A Review of 5G

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Source of this Knowledge

- Cellular industry trade shows that I have attended
- Cellular industry articles and webinars
- EMF and 5G community activists and advocates
- This lecture complements, clarifies and expands upon the important information presented by EMF/5G activists
- More in 57-page online 5G course on Building Biology Institute website, https://buildingbiologyinstitute.org/course/electromagnetic-radiation/5g/
- Also 5G article on my website, www.createhealthyhomes.com/education/5g

The Problem

Here are components that make dealing particularly with RF such a difficult problem, as I see it:

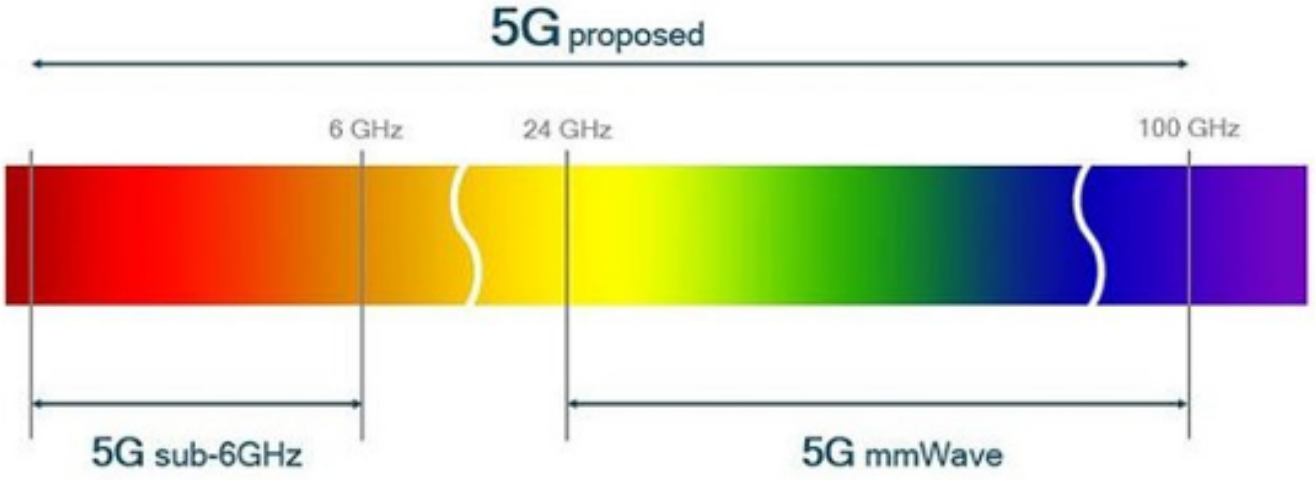
- RF fields created by wireless devices and technologies are invisible, silent and odorless, unlike cigarette smoke
- Most people want convenience of portability and love ability to instantly connect with information and other people
- The cell/wireless industry makes *a lot* of money
- Industry controls flow of information and regulation of health effects on federal, state and often, local level
- Most people do not feel harmful effects of RF

Overview of 5G

- "5G" stands for cell technologies deployed between 2018-2028
- 5G found in low band (600 MHz–1 GHz), mid band (1–6 GHz) and high, millimeter Wave (mmWave) band (above 20 GHz)
- Only slightly faster data download speeds than 4G LTE in low band
- Ten times faster than 4G LTE in mid band, 20 times faster in mmWave band
- 5G in mid band at 2.5GHz, 3.4-3.5GHz (CBRS) & 3.5-3.7GHz (C-band)
- Fifth (5) Generation often confused with unlicensed 5.8 GHz band
- 2.4 and 5.8 GHz provided by FCC to wireless industry as unlicensed frequencies for Wi-Fi, Bluetooth and cordless telephone service

Components of 5G NR (New Radio)

- Deployment of 5G in sub-6 GHz low and mid band frequencies
- Repurposed 600 & 850 MHz 4G LTE frequencies in low band
- T-Mobile acquired Sprint's 2.5 GHz mid band frequency
- New deployment at 3.4-3.7 GHz (CBRS & C-band)
- New use of 24, 28, 39 GHz (and higher) frequencies for 5G
- So-called "millimeter Wave" (mmWave) band or high band



https://appleinsider.com/articles/19/05/01/what-is-5g-and-mmwave-and-when-will-you-be-able-to-realistically-use-it

Main Points of 5G NR

- 5G increases capacity of crowded 4G LTE cellular data networks
- Currently, 4G LTE data usage doubling every two years
- Increasing capacity by:
- Installing small cell antennas in between legacy, macro towers — in residential neighborhoods
- Current cell phones provide 5G cell service through repurposed spectrum in low band and new service in mid and high, mmWave bands
- Low band 5G service is only slightly faster than 4G LTE
- Mid band and mmWave 5G service 10 to 20 times faster than 4G

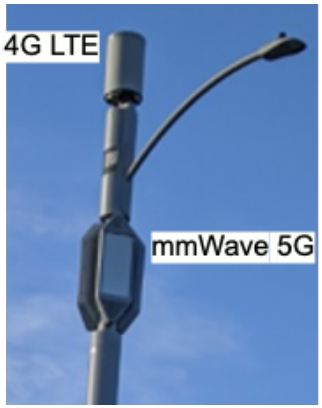
Main Points of 5G NR

- Greatest concern in EMF community is 5G in mmWave band
- Primarily deployed in urban areas with high population densities
- Found in stadiums, arenas, downtown streets, metro stops, airports, college campuses, office complexes – areas with high foot traffic
- Spreading into suburbs
- mmWave 5G reception *only* reliable outdoors
- mmWave coverage from outside very poor to non-existent indoors
- mmWave repeaters needed inside buildings for indoor coverage
- Now have massive expansion of mid band 5G antenna networks with C-Band service at 3.5-3.7 GHz, including private enterprise networks
- CBRS at 3.4-3.5 GHz coming later in 2023

Main Points of 5G NR

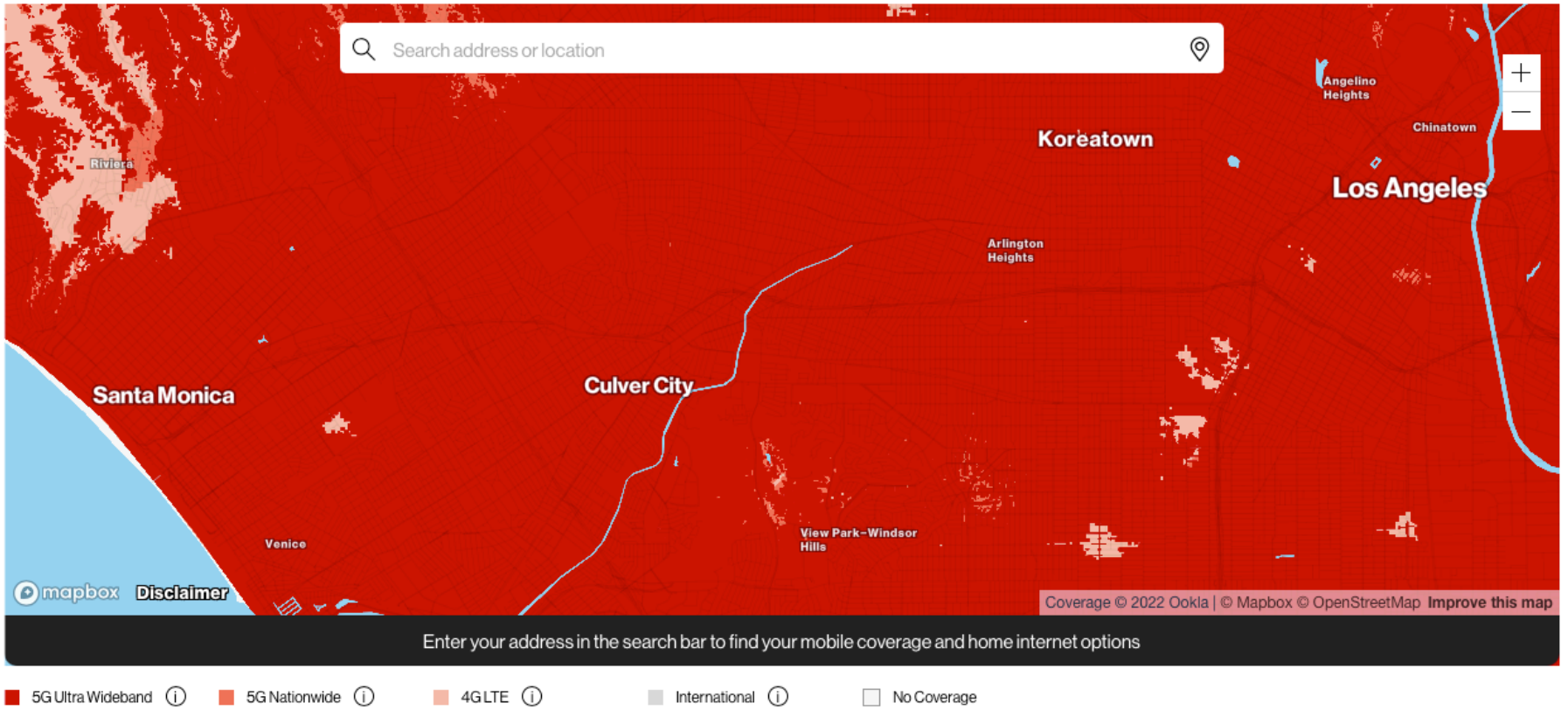
- Existing 4G LTE macro "tall" cell antenna arrays located 1-1.5 miles apart
- Carriers upgrading existing 4G LTE radios and antennas at macro cell arrays
- Advanced technology – more modulated
- Adding small cell 4G LTE Advanced radios and antennas in residential neighborhoods
- 4G and 5G technology together on small cell antennas, and macro sites
- Expect massive antenna densification

connectedremag.com



Main Points of 5G NR

- mmWave 5G not a "coverage spectrum"
- Supplements low and mid band 4G LTE and 5G network
- mmWave 5G on streets in urban neighborhoods in several dozen cities
- 4G/5G coverage maps at https://createhealthyhomes.com/education/5g/



