mid) Band 4G Frequencies

After criticizing T-Mobile three years ago for calling their repurposed 4G service at 600 MHz “5G”, and after also criticizing AT&T for calling their repurposed 4G service at 850 MHz “5G”, Verizon jumped on the bandwagon in the last year by also offering what they call their “5G Nationwide” service.

Verizon now repurposes their 850 MHz 4G frequency, like AT&T, while also using their 1,900 PCS and 2,100 AWS frequencies when their 850 Hz transmitters are not available to provide their new “5G Nationwide” service to customers. “5G Nationwide” service offers download speeds somewhere between mmWave and C-band 5G service at the fast end, and 4G LTE service at the slower end.

Verizon Hits the Jackpot By Buying the Bulk of First-Tranche C-Band Service

The C-band within the mid band that Verizon and AT&T bought at the FCC’s auction in early 2021 was turned on one year later, in early 2022. Verizon has the bulk of the first tranche, with AT&T also deploying some of their C-band spectrum in the first tranche that they also purchased. AT&T will have much more of the second tranche of C-band service scheduled to be turned on in 2023. C-band frequencies were reclaimed by the FCC from the satellite industry, which sold that bandwidth back to the FCC for sale to domestic cell carriers.

Verizon previously had no significant 5G service below the high, millimeter Wave (mmWave) band above 20 GHz, with all of its limitations of range and the inability of cell signals to pass into buildings. That is why they spent so heavily for new C-band service, which resides in the mid band with signals that can more easily pass into buildings, when it became available for auction in early 2021. Verizon then spent all of 2021 installing this new C-band service, primarily at existing 4G legacy and small cell sites.

Cell antennas transmit in the C-band at 3.7 GHz and neighboring frequencies, all in the mid band. The C-band offers download speeds of 250-300 Mbps, which is ten to fifteen times faster than today’s 4G LTE service, which range only from 12 to 60 Mbps. C-band service has a fairly wide reach, up to a few blocks (compared to miles for low band and lower mid-band 4G service and only a block or so effectively for high mmWave service).

The wavelength of C-band, at 3 inches or so, can still penetrate building walls and windows (compared to 15 inches down to 5 inches for 4G signals, which can easily pass through all walls and windows). Remember, as the frequency goes up, the wavelength gets shorter.

Verizon's C-band mid-band service is poised to compete against rival T-Mobile's 2.5 GHz mid- band service. However, T-Mobile far exceeds Verizon in nationwide coverage of PoPs (Points of Presence), as Sprint began rolling out that service three years ago.

T-Mobile is planning on rapidly deploying its 2.5 GHz mid-band 5G service to new customers in small towns and rural areas. That means, electrically hypersensitive (EHS) people will need to watch for this deployment if they have retreated to rural areas to get away from cellular antennas/towers in more urban and suburban areas. Most of the rural deployment will likely be in towns where populations are somewhat higher, at least initially. Remember that mid- band 5G cell service does not travel the miles that low band and lower mid-band 4G service does. See more information below in this update on 5G in rural areas.

What's New in the mmWave Band?

Regarding the mmWave band above 20 GHz, Verizon has used only that band for its 5G service, broadcasting at 28 and 39 GHz until 2022 when they launched their C-band service (along with their low and lower mid-band Nationwide 5G service, also launched in 2021).

T-Mobile and AT&T had not increased their mmWave 5G presence in the past few years beyond downtown urban areas and stadiums, arenas and other public places within a few cities, focusing instead on rolling out their low and mid-band 5G services, which all have different characteristics than 5G signals in the mmWave band. However, both T-Mobile and AT&T are now expanding their mmWave 5G service as of 2021 and 2022.

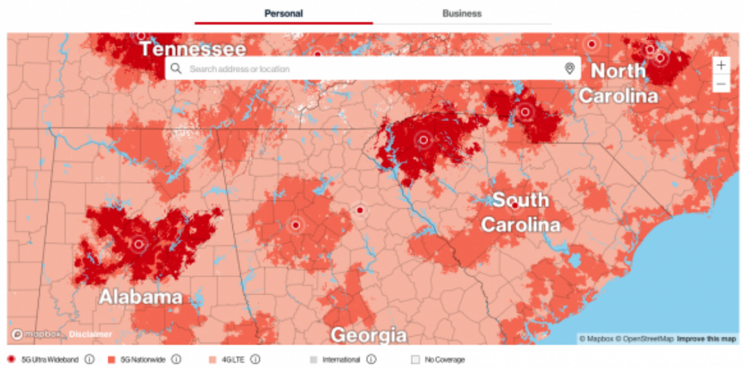
We used to be able to see exactly which streets Verizon's mmWave 5G transmitters were located on when viewing Verizon's coverage map as you zoomed in far enough in any of the 90 cities that have mmWave 5G Ultra Wideband coverage, seen here (https://www.verizon.com/coverage-map/). However, when Verizon turned on their C-band 5G transmitters in late January 2022, they also began to call their C-band antennas "5G Ultra Wideband" service, thereby combining C-band antennas broadcasting in the mid-band at 3.7 GHz with their mmWave antennas, broadcasting at 28 and 39 GHz.

That means that now all you see for the designation "5G Ultra Wideband" on Verizon's coverage maps is entire neighborhoods awash in one uniform, deep red color, at least for those cities included in the first tranche of C-band coverage. This is because C-band transmitters cover a much wider area (several blocks) compared to the one block or less effectively covered by mmWave antennas.

Thus, all you see now on Verizon's coverage map (https://www.verizon.com/coverage-map/) in most downtowns and surrounding suburbs in those cities with a glowing red dot is a uniform deep red color without individual streets delineated with black lines, as was the case for just their mmWave coverage prior to late January 2022.

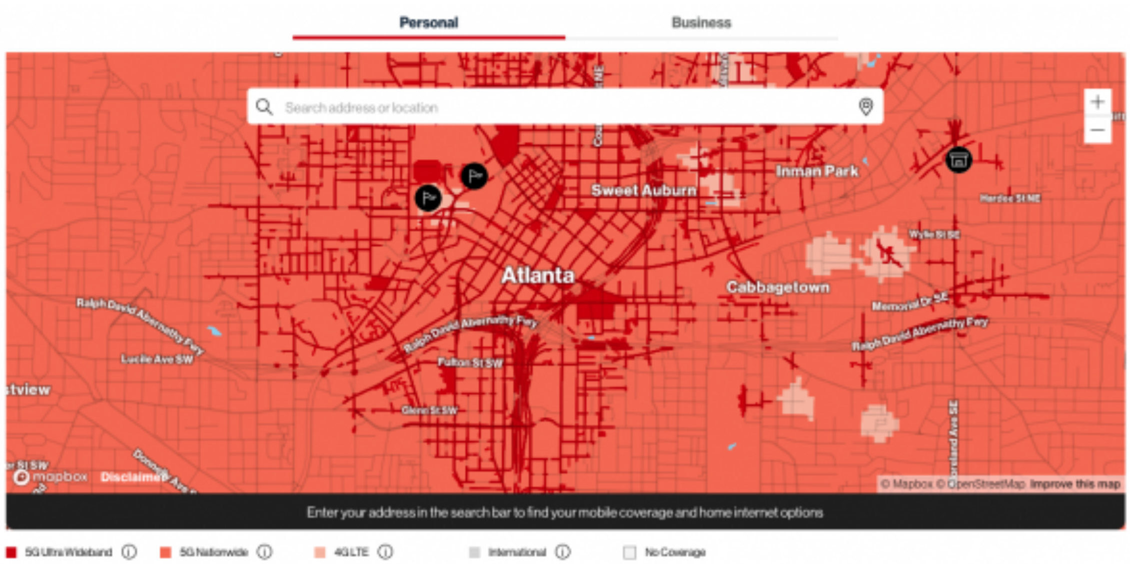
However, I have noticed an interesting phenomenon. In those cities that are not in the first tranche of C-band coverage, like Denver and Atlanta, you will notice that you can *still* see where Verizon's mmWave antennas are installed because they are delineated by dark red lines on portions of certain streets. This is helpful for EHS people to know where to avoid, at least in those cities.

You can also tell which cities have C-band coverage in this first tranche, and which do not. Those with C-band coverage have a large swath of deep red with a glowing red dot in the middle of it, while those cities that do not have C-band coverage yet only have a single glowing red dot with no swath of dark red around it. This will all change in 2023 and 2024, when the second tranche of C-band service is released for Verizon and AT&T.

