June 2, 2020

VIA ECFS

Ms. Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, D.C. 20554

RE: *The Rural Digital Opportunity Fund Auction*, AU Docket No. 20-34; *Rural Digital Opportunity Fund*, WC Docket No. 19-126; *Connect America Fund*, WC Docket No. 10-90

Dear Ms. Dortch:

On Friday, May 29, 2020, Brian O'Hara from the National Rural Electric Cooperative Association, Brett Kilbourne from the Utilities Technology Council, Thomas Cohen of Kelley Drye & Warren LLP on behalf of the Fiber Broadband Association (collectively the "Associations"), and the undersigned held separate telephone conversations with: (1) Joseph Calascione, legal advisor to Commissioner Brendan Carr; (2) Preston Wise, rural broadband advisor to Chairman Ajit Pai; and (3) Austin Bonner, legal advisor to Commissioner Geoffrey Starks, respectively. On Monday, June 1, the same parties held separate telephone conversations with Arielle Roth, legal advisor to Commissioner Michael O'Rielly, and Travis Litman, chief of staff to Commissioner Jessica Rosenworcel.

The Associations started each conversation by expressing support for the work of the Federal Communications Commission (the "Commission") in building upon the successful structure of the Connect America Fund Phase II auction and applying lessons learned from that prior effort to develop an effective framework for the Rural Digital Opportunity Fund ("RDOF"). We further support moving forward on the timeline outlined in the *Draft Public Notice*[1] scheduled for a vote at the June open meeting and noted that our members are eager to be participants in this process.

Nonetheless, the Associations raised one concern with respect to the *Draft Public Notice*, relating specifically to the proposal to provide a special opportunity for fixed wireless and DSL technologies to bid in the Gigabit tier despite scant evidence of service offerings at such a level on a widespread basis in rural areas at least. To be clear, the Associations all have members that utilize fixed wireless services to help in delivering broadband services in certain cases, and NTCA also has a number of members who continue to use DSL technology to deliver broadband in certain areas. Their members recognize the value proposition of various technologies and view them as necessary and useful "tools in the toolkit" for addressing consumer demand for broadband.

---

[1] *Rural Digital Opportunity Fund Phase I Auction*, Notice and Filing Requirements and Other Procedures for Auction 904, FCC-CIRC2006-01 (rel. May 19, 2020) ("*Draft Public Notice*"),

Despite that fact, these members' experiences belie the notion that either technology is capable of delivering consistent and reliable Gigabit level service in rural areas. For example, while the Commission indicates at one point that 1.8% of fixed wireless providers report offering Gigabit level service based upon current Form 477 data,[2] there is no sense of how many locations are in fact served at this level or where these locations are. Moreover, while the Wireless Internet Service Providers Association ("WISPA") recently reported on the capabilities of certain of its members and their vendors to deliver Gigabit level service,[3] the websites of the vendors participating in that meeting indicate that using high-band (*e.g.,* 60 GHz) spectrum they can deliver higher speed service over distances that in many rural areas often translate only to hundreds of meters – and often only through configurations that share all of the available bandwidth across an aggregated sector.[4] In addition, even these "ideal" claims are questioned by other participants in the proceeding, including GeoLinks.[5]

The Commission acknowledges such concerns in highlighting the many limitations and constraints that would render it a "high burden" to "make a case" for the offering of a Gigabit level service via these technologies.[6] The Commission does not, however, explain in the item the standards by which it will evaluate whether any given party can in fact meet that high burden and have made its case. Indeed, elsewhere in the item, the Commission declines to adopt standards or establish

---

2 *Id*. at n. 236.

3 Letter from Louis Peraertz, Vice President of Policy, WISPA, to Ms. Marlene H. Dortch, Secretary, Federal Communications Commission, WC Docket No. 19-126, *et al*. (May 15, 2020).

4 *See, e.g.,* https://www.ignitenet.com/technology/metroling/ (indicating the longest link deployed using its products transmitted 800 Mbps over a 1.5 mile distance using 60 GHz spectrum); https://www.siklu.com/product/multihaul-series/ (indicating that a sector capacity of 1.8 Gbps net throughput could be achieved for up to 1310 feet); https://portal.adtran.com/web/fileDownload/doc/34832 (indicating a range of 500 meters for its high-speed fixed wireless broadband equipment).