Verizon's 4G/5G coverage in Los Angeles

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5G Coverage by Carrier

- **Low band 5G** (600 MHz t0 1 GHz) — *repurposed* 4G LTE:
- T-Mobile at 600 MHz for 200 million customers
- AT&T's "5GE" (Enhanced) at 850 MHz for majority of customers
- Verizon's "5G Nationwide" at 850 MHz for majority of customers
- **Mid band 5G NR** (1-6 GHz):
- T-Mobile at 2.5 GHz (inherited from Sprint with merger in April 2020)
- 3.4-3.5 GHz CBRS and 3.5-3.7 C-Band — all three carriers (Verizon, T-mobile, AT&T)
- Verizon's CBRS service called "5G Ultra Wideband" (along with mmWave service)
- **High, mmWave band 5G NR** (28 & 39 GHz):
- Verizon's "5G Ultra Wideband" service — combined CBRS and mmWave, in more than 100 cities covering 175 million people — to be nationwide in Q1 2023
- T-Mobile's "5G Ultra Capacity" service — combined 2.5 GHz and mmWave
- AT&T "5G+" in 19 cities — mostly sports arenas, stadiums and airports

Main Points of 5G NR

- 4G LTE — emits continuous, *always on* RF signal
- 4G power density up to 800-1,000 Watts of Effective Radiated Power (ERP) from existing macro cell sites, located1-1.5 miles apart
- New 4G/5G small cell antennas in residential neighborhoods use lower power of 10-400 Watts ERP
- But located only 30-100 feet from houses
- High RF levels measured inside nearby homes — 10,000s to 100,000s $\mu W/m^2$

https://www.change.org/p/april-barker-stop-5g-bellingham

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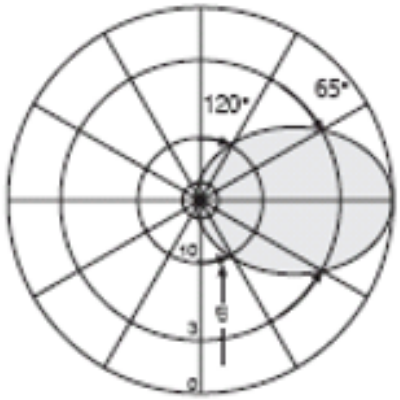
Main Points of 5G NR

- mmWave 5G signals *on-demand* & narrow signal
- mmWave 5G signals must be beam-formed to pass through standard building materials, due to short wavelength — very little RF passes through
- mmWave 5G (and 4G) signal 120 degrees wide
- Sliced into 10-12 horizontal zones (mmWave only)
- Each zone only 10 degrees wide
- Only one zone turns on at a time for each phone
- mmWave antennas idle until 5G-enabled phone comes in front of it and activates connection
- mmWave 5G signals do not sweep neighborhoods with constant, full-strength signal (4G, low/mid band 5G does)
- mmWave 5G only deployed on certain streets near city's downtown, but spreading into suburbs — mostly Verizon



Horizontal Pattern

Vertical Pattern

https://en.wikipedia.org/wiki/Sector_antenna

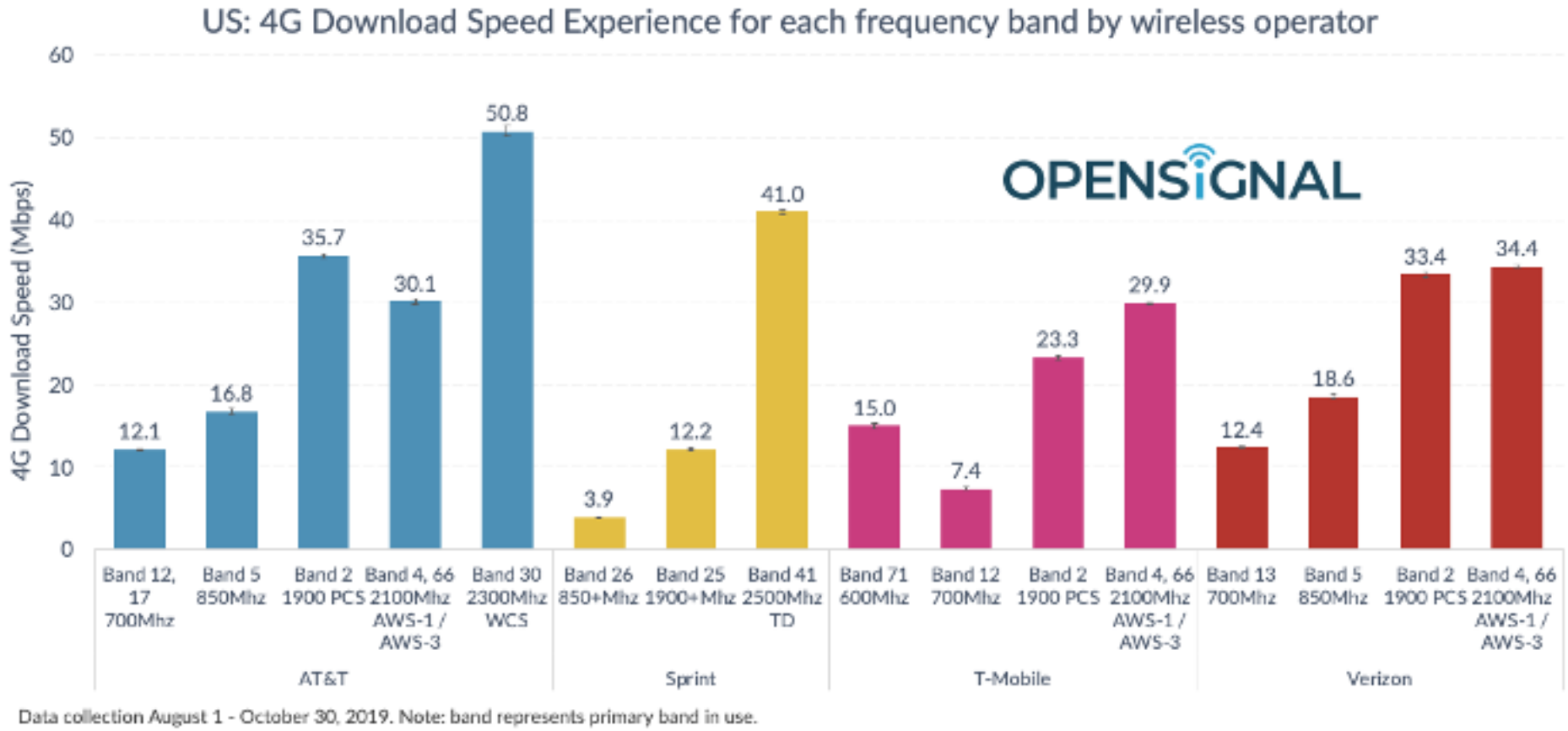
Broadcast pattern of 4G LTE & low and mid band 5G cell antenna

Main Points of 5G NR

- 5G primarily data connections, not voice (but VoNR coming)
- mmWave 5G connections not sustainable indoors (from outdoors)
- Indoors, most cell phones connect to WiFi, 4G LTE and low/mid band 5G, not mmWave 5G, for data connections inside residences
- mmWave 5G used for data connections while outdoors
- Existing 4G LTE data download speeds generally 12-50 Mbps
- Low band 5G download speeds marginally faster (3X)
- Mid band 5G speeds approach 250 Mbps (5 to 10 times faster)
- High band mmWave 5G speeds measured at 600-1,000 Mbps, outdoors in downtown urban areas with high foot traffic

Characteristics of 5G Usage in U.S.

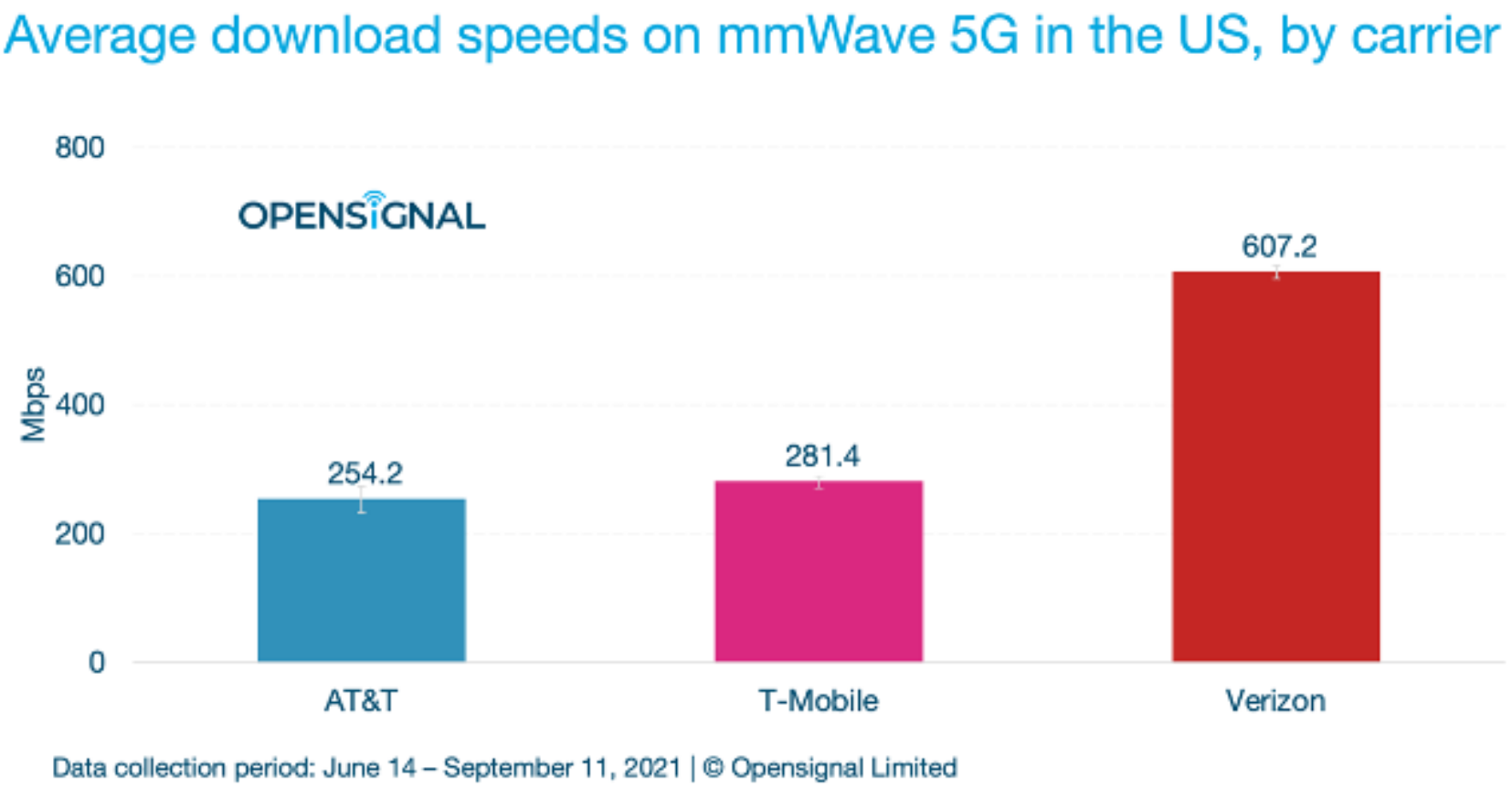
- Start with 4G LTE data download speeds
- Varies from roughly 12 to 50 Mbps
- T-Mobile merged with Sprint in April 2020



https://www.opensignal.com/2019/12/06/why-us-carriers-have-an-insatiable-appetite-for-new-spectrum

Characteristics of 5G Usage in U.S.