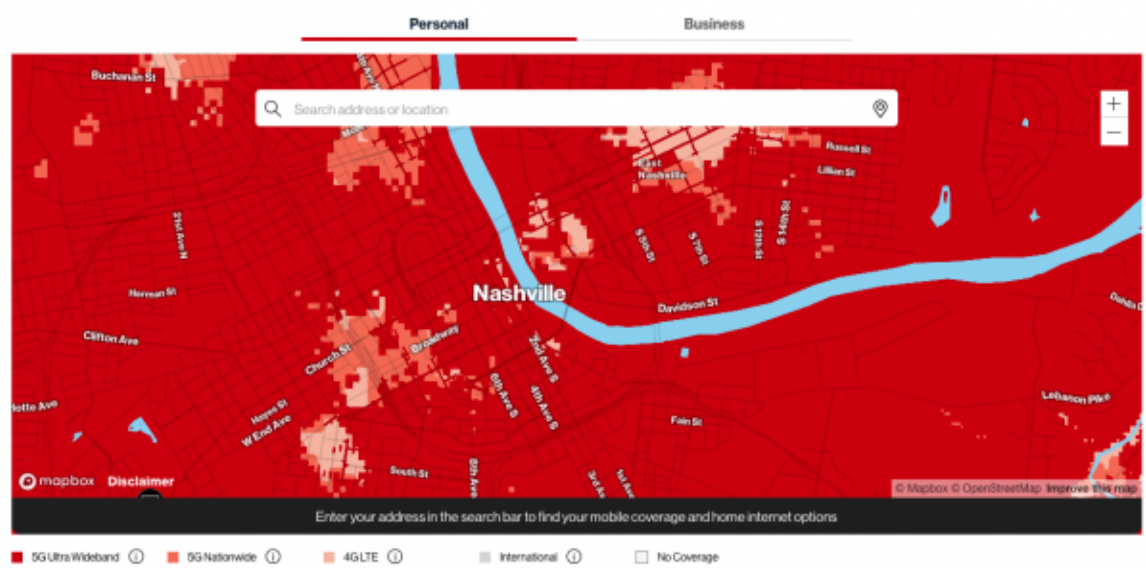


As an example, notice in the screen shot to the right showing Verizon's 5G coverage in the Southeast U.S. that Nashville, Tennessee, Greenville, South Carolina, Charlotte, North Carolina, and Birmingham, Alabama all have C-band coverage, seen as red swaths around a central red dot, while Atlanta, Georgia and Columbia, South Carolina do not have C-band coverage. Hence, they are not surrounded by a swath of dark red color like the other cities. (The orange color around Atlanta and Columbia indicates Verizon's "Nationwide 5G" coverage using repurposed 4G frequencies, which is now available everywhere but is not beam-formed.)

You can therefore still see the street-by-street deployment of mmWave antennas as dark red lines on the map below in Atlanta and other cities not in the first C-band tranche. Again, this can be helpful for electrically sensitive people living and working in those cities with Verizon's mmWave service but not C-band service.



Nashville, on the other hand, where C-band service *has* been established, has a map, seen below, that is almost solid red, showing no distinction between the location of C-band antennas and mmWave antennas.



Remember, Verizon’s mmWave antennas are also present in cities with swaths of red. We just do not know any longer where they are, at least, not from the map (nor do we know from the map exactly where C-band antennas are located in any city where they are deployed).

So unfortunately, you no longer can see exactly where Verizon’s mmWave antennas are located (in those cities with C-band coverage) unless you drive around and look for them. They have a rectangular shape.

Verizon’s mmWave antennas are definitely beam-formed antennas, emitting focused energy to cell users when mmWave 5G-enabled phones are in front of them. We cannot measure the mmWave cell signals they transmit with our RF meters.

T-Mobile and AT&T do not have much in the way of mmWave service, again having focused more on deploying their low and mid-band 5G service over the past three years. However, they, too, are both now expanding 5G service in the mmWave band beyond stadiums and minimal downtown coverage in a handful of cities. Click here for an updated description lower down in this article of and links to T-Mobile’s and AT&T’s coverage maps.

Cell companies are expanding mmWave service even into small towns (though probably not out into the countryside to any significant degree, since populations are sparse and there is no foot traffic there).

It is Important to Understand the Physics of the mmWave Band

As a review, cell signals that are broadcast in the mmWave band (above 20 GHz) have a wavelength of roughly one-half inch or less. These signals must therefore all be beam-formed in order to effectively transmit to user's devices. They do not penetrate walls and windows well at all. The signals only transmit with any significant strength about one block or so and are easily blocked by buildings, trees, and rain and snow.

It is important that we all remember that mmWave signals can only be picked up by cell phones when outdoors. Hence, they are only deployed where there is good foot traffic, such as on sidewalks in downtown areas and in public places where a lot of people walk. Cell carriers need to install mmWave antennas inside buildings to get coverage there, such as in arenas, airports and other public places. All low and mid-band cell signals, whether 4G or 5G, on the other hand, can pass through walls and windows into buildings.

You see Verizon's mmWave 5G service, which they call "5G Ultra Wideband", in almost 90 cities around the U.S. (as of March 2022) in and around downtowns and spreading out into nearby suburbs. You also find it in stadiums, sports arenas, airports, metro stops, college campuses and inside buildings. mmWave cell antennas are rectangular in shape. Download speeds with mmWave service are 600-1,000 Mbps, easily 20 or more times faster than today's 4G LTE data service.

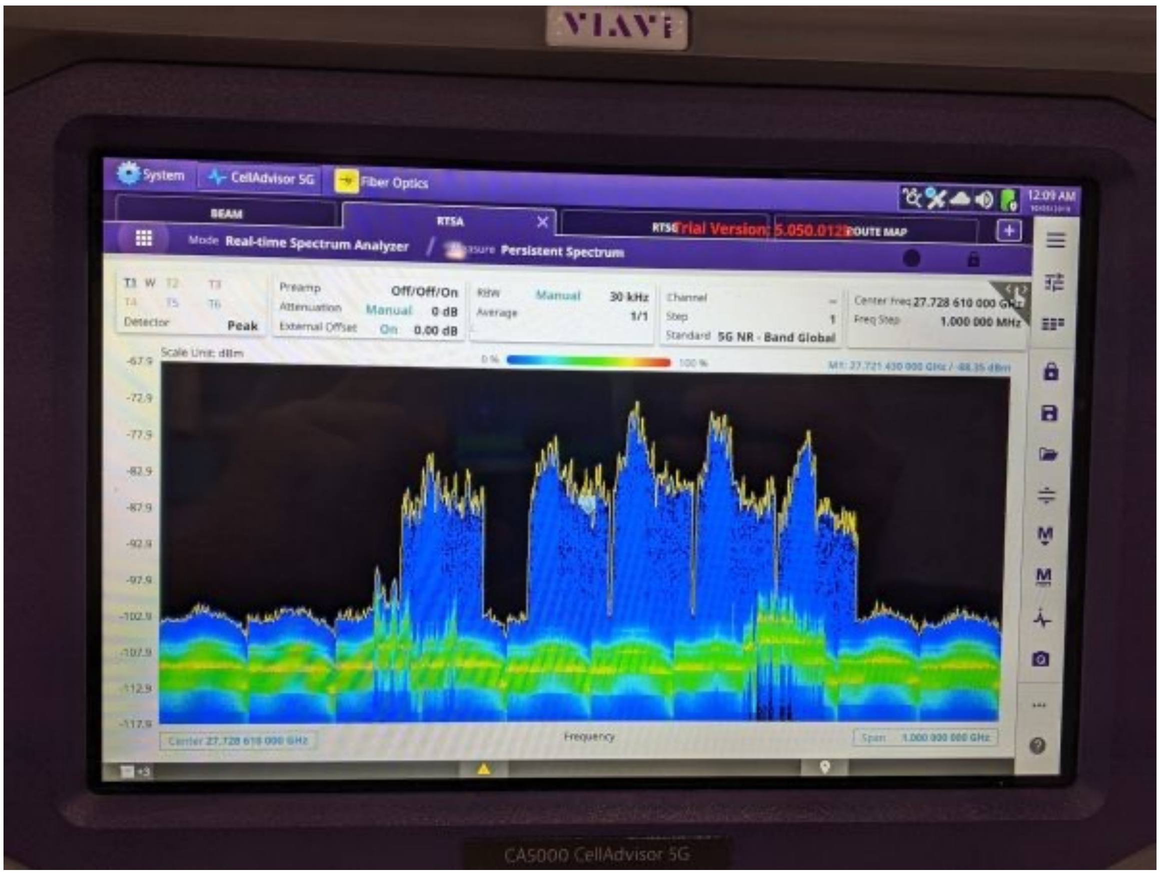
As stated in earlier parts of this 5G article, what everyone is unaware of is that 5G cell antennas in the mmWave band are for the most part, idle, except for a weak beacon signal, until someone with a mmWave 5G-enabled phone walks by using data services. Then the 5G mmWave cell antenna sends out a beam-formed signal to that phone for data activity (streaming audio or video, uploading/downloading content, etc.). However, this only happens in one zone at a time as the phone moves through its service area in front of the antenna. That means, a mmWave 5G's antenna sends out its signal only in one of the 8-10 zones arrayed in the 120 degrees of coverage in front of it, from left to right, with each zone measuring roughly 10 degrees wide when viewed from above. Which zone is active changes as the user device moves through the 8-10 zones.

