Wireless Beyond 100 GHz: Opportunities and Challenges for 6G and Beyond

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5G: How we got here and how we will move to 6G

How 5G and small cells are evolving

FCC Rulemaking/Regulatory Pressures and Needs

Practical 5G and 6G Deployment issues

6G and Beyond! How it will happen
Research Goals (from 2010)

- Create integrated circuits (ICs) operating at millimeter-wave and terahertz frequencies (60 GHz and beyond)
- Using CMOS process – mainstream inexpensive fabrication technology that creates computer chips, digital cameras, and USB thumb drives
Why mmWave? (from 2010)

- **Huge** amounts of wireless spectrum available (currently unused)
- Able to send **massive** amounts of data (billions of bits every second) over local area (~10 meters)
- **Directionality** in sensing – vehicle radar
- mmWave antennas sizes are comparable to integrated circuit (IC) sizes
- Tiny metal sheets available on ICs to fabricate mmWave/THz antennas
- Reduces fabrication costs
- Low power, light weight, won’t vibrate loose.
• Spectrum = real estate

Shaded Areas = Equivalent Spectrum!

60GHz Spectrum

77GHz Vehicular Radar

AM Radio

TV Broadcast

FM Radio

Cellular

Wi-Fi

Active CMOS IC Research
Applications - Vehicle Radar

- Phased array of IC antennas
  - Directional beam for long distance vehicle radar and collision avoidance
  - Steerable beams
Information Showers

- The future: Showering of information
- Mounted on ceilings, walls, doorways, roadside
- Massive data streaming while walking or driving
- Roadside markers can provide safety

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The Radio Spectrum

5G Motivation & mmWave Measurements

- **Spectrum shortage** in microwave band motivates use of millimeter wave (mmWave) for 5G cellular
- **Channel measurements** and **channel model** needed for mmWave communications

Pioneering mmWave propagation measurements in New York City by NYU WIRELESS

28 GHz & 73 GHz urban microcell (UMi), urban macrocell (UMa), small-scale fading, indoor office measurements, and 73 GHz rural macrocell (RMa) measurements from 2012 to 2017

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier Freq.</td>
<td>28 GHz</td>
</tr>
<tr>
<td>RF Bandwidth</td>
<td>800 MHz</td>
</tr>
<tr>
<td>TX &amp; RX Antenna Type</td>
<td>Rotatable Horn Antenna</td>
</tr>
<tr>
<td>TX &amp; RX Ant. Gain</td>
<td>24.5 dBi; 15 dBi</td>
</tr>
<tr>
<td>TX &amp; RX AZ Ant. HPBW</td>
<td>10.9°; 28.8°</td>
</tr>
<tr>
<td>TX &amp; RX EL Ant. HPBW</td>
<td>8.6°; 30°</td>
</tr>
<tr>
<td>TX &amp; RX Ant. Sweep</td>
<td>Yes</td>
</tr>
<tr>
<td>TX Height</td>
<td>7 m, 17 m</td>
</tr>
<tr>
<td>RX Height</td>
<td>1.5 m</td>
</tr>
<tr>
<td>Max. TX Power</td>
<td>30.1 dBm</td>
</tr>
<tr>
<td>Max. Measurable Path Loss</td>
<td>178 dB</td>
</tr>
</tbody>
</table>

28 GHz UMi & UMa measurements in 2012


T. S. Rappaport et al., “Wideband millimeter-wave propagation measurements and channel models for future wireless communication system design,” *IEEE Transactions on Communications*, vol. 63, no. 9, pp. 3029-3056, Sep. 2015.

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5G Standard timeline

[Diagram showing the timeline of 5G standardization with key events and milestones]

https://www.netmanias.com/en/post/oneshot/11147/5g/timeline-of-5g-standardization-in-itu-r-and-3gpp
5G in a Nutshell

• Pre-5G: Cellphone systems operated at 1-2 GHz (microwave)

• 5G uses 1-2 GHz (low), 2.6 GHz (mid) and mmW (high band)
  high band is 24, 28, 37, 39 GHz spectrum

• 5G mmW Channel Bandwidths are 20X 4G → 50X 4G speed!

• 5G Latency is less than 10 milliseconds (imperceptible)

• 5G: 10 Gigabit per second transmissions to a phone (like fiber!)

• 5G exploits smaller wavelengths → permits more antennas in each cellphone and base station – steerable beams!