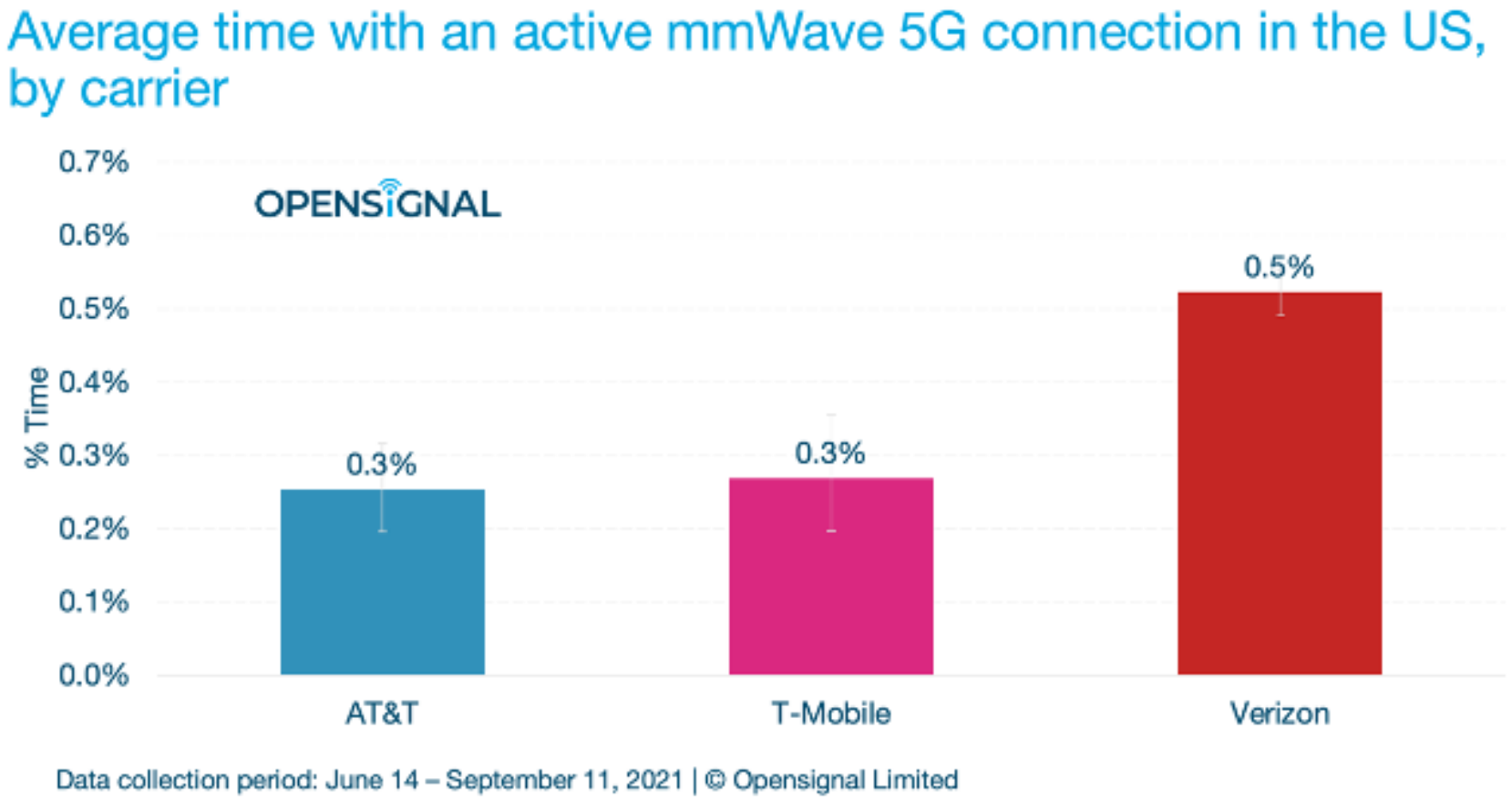
- mmWave download speeds 10-30 times faster than 4G LTE
- Verizon leads other carriers



https://www.opensignal.com/2021/10/14/quantifying-the-mmwave-5g-experience-in-the-us-october-update

Characteristics of 5G Usage in U.S.

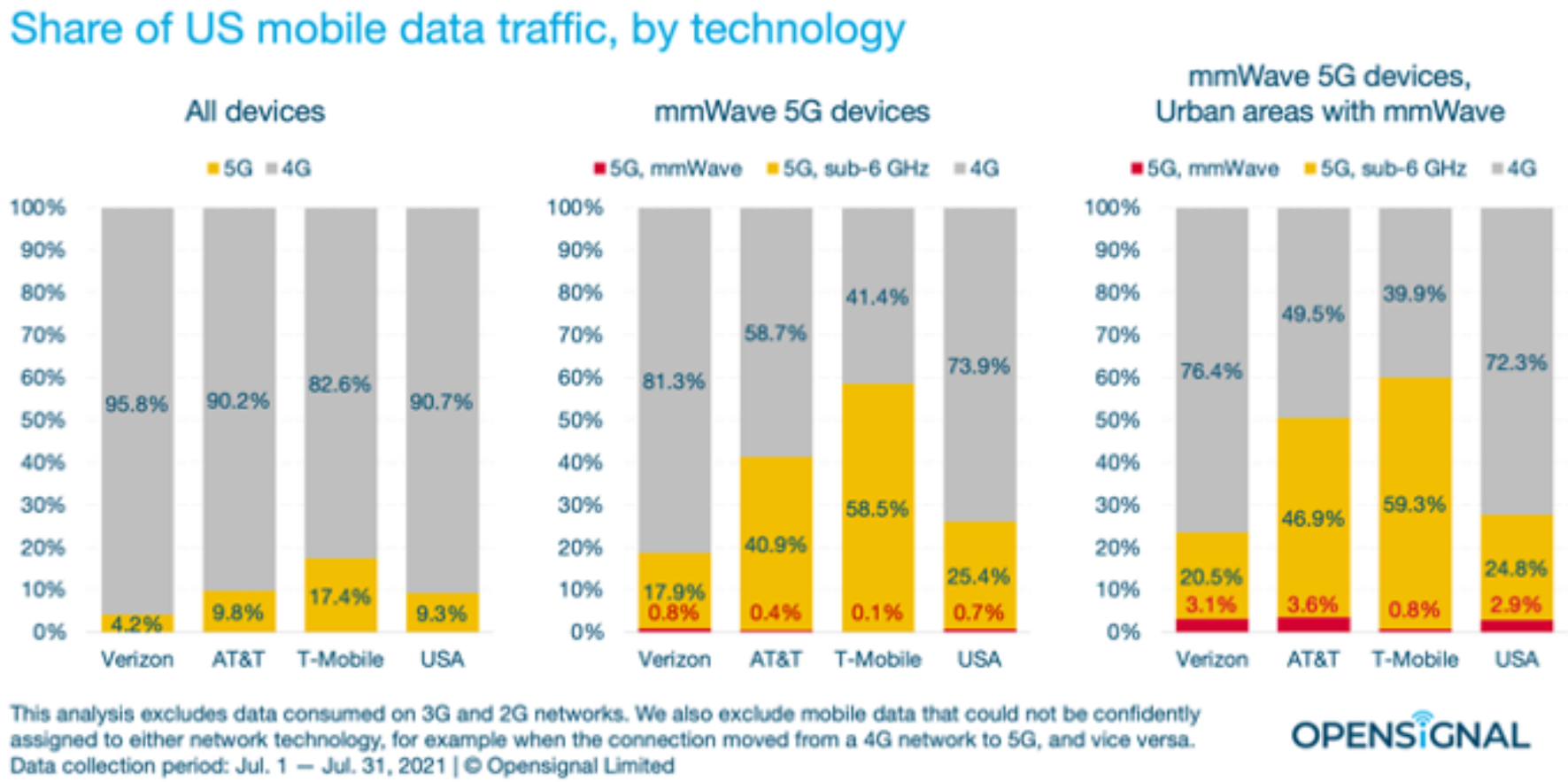
- However, 5G mmWave service less than 1% of cellular connections
- mmWave 5G service only available in urban and suburban areas



https://www.opensignal.com/2021/10/14/quantifying-the-mmwave-5g-experience-in-the-us-october-update

Characteristics of 5G Usage in U.S.