Of course, in areas with foot traffic, there will be multiple users connected simultaneously to one 5G mmWave antenna, making such areas virtually inhospitable for electrically hypersensitive (EHS) people, and not safe for the rest of us.

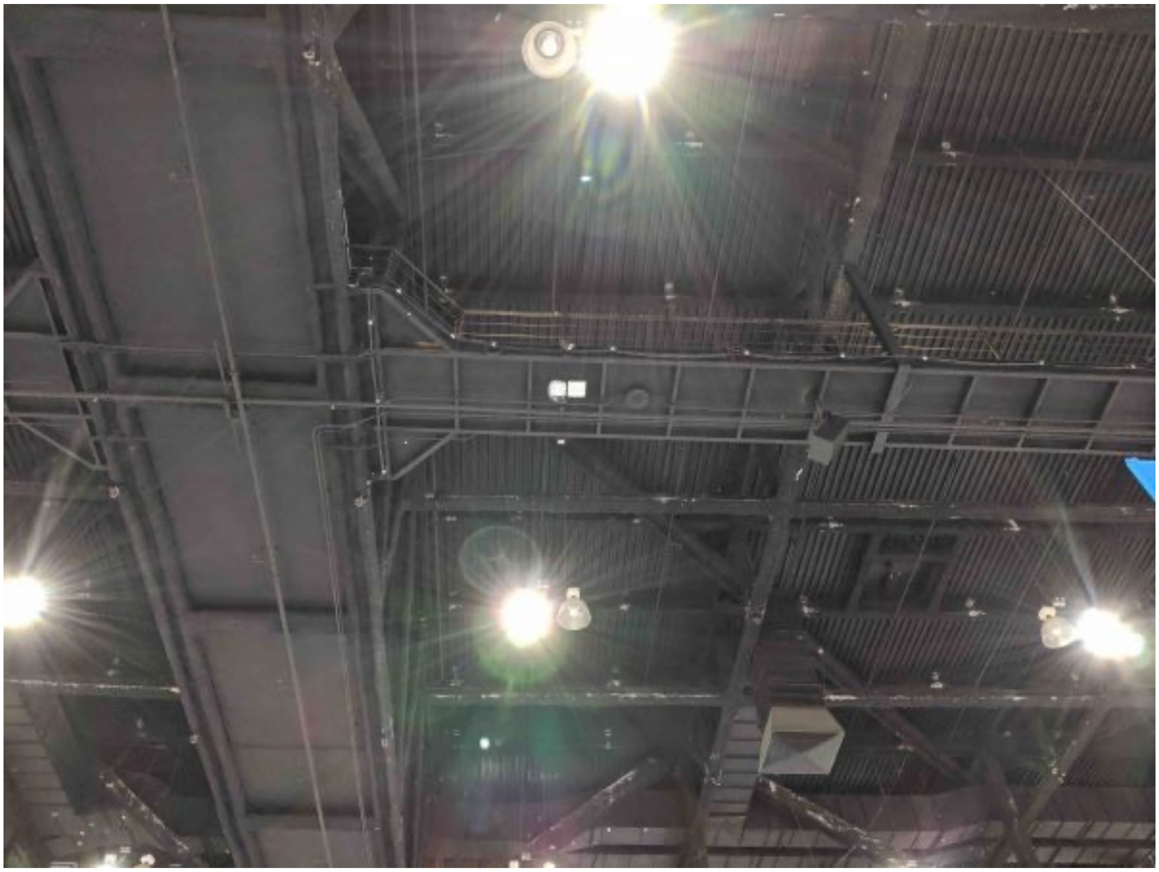
There can be no obstructions, such as a building or tree, between a mmWave 5G antenna and your phone or tablet to have a usable data connection. If there is no longer any mmWave 5G-enabled phone in front of a mmWave 5G antenna, meaning once that phone moves through its service area, that antenna becomes idle once again.

It is the case that mmWave 5G antennas do send out a beacon signal several times a second, however, the power flux density (PFD) of that beacon signal is measured at 1% of the broadcast signal strength when a connection is made to a mmWave 5G-enabled phone (mostly for Verizon customers). The strength of that weak beacon signal is measured at only -60 to -70 dBm, which is equivalent to roughly 0.01 microWatt/meter squared (µW/m2) on a standard RF meter (however we cannot measure these mmWave signals because by broadcasting at 28 and 39 GHz, they are much faster than our RF meters are capable of measuring—see below).

The image below shows mmWave 5G beacon signals on the display of a Viavi spectrum analyzer (https://www.viavisolutions.com/en-us) that is capable of measuring cell frequencies in the high, mmWave band above 20 GHz (the meter is shown in the RF meter section below). You will see the yellow peaks on top of blue columns measuring at -72 to -87 dBm from beacon signals being broadcast by Verizon mmWave 5G antennas in the rafters of the Los Angeles Convention Center. Notice the frequency listed in the box in the lower left corner of the screen of the Viavi spectrum analyzer, showing "Carrier 27.728 GHz" (28 GHz), the frequency that the 5G transmitter uses in the high, mmWave band.



The Verizon mmWave antenna in the ceiling of the Los Angeles Convention Center, the source of these beacon signals, is seen below as one of the white, square boxes in the center of the photo on the next page:



Compare that power density of 0.1 μW/m2 to the typical 5 to 200 μW/m2 of RF power density, or strength, that we usually measure standing in front or back of our client's houses in any suburban neighborhood. That is what I typically measure with my RF meter at clients' homes here in Los Angeles, but all cities and suburbs are the same.

Certainly to electrically sensitive people who do not use wireless devices in their homes and who are sensitive to wireless frequencies, even this beacon signal from mmWave 5G antennas causes them to react and become symptomatic. I fully understand and respect that, which is why urban areas are not hospitable for such individuals, and all cell service is harmful to all of us and to the biosphere.

From a realistic standpoint, however, I look at the fact that the vast majority of my clients, half of whom are symptomatic or sensitive and half are not, still use a cell phone. I also look at existing cellular RF saturation in my clients' residential neighborhoods already measuring in the dozens to hundreds of microWatts/meter squared.

For these reasons, as a practicing building biologist in a large city, I am not nearly as concerned about the mmWave beacon signal for the majority of my clients as I am about the beam-formed signals when data connections are in use and as I am about continued heavy use by some of them of their handheld wireless devices in their personal space.

Certainly those who are electrically sensitive would not be able to live near *any* cell antenna, no matter what the generation.

In discussing the energy consumption of 5G cell technology, it was pointed out that 5G base stations (cell site radios and antennas) can put themselves into sleep mode, as part of what is termed, “ultra-lean design,” when users are not present. This is done to reduce energy consumption, which will be much higher overall when many small cell antennas come online. It was not specified which 5G band this referred to, but we know that all mmWave 5G antennas power down, except for the beacon signal, when a customer with a mmWave 5G- enabled phone is not in front of it.

4G LTE cell sites, including small cells, on the other hand, "need to transmit a lot of control signals even when no one is listening—for example, at night," according to Emil Bjornson, professor at Linkoping University in Sweden, where extensive cell network research is conducted, in an article published by the IEEE, "The 5G Dilemma: More Base Stations, More Antennas—Less Energy?" (https://spectrum.ieee.org/will-increased-energy-consumption-be-the-achilles-heel-of-5g-networks) This points out the fact that existing and new 4G LTE networks, particularly small cell sites in residential neighborhoods, are a big dilemma because they are always on, transmitting into nearby homes—see below. Most small cell sites still primarily use 4G LTE technology, though even that is more advanced and modulated, as they rapidly add 5G technology.

Overall, according to 5G expert, Angela Tsiang (tsiangaw@gmail.com), cell carriers are asking for increased safe thresholds for cell transmission because they are increasing transmission strengths to increase coverage. This is pushing energy/electricity consumption up. New proposed rules by the FCC would allow exposure thresholds four times higher than they already are, which is currently far too high to protect human health. These higher RF levels will result in symptoms of "microwave sickness" in many, according to Dr. Lennart Hardell of the Environment and Cancer Research Foundation (https://environmentandcancer.com) and Mona Nilsson, Managing Director of the Swedish Protection Foundation (https://www.stralskyddsstiftelsen.se/english/).

How Much 5G Will Actually Be Fully Available in the 2020s?

This is an important question what with the industry’s marketing arm beating the drum on 5G, as does the larger EMF safety community, for good reason. 5G has certainly focused the public’s attention on EMFs, which is always good. We as practitioners need to make people aware of the full range of EMFs in their lives, and the focus on 5G has only helped to increase that awareness.