• Cross Polarization Discrimination (XPD) and small cells
  overcome penetration loss, human blockage, foliage loss in 5G

  https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6515173

# A Simple Comparison Between LTE and 5G New Radio (NR)

<table>
<thead>
<tr>
<th>Feature</th>
<th>LTE</th>
<th>5G NR (eMBB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Streams</td>
<td>SISO</td>
<td>SISO</td>
</tr>
<tr>
<td>BW</td>
<td>20 MHz</td>
<td>800 MHz</td>
</tr>
<tr>
<td>Subcarrier spacing</td>
<td>15KHz</td>
<td>240KHz</td>
</tr>
<tr>
<td>FFT size</td>
<td>2048</td>
<td>2048</td>
</tr>
<tr>
<td>Number of Occupied Subcarrier</td>
<td>1200</td>
<td>~1600</td>
</tr>
<tr>
<td>Spectral Occupancy</td>
<td>90%</td>
<td>98%</td>
</tr>
<tr>
<td>Slot Duration</td>
<td>0.5 ms [7symbols]</td>
<td>65us [14 symbols]</td>
</tr>
<tr>
<td>Antenna</td>
<td>Omni</td>
<td>64 Beams</td>
</tr>
</tbody>
</table>
4G LTE Advanced Pro [1,2]:

- ≤ 64 antenna elements
- 1-2 Gbps data rate
- ~10 ms latency
- Digital beamforming

5G NR [3, 4]:

- ≥ 256 antenna elements (but same size)
- BS Placement: site-specific sensitivity
- > 10 Gbps data rate
- < 1 ms latency
- Hybrid beamforming [4] (most possible)
5G Multi-tier network [1]


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Example illustrations showing the difference between non-CoMP and CoMP (coordinated scheduling/beamforming from Transmission Points TP)

**Non-CoMP**
- Each TP serves UEs in its own cell
- 2 UEs per cell

**CoMP**
- (coordinated scheduling/beamforming) [1]
- TPs exchange CSI
- Each TP serves UEs in its own cell

5G base stations (Nokia 5G AirScale Base Station [2]).

The directionality of 5G base stations.

5G Massive MIMO, here ten user terminals and one hundred BS antennas. The antenna array is scalable.

Heterogeneous 5G networks, Small cells and WiFi [3]

4G LTE Base Stations and Antennas [1,2]

- Cellular antennas on a lattice tower: low/mid band (Katherin)
- Bass drum in the sky, courtesy of CommScope [3].
- A example of 8×2 antenna array architecture [4].

Streetlight small cells (CommScope).

Cell sites on rooftops.

Typical and Relative Multi-column Antenna Size for [4]:

- 850 MHz, 1900 MHz, 2500 MHz (2.6 GHz)
- 4-column planar arrays with 0.5 wavelength spacing

Sprint Massive MIMO at 2.6 GHz in New York City [1]

Sprint Massive MIMO and In-band backhaul @2.6 GHz

5G RF front end and antenna on light pole

5G Base Station at 28 GHz on top of 4G LTE in Chicago on the Verizon Network [2].

Reddit 2018 Sprint in NYC

PC Magazine 2019 Verizon Chicago
• Small cells, zoning efforts
• How to manage radiated power with beamforming antennas
• Political/technical debate at 24 GHz- Weather Forecasting at 24 GHz
• Freeing up mid-band spectrum (3.2 – 4.7 GHz) for wireless industry
• There are many more- these are just some examples
Small Cells, Zoning Efforts

• Declaratory Ruling: Small Cells WT Docket 17-79, WC Docket 17-84 [1]

• Broad industry standards better than individual local govt. ordinances

• Examples of individual cities/municipalities, 9 cu. ft. footprint:
  • San Mateo, CA:
  • Council Bluffs, IA:
  • Charleston, SC:
  • Syracuse, NY:
  • San Francisco, CA (Steel poles):
    • http://default.sfplanning.org/currentplanning/wireless/FAQ_Small_Cells_on_Steel_Light_and_Transit_Poles.pdf
  • San Francisco, CA (Wooden poles):

• Multiple antenna elements and beamforming are new

• Part 30 currently states:

§30.202 Power limits.

(a) For fixed and base stations operating in connection with mobile systems, the average power of the sum of all antenna elements is limited to an equivalent isotopically radiated power (EIRP) density of +75 dBm/100 MHz. For channel bandwidths less than 100 megahertz the EIRP must be reduced proportionally and linearly based on the bandwidth relative to 100 megahertz.

(b) For mobile stations, the average power of the sum of all antenna elements is limited to a maximum EIRP of +43 dBm.