- 5G includes low, mid and mmWave band
- 4G LTE still dominates
- Most 5G is sub-6 GHz (low and mid bands)



https://www.opensignal.com/2021/09/22/mmwave-5g-provides-a-big-capacity-boost-to-us-users-in-high-traffic-areas

Physics of mmWave Band

mmWave (>20 GHz) spectrum currently used by:

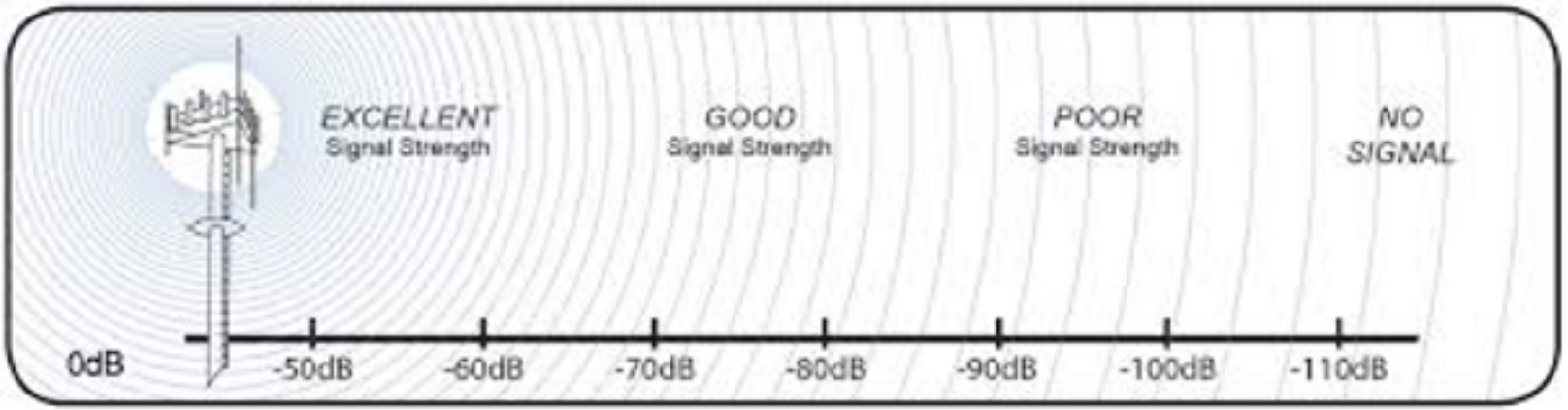
- Satellite TV, radar, military, aviation
- Massive, unused bandwidth available in mmWave band (above 20 GHz)
- Very short wavelengths, only 5-10 millimeters long (less than ½ inch)
- Cell signals in low and mid bands, by contrast, have longer wavelengths – 15 to 3 inches, which easily pass through walls and window glass

smart aerials.co.uk

airlive.net

Physics of mmWave Band

- Industry favors sub-6 GHz (low & mid) bands
- Mid band is "sweet spot" – higher speed than 4G LTE, farther distances than mmWave, can pass through walls and enter buildings (mmWave cannot)
- Low and mid band signals travel for miles – considered "coverage spectrum"
- Yet, data transmissions not as fast as in mmWave band
- Data download speeds only marginally faster with 4G LTE Advanced and low band 5G than existing 4G LTE



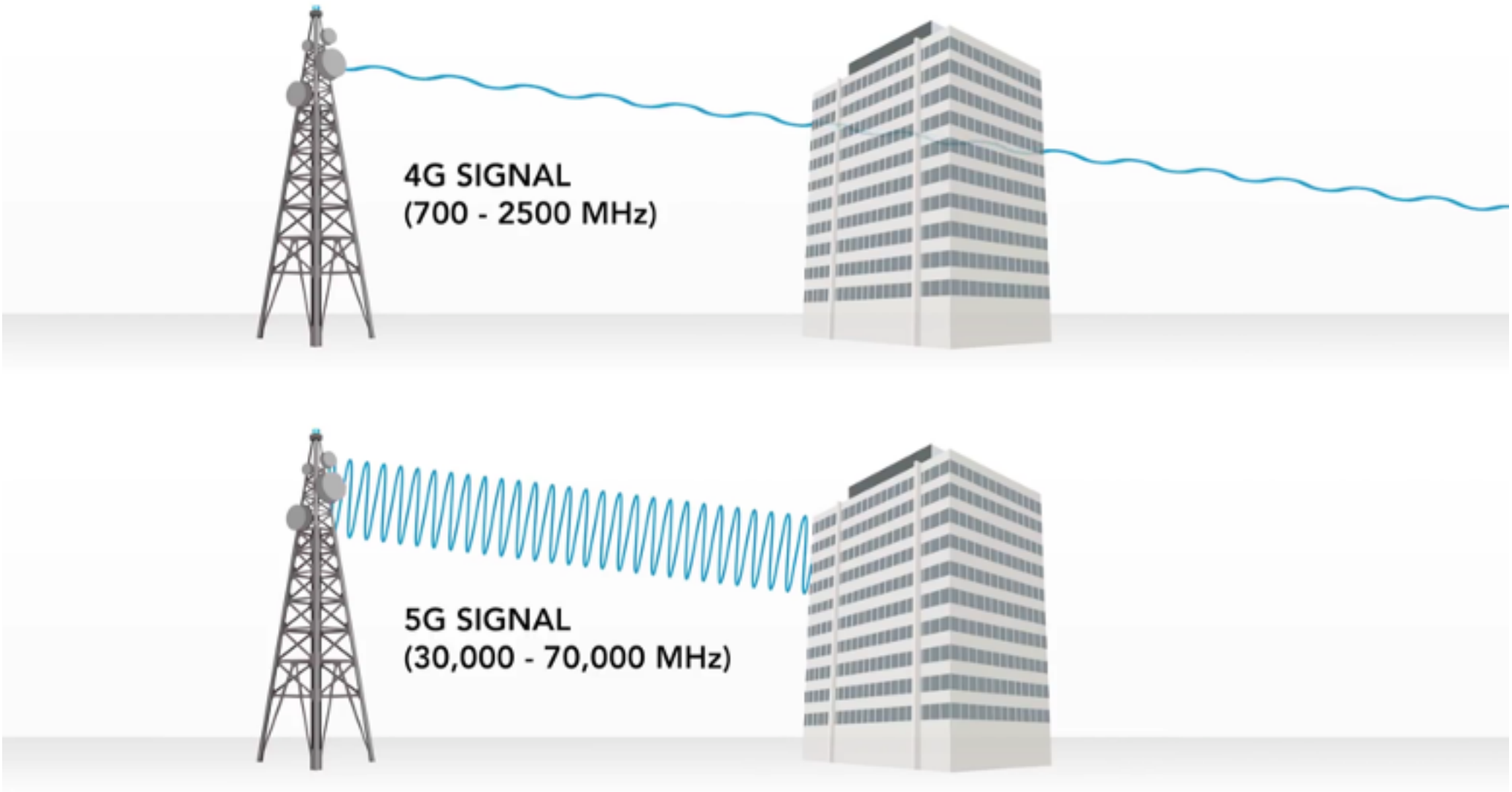
cellphonesignalbooster.us

Physics of mmWave Band

Physics continued:

- mmWave signals above 20 GHz easily blocked, slowed and scattered by standard building materials: wood, brick, stucco, Low-E and regular window glass
- Also blocked by leaves, rain, air molecules, user's body
- Full mmWave 5G signals only travel effectively for 300 feet (one or two blocks) – have decreased data reception out to 1,200 feet
- mmWave signals provide much faster data download speeds, greater bandwidth and lower latency (more real-time)
- Yet covers much smaller area than 4G LTE and 5G in low and mid bands (1-2 blocks vs. many square miles)

Physics of mmWave Band



technoupdate88.com

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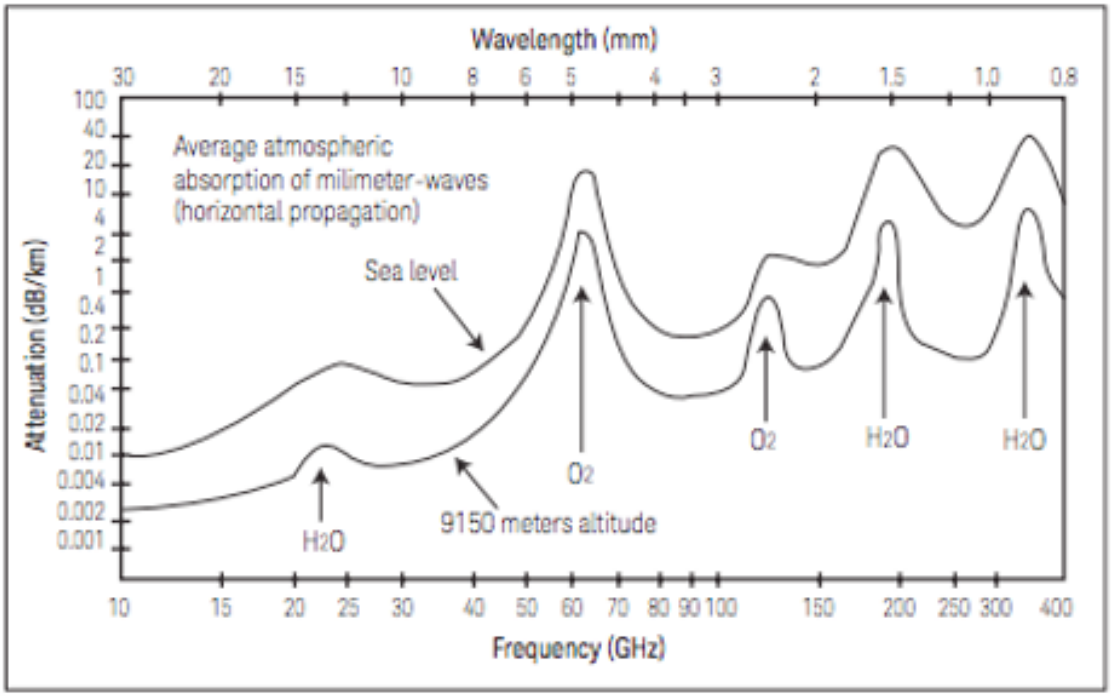
Physics of mmWave Band

- Water vapor blocks ("attenuates") RF at 23-24 GHz
- Oxygen strongly attenuates RF at 60 GHz (new WiFi band)
- Air at sea level attenuates RF at all frequencies more than thinner air at higher altitude of 9,150 meters (5.7 miles)