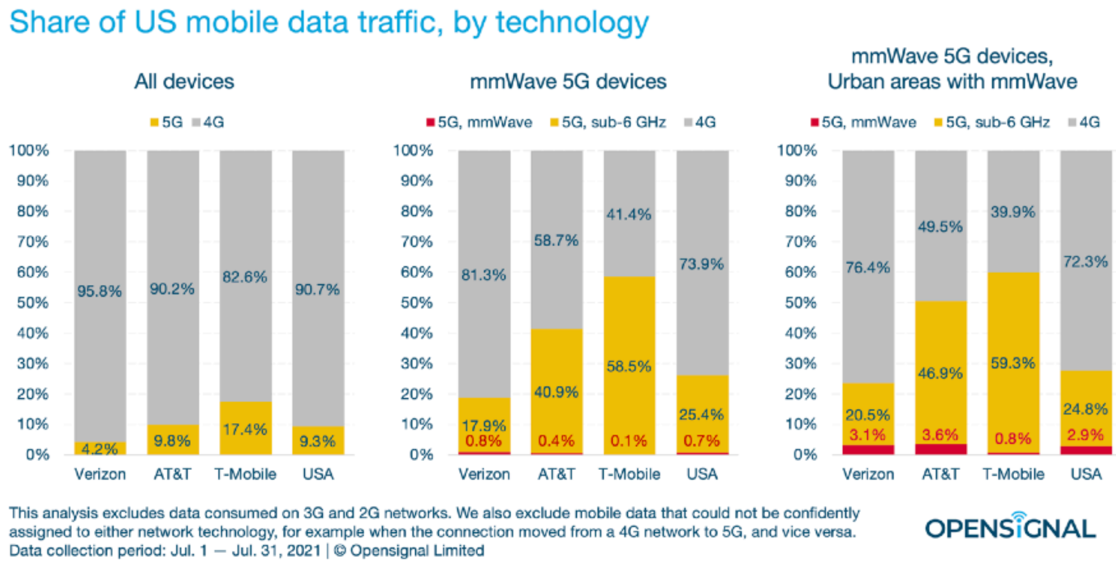
It is important, at the same time, to understand that in reality, in any given decade, we mostly see the full use of the generation of technology deployed in the *previous* decade, while the technology of the *next* generation is mostly being installed in the current decade, only to be fully realized in the next decade. Doug Dawson, wireless industry consultant at CCG Consulting and publisher of the industry watchdog blog, POTs and PANs (https://potsandpansbyccg.com), points out that the 2010s was the decade that 4G LTE technology was deployed while the 2020s, the decade we are in now, is the decade that 4G is being fully utilized. He reminds us that the first fully functional 4G LTE cellular antenna did not go online in the U.S. until 2018, the first year we started talking about 5G. See Doug's January 19, 2022 POTs and PANs blog post, "When will we see real 5G?" (https://potsandpansbyccg.com/2022/01/19/when-will-we-see-real-5g/) for details.

In his article, Doug quotes an October 2021 article (https://www.pcmag.com/news/why-you-wont-really-feel-5g-until-2027) in PC Magazine which itself quotes Ari Pouttu of Finland's University of Oulu, where a good deal of cell technology is developed. Doug said most 5G is actually made up of more 4G spectrum and moderately faster cellular service that most people don't know what to do with or need. The increased spectrum that 5G has provided has mostly helped the cell industry cope with vastly increased data usage of their overloaded 4G LTE cellular data networks. Ari Pouttu says most of the usable innovation from 5G on a practical basis is in industrial settings, where vast amounts of data need to be handled efficiently.

That means the 2020s is the decade when 5G technology is being deployed, but its data and voice usage is still only a percentage of that for 4G LTE. Ari Pouttu says each generation's technological promises won't be fully implemented for ten to twenty years, and most 5G features that we hear about now won't be realized for at least five to six years.

Opensignal is a good resource to use to follow the rollout of 5G and see how it actually compares to 4G service. They have thousands of actual cellphone users around the world collecting data for their database. Opensignal then publishes surveys every quarter showing cell usage in countries around the world comparing cell service provided by each country's carriers. Their March 10, 2022 article, "How the 5G experience has improved across 50 US states and 300 cities," gives a detailed analysis of 5G use as of early 2022. It is available here (https://www.opensignal.com/2022/03/10/how-the-5g-experience-has-improved-across-50-us-states-and-300-cities).

A chart published in July 2021 by Opensignal and seen on the next page is most instructive at showing how much 4G LTE service we still have, at least as of summer 2021.



You will notice that when you compare 5G to 4G service in the bars on the left for all devices and all frequency bands for the three major carriers, plus USA Cellular (in the Midwest and Mid-Atlantic states), 4G service was still 82 to 95% of total data usage. That meant that 5G service was not more, as of summer 2021, than 17.4% of *all* data usage on T-Mobile, with Verizon's 5G data usage only 4.2% of their customers' total data usage, while AT&T stood at 9.8% (USA Cellular was 9.3%.)

When you break that down further into mmWave 5G service vs. sub-6 GHz 5G service (which includes both repurposed low band and mid band 5G) in the middle gray bars above, you see that mmWave service, with its beam-formed signal, comprised less than 1% of total 5G usage as of summer 2021.

That, of course, was before the switching on of the first tranche of C-band service in late January 2022, which has increased mid-band service, including Verizon's massive MIMO beam-formed signals.

Other carriers are also spending significant resources expanding their 5G service, particularly in the mid band, but also in the low and high, mmWave bands. T-Mobile has announced that it expects its total 5G footprint to be close to 50% of all of its customers' data service later in 2022 (due to continued expansion of its mid-band 2.5 GHz service, which they are putting much emphasis on).

A resource for learning about activity in this area within the cell industry, the Small Cell Forum (https://www.smallcellforum.org), stated in a 2018 survey (https://www.smallcellforum.org/press-releases/market-status-apac-north-america-lead-network-densification-2021/) that 5G usage was expected to overtake 4G by 2024, and that "The total installed base of 5G or multimode small cells in 2025 is predicted to be 13.1m, over one-third of the total in use," and "...the vast majority of new deployments to be in dense or Hyperdense environments by 2025." This means, dense, urban areas, which are more and more becoming no-go zones for electrically sensitive people.

Whether these predictions made in 2018 will come true or not, 5G is being deployed in this decade and will become fully integrated into networks in the 2030s. Yet the industry is pushing to make 5G available to as many customers as possible, as soon as possible. We therefore certainly need to watch out for C-band and other mid band transmitters, as well as mmWave transmitters, deployed in our residential neighborhoods, both appearing as rectangular antennas. We can measure some of them with our RF meters, while others (in the mmWave band), we cannot.

Learn about efforts to educate communities and local officials about the dangers of deploying cell technology, of whatever generation, in residential neighborhoods. See links at the end of this article for organizations and individuals involved in that effort, accessed here (https://createhealthyhomes.com/education/5g/#Resources_on_5G).

Another source of cellular deployment collected by the lay public has been organized by Prof. Dr. Magda Havas (https://magdahavas.com) in Ontario, Canada. Magda created the Global EMF Monitoring Network (https://magdahavas.com/5g-and-mm-waves/global-emf-monitoring-network-progress-report/) in 2021. Over 150 volunteers around the world follow a protocol to measure RF exposure in towns and cities with their RF meters. Data compiled by this group of volunteers is updated monthly on the Global EMF project's website. Follow their progress here (https://globalemf.net).

Strand-Mounted 4G and 5G Antennas Coming to a Neighborhood Near You

Cell carriers are using every avenue they can to deploy new 4G and 5G cell antennas in urban and suburban areas, resulting in what is termed "antenna densification" of cell service. Small cell antennas that transmit at power densities lower than legacy antennas (which are themselves spaced at one to one and one-half miles apart), are dropped into residential neighborhoods on light poles, traffic lights, buildings, electric transmission towers and utility poles. These small cell antennas are much closer together than the 1-1.5 miles between legacy antennas, often appearing every block or two. However, from the cell industry's perspective, siting small cell antennas on light poles, buildings and traffic lights requires permits, which are time consuming and provide avenues for citizen groups to protest deployment, which is the focus of our activists and advocates.

The cell industry has turned to manufacturers, such as CommScope (https://www.commscope.com/blog/2020/rolling-out-5g-with-outdoor-small-cell-strand-mounts/), to provide small cell antennas mounted on low voltage telephone and cable aerial wires that are mounted above ground on utility poles. This is a way to streamline and bypass the standard permitting process because utility poles and the lines they carry are already in place. Examples of strand-mounted cell antennas can be seen here (https://www.future-infrastructure.com/portfolio/wireless-4g-and-5g-2/) and here (https://www.montgomerycountymd.gov/cable/Towers/wireless-telecomm.html).