5 GeoLinks provides some illuminating insights into the challenges of fixed wireless engineering in its recent *ex parte*. *See* Letter from Skyler Ditchfield, Chief Executive Office, GeoLinks to Marlene H. Dortch, Secretary, Federal Communications Commission, AU Docket No. 20-34 *et al*. at 3-4 (May 29, 2020) ("During the call with RBATF, GeoLinks was asked about certain manufacturers' claims that equipment may support Gigabit speeds under certain conditions. Specifically, RBATF staff asked GeoLinks to comment on the information set forth in Footnote 238 of the Public Notice. GeoLinks explained that while the claims made regarding throughput are technically attainable, in GeoLinks' experience, real world throughput, even in a very clean environment, never comes close to as-advertised over-the-air ('OTA') link rates. In fact, GeoLinks finds that, in general, the equipment it procures obtains about 1/3 to 1/2 the capacity of the manufacturer's OTA rate in real world deployments with a 10% reduction for each additional client added. It is simply not realistic to expect full modulation on every link, especially with point-to-multipoint ('P2MP') deployments or as additional customer connections are added to the same equipment… As exemplified by the above, there is a distinct difference between what certain equipment manufacturers claim to be capable of (and may be in laboratory-type settings) vs. what they are more likely capably of in real-world settings. GeoLinks asserts that the above information shows clearly why the Commission cannot rely on information provided by service providers wishing to bid the Gigabit tier what simply parrot the information provided from the manufacturer(s) whose equipment they plan to utilize, and which is also not applicable to end user speed (as discussed below).") ("GeoLinks Ex Parte"); *see also* Letter from Derrick Bulawa, CEO and General Manager, BEK Communications, to Ms. Marlene H. Dortch, Secretary, Federal Communications Commission, WC Docket No. 19-126, *et al*. (Jan. 23, 2020) (providing 57 pages of technical analysis related to proposed offerings of 100/20 Mbps broadband service via fixed wireless in North Dakota).

6 *Draft Public Notice*, at ¶¶ 102 and 104.

the kind of processes that would seem necessary to do so, rejecting requests to define generally applicable technical standards and assumptions,[7] implement standardized assumptions for busy hour overload or oversubscription,[8] or identify a "maximum level of performance" that would be achievable using any given spectrum bands.[9] While this may all have made sense were the Commission not providing fixed wireless or DSL providers a unique chance to bid in the highest performance tier, it is not clear how the Commission can determine whether the "high burden" has been met by such would-be bidders in the absence of such information. This is especially the case for fixed wireless providers because, as discussed above, there is a very limited track record for gigabit fixed wireless networks and because – while DSL coverage is largely driven by loop length[10] – fixed wireless coverage depends on many variables, some of which can only be determined by gathering data "in the field."[11] In other words, while the Commission may require fixed wireless providers to submit information about the spectrum band and amount, it cannot determine coverage without knowing propagation and line of sight characteristics, both of which vary greatly from area to area and both of which will impact required network antenna heights, maximum link length, and customer transceiver placement. And, even knowing whether fixed wireless transmissions can reach all locations does not indicate whether the network itself can in fact support gigabit transmissions for each of those locations. In essence, without all of this information, it is hard to envision how the Commission makes a reasoned decision about permitting a fixed wireless provider to bid in the Gigabit tier.

In the first instance, the Associations support the Commission returning to its original "bright-line" rule with respect to determining which parties can bid in given tiers.[12] To the extent that the Commission may nonetheless permit some fixed wireless and DSL technologies to bid in the Gigabit tier in RDOF Phase I, the Associations wish to provide a solution that meets the Commission's objective while ensuring that consumers in unserved areas receive the service they are promised, that integrity of the auction process is preserved, and that participation in the auction is maximized. To that end, the Associations propose below how the Commission should evaluate

---

7 *Id*. at ¶ 123.

8 *Id*. at ¶ 80.

9 *Id*. at ¶ 89.

10 *See, e.g.*, Comments of ADTRAN, WC Docket No. 19-126, *et al*. (filed Mar. 27, 2020), at 5 (explaining how "innovative DSL technologies" may provide "ultra-broadband speeds" through "the embedded copper base over the last few hundred feet").

11 *See e.g.,* Letter from B. Lynn Follansbee, Vice President—Policy & Advocacy, USTelecom to Ms. Marlene H. Dortch, Secretary, Federal Communications Commission, WC Docket No. 19-195 at 2 (May 14, 2020) ("The ability to successfully install fixed wireless service at a discrete location is very dependent upon the geography immediately proximate to the home and the positioning and type of equipment installed by the provider."); GeoLinks Ex Parte at 4.

12 *See also* GeoLinks Ex Parte at 2 ("GeoLinks proposed that the Commission return to its original proposal to prohibit certain service providers who have not previously offered Gigabit services to customers (and have not reported doing so via their Form 477s) from being able to bid the Gigabit Tier during RDOF.")

whether any given bidder proposing to use either technology, but fixed wireless in particular, in a given area will be capable of performing at the Gigabit tier level.[13]

With respect to standards for fixed wireless performance and coverage in particular, it should be noted that the concerns arising here are not new – they are the same concerns that have arisen for years in the context of broadband mapping more generally. In the absence of well-defined technical standards, parties have been free to self-determine and self-report coverage by whatever means they deem appropriate, leading to the collapse ultimately of the Mobility Fund II proceeding and the enactment of a new law directing the Commission to develop just these kinds of standards going forward.[14] Yet, even before the Commission has finalized that rulemaking,[15] the same sorts of concerns could now ironically be injected into the RDOF, with parties asserting the ability to deliver Gigabit level service and Commission staff then placed in the difficult position of having to evaluate those claims without reference to the very kinds of standards that are still subject to development in the mapping proceeding. Nonetheless, if the Commission will go down this path, it is essential that well-defined and well-founded technical standards be established in advance, so that all stakeholders can know with greater precision what the "goalposts are through which the ball must be kicked." Further, the Associations believe such standards can be established without unduly burdening providers filing short form applications, and they would facilitate Commission review, thus enabling the auction to begin on schedule, later in October.