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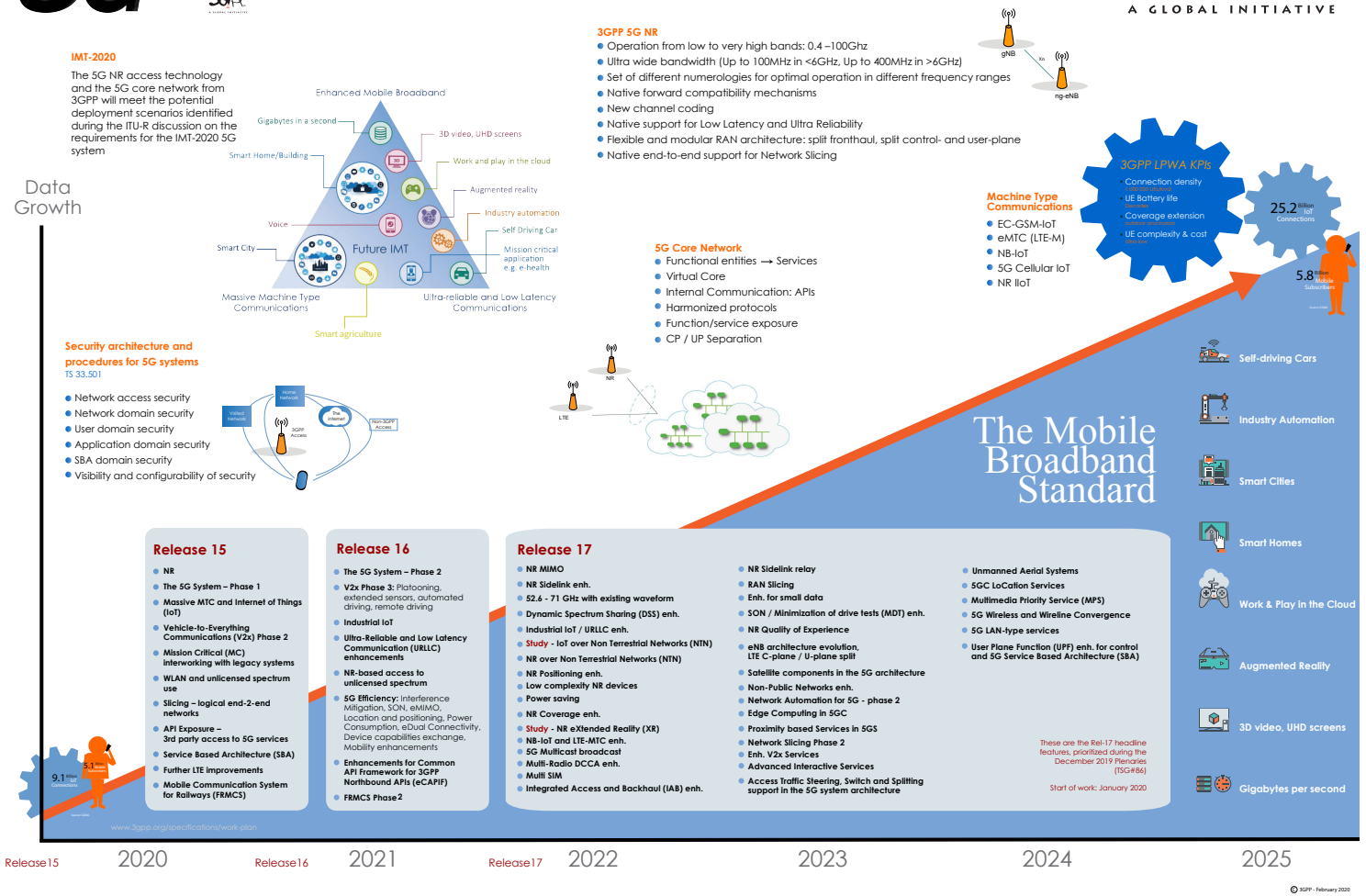
Industry Led by 3GPP

- Third Generation Partnership Program (3GPP) determines technical direction of worldwide cellular industry
- www.3gpp.org
- Established in 1996

5G by 3GPP Evolution across three major Releases

3GPP A GLOBAL INITIATIVE



https://www.3gpp.org/ftp/Information/presentations/presentations_2020/Poster_2020_MWC_v6_OPTIMIZED.pdf

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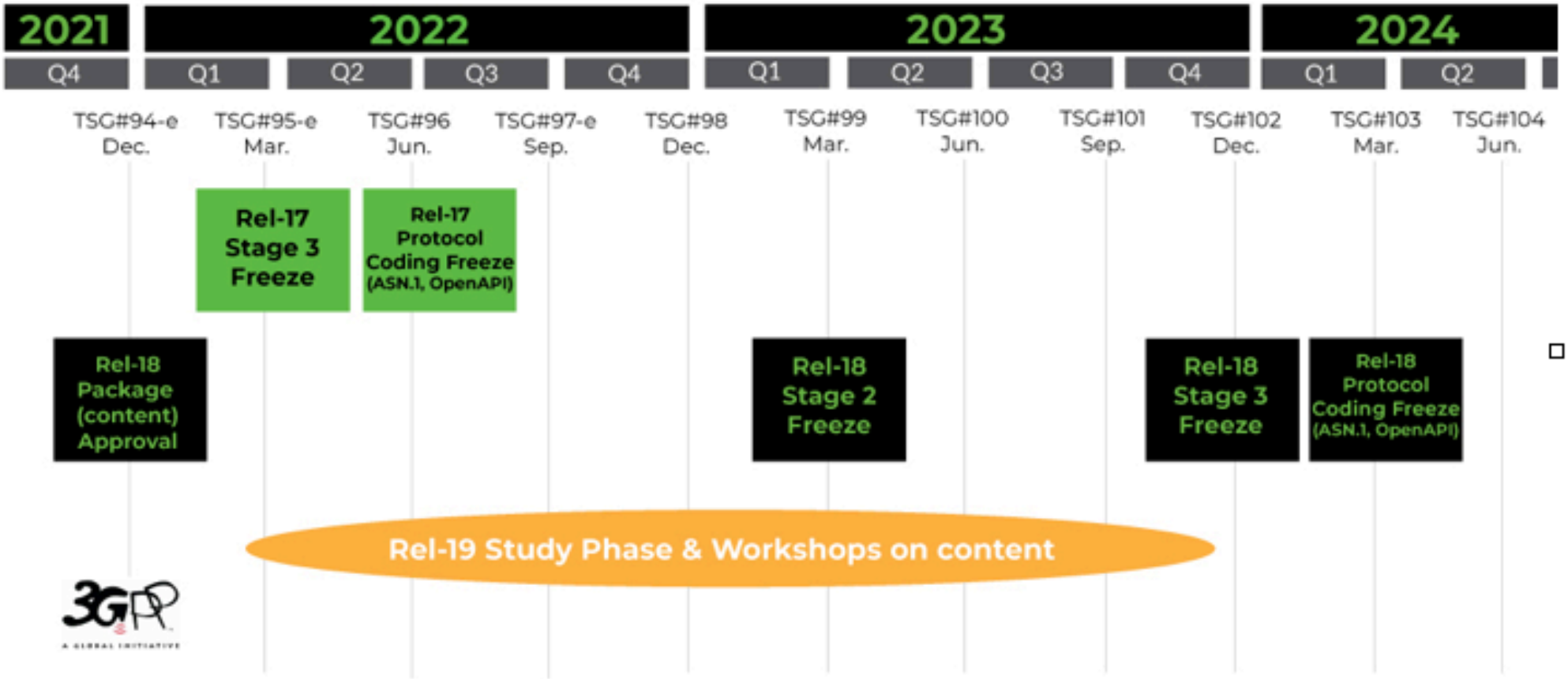
Timeline of 3GPP

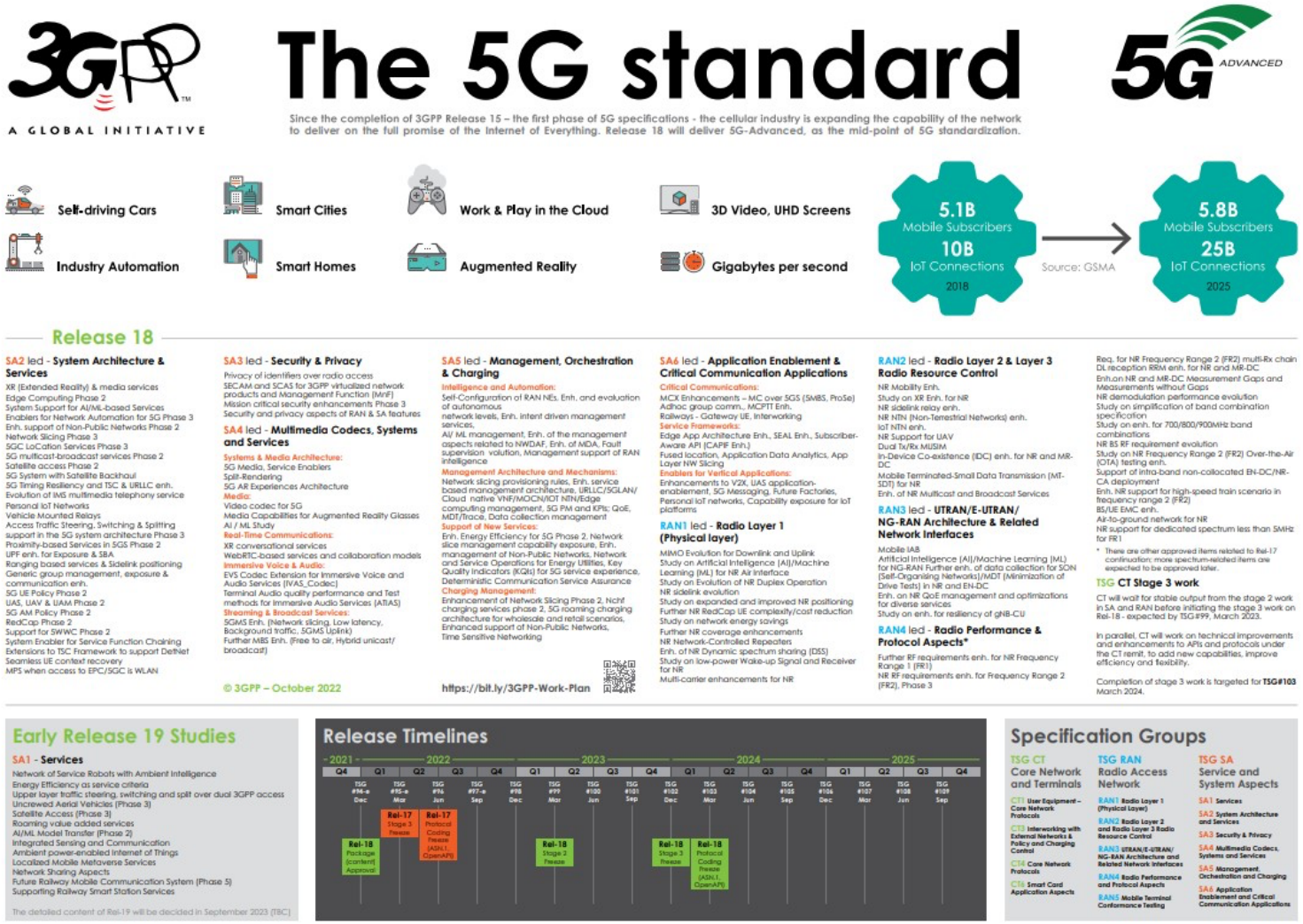
- Work is done by committees on separate tracks simultaneously
- Releases 15, 16 and 17 already implemented