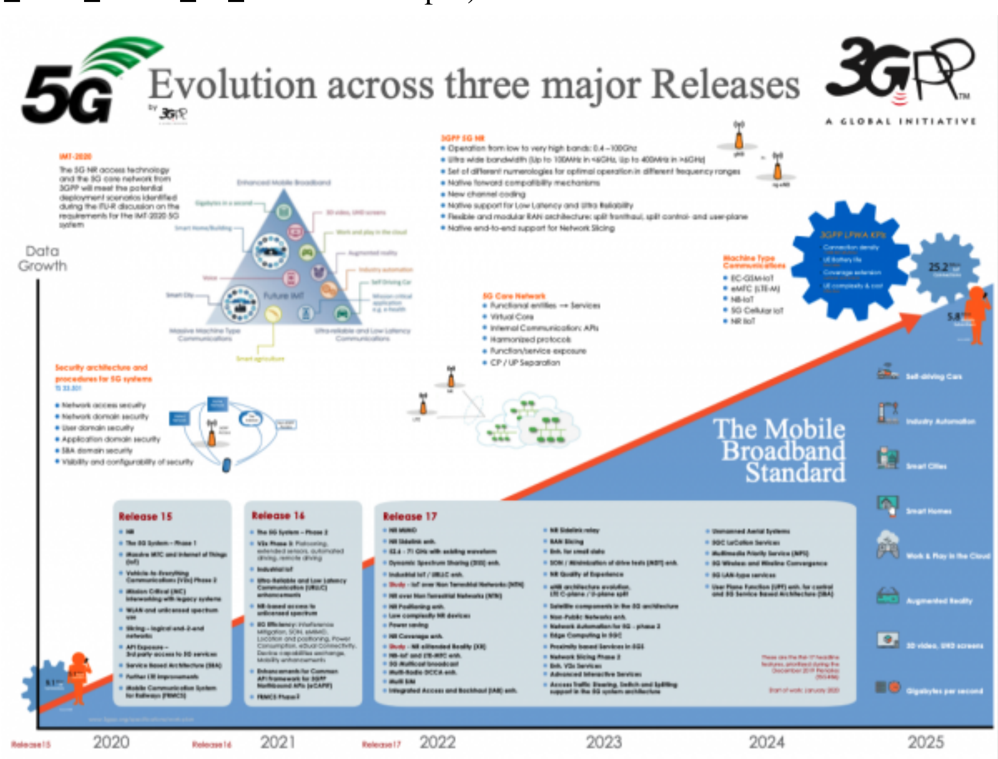
You can spot the rectangular cell antennas on these small cell strand mounts if you look closely. Plus, if the antenna is transmitting in the low and mid bands, whether using 4G or 5G technology, you will also be able to measure it with most RF meters, depending upon the precise frequency used and the frequency range your RF meter can pick up (see below).

How Do Cellular Engineers View "5G"?

Engineers who work in the cellular industry do not use the monikers "4G" and "5G" like the rest of us do. They leave that up to the marketing guys who sell their company's services to the general public. Cellular engineers and developers, on the other hand, speak in terms of Releases 15, 16, 17 and 18.

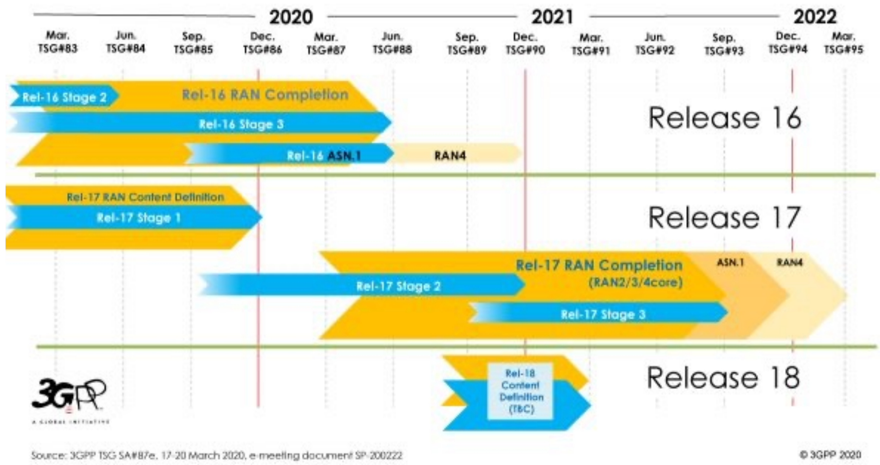
The Third Generation Partnership Program, or 3GPP, (https://www.3gpp.org) is a worldwide consortium of cell carriers from around the globe. It has been meeting since the 1990s to guide the industry in adopting technical standards to advance the performance of cellular devices and networks. At any given time, teams of committee members work on numbered releases who's publications are staggered as other guidelines are being worked on by other committees. If you want to know what the industry is planning for the future, this is where to look.

Below you will see a poster (https://createhealthyhomes.com/education/wp-content/uploads/sites/2/2022/03/Poster_2020_MWC_v6_OPTIMIZED-1.pdf) published by the 3GPP in 2020 summarizing their view of 5G and Releases 15, 16 and 17. This shows you how the cell industry understands 5G. Download it directly from the 3GPP.org website here (https://www.3gpp.org/ftp/Information/presentations/presentations_2020/Poster_2020_MWC_v6_OPTIMIZED.pdf).



As of early 2022, Releases 15 and 16 have already been published and begun to be adopted by the industry. Releases 17 and 18 are at various stages of development. Release 17 will be released this year (2022), while Release 18, which is being called "5G Advanced," will be released in 2023 and 2024.

Below you will find a flow chart published by 3GPP (https://www.3gpp.org/images/articleimages/Releases/graphic_version3_SP-200222.jpg) showing how releases overlap and are staggered.



Features of these Releases include all the technological advances listed at the start of this update. They also include topics such as security, industrial automation, artificial intelligence, machine-type learning, vehicle-to-everything connectivity, and private and public networks.

All of these technologies have potential biological implications that we must learn about. We must know the specific biological effects of each of the features listed in these releases, because these influence the technology that shapes and configures the RF signals being broadcast from modern day cellular radios and antennas.

Besides the information found on the 3GPP website (https://www.3gpp.org), you will find a good synopsis of Releases 17 and 18 from Ericsson by clicking here (https://www.ericsson.com/en/reports-and-papers/ericsson-technology-review/articles/5g-evolution-toward-5g-advanced).

Why Is Apple's New iPhone SE Not Carrying mmWave 5G Service?

Apple's new iPhone SE is designed for simplicity and affordability, costing less than half what a new iPhone normally costs. That means, its components are priced more affordably, including its antennas and processors. As such, it will not support mmWave service, which requires more costly components (it will also not support AT&T's new 3.45 GHz mid-band service).

This will mostly impact Verizon customers, but only for mmWave service, because the iPhone SE will connect to Verizon's (and AT&T's) new C-band service at 3.7 GHz, thus providing lower cost access to faster mid-band speeds. This shows Verizon's emphasis on its new mid-band presence, although they continue to roll out their mmWave service, as well.

Can We Measure 5G With Our RF Meters?

As I have written extensively before, we can measure some of the 5G frequencies available today while we are not able to measure others. This is simply due to the physics of the wavelengths and frequencies of radio waves.

If you look carefully at the range that your RF meter can measure and then pay close attention to the frequencies transmitted by each cell carrier for their 4G LTE and various flavors of 5G services, you will know whether your meter can measure a particular cell signal or not.

Most consumer-grade RF meters measure between 27, 200 or 800 MegaHertz (MHz) at the low end and 8 to 10 GigaHertz (GHz) at the upper end. Since no U.S. cell carrier transmits signals for consumer-grade cell service below 600 MHz, their low band 4G LTE and repurposed 5G cell signals in the low band between 600 and 1,000 MHz will be picked up by all RF meters that start lower than 800 MHz.

Gigahertz Solution's HF35C, which starts to measure RF frequencies at 800 MHz, however, will not measure T-Mobile's low band 4G signals, nor their 5G signals, at 600 MHz. Nor will the HF35C measure 700 MHz used for 4G by Verizon and AT&T.

Gigahertz Solution's HF38B begins at 700 MHz and should therefore pick up 700 MHz 4G from AT&T and Verizon, but not T-Mobile's 600 MHz 4G nor its repurposed 5G at that frequency.

Gigahertz Solution's HFE35C and HF59B RF meters start at 27 MHz, and will therefore pick up all low band 4G and 5G frequencies, as will most other popular RF meters on the market.

U.S. cell carriers transmit 4G LTE up to 2,500 MHz (2.5 GHz), which will be picked up by all popular RF meters.

As we get up into new 5G signals in the mid band at and above 2,500 MHz, however, those signals may not be picked up by some RF meters. To review, T-Mobile's mid-band 5G service is at 2.5 GHz, and Verizon and AT&T's new C-band service is at 3.7 GHz. AT&T's new mid-band acquisition, going live in 2023, is at 3.45-3.55 GHz.

The Safe and Sound Classic II and Pro II RF meters measure accurately up to 8 GHz, so they will pick up these frequencies easily. The Acoustimeter and

Acousticom2 will likewise pick up all mid-band 5G signals, as they also measure up to 8 GHz. The Cornet ED88t and Tri-Field TF2 should also pick up these mid-band 5G signals because they, too, reportedly measure up to 8 GHz and 6 GHz, respectively.