---

[13] The best and most transparent process for doing so would be to require a fixed wireless or DSL provider seeking to bid at the Gigabit level to file with the short form application an accompanying waiver that can then be evaluated within the context of established procedure; the waiver request would simply set forth the supplemental information necessary to establish that the high burden has been met, and would permit confidential information to be submitted under seal to protect competitively sensitive material. The filing of a waiver would also provide transparency in allowing all stakeholders to know that such a case-by-case process is underway and to weigh in on the public aspects of it to the extent they are interested. To be clear, the Commission can and should revisit such considerations in subsequent phases of RDOF and other proceedings, at which time updated deployment data (based upon better mapping standards) may indicate a more consistent and widespread offering of Gigabit level services by other technologies. But, in the current context, a waiver process would appear to offer the only means of evaluating such requests in a well-defined and relatively transparent way. The Associations would be pleased to submit sample language to implement such a process upon request if necessary and desired.

[14] *See FCC to ditch flawed Mobility Fund II over unreliable 4G LTE coverage maps*, Fierce Wireless (Dec. 5, 2019), available at: https://www.fiercewireless.com/regulatory/fcc-to-scrap-flawed-mobility-fund-ii-program-over-inaccurate-4g-lte-coverage-maps; *Bill to Improve Broadband Maps Signed into Law*, U.S. Senate Committee on Commerce, Science, and Transportation, Press Release (Mar. 23, 2020), available at: https://www.commerce.senate.gov/2020/3/bill-to-improve-broadband-data-maps-signed-into-law.

[15] *Establishing the Digital Opportunity Data Collection*, *et al*., WC Docket No. 19-195, *et al*., Report and Order and Second Further Notice of Proposed Rulemaking, at ¶¶ 78-87 (rel. Aug. 6, 2019) (seeking comment on technical standards necessary to improve fixed broadband service coverage maps).

To achieve these objectives, the Associations consulted with network engineers to examine fixed wireless deployment parameters and establish a set of presumptions upon which the Commission staff can conduct its case-by-case review of fixed wireless applications for the Gigabit tier and reach well-reasoned decisions. As set forth in the attachment hereto, fixed wireless network performance depends on the following parameters:[16]

- Frequency (Spectrum Band) – with lower band spectrum providing greater coverage than higher band spectrum;

- Licensed versus Unlicensed Spectrum – with exclusively licensed spectrum providing greater assurance of performance and lack of interference than unlicensed (shared) spectrum;

- Amount of Spectrum – with larger amounts of spectrum needed to provide greater throughput;

- Network Architecture – with greater sharing of spectrum and capacity resources occurring in point-to-multipoint and mesh deployments than in point-to-point deployments;

- Spectrum Propagation Characteristics – with greater signal attenuation, and even complete signal blockage, occurring at higher frequencies;

- Atmospheric Conditions – with greater signal attenuation occurring, depending on the frequency and intensity of the event, due to rain, fog, or other conditions;

- Line of Sight Requirements – with greater signal attenuation occurring at higher frequencies where there is not a clear line of sight (e.g., trees, buildings) between the transmitter and receiver;

- Suitable Locations for Access Point Antennas – with a limited density of tall structure for antenna placement in a rural environment to overcome propagation and line of sight limitations at higher frequencies;

- Premises Equipment – with greater signal attenuation occurring at higher frequencies when transceivers are placed indoors; and

- An additional – non-spectrum – factor is the capability of backhaul facilities from the last-mile wireless link to the network – with fiber facilities having greater performance, even if shared, and reliability.

[16] *See* GeoLinks Exparte at 2 ("GeoLinks explained that specific performance of individual equipment types is dependent on many factors including available spectrum, weather, topography, topology, the number of customers being served, oxygen absorption and, most importantly, engineering.").

To capture these parameters in the short form application, the Associations propose the Commission add the following language at the end of Section 4(e) of its proposed short-form application (Appendix A of the *Draft Public Notice*), which would apply to fixed wireless applicants seeking to bid in the Gigabit tier:[17]

"A fixed wireless applicant seeking to bid in the Gigabit Performance tier should provide the following information: the frequency band(s) it will use for the service; the proposed channel size for connections from the network to locations; the proposed wireless topology (e.g., point-to-point, point-to-multipoint, or mesh); the maximum link range (per the stated topology and link speed) from the network to the location; the transport technology used to backhaul traffic from the service link(s) to the network; the type of customer premises installation (e.g., indoor self-install or rooftop) and the antenna size and type; and its assumptions as to busy hour overload and other oversubscription metrics that informed its belief that it can deliver a Gigabit level service throughout the area(s) for which it intends to bid."