(c) For transportable stations, as defined in §30.2, the average power of the sum of all antenna elements is limited to a maximum EIRP of +55 dBm.

(d) For fixed point-to-point and point-to-multipoint limits see §30.405.

Passive Satellites measure the noise temperature of water molecules
Measure passively at 22.8 GHz and surrounding bands to 30 GHz
The weather models are incredibly noisy!
No wonder weather radar prediction is so poor (See figs 1-3!)

415 MHz separation from 23.835 GHz (WX) and 24.250 GHz (5G)
Up for debate, but easy to calibrate out any out of band – if an issue!
Systematic study could easily be done. I think § 30.202 has it right
-20 dBW per 200 MHz out of the passband (10 mW over 200 MHz!)
FCC View:
NOAA/NIST View:
https://physicsworld.com/a/debate-rages-over-5g-impact-on-us-weather-forecasting/

Myriad of Satellites are used (mmWave use Low Earth Orbit ~ 500 mi)

https://severe.worldweather.wmo.int/TCFW/RAIV_Workshop2016/06_Satellites_JackBeven.pdf

23.835 GHz is just a single frequency from myriad inputs

Types of Satellite Data

- Tropical Cyclone Intensity Estimates (VIS, IR, MW)
  - NOAA (Advanced Microwave sounding Unit or AMSU)
  - DMSP (SSM/IS), GPM, GCOM, METOP, NPP (ATMS)
  - Satellite Vertical Soundings (IR, WV/EHF, MW)
    - GOES, NOAA, DMSP, METOP, Aqua, NPP
  - Ocean Wave Heights (Jason2, Jason 3, Cryosat, Altika)
  - Oceanic Heat Content (Jason2, Jason 3, Cryosat, Altika)


https://severe.worldweather.wmo.int/TCFW/RAIV_Workshop2016/06_Satellites_JackBeven.pdf
5G mmW Propagation within Cities (consider New York City):
- Local Law 10, 11 – all building facades must be inspected 4-5 years
- 25% of all buildings in Manhattan will always have scaffolding in front!
- Estimate a 2X increase in small cell base sites due to this effect!
The 5G Health Hazard that isn’t (NYT: William Broad, July 16, 2019)

Radio Waves do not travel deeply into people as frequencies go up to mmW and above
People are more reflective than they are absorbing – RF heating is the key issue to avoid
NYU did key work on this in 2015: “Safe for Generations to Come”, “Human Body Interactions”
FCC needs to make safety regulations for above 95 GHz (JA, RUS, EU goes to 300 GHz)
Coherent energy from multi-element antennas should be considered into the future

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4629874/
Moving to 6G above 100 GHz

The THz Band

100 Years - Sub-6 GHz!

1933
FM Radio
(~100 MHz)

1973
First handheld phone
(~850 MHz)

2019
Foldable Smart Phone
(~3.5 GHz)

1993
WIFI (~2.4 and 5 GHz)

1973
WIFI (~2.4 and 5 GHz)

2019
Foldable Smart Phone
(~3.5 GHz)


140 GHz Channel Sounder

Conducting indoor/ outdoor measurements [21]


140 GHz broadband channel sounder [22]

[22] https://ieeetv.ieee.org/event-showcase/brooklyn5g2018
NYU 140 GHz Channel Sounder System

<table>
<thead>
<tr>
<th>Description</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO Frequency</td>
<td>22.5 GHz × 6 = 135 GHz</td>
</tr>
<tr>
<td>IF Frequency</td>
<td>5-9 GHz (4 GHz bandwidth)</td>
</tr>
<tr>
<td>RF Frequency</td>
<td>140-144 GHz</td>
</tr>
<tr>
<td>Upconverter IF input</td>
<td>-5 dBm typically 10 dBm (damage limit)</td>
</tr>
<tr>
<td>Downconverter RF input</td>
<td>-15 dBm typically 0 dBm (damage limit)</td>
</tr>
<tr>
<td>TX output power</td>
<td>0 dBm</td>
</tr>
<tr>
<td>Antenna Gain</td>
<td>25 dBi / 27 dBi</td>
</tr>
<tr>
<td>Antenna HPBW</td>
<td>10º / 8º</td>
</tr>
<tr>
<td>Antenna Polarization</td>
<td>Vertical / Horizontal</td>
</tr>
</tbody>
</table>

FSPL verifications following the proposed method at 28, 73, and 140 GHz [23] (after removing antenna gains)

As expected, FSPL at 140/73/28 GHz follows the Laws of Physics and satisfies Friis’ equations with antenna gains removed.