Finally, while the Gigahertz Solutions HF35C, HFE35C, HF38B and HF59B RF meters will measure T-Mobile's 2.5 GHz 5G service, because they measure up to 2.5 GHz (and really measure up to 3.3 GHz), those RF meters are not expected to pick up Verizon's and AT&T's C-band service at 3.7 GHz nor AT&T's new 3.45 GHz service.

Bear in mind that *none* of these RF meters can measure 5G service in the millimeter Wave (mmWave) band above 20 GHz. As I have written previously, we know of several meter manufacturers and individual engineers hard at work on developing affordable RF meters that can measure 28, 39 and 60 GHz signals, as well as other mmWave frequencies yet to be auctioned off by the FCC.

Spectrum analyzers sold by Viavi (https://www.viavisolutions.com/en-us), Rohde and Schwarz (https://www.rohde-schwarz.com/us/home_48230.html) and others are used by the cell industry to monitor their radios and antennas broadcasting in the mmWave range, but they retail for $35,000 to $85,000 each. Viavi's spectrum analyzer is shown at right. Several of us have demo'd them at the booths for these retailers at the Mobile World Congress America/Los Angeles (https://www.gsma.com/northamerica/gsma_events/mwc-los-angeles-2021/) 5G trade shows in Los Angeles in 2019. We were able to see the beacon signal on the spectrum analyzer at -60 to -70 dBm for Verizon's mmWave antennas mounted up in the rafters near the ceiling of the Los Angeles Convention Center. See this described above, with a photo of the display on the Viavi spectrum analyzer showing the beacon signal of Verizon's 28 GHz mmWave 5G antenna.

What Should We Be Paying Attention To Regarding Health Effects from Advanced Cell Technology?

As we focus on the impact that 5G technology has on our health, an important related question for all of us is, are we possibly focusing on a new generation of cell technology while ignoring the continued presence of and harmful impact from previous generations of cell technology that are still far more prevalent than we think? We rightly read and hear a lot about 5G, which is necessary to know about because of the detrimental biological impact that it produces. I praise the hard work of EMF activists and advocates around the world for bringing this important issue to the public's attention. They have certainly a great job, judging by the number of calls and emails I and my colleagues get on a daily basis asking about 5G. You can find a list of these organizations further down in this report, in the section entitled, "Resources on 5G," linked to here (https://

createhealthyhomes.com/education/5g/#Resources_on_5G) and from the last item on the Table of Contents to the left.

In addition, in my opinion, there tends to be a certain degree of genuine misunderstanding and confusion concerning what is truly going on with 5G. This is quite understandable because this is a vastly complex subject. Beam-formed signals in the mmWave band are very damaging to our health, to be sure, but they do not yet constitute the majority of cellular data or voice traffic and will not come close to being the majority type of signal for years to come, if ever. We need to keep in mind that mmWave signals realistically do not travel more than a block or two and are currently limited to downtown urban areas with a lot of foot traffic and surrounding areas (mainly from Verizon). Remember that mmWave antennas also only transmit when a 5G-enabled cell phone comes in front of them, and only in one 10 degree-wide zone at a time. Your house is therefore not being "blasted" with mmWave 5G signals, and it is quite likely your house does not even have a mmWave 5G antenna in front of it.

However, we now have the deployment of massive MIMO, beam-formed signals in the mid-band with the advent of C-band deployment by Verizon and AT&T in late January 2022, as well as MIMO, beam-formed mid band signals transmitted by T-Mobile at 2.5 GHz (initiated three years ago by Sprint). Both of these signals are more prevalent, are quite modulated, may be always-on, travel farther than mmWave signals, and can penetrate into buildings because of their longer wavelength (in contrast to mmWave signals, which, again, cannot pass through walls or windows). They are deployed on both legacy cell arrays located every 1-1.5 miles as well as on small cell arrays in residential neighborhoods.

C-band signals are turning out to be a game-changer for electrically hypersensitive (EHS) people in a not so helpful way, and will also impact the rest of us. Many EHS people have reported an increase in symptoms while traveling and living in their suburban and urban neighborhoods since the C-band was turned on in late January 2022. We can still shield C-band signals, perhaps somewhat more easily than lower frequency 4G and repurposed 5G signals due to the C-band's shorter wavelength. However, EHS people definitely notice it when they are outdoors, and even when indoors for some of them. This is disconcerting, and more C-band and other mid band deployment is coming in 2023 and 2024, as noted above.

What has been as significant a health risk in the past two to three years from what I have seen is the deployment of many more lower power small cell 4G LTE and low and mid-band 5G antennas in residential neighborhoods as part of "antenna densification". These small cell antennas are placed in between legacy, macro 4G LTE antennas, which broadcast at 800-1,000 Watts and are separated from each other by one to one and one-half miles. Legacy 4G LTE antennas will remain the backbone of the cellular network for all three main, established U.S. carriers for years to come.

These small cell antennas, on the other hand, broadcast at somewhat lower power densities and are intended to take the data load off of older, established legacy 4G antennas.

Small cell 4G/low and mid-band 5G antennas are located deep in residential neighborhoods, broadcasting at 100-400 Watts. I show two examples here in Los Angeles at right. These small cell antennas in front of people's homes wreak havoc on second floor bedrooms in the front of the house, where many of us have measured RF levels in the tens of thousands of microWatts/meter squared of RF power density, well above our acceptable RF levels for sleeping areas (https://createhealthyhomes.com/education/5g/#Resources_on_5G) of less than 10 microWatts/meter squared.

Both legacy, macro and small cell 4G LTE antennas are always-on and transmit fully across the entire 120 degree-wide space in front of them, not just in one 10-15 degree-wide zone, like on-demand mmWave 5G and higher mid-band antennas do.

Thus, in my mind and in the opinion of other consultants, small cell 4G LTE antennas that are dropped into residential neighborhoods in front of people's homes with strong always-on coverage can be as problematic as mmWave 5G antennas. And now, C-band and other mid band cell antennas are adding to that.

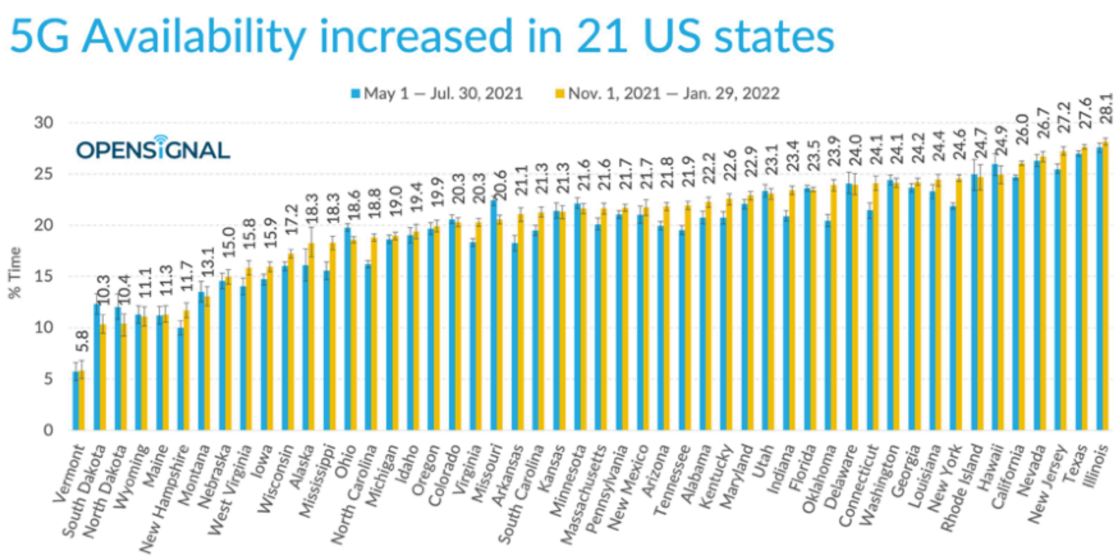
The bottom line is, cell antennas of *any* generation are all bad, but we should understand which type of antenna is located where and what frequency it is using to better understand potential adverse health impacts and how to shield against it, which I discuss further down in this article here (https://createhealthyhomes.com/education/5g/#How_Can_We_Protect_Ourselves_From_5G). Those parameters determine the characteristics of the signals being transmitted.

Electrically Sensitive People Retreating to Rural Areas for Protection

Many electrically hypersensitive (EHS) people are moving to rural areas because they are too symptomatic in urban and suburban neighborhoods. The cell industry puts cell antennas where customers are located. That is, after all, their business model. Most of the deployment of 5G in all bands as well as upgrades of 4G LTE are going into densely populated urban areas. mmWave signals, as you have learned, can only be received outdoors and so their antennas are being deployed where heavy foot traffic occurs, as well as inside public buildings. Mid-band deployment in the C-band and related frequencies are bringing beam- formed signals into suburban, residential neighborhoods.