The Associations submit, based on industry-standard practices, the Commission use these parameters to establish the following rebuttable presumptions to assess whether to approve the short form application of a fixed wireless provider to bid in the Gigabit tier.[18] The Associations note that these presumptions seek to capture factors that are more certain (i.e. frequency, spectrum amount, and customer transceiver placement) and factors that can only be known by examining deployment in-depth and in the field (*i.e.*, localized atmospheric and line of sight conditions). Accordingly, because so much is unknown about the actual performance of the proposed fixed wireless gigabit network in any given instance and because there are few such deployments anywhere in the country – and since consumers in unserved areas are at risk of not obtaining the bid-for service – the Associations' assert any metrics the Commission staff uses should be conservative.[19]

---

[17] The Commission should amend Section 4 of Appendix A to require DSL applicants seeking to bid in the Gigabit tier to provide information regarding the maximum length of copper within the loop network it will deploy.

[18] The Associations note that GeoLinks too supports the Commission staff using a set of metrics, albeit different from the ones proposed by the Associations, to review claims in short form applications filed by fixed wireless providers seeking to bid in the Gigabit tier. *See* GeoLinks Ex Parte at 5 ("It is GeoLinks' strong suggestion, based on the forgoing, that the Commission implement the following to ensure stringent short-form review during the RDOF process. First, the Commission should only allow for equipment that has a capacity of at least 1500 Mbps aggregate on the client device, so that full 1000 Mbps/500 Mbps data rates can be achieved in all real-world applications. A higher threshold of 1750 Mbps aggregate to ensure adequate headroom for varying link conditions would be ideal. Second, the Commission should require all applications to make a showing that throughput capacity of their intended end user equipment meets or exceed the above standards in TCP/IP testing.").

[19] The Associations note that fixed wireless equipment vendors may have network deployment "calculators" on their websites which may indicate, for instance, that the maximum link length that will enable a provider to deliver gigabit service is much greater than set forth in the presumptions herein. The Associations caution the Commission that these are ideal case, marketing tools that do not reflect actual performance in the field. GeoLinks makes this same point in its recent *ex parte*. *See* n.5 *supra*.

Proposed Short Form Review Presumptions[20]

- Because a fixed wireless provider is unlikely to be able to aggregate a sufficient amount of dedicated spectrum below 10 GHz, the Commission should presume that the provider is incapable of meeting the Gigabit tier performance requirements if it proposes to use such spectrum.

- The Commission shall presume a fixed wireless provider using spectrum in the 24, 28, 37-39 GHz bands is capable of meeting the Gigabit tier performance requirements only if it has all of these system characteristics – an aggregate of more than 200 megahertz of spectrum,[21] a point-to-multipoint architecture with limited oversubscription (or a point-to-point architecture), a maximum link length of 500 feet as measured from a point of fiber backhaul,[22] and plans to deploy outdoor-mounted customer premises transceivers.

- The Commission shall presume a fixed wireless provider using the 60 GHz band is capable of meeting the Gigabit tier performance requirements only if it has all of these system characteristics – a point-to-multipoint architecture with limited oversubscription (or a point-to-point architecture),[23] a maximum link length of 200 feet as measured from a point of fiber backhaul, and plans to deploy outdoor-mounted customer premises transceivers.[24]

Similarly, for DSL providers seeking to bid in the Gigabit tier, the Commission should adopt a presumption that a provider is capable of doing so and performing only if the maximum length of copper loops in its network is no more than 200 feet as measured from a point of fiber backhaul.

---

[20] The Associations propose the Commission include these presumptions at the appropriate places in the *Draft Public Notice.*

[21] *See* "Nokia Achieves World-Record 5G Speeds," (May 19, 2020), available at https://www.nokia.com/about-us/news/releases/2020/05/19/nokia-achieves-world-record-5g-speeds/. Nokia achieves up to 4.7 Gbps utilizing 800 MHz of mmWave spectrum and dual connectivity under lab conditions. Scaling down the bandwidth to 200 MHz should provide a gigabit level of service. This is based on a sector throughput for one user (a 1:1 relation between cell and user). If multiple end users are required to be served, then more bandwidth will be required. For instance, based on the Nokia test, 800 MHz of bandwidth will support up to four users simultaneously with gigabit level service.

[22] Even with sufficient spectrum and very good transmission conditions for last-mile links, it is critical to have adequate backhaul to support multi-gigabit service to ensure the network provides gigabit service to each user. Fiber alone will ensure such performance. By contrast, microwave transmission will be relied upon only in select instances because it requires a large amount of dedicated bandwidth and very good transmission conditions to achieve multi-gigabit service.

[23] The Associations do not include a mesh architecture because it requires extensive daisy chaining/bandwidth sharing, it is very challenging to scale in deployments to achieve coverage, and network planning is both very challenging and highly site specific.