Penetration Loss: 28, 73 & 140 GHz

![Theoretical Received Power vs. Distances](image)

**Penetration Loss at 28, 73, and 140 GHz**

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>Material Under Test</th>
<th>Thickness (cm)</th>
<th>Penetration Loss (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>Clear glass No.1</td>
<td>1.2</td>
<td>3.60</td>
</tr>
<tr>
<td></td>
<td>Clear glass No.2</td>
<td>1.2</td>
<td>3.90</td>
</tr>
<tr>
<td></td>
<td>Drywall No.1</td>
<td>38.1</td>
<td>6.80</td>
</tr>
<tr>
<td>73</td>
<td>Clear glass No.3</td>
<td>0.6</td>
<td>7.70</td>
</tr>
<tr>
<td></td>
<td>Clear glass No.4</td>
<td>0.6</td>
<td>7.10</td>
</tr>
<tr>
<td></td>
<td>Drywall No.2</td>
<td>14.5</td>
<td>10.06</td>
</tr>
<tr>
<td>140</td>
<td>Clear glass No.3</td>
<td>0.6</td>
<td>8.24</td>
</tr>
<tr>
<td></td>
<td>Clear glass No.4</td>
<td>0.6</td>
<td>9.07</td>
</tr>
<tr>
<td></td>
<td>Drywall No.2</td>
<td>14.5</td>
<td>15.02</td>
</tr>
<tr>
<td></td>
<td>Glass door</td>
<td>1.3</td>
<td>16.20</td>
</tr>
<tr>
<td></td>
<td>Drywall with Whiteboard</td>
<td>17.1</td>
<td>16.69</td>
</tr>
</tbody>
</table>

**DIRECTIONAL ANTENNAS WITH EQUAL APERTURE HAVE MUCH LESS PATH LOSS AT HIGHER FREQUENCIES ([24] Ch.3 Page 104) !!!**

Penetration loss increases with frequency but the amount of loss is dependent on the material ([21]


FCC opens above 95 GHz

NYU WIRELESS first university in the mmWave Coalition- pushed for rules > 95 GHz
Experimental licenses for 95 GHz to 3 THz - Spectrum Horizons ET Docket 18-21
21.2 GHz Unlicensed Spectrum to be allocated.
Rules on Licensed spectrum deferred until sufficient technical and market data is obtained (NYU Thurst area)

Spectrum Horizons Experimental Radio Licenses

- Frequency within **95 GHz to 3 THz**
- No interference protection from pre-allocated services.
- Interference analysis before license grant.

FCC Approved on March 15th 2019

### Unlicensed Operation

- Maximum EIRP of 40 dBm (average) and 43 dBm (peak) for **mobile**.
- Maximum EIRP of $82-2*(51-G_{TX})$ dBm (average) and $85-2*(51-G_{TX})$ dBm (peak) for **fixed point-to-point**.
- Out-of-band emission limit 90 pW/cm² at three meters.

<table>
<thead>
<tr>
<th>Frequency Band (GHz)</th>
<th>Contiguous Bandwidth (GHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>116-123</td>
<td>7</td>
</tr>
<tr>
<td>174.8-182</td>
<td>7.2</td>
</tr>
<tr>
<td>185-190</td>
<td>5</td>
</tr>
<tr>
<td>244-246</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>21.2</strong></td>
</tr>
</tbody>
</table>
### Applications Above 100 GHz

**mmWave & THz Applications—the potential for 6G** [1]

| Wireless Cognition          | Robotic Control [27, 28]  
|                            | Drone Fleet Control [27]  |
| Sensing                     | Air quality detection [5]  
|                            | Personal health monitoring system [6]  
|                            | Gesture detection and touchless smartphones [7]  
|                            | Explosive detection and gas sensing [8]  |
| Imaging                     | See in the dark (mmWave Camera) [9]  
|                            | High-definition video resolution radar [10]  
|                            | Terahertz security body scan [11]  |
| Communication               | Wireless fiber for backhaul [12]  
|                            | Intra-device radio communication [13]  
|                            | Connectivity in data centers [14]  
|                            | Information shower (100 Gbps) [15]  |
| Positioning                 | Centimeter-level Positioning [9,16]  |

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The Human Brain & Human Intelligence

How powerful is the human brain?