Until now, EHS people have been able to retreat to rural areas to get away from most of this. However, the cell industry, having moved well along on their 5G deployment plans in urban and suburban areas, are now focusing on expanding Advanced 4G LTE and 5G coverage, in all bands, in rural areas. If you are EHS, you are probably still relatively safe out in the country, away from other people (except for the occasional legacy 4G/low-mid band repurposed 5G cell antenna that covers a large area). You will not have mmWave antennas out in the country.

To see which states have the least rural 5G coverage to date, go to Opensignal's March 10, 2022 article, "How the 5G experience has improved across 50 US states and 300 cities," available here (https://www.opensignal.com/2022/03/10/how-the-5g-experience-has-improved-across-50-us-states-and-300-cities). They say, "Smartphone users have a diminished 5G experience in sparsely populated U.S. states," and "we...once again found that our 5G users in sparsely populated U.S. states had a comparatively reduced 5G experience compared to our 5G users in more populated states." That included slower 5G download speeds and also a harder time finding a 5G signal. See the graph below.



Data collection periods: May 1 — Jul. 30, 2021; Nov. 1, 2021 — Jan. 29, 2022 | © Opensignal Limited

Opensignal does report "signs showing that U.S. carriers are planning to address the challenges of providing a good 5G experience in small rural states." However, that progress is spotty and not consistent, which is good news for EHS people. Read Opensignal's full report (https://www.opensignal.com/2022/03/10/how-the-5g-experience-has-improved-across-50-us-states-and-300-cities) to see the states where improvement in 5G coverage has not yet occurred, as well as in the graph above.

Pay Equal Attention to Wireless Devices In Your Home, Hand and Personal Space

Furthermore, more EMF consultants and advisors should, in my opinion, also mention the need to pay attention to the wireless device in people's hand, pocket, on their bedside table and so on when talking about 5G antennas outside their home. I am not being critical of the good work being done by activists, who work tirelessly to spread the word about these technologies. All who speak out in the EMF community and to family and friends deserve our praise for raising awareness of this issue.

I would only add, as I always have, that we need to *also* pay attention to the strong RF-producing devices we keep within our personal space that constantly transmit invisible, silent, and odorless radio frequencies that are just as harmful to our bodies at subtle and gross levels as signals from outdoor antennas.

What should we therefore focus upon as EMF practitioners and as the public at large? I would say, first, focus on what wireless devices they and their clients have in their pocket, hand, next to their head and inside their houses, in bedrooms, kitchens, at desks, baby's cribs, etc. If they are worried about 5G, make sure they also take care of all the portable devices they have in their possession. All those devices produce RF energy at higher levels than what comes into their house from outside.

Second, how close is their house to legacy, macro as well as repurposed small cell 4G LTE antennas on the street in front of their house or apartment? Right now, legacy and small cell 4G LTE antennas are quite problematic because they are always on and much closer to people's houses. Plus, all new, upgraded 4G LTE antennas transmit what is called, 4G LTE Advanced signals, which are far more modulated than they used to be. Finally, do they have any rectangular mid band and mmWave 5G antennas, whether strand mounted or pole mounted, near where they live, work or learn?

More modulated means how radio signals are generated within a cell antenna's radio and how they are transmitted, using technologies provided in industry Releases (15, 16, 17 and 18) meant to increase speed, reduce latency, and allow more slicing, optimization and automation of the processing of the signal. Cellular transmissions are more digitized and polarized than they used to be as a result.

EHS people were already reacting to this higher degree of modulation from 4G LTE and repurposed 5G antennas, which is a big problem, even before the C-band was turned on in early 2022.

I suggest that we not think in terms of the numbers 4G or 5G. I suggest we simply call them "cellular signals", or "4G/5G", stating that antennas are now more modulated than they were previously. If you can pick up a cell signal on your RF meter, it is 4G LTE, increasingly with some low and mid-band 5G mixed in. We must pay attention to both power density as well as the modulation of the signal, regardless of the signal strength. But in addition, your client needs to pay as much attention to the wireless devices in their pocket, hand, next to their head, and rooms inside their house as they do to outdoor cell antennas.

Links to Cell Industry Websites for Detailed Information, Blogs and Webinars

There are many valuable websites for learning the details of how the cellular industry plans to implement 5G technology and upgrade 4G LTE technology. You can sign up and attend one hour-long webinars, presented by many of the sites below, to deeply learn the details about the technology. You can also sign up to receive regular email updates from many of these industry news sources on the latest in the field, including webinar announcements. Here are sites that have been helpful for me to keep up with what is going on:

- FierceWireless (https://www.fiercewireless.com)
- POTs and PANs (https://potsandpansbyccg.com)
- Rohde & Schwarz (https://www.rohde-schwarz.com/us/home_48230.html)
- Viavi Solutions (https://comms.viavisolutions.com/subscription-preferences/)
- RCR Wireless News (https://createhealthyhomes.com/education/5g/#Links_to_4G_LTE_and_5G_Maps_for_US_Cell_Carriers)
- PCMag (https://www.pcmag.com/news)
- Opensignal (https://www.opensignal.com)
- Mobile World Live (https://www.mobileworldlive.com)
- 5G Americas (https://www.5gamericas.org)
- Qualcomm (https://www.qualcomm.com/news/onq)
- Nokia (https://www.nokia.com/about-us/newsroom/news-releases/subscribe-to-the-latest-nokia-news/)
- Small Cell Forum (https://www.smallcellforum.org)

Links to Educational and Activist Organizations on 5G

Links to websites of organizations that are educating the public and government officials about 5G can be found further down in this report, in the section entitled, "Resources on 5G," linked to here (https://createhealthyhomes.com/education/5g/#Resources_on_5G).

Sources of Information for This Update

Besides attending the last three Mobile World Congress America/Los Angeles 5G Conferences held in Los Angeles in the past four years (not held in 2020), I researched this information in trade publications and webinars sponsored by the 5G industry (presented in the list above). You will find specific references for the information in this update here (https://www.pcmag.com/news/the-iphone-se-steers-clear-of-atts-new-5g-band), here (https://www.fiercewireless.com/operators/how-s-5g-standalone-doing-u-s), here (https://spectrum.ieee.org/will-increased-energy-consumption-be-the-achilles-heel-of-5g-networks), here (https://www.fiercewireless.com/5g/t-mobiles-5g-head-start-shows-latest-opensignal-report), here (https://www.fiercewireless.com/wireless/t-mobile-stokes-mid-band-5g-coverage-rivalry), here (https://www.fiercewireless.com/5g/att-plans-deploy-345-ghz-c-band-one-climb-tower-strategy), here (https://www.fiercewireless.com/5g/verizon-ramps-c-band-speeds-massive-mimo), here (https://www.fiercewireless.com/operators/verizon-launches-dss-takes-center-stage-during-5g-iphone-launch), here (https://www.rcrwireless.com/20220310/business/t-mobile-us-says-almost-50-percent-of-traffic-is-carried-on-its-5g-network?), and here (https://www.fiercewireless.com/wireless/apples-new-iphone-se-offers-5g-sans-mmwave).

In addition, for a review of how the FCC is dominated by individuals who come straight from the industry they are tasked with overseeing, read Captured Agency: How the Federal Communications Commission is Dominated by the Industries It Presumably

Regulates, by Norm Alster and published by Harvard University (https://ethics.harvard.edu/files/center-for-ethics/files/capturedagency_alster.pdf).

(End of March 23, 2022 update.)

Links to 4G LTE and 5G Maps for U.S. Cell Carriers

*Here are links to **4G LTE/5G maps** for the three major U.S. cell carriers, **T- Mobile**, **AT&T**, and **Verizon** (T-Mobile merged with Sprint in April 2020), as well as **US Cellular**, plus a word about **Dish Networks's** cellular network deployment (this information is updated as of March 24, 2022):*