[24] As discussed herein, among other factors, local atmospheric conditions and line of sight information are critical to ensuring a fixed wireless network can deliver gigabit speeds. The Associations, however, recognize that it is unlikely to be practical for the Commission to collect and assess such information as part of the short-form process it has established. Consequently, the Associations reflect this information by reducing the "ideal" maximum link length. The maximum link lengths proposed herein are based on the atmospheric and line of sight limitations expressed in Figures 1, 2, and 3 in the attachment.

As we discuss above, the Commission is undertaking an exceptional process in reviewing applications by fixed wireless providers to bid in the Gigabit tier on a case-by-case basis – one that is not applicable to any technology other than DSL and one that, even as compared to an evaluation of DSL capability, is fraught with uncertainty because it will lack critical information on which to base its decision. As a result, should the Commission proceed on this path, it may deter participation in the auction by other applicants for the Gigabit tier using well-established technologies not requiring case-by-case review. Moreover, should a fixed wireless or DSL bidder win at the Gigabit tier and not file sufficient technical data in the long-form, it would undermine the integrity of the auction. And, even more importantly, even if a long-form application is approved, should the fixed wireless or DSL provider not perform in the field, it would harm consumers in eligible areas. For all these reasons, the Associations propose the Commission include the following additional penalties, beyond the default penalties, support reductions, and other non-compliance measures in the *Draft Public Notice*,[25] for fixed wireless providers who are permitted to bid after case-by-case review by the Commission:

- While the *Draft Public Notice* requires that applicants certify under penalty of perjury that they are technically qualified to provide the performance tier they selected,[26] the Commission should adopt a presumption that the failure by a winning fixed wireless or DSL bidder to demonstrate its capability to deliver, or ultimately to deliver, Gigabit performance to the locations required for buildout after having sought a special opportunity to bid in that tier based upon limited information in the short-form application is a misrepresentation/lack of candor violation.[27]

- While the *Draft Public Notice* subjects an applicant that defaults to the same forfeiture upward adjustment criteria as other rule violations, the Commission should adopt a presumption that the failure by a winning fixed wireless or DSL bidder to demonstrate its capability to deliver, or ultimately to deliver, Gigabit performance to the locations required for buildout warrants an "intentional violation" upward forfeiture adjustment because, as noted above, such winning bidder certified that it could provide Gigabit service.[28] Similarly, the Commission should adopt a presumption that the failure of a winning fixed wireless or DSL bidder to demonstrate its capability to deliver, or ultimately to deliver, Gigabit performance to the locations required for buildout warrants a "substantial harm" upward forfeiture adjustment because its inaccurate application potentially prevented another service provider from winning RDOF support.[29] Further, the Commission should adopt a presumption that a winning fixed wireless or DSL bidder's failure to demonstrate its capability to deliver, or ultimately to deliver, Gigabit performance to the locations

---

[25] *Draft Public Notice* at ¶¶ 318-320. The *Draft Public Notice* provides that a service provider's failure to perform would be subject to the same enforcement tools available for other FCC rule violations. Consequently, fixed wireless or DSL providers permitted to bid in the Gigabit tier would not have a "fair notice" objection if the Commission adopted the penalty enhancements discussed herein.

[26] *Id.* at ¶ 105.

[27] *See* 47 C.F.R. § 1.17.

[28] *See* 47 C.F.R. § 1.80, Section II

[29] *See id.*

required for buildout warrants a "substantial economic gain" upward forfeiture adjustment considering the potentially large support amounts to be won at the RDOF auction.[30]

- Furthermore, the Commission should subject a winning fixed wireless or DSL provider that fails to demonstrate its capability to deliver, or ultimately to deliver, Gigabit performance to the locations required for buildout to non-monetary penalty enhancements (*e.g.,* prohibiting the provider from participating in RDOF Phase II or future high-cost auctions).

In closing, the Associations and their members believe the RDOF represents a substantial opportunity to deliver services to Americans waiting far too long for access to robust broadband, and we applaud the Commission for moving this process forward. We are hopeful that the recommendations set forth herein will help flesh out the standards and processes necessary for a fixed wireless or DSL provider to "make a case" and satisfy the "high burden" of showing capability to bid in the Gigabit tier. We believe such changes are necessary to promote the integrity of the auction, to maximize participation by truly qualified bidders of all kinds, and to ensure that as many unserved consumers as possible realize the benefits of the better voice and broadband services promised by the RDOF.

Thank you for your attention to this correspondence. Pursuant to Section 1.1206 of the Commission's rules, a copy of this letter is being filed via ECFS.

Sincerely,

/s/ *Michael R. Romano*
Michael R. Romano
Senior Vice President –
Industry Affairs & Business Development
NTCA–The Rural Broadband Association

Attachment: "Challenges in Delivering Gigabit Speeds Using Fixed Wireless in Rural Residential Markets"

cc: Preston Wise
Arielle Roth
Joseph Calascione
Travis Litman
Austin Bonner

30 *See id.*

Challenges in Delivering Gigabit Speeds Using Fixed Wireless in Rural Residential Markets

There are many elements that affect a service provider's ability to deliver 1+ Gbps to rural residences on a consistent and ubiquitous basis. These include what spectrum is being used, whether the spectrum is licensed or unlicensed, what channel size is available, the choice of wireless network technology and topology, and what is the topography of the residential market. These elements of concern and their impacts on fixed wireless coverage and capacity are discussed herein.