• 100 billion neurons
  Fire 200 times per second (5 milliseconds)

• Each neuron connected to 1000 others

• Speed = \(10^{11} \times 200 \times 10^3 = 20 \times 10^{15}\)
  • (20 petaflops)/second = 20,000 Tbps

• Each neuron has write access to 1000 bits
  Storage = \(10^{11} \times 10^3 = 10^{14} = 100 \times 10^6 \times 10^6\)
  = 100 million megabytes = 100 terabytes
$1000 Buys

Computations / sec

Year


1E-6

1E-3

1E+0

1E+3

1E+6

1E+9

1E+12

Mechanical

Electro-mechanical

Vacuum tube

Discrete transistor

Integrated circuit

after Kurzweil, 1999 & Moravec, 1998
$1000$ Buys

Computations / sec

Year

1900 1920 1940 1960 1980 2000 2020

1E-6 1E-3 1E+0 1E+3 1E+6 1E+9 1E+12

Mechanical  Vacuum tube  Integrated circuit
Electro-mechanical  Discrete transistor

Today's Technology

Human brain 2036

after Kurzweil, 1999 & Moravec, 1998
Can we remote the Human Brain?

Wireless in 2036: 6G or 7G?

- 10 GHz RF User Channels \((10^{10})\) Hz
- 1024 QAM (10 bits/second)
- 1000 X Channel/Antenna Capacity (Beyond M-MIMO)
- PHY: 100 Terabytes/second (0.5% of human brain)

- 100 GHz channels: 1 Petabyte/second (5% of human brain)
- Other wireless breakthroughs may increase link speed
Applications Above 100 GHz

Autonomous cars

Drones Deliver

Robotics

Holographic Imaging and Spatial cognition

Wireless Cognition (Network Offloading) [17]

Applications Above 100 GHz

Body scanner using THz imaging to detect explosives [1]

mmWave imaging and communications for Simultaneous Localization And Mapping (SLAM) exploiting the scattering properties at mmWave [18]

Glass, rock and a metal screw identified in a chocolate bar using THz imaging [17]


Applications Above 100 GHz

100 Gbps ~ 1 Tbps backhaul links over rooftops [12]

Range: 10mm-1mm

Frequency: 100GHz - 1THz

On-chip & chip to chip Terahertz communication links [20]

Marcrocells

Small Cells

WiFi

Short-range THz wireless connectivity in data centers [2]

Beamforming and Spatial Multiplexing [30]

Mobile Communications [12]

Maps of 2 MetroTech Center 9th floor. There are 9 TX locations (stars) and 37 RX locations (dots). The 140 GHz indoor measurement campaign will use the same measurement locations as used at 28 and 73 GHz, providing 48 TX-RX combinations ranging from 4 to 48 m [25, 21].

Scattering Models at 140 GHz

Comparison between measured data and the dual-lobe Directive Scattering (DS) model at 142 GHz [1,26].

Tools for Localization

cm-level localization at mmWave and THz, assuming materials are perfect reflectors [1,18]

1. mmWave image of surrounding environment constructed
2. User location is projected on the constructed mmWave image.


cm-level localization with map, AoA, and ToF information at mmWave & THz, on-the-fly in the phone or from edge [1].

Materials not assumed to be perfect reflector at mmWave

The map of the environment used to retrace signal paths

3-D error spheres depicting typical positioning accuracy on map


Results and Conclusions

- 5G has seen enormous progress since the “It Will Work!” paper in 2013
  - Global rollouts: engineers and technicians learning about mmWave and directional channels
  - Governments are creating spectrum opportunities

- Now is the time to work on 6G!

- Early work shows **clear sailing** up to 700 GHz!
- Mobile, fixed, sensing, position location, human cognition
- Wireless – NYU helped lead the world to mmW and now > 95 GHz

- THz Communications and Sensing at NYU WIRELESS
  - New uses cases: Aerial, robotics, see-in-the-dark imaging, bio/health monitoring
  - THz / Sub-THz Channel models, coverage/blockage/ planning tools for indoor/outdoor/penetration
  - Market Challenges: Power consumption, power efficiency, digital arrays, deployment tools and experience
Acknowledgement to our NYU WIRELESS Industrial Affiliates and NSF

This work is supported by the NYU WIRELESS Industrial Affiliate Program and National Science Foundation (NSF) (Award Number: 1702967, 1731290 1555332, 1302336, and 1320472).
Thank You!
• Practical difficulties with mmW propagation penetrating into buildings
• Input that NYU WIRELESS gave FCC TAC in 2018 for Small Cells
• Selected References on 5G millimeter wave issues
• NYU WIRELESS Industrial Affiliates (Thank you Crown Castle)
## 28 GHz Millimeter Wave Cellular Communication