To see a map of **T-Mobile's** 4G LTE and 5G service, click here (https://www.t-mobile.com/coverage/coverage-map). T-Mobile's "5G Ultra Capacity" coverage is their own millimeter Wave (mmWave) service that they installed in 2019 in downtown areas of six major cities, plus the much more extensive mid band 2.5 GHz 5G service they inherited from Sprint when they merged with them in April 2020. Both are beam-formed signals, but only the 2.5 GHz signal, with a wavelength of 5 inches, can get through walls and windows (the beam-formed millimeter Wave signal with a wavelength of one-half inch, however, cannot). They call it, "A more reliable connection in crowded locations", meaning, they put these 5G Ultra Capacity antennas in urban areas where there is a lot of foot traffic. That is in dark purple on the map, concentrated in denser parts of cities and surrounding suburbs. However, you cannot tell which antennas are broadcasting in the mmWave band, at 28 and 39 GHz, and which are in the mid band at 2.5 GHz. You can look at an archived view of T-Mobile's website's coverage map from 2019 to see the relatively small extent of their mmWave 5G coverage in parts of downtown Los Angeles, New York, Cleveland, Las Vegas, Dallas, Cleveland and Atlanta by clicking here (https://web.archive.org/web/20201031234834/https://www.t-mobile.com/devices/samsung-galaxy-s10-5g?filter=view-all). I checked back to that page several times during 2019 and 2020 and saw no change in T-Mobile's mmWave coverage maps until they merged with Sprint in April 2020, likely due to a focus on their Nationwide low band 5G rollout at 600 MHz. Thus, we do not know if T-Mobile put up more mmWave antennas in those six cities or anywhere else beyond the coverage you see in these archived 2019 maps. (Update 3/24/22: T-Mobile is now extending their mmWave, beam- formed 5G service beyond limited service in downtown areas of six cities.) The bulk of their 5G Ultra Capacity today is likely their 2.5 GHz coverage (although mmWave service is now also included in more areas). T-Mobile's 2.5 GHz 5G service is more extensive than its mmWave 5G service and has properties of cell signals in the mid band, not the high band, (farther reach, passes through walls and windows), however, it does also use beam-formed massive MIMO (Multiple Input, Multiple Output) antennas arrayed as 8X8, just as they use for mmWave service above 20 GHz. Next, T-Mobile's "5G Extended Range", available throughout suburbs and rural areas in most of the rest of the country, is medium pink on their current map. This is their repurposed use of their 600 MHz 4G LTE signal, and represents only a slight increase in speed over standard 4G LTE service at that frequency. They say it is available “indoors and out”, as signals at 600 MHz have a wavelength of about 15 inches and easily go through walls. Download speeds are “Faster than 4G LTE speeds in more places.” The signal is not beam-formed, but it is always on and somewhat more modulated than older 4G LTE. However, bear in mind that all 4G LTE antennas are being upgraded to “Advanced 4G LTE”, which is itself more modulated than previous 4G LTE broadcast technology, and therefore more potentially harmful to us. T-Mobile’s 5G Extended Range and 4G LTE signals are always on, broadcast from traditional legacy cell towers as well as newer small cell antennas that are now closer to homes in residential neighborhoods.

To see **AT&T’s** 4G LTE, 5GE and 5G+ coverage map, click here (https://www.att.com/maps/wireless-coverage.html). What is listed on their coverage map as “5G” in lighter blue is their repurposed 4G LTE 850 MHz signal. This is extensive throughout the country but is only slightly faster than 4G LTE. Like T-Mobile’s “5G Extended Range” service, AT&T’s “5GE”, as it appears on your phone, is a non- beam-formed signal that is, however, more modulated than older 4G LTE (and is like the Advanced 4G LTE that existing 4G LTE transmitters are being upgraded to). AT&T’s millimeter Wave 5G service, on the other hand, called “5G+”, which is now available to all of their customers since April 2021, is now available in “select high-speed zones and venues in over 20 states across the U.S.”, according to their website. This means in certain cities as well as inside convention centers, sports arenas and stadiums in the downtowns of certain major cities as well as a growing number of airports. (That would be parts of downtown Los Angeles, West Hollywood, in Dodger Stadium and in San Diego for those of you in Southern California, and in parts of Menlo Park, Oakland, Redwood City, San Bruno, San Francisco, San Jose and in Oracle Park in Northern California.) This is seen as an emblem that looks like a “+” sign inside a circle on their coverage map. To see a list of those cities that have coverage, go to their coverage map. You will see a box in the upper left corner labeled, “Wireless coverage”. In the lower left corner of the box, you will see “5G+ Available”. A pop-up box will appear labeled, “Available high-band *5G+* venues” that lists states. Click on a state to see a list of cities, then click on the city to see the venue(s) within it that have AT&T’s 5G+ service. There are 22 states listed as of March 2022 (up from 16 states as of November 2021). You will also see these circles with a “+” sign inside of them show up in these 22 cities as you zoom into the national map. Click on the emblem to see the exact location and name of the venue. Venues appear to be sports arenas, convention centers and airports.

To see **Verizon’s** 4G LTE and 5G service map, click here (https://www.verizon.com/coverage-map/). Verizon calls their millimeter Wave 5G service “5G Ultra Wideband”, which is “Available outdoors” in almost ninety cities (as of March 2022), seen on the map with glowing black dots. You used to be able to zoom in on any city with a glowing dot to see street coverage of their mmWave antennas, shown as black-lined portions of streets. However, with Verizon’s launch of their mid-band C-band 5G coverage in late January 2022, they now include their C-band service with their mmWave service in their “5G Ultra Wideband” coverage. In those cities that allowed the first tranche of C-band coverage, you now only see a wide swath of red to indicate this 5G Ultra Wideband mmWave and C-band coverage, meaning, you cannot distinquish between C-band and mmWave antennas and can no longer see mmWave antennas on individual streets. However, in those cities that are not in the first tranche of C-band coverage, like Denver and Atlanta, you will notice that you can still see only mmWave antennas as dark red lines on portions of certain streets, which is helpful for EHS people to know where to avoid. You can also tell which cities have C- band coverage in this first tranche, and which do not. Those with C-band coverage have a large swath of deep red with a glowing red dot in the middle of it, while those cities that do not have C-band coverage yet only have a single glowing red dot with no swath of red around it. (That will change in 2023 and 2024, when the second tranche of C- band service is released for Verizon and AT&T.) In addition, Verizon also now has its own "5G Nationwide" service, which they say, "Includes 4G LTE coverage" and like their competitors, is repurposed 4G. Verizon repurposes their 850 MHz signal for their "5G Nationwide" service. Where 850 MHz is not available, they use their 1,900 MHz PCS signal and their 2,100 MHz AWS signal. None of these repurposed 4G signals for Verizon's "5G Nationwide" service are beam-formed. Verizon has the most extensive mmWave coverage of any company and they are pouring millions of dollars into expanding it. They went from 70 cities in autumn 2021 to almost 90 cities by March 2022. I noticed this service spreading into suburbs of the cities they cover (when I could see only the mmWave antennas in all cities they cover). However, remember, Verizon's mmWave coverage is only available outdoors (mmWave signals cannot easily penetrate through walls or windows) and it is weaker than all 4G LTE signals or 5G signals in the low and mid bands (with their new C-band service), meaning it only realistically extends a block or two and is easily blocked by buildings. We have learned that mmWave 5G antennas sit idle except when a customer with a mmWave 5G-enabled Verizon phone walks or rides in front of it, and then, the beam-formed signal is only beamed into one ten degree-wide zone at a time among the 8-10 zones in front of each mmWave 5G antenna as the person walks/rides from zone to zone. The mmWave antenna then reverts back to idle mode when that person walks or rides through its service area, only sending out a beacon signal at -65 to -70 dBm, equivalent to roughly 0.1 microWatt/meter squared. (Your cell phone in your pocket regularly puts out hundreds of thousands to millions of µW/m2 at close range, which is very harmful, and we routinely measure 5 to 50 µW/m2 or more of RF exposure on people's lawns from distant 4G LTE cell towers, much stronger than the 0.1 µW/m2 emitted by an idle mmWave 5G antenna.) To be sure, millimeter Wave 5G signals are certainly harmful, more-so than 4G LTE, but please be aware of the physics regarding precisely how it actually works along with where it is available, and where it is not. We recommend that we think of this whole topic as combined "4G/5G", taking into account the harm from all generations of technology and frequencies.

Two more cellular networks exist in the U.S. The first is US Cellular (https://www.uscellular.com), with coverage in the Midwest and mid-Atlantic states. They partner with another network for customers to have coverage outside their primary service area. Their 4G/5G coverage map is available here (https://www.uscellular.com/coverage-map). They say, "UScellular® 5G uses a spectrum that isn't blocked by walls or barriers the way other carriers' 5G can be." That means to me that they are not using millimeter Wave frequencies, which are blocked by walls and windows, but since they also say, "UScellular 5G is so much faster than today's 4G it virtually eliminates latency, responding in what seems like real time", that probably means they are using mid band frequencies for their 5G, such as 2.5 GHz. Those signals are beam-formed.

Finally, Dish Network (https://www.dishwireless.com/home) is building out their new cellular network, advertising themselves as "America's first cloud-native 5G network." The FCC required the development of a fourth cellular network in the U.S. as a condition for allowing the T-Mobile/Sprint merger to take place in 2020. Dish has a deadline to build out their network, and they are using all new 5G-compatible technology for their cellular radios and antennas, including full Standalone (SA) 5G technology. They plan to cover 70 percent of the U.S. population by June 2023, starting with a beta test network in Las Vegas. Read about their progress here (https://www.theverge.com/2021/8/9/22617029/dish-network-5g-las-vegas-wireless-service-beta). They will use AT&T and T-Mobile's networks in the meantime as they build out their own network of antennas, bringing us back to four national cellular networks.

(End of cellular coverage map links for the U.S.)

To read the remainder of this 5G article, please go to https://createhealthyhomes.com/education/5g/ .