Spectrum Bands

The specific frequency band, amount of spectrum and whether it is unlicensed/shared or exclusively licensed has a direct impact on service range and amount of bandwidth that can be offered to customers through a wireless broadband service. The relevant available commercial spectrum bands that might be considered by some for Gigabit-level fixed wireless services include:

Low-band - < 2.5 GHz

This spectrum includes the 600/700/800 MHz, Cellular, PCS, AWS, and WCS bands and is typically used by mobile carriers for broad mobility coverage. Channel sizes are less than 20 Mbps, limiting the amount of throughput that could be achieved on a single channel.

Challenges for Gbps Fixed Service

While low-band spectrum can easily propagate several miles from a tower, making it attractive for rural areas, the limited channel sizes would hinder deploying Gbps speeds to residential users. Advanced LTE techniques, such as carrier aggregation and MIMO, could potentially achieve peak speeds of up to 1 Gbps, but that would be shared across all users in a sector. Average customer speeds in these bands would typically fall within a range of 5-10 Mbps.

Mid-band - 2.5 GHz – 6 GHz

2.5 GHz EBS/BRS

While there is abundant spectrum in this band, almost all the available spectrum (up to 196 MHz per market) is owned and/or leased by T-Mobile/Sprint. The unassigned white spaces in the band will eventually be auctioned by the FCC, but the timing of the auction remains unclear.

Challenges for Gbps Fixed Service

Large channels and good propagations characteristics will make this spectrum a prime target for nationwide mobile 5G operations. Obtaining access to this band for residential Gigabit-level fixed wireless service would appear difficult and uncertain at this time.

3.55– 3.7 GHz CBRS

The CBRS band consists of 150 MHz of total spectrum divided into 10 MHz channels. Seven of the channels (PALS) are protected (licensed) and eight are general access (essentially unlicensed) and referred to as GAAs. A single company can acquire no more than four PALs (40 MHz total) for exclusive

use in each market/county. Companies will contend for GAA channels and any unassigned PAL channels on a per location basis, limiting the total amount of spectrum that could be used by each for service delivery.

Challenges for Gbps Fixed Service
While this band is expected to see significant fixed wireless deployments, questions persist regarding the ability of this band to sustain higher-speed services at levels greater than a Gigabit given the limited number of channels and aggregate bandwidth that a single operator could be guaranteed.

C-band
This block of mid-band spectrum is planned to be auctioned in late 2020. It is ideally suited for 5G mobility and the channel sizes and market areas are dimensioned accordingly.

Challenges for Gbps Fixed Service
Given the significant interest in this band for nationwide 5G mobility operations, it is uncertain at this time whether sufficient spectrum could be obtained in a future auction to enable a fixed wireless business case.

5 GHz
This unlicensed band is primarily used for WiFi, both in-building and outdoor. Utilizing the maximum 160 MHz channel size and the latest WiFi standards (WiFi 6), 1+ Gbps can be achieved, but only in close proximity to the WiFi router. The tremendous popularity of the band and ubiquity of WiFi devices also creates interference, which will limit throughput and range in a macroenvironment. Interference cancellation and other techniques to better enable high speed residential access in this band remain works in progress at best.

Challenges for Gbps Fixed Service
While this band can be used for residential access, transmit power restrictions and proliferation of WiFi devices in the band (i.e. interference) limit range and throughput.

6 GHz
Predominantly used for long haul PTP microwave links, this band was recently approved for unlicensed use to help ease the congestion in the 5 GHz unlicensed band. There is enough spectrum in the band for seven additional 160 MHz WiFi channels. However only four of the channels are authorized for outdoor use and even then can only operate at relatively low transmit power and must coordinate with the thousands of incumbent PTP links using a yet to be approved Automatic Frequency Coordination system.

Challenges for Gbps Fixed Service
Transmit power restrictions, limited spectrum allocated for outdoor use, and required coordination around high-power PTP microwave links (which has yet to be defined), will limit this band to mostly in-building WiFi use, at least in the near-term.

High-band – 24 GHz – 80 GHz

24, 28, 37/38/39 GHz

Referred to as mmwave bands, these frequencies were recently auctioned by the FCC with the intent of being used for high bandwidth 5G services. National and larger regional operators and investors own most of the licenses, either through auction or acquisition.

Large channels of 100 – 400 MHz will allow for throughputs of over 1 Gbps with 5G technology. Some providers have deployed high-bandwidth fixed residential services in these bands, but only in urban and dense suburban areas due to the restrictive propagation characteristics of these frequencies. Mmwave frequencies will not penetrate most solid objects, including typical building materials such as brick, concrete, and wood. Even coated glass will attenuate a mmwave signal by 40 dB or more. Rain is another impediment to long distance propagation of mmwave signals. As shown in Figure 1 below, heavy rain will significantly attenuate a mmwave signal, particularly above 10 GHz.