https://www.3gpp.org/specifications-technologies/releases

Timeline of 3GPP

- Work continues on Releases 18 and 19



https://www.3gpp.org/specifications-technologies/releases/release-18

New Technologies Used by 5G

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New Technologies used by 5G

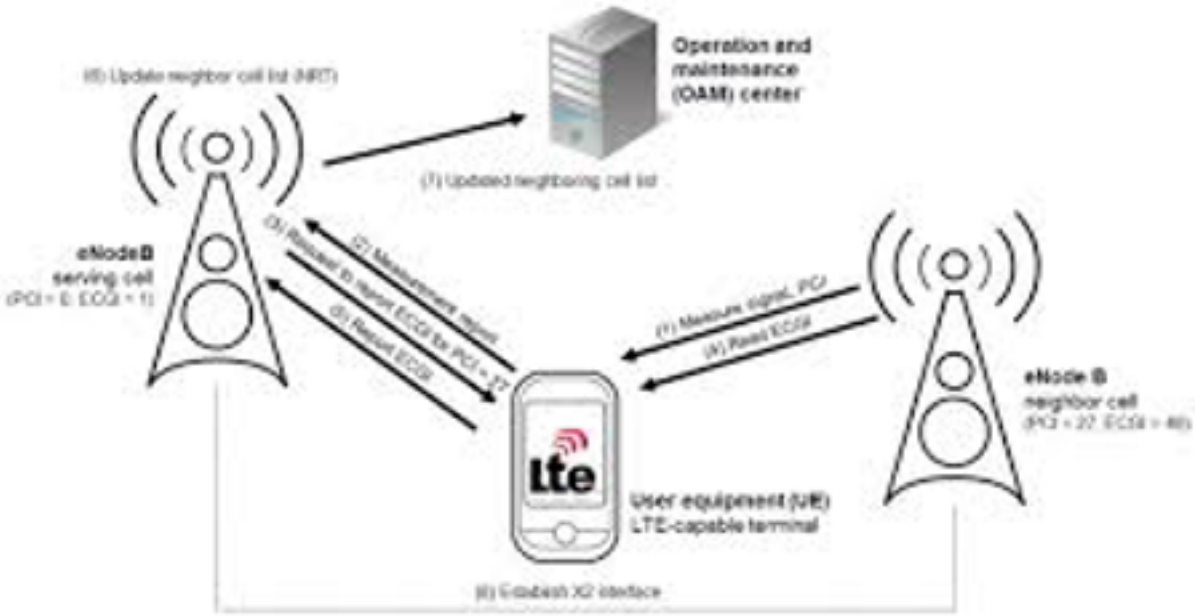
These features come from Releases by 3GPP:

- Massive MIMO – Multiple Input, Multiple Output
- Upgrading 4G LTE 2X2 MIMO to 4X4 MIMO with 4G LTE Advanced
- Doubles number of callers in same airspace
- Beam-forming used in mid band (> 2 GHz) and mmWave/high band
- Carrier Aggregation
- 256 QAM (Quadrature Amplitude Modulation)
- Virtualization of network
- Improvements in core network to reduce latency
- New 4G cellular radios/antennas can be upgraded to 5G with software change (when more 5G phones are in use)
- This all means more modulation of signal, affects our health

New Technologies used by 5G

(New technologies continued)

- More fiber between cell antennas and core, allowing faster transfer of data over backhaul portion of network
- 5G core controls 5G radio access network (RAN)
- Moving to O-RAN (Open RAN) and massive use of AI, shifting computing from core to "edge" (at and between individual cell antenna arrays)
- Allows system to run itself
- "Load balances on the fly"



industryreports24.com

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New Technologies used by 5G

(New technologies continued)

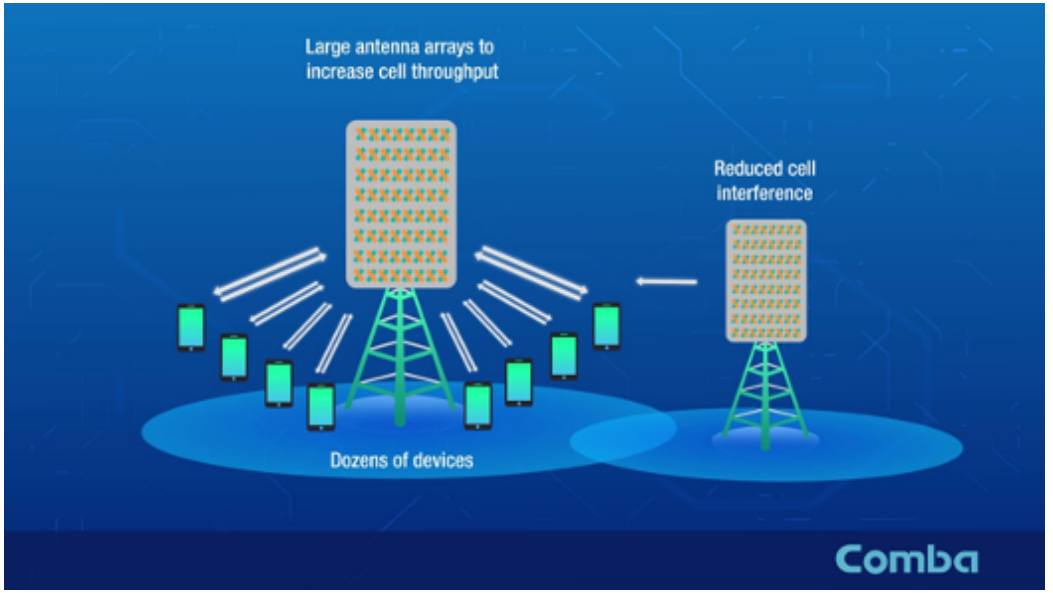
- DSS (Dynamic Spectrum Sharing) – connects cell phones seamlessly to 4G LTE or 5G, depending upon what is available in neighborhood
- Frequency slicing – carrier assigns bandwidth by needs of user's phone
- Ultra-low latency
- Integrated Access and Backhaul – cell antenna connects to phone and other small cell antennas simultaneously
- Phone connects to multiple cell sites simultaneously
- Carriers fully switch from Non-Standalone to Standalone (SA) 5G technology
- Expected to speed up data service when fully deployed by end of decade
- See 3GPP Releases 15-18 for full review, at https://www.3gpp.org/about-3gpp

New Technologies used by 5G

Massive MIMO – Expanded Multiple Input, Multiple Output

- 2T2R (two transmitting antennas, two receiving antennas) upgraded on new 4G LTE Advanced cell arrays to 4T4R
- 64T64R (eight by eight) MIMO used in new 5G antennas in mid band and mmWave (shorter wavelengths mean smaller antennas)
- T-Mobile using 32 antennas for 4G and 32 for 2.5 GHz mid band 5G until more 5G phones in use
- Eventually will switch all 64 antennas to 5G with software update

theridgefieldpress.com



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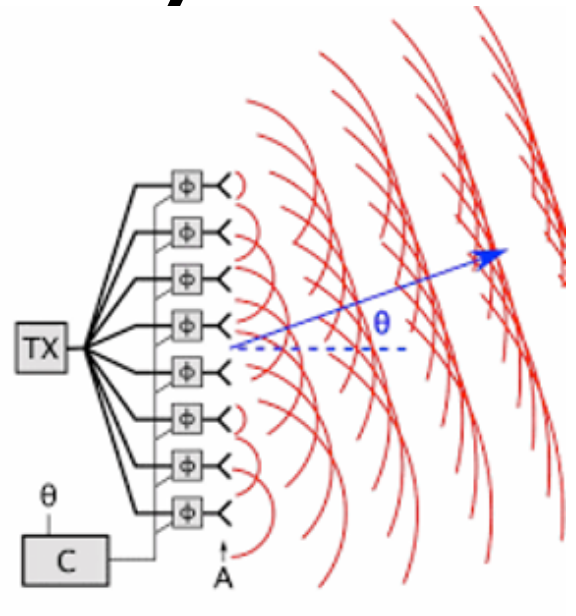
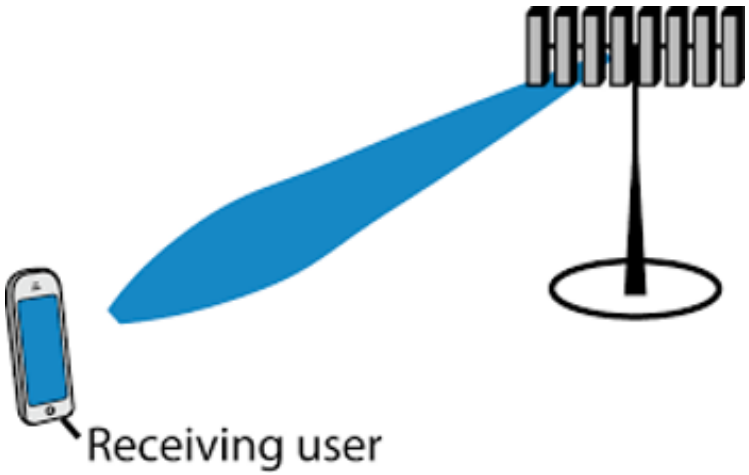
New Technologies used by 5G

Beam-formed signal

- Generated by all 64 antennas at once
- Each antenna contributes different power density independently
- Focuses and angles total signal to one or more mobile devices simultaneously
- Uses phased-array technology
- Transmits separately in 10-12 zones, with each zone only 10 degrees wide
- Used in mmWave and mid band (to 2GHz)
- 4G LTE signal is 120 degrees wide, always on





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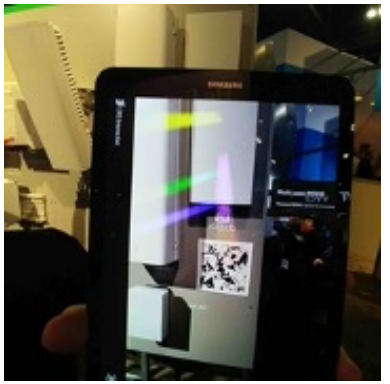
New Technologies used by 5G