Measurements for Penetration Loss in and around Buildings in New York City

<table>
<thead>
<tr>
<th>Environment</th>
<th>Location</th>
<th>Material</th>
<th>Thickness (cm)</th>
<th>Received Power - Free Space (dBm)</th>
<th>Received Power - Material (dBm)</th>
<th>Penetration Loss (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor</td>
<td>ORH</td>
<td>Tinted Glass</td>
<td>3.8</td>
<td>-34.9</td>
<td>-75.0</td>
<td>40.1</td>
</tr>
<tr>
<td></td>
<td>WWH</td>
<td>Brick</td>
<td>185.4</td>
<td>-34.7</td>
<td>-63.1</td>
<td>28.3</td>
</tr>
<tr>
<td></td>
<td>MTC</td>
<td>Clear Glass</td>
<td>&lt;1.3</td>
<td>-35.0</td>
<td>-38.9</td>
<td>3.9</td>
</tr>
<tr>
<td>Indoor</td>
<td>WWH</td>
<td>Tinted Glass</td>
<td>&lt;1.3</td>
<td>-34.7</td>
<td>-59.2</td>
<td>24.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clear Glass</td>
<td>&lt;1.3</td>
<td>-34.7</td>
<td>-38.3</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wall</td>
<td>38.1</td>
<td>-34.0</td>
<td>-40.9</td>
<td>6.8</td>
</tr>
</tbody>
</table>

### TABLE II

Comparison of penetration losses for different environments at 28 GHz. Thicknesses of different common building materials are listed. Both of the horn antennas have 24.5 dBi gains with 10° half power beamwidth.

NYU WIRELESS, Rappaport, et. al. "Millimeter Wave Mobile Communications for 5G Cellular, it will work!" IEEE Access Vol. 1, 2013
Great technology must be deployed rapidly and efficiently (time/$), This is VITAL for US competitiveness. Order last week is excellent first step, MUST PROCEED AGGRESSIVELY with Spectrum Auctions, 39 GHz needed quickly (24, 28 GHz good first step, but 39 GHz needed now)!

Efforts are needed to streamline deployment and reduce fees for deployment of 5G technology in the Right of Way (ROW).

Jurisdictions should only charge cost-recovery (not general revenue – be just like other public utilities) w/ non-discriminatory fees to access the ROW incl. municipal poles. No “hidden” broadband tax.

Applications need review within FCC “shot clock” limits of 90 days (co-locations) and 120 days for new poles in ROW: Sec. 332 and 253.
Consider “overlashing” of new cables w/o application to pole owner.

Ensure pole owners follow the Commission’s intended pole-attachment processes and timelines (pole owners use delay w/pre-applications – these delays and lack of clarity hurt deployment/plans). Amend pole rule to follow wireless Shot Clock and Section 6409 rules.

Have timeline start immediately upon submission of a request for access. This will prevent utilities from evading Commission timelines.

Pole owners (investor owned utilities, ILECs, etc.) need to break down costs for fair disputes, as carriers/infrastructure companies want to avoid legal complaints.
NPRM 17-79 and 17-84: FCC should adopt a best practice for all carriers and infrastructure players. Example: Automated databases and notifications systems, such as those provided by National Joint Utilities Notification System (NJUNS) as a “best practice” for all utilities and attaching parties.

Key FCC regulation for Interference, Adjacent Channel Leakage Radiation Power (ACLR), Adjacent Channel Selectivity (ACS): EIRP and OOBE still defined as an isotropic radiator in FCC rules. Using directional radiation requires massive overkill (cost and size/weight) for filtering to meet isotropic requirements over a directional array. FCC should adopt directional RF emission parameters (beamwidth dependent) rather than Isotropic for OOBE, ACLR, ACS, etc.
Consider relaxation of wireless power charging rules for devices. 5G CPE and UE devices have lower RF power efficiency at mmWave, and thus may require higher power levels for battery charging than today’s CPE/UE devices. Higher electromagnetic fields created by the charging coils may be needed.

Jurisdictions need to relax control of locations: 5G small cells will have lower antenna heights, making it more critical to precisely place antennas for proper RF coverage at mmWave. Moving the antenna “a couple of poles away” can completely change the coverage of the site. FCC should enable proper placement without undue delays.

Avoid zoning if infrastructure falls within a specific physical size or within a prescribed acceptable aesthetic footprint.
Selected References

Selected References


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