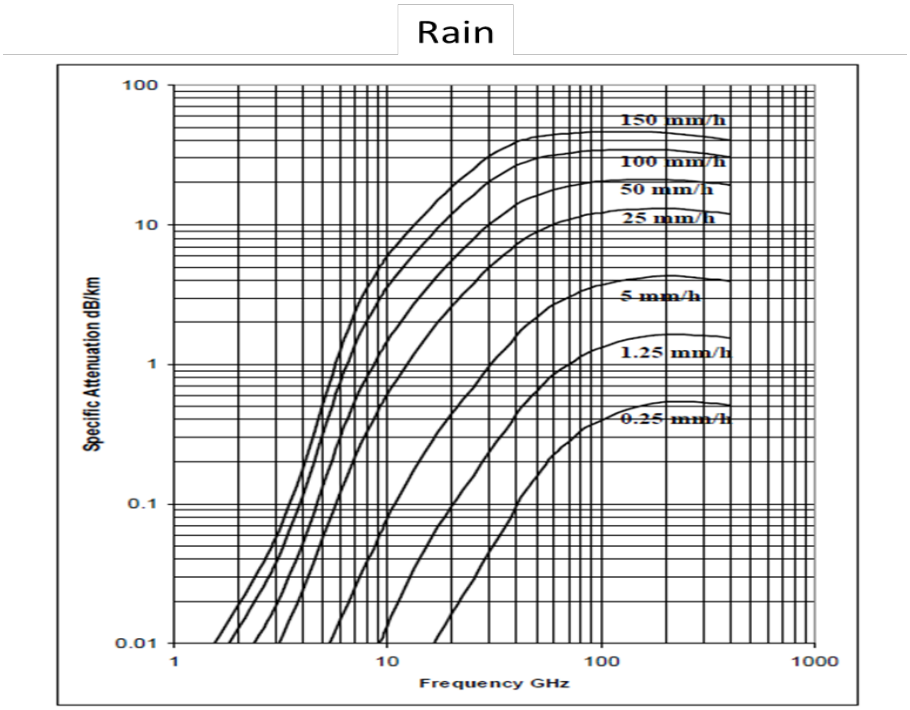


Figure 1. Signal Attenuation by Rain vs. Frequency

Challenges for Gbps Fixed Service

This spectrum will primarily be used for small cell and macro-tower backhaul, 5G mobility in urban areas/hot spots, and niche 5G applications such as sports venues, agri-tech, smart cities, V2X, industrial, and healthcare. As noted, propagation in these bands is blocked by physical structures and heavily attenuated by rain and therefore the spectrum is best suited for short range, line of sight (LOS) connections. Initial deployments have shown that fixed wireless networks can be deployed for residential access but range is limited to a few hundred meters, which is not practical in low density, rural environments.

60 GHz V Band

This is an unlicensed band that will be capable of delivering 1+ Gbps speeds to a single user via radios incorporating the latest 802.11ay standards. Most currently available radio products, however, still use the older 802.11ac technology which will not be able to deliver user speeds of 1 Gbps down and 500 Mbps up. As illustrated in Figure 2 below, Oxygen molecules attenuate the RF energy of a 60 GHz signal, limiting range to under 1 km in even the best point to point propagation conditions. Higher throughput links, such as those employing 802.11ay, will likely have ranges less than 300 meters. Like the 24-39 GHz bands, 60 GHz is also attenuated by heavy rain and typically requires LOS between antennas as it will not propagate though most solid objects.