Beam-formed continued

- 5G 64T64R MIMO antenna in photo at upper right (mid and mmWave/high bands only)
- Middle and lower photos show simulation of beam-forming from 5G antenna behind antenna company tablet that I am holding up
- In middle photo, colored beams represent signals to four separate phones connected simultaneously
- In lower photo, if only one customer is present in antenna's service area, all four beams will be directed to one device (strong, focused RF signal)



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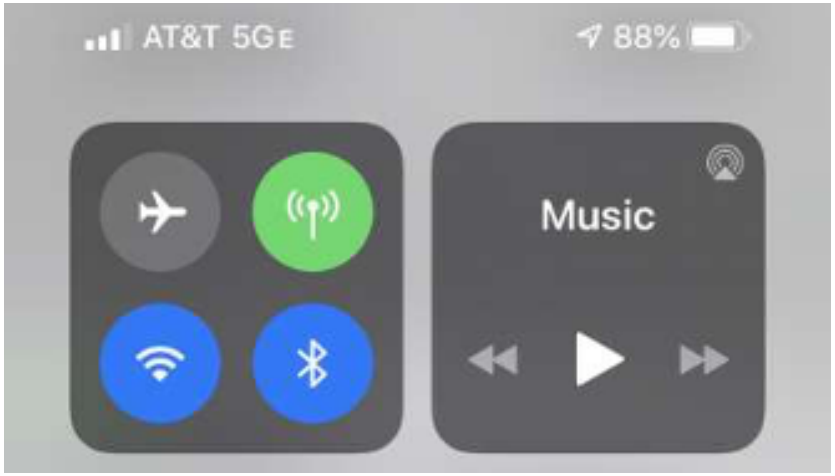
5G in Cell Phones

- New phones now "5G compatible"
- AT&T's 5GE "enhanced" low band 5G is repurposing of 850 MHz 4G signal
- Verizon's Nationwide 5G at 850 MHz
- All new 5G phones still have 4G LTE service (4G will dominate for years)
- New phones shift seamlessly from 4G LTE to 5G and back again using DSS (Dynamic Spectrum Sharing)



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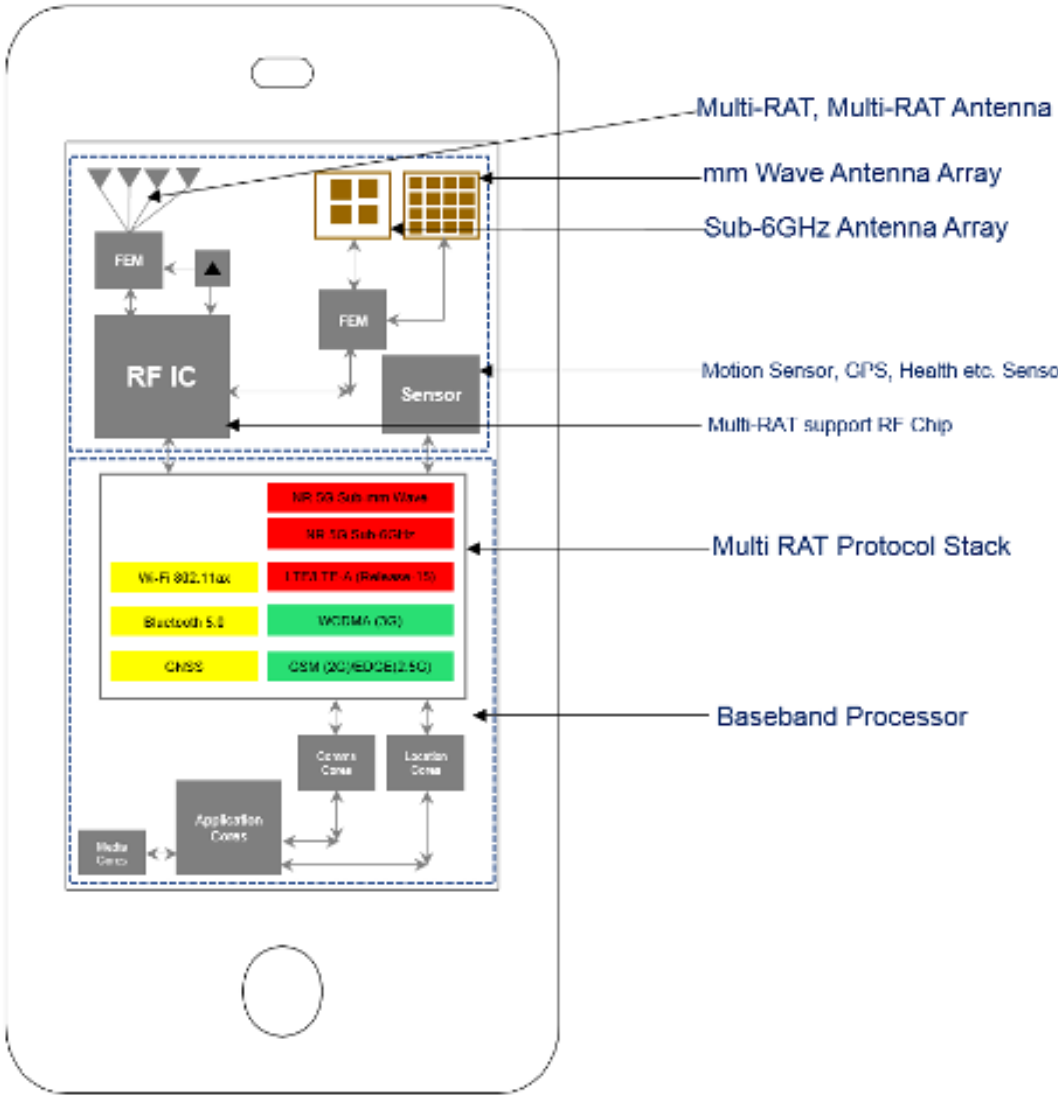
5G in Cell Phones

- 4G and 5G antennas located in new 4G/5G hybrid cell phones – shown in upper right corner
- Larger size of four antennas labeled "Sub-6GHz Antenna Array" for longer wavelengths
- Smaller size of sixteen antennas labeled "mm Wave Antenna Array" for shorter wavelengths
- New phones are now also 3.4-3.5 GHz (CBRS) and 3.5-3.7 GHz (C-Band) compatible



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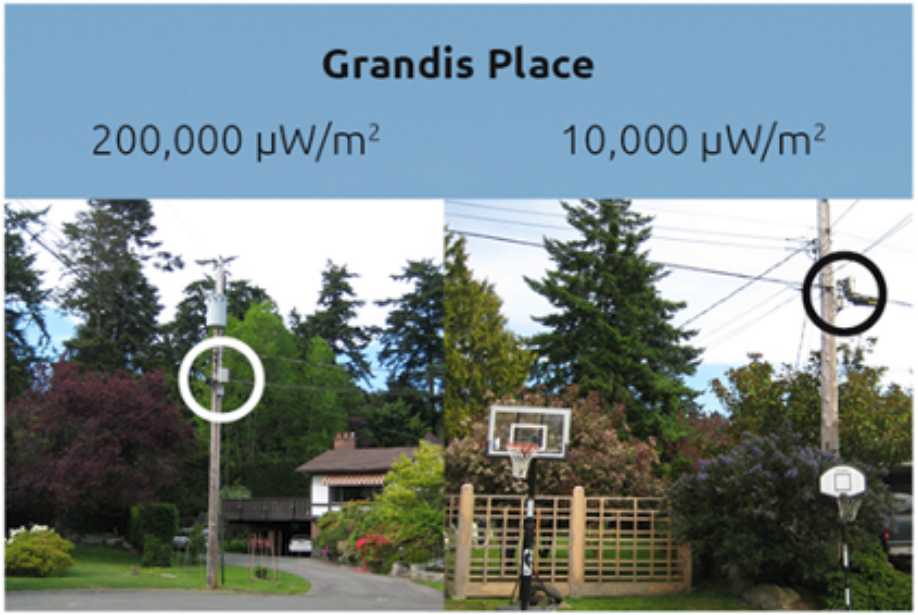
How Do We Measure 5G?

- Measure 4G LTE and 5G at low and mid band frequencies with existing RF meters
- mmWave GHz beam-formed 5G (>20 GHz) cannot be measured with existing RF meters (they only measure up to 8-10 GHz)
- Use new FM5 or Safe & Sound mW
- Always-on 4G LTE and 5G below 6 GHz still very harmful, especially with small cell antennas close to homes and more modulated 4G LTE signal
- RF readings in photos at right would be from 4G or low/mid band 5G, not mmWave 5G antenna



wi-cancer.info

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How Do We Measure 5G?

- Consumer-grade RF meters only measure low and mid band 5G (and all of 4G LTE), not mmWave 5G
- No cell frequencies present in U.S. between 6 and 20 GHz (but other harmful RF sources do exist — radar, satellite, aviation, police, military)
- New cell and Wi-Fi frequencies coming in near future at 6, 7 and 12 GHz
- Commercial-grade mmWave RF detectors used by cell carriers (spectrum analyzers) — $35,000 to $85,000
- Viavi Solutions and Rohde & Schwarz

viavisolutions.com

www.rohde-schwarz.com

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How Do We Measure 5G?

- Measure low and mid band 5G (and all 4G):
- Safe and Sound Pro II
- Safe and Sound Classic II
- Acoustimeter and Acousticom2
- Gigahertz Solutions HF35C, HFE35C, HFE59B & HFW59D
- FM5 RF Meter
- Cornet ED88TPlus5G
- Tri-Field TF2
- Learn sounds of 4G LTE & 5G cell towers

— www.safelivingtechnologies.com

Gigahertz Solutions HF35C

Safe & Sound Pro II

Safe & Sound Classic II

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How Do We Measure 5G?