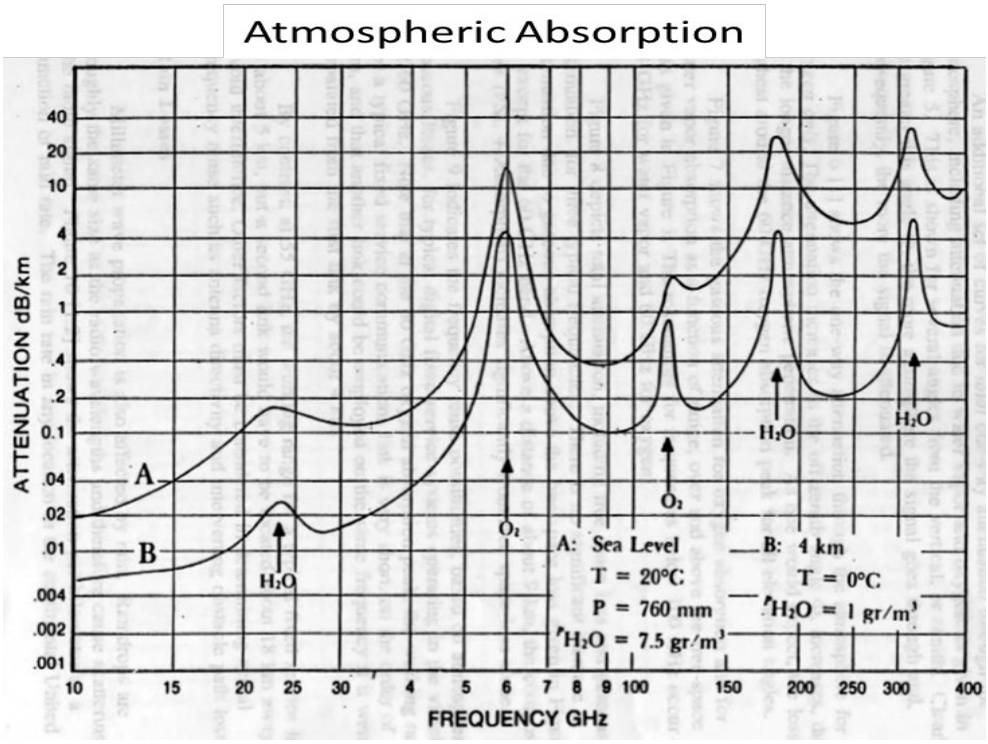


Figure 2. Atmospheric Absorption vs. Frequency

Challenges for Gbps Fixed Service

While offering wide channels and potential for 1+ Gbps throughput, the propagation challenges of the V-band make it a much better solution for high capacity PTP access and small cell backhaul in an urban environment rather than rural residential service.

80 GHz E Band

This is a "lightly licensed" band allocated for high capacity PTP use. 80 GHz radios can deliver up to 10 Gbps of throughput. The propagation characteristics are slightly better than 60 GHz, but the technology still requires clear line of sight between each end of the link.

Challenges for Gbps Fixed Service
Due to the cost of 80 GHz radio equipment and installation complexity and expense, this band is not practical for residential access. 80 GHz is primarily used in urban areas for backhaul, enterprise access, and redundancy to fiber for mission critical applications.

Last Mile Network Topology

The choice of network topology for last mile wireless access, will also affect a service provider's ability to offer residential Gbps speeds on a consistent and cost-effective basis.

Point to Point (PTP)
PTP microwave radios are capable of delivering higher speeds, but the radio cost and installation expense make them ill-suited for residential use. Both ends of the radio link need to be carefully aligned, which requires a skilled installer at both ends. Due to the 1:1 relationship between the hub location and the end user, a hub serving 20 customers would require 20 separate antennas, which is operationally impractical and cost prohibitive. Primary use cases for PTP microwave links would be for cell tower backhaul, enterprise access, and redundancy services.

Point to MultiPoint (PMP)
Point to MultiPoint is the favored access technology for residential service due to the reduced capital and operational expenses. One antenna at the hub site can serve multiple homes and the installation processes only requires alignment of the residential antenna.

Unlike a PTP link though, bandwidth of a PMP sector is shared across all users within the sector. A given user might be able to reach the peak speed of a sector at certain times of day, but average user experience will be much less than peak. Radio vendors may also refer to the "aggregate" throughput of a sector, which is the summation of uplink and downlink rates for all users in a sector. A radio that is advertised to achieve 1 Gbps aggregate throughput for a sector, for example, would *not* be able to deliver 1 Gbps down and 500 Mbps up to a single customer.

Another operational consideration when employing a PMP topology is the inherent single point of failure. If an access point or hub fails, all the users being served by that access point will be affected.

Mesh
A Mesh topology is typically promoted by mmwave radio vendors (particularly at 60 GHz) to get around LOS and range limitations. Links can be "daisy chained" from one customer premise location to another without having to have LOS back to a hub. The challenge of relying on mesh technology in a rural residential deployment is scale. The operator would need mesh radios to be installed on the majority of homes in an area in order for the mesh technology to work properly. And homes would still need to be in range and have LOS to one another.

Residential mesh deployments also have operational challenges. If a customer decides it no longer wants the service, if the customer moves, or if the customer's antenna is damaged, other homes linked

to that node could lose their service. This technology is best suited for small cell backhaul and access in urban environments.

Market Topography

The choice of technology and spectrum is greatly affected (and thus driven) by local market topography – and each area is unique. For example:

- Mid-Atlantic and North-Eastern US suburban and rural residential areas are heavily treed and have rolling hills, particularly along the Appalachians, making propagation very challenging for mmwave. Mid and low-band spectrum would have the best propagation characteristics to overcome these challenges but would not enable the kinds of higher speeds seen using mmwave in more densely populated environments.
- Residential areas that might have flat terrain, such as Florida, often have predominantly one-story homes. Even with relatively light tree density, the roofs are below the treetops and LOS complicate the use of mmwave in achieving connectivity and higher speeds across a majority of the homes.
- Many residential areas, particularly new ones, have buried utilities and therefore limited options to attach antennas for wireless penetration into neighborhoods. Even traditional towers would typically be spaced too far apart for high