- Measure high, mmWave band 5G with following meters:
- FM5 RF Meter — Shielded Healing
- Safe & Sound mmW — Safe Living Technologies, available early 2023
- Additional affordable mmWave RF detectors under development

FM5 RF Meter

Safe & Sound mmW

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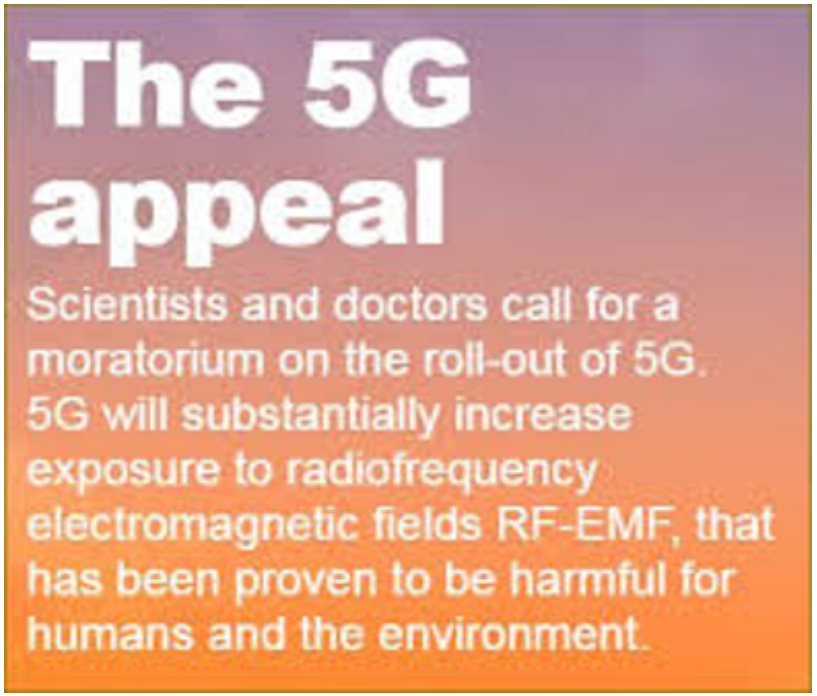
Health Effects of 4G/5G

- Over 233 scientists from 40 countries have issued health alert about 5G
- https://ehtrust.org/scientists-and-doctors-demand-moratorium-on-5g-warning-of-health-effects/



Additional EMF Organization

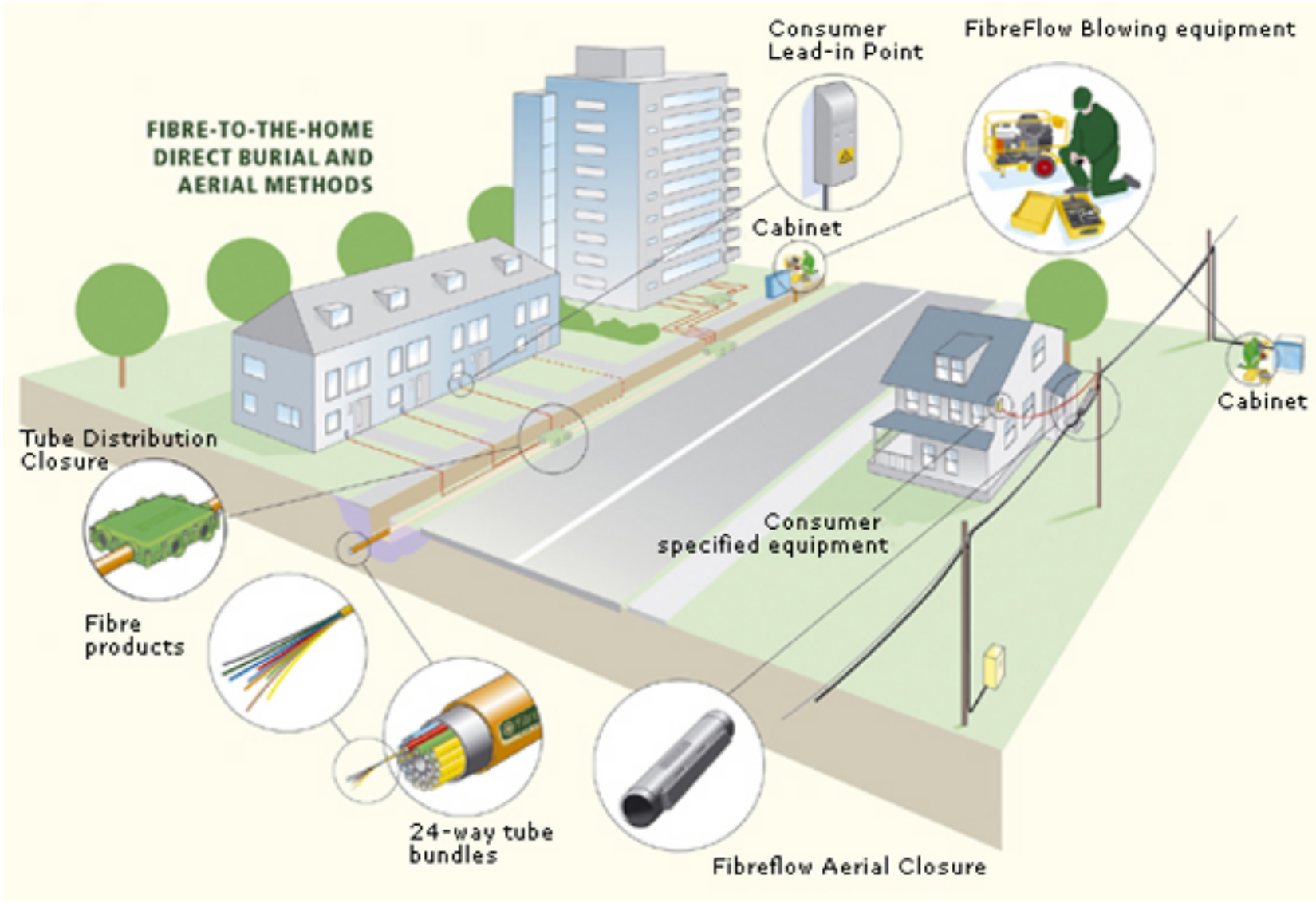
ICBE–EMF INTERNATIONAL COMMISSION ON THE BIOLOGICAL EFFECTS OF ELECTROMAGNETIC FIELDS

International Commission on the Biological Effects of Electromagnetic Fields

"A multi-disciplinary consortium of scientists, doctors and related professional who…have been involved with research related to the biological and health effects of electromagnetic frequencies up to and including 300 GHz."

www.icbe-emf.org

The Way It Should Be: Fiber-optic Connections



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Stance of 5G Activists

5G antennas should be restricted to 4G macro cell sites

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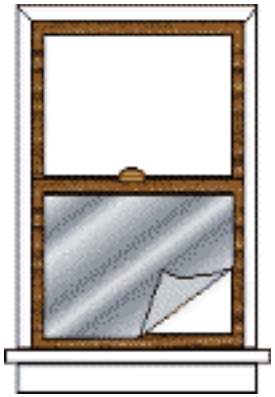
RF Mitigation Strategies

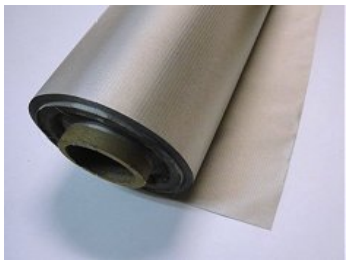
Block RF from outside sources (cell towers, smart meters, radio & TV towers):

- RF shielding paint
- Fabric for curtains, bed canopy
- Metal window screen, film on windows
- www.lessemf.com
- www.safelivingtechnologies.com

Y-shield® Paint



Scotchtint® Window Film



RF Shielding Materials & Fabrics

Bed Canopy

Oram Miller, BBEC, EMRS

RF Mitigation Strategies

- Era of IoT (Internet of Things) — Expanded indoor use of wireless devices with beam-formed WiFi routers, Bluetooth signals Safe and Sound Pro II
- New routers and smart speakers will interface with outdoor 5G antennas
- Avoid bringing these devices into your home

medium.com

RF Mitigation Strategies

Follow three guiding principles regarding use of wireless devices while indoors and outside home:

- Reduce use
- Increase distance
- Favor hardwired connections for Internet, telephone, TVs and players, security system, music speakers, thermostats, baby monitors
- Read "Safer Use of Cell Phones" article
- Opt out or shield smart meters
- One-half to three-quarters of mile from cell towers
- Avoid 4G LTE/5G small cell antennas in residential neighborhoods
- Shield walls and windows as necessary

pcworld.com

shutterstock.com

Protection from 5G for EHS

For EHS, follow these principles:

- Avoid dense urban areas, including private networks inside buildings
- mmWave 5G on streets near downtown areas of select cities, but growing — full mmWave data signal only on-demand in narrow zone
- Biggest threat is 4G LTE & low/mid band 5G service from always-on macro and small cell antennas at close range in residential neighborhoods
- Provide shielding for incoming 4G/low/mid band 5G signals
- 5G in all forms coming to rural areas, but mostly restricted to towns
- Always measure and avoid indoor RF sources
- Keep cell phones off when at home, answer calls on computer or call forward to corded landline telephone or Google Voice
- Text on computer, or corded cell phone via Whats App, Facebook, Messenger, et. al.

Hardwired Alternatives

Includes:

- Fiber to the Premises (FTTP)
- Hardwired Ethernet Local Area Networks (LANs) inside homes, schools and businesses, then disable WiFi
- Wires provide fast, stable, reliable, secure and safe data and voice connections
- Re-Inventing Wires: The Future of Landlines and Networks, published by National Institute for Science, Law and Public Policy and Camilla Rees

5G Technical Resources

Websites:

- www.rhode-schwarz.com
- https://www.3gpp.org/about-3gpp
- https://www.opensignal.com/usa
- https://www.fiercewireless.com/
- https://www.mobileworldlive.com/
- https://potsandpansbyccg.com
- https://www.rcrwireless.com/
- https://arstechnica.com/

Support 5G Awareness

Websites:

- www.safeg.net
- www.5Gcrisis.com
- www.americansforresponsibletech.org
- www.wearetheevidence.org
- www.whatis5g.info
- www.telecompowergrab.org
- https://www.rcrwireless.com/
- www.5gspaceappeal.org
- www.ehtrust.org
- www.mdsafetech.org
- www.mystreetmychoice.com
- www.cellphonetaskforce.org
- https://takebackyourpower.net/5g-the-big-picture/
- www.gettingsmarteraboutthesmartgrid.org/
- https://www.rcrwireless.com/
- www.electromagnetichealth.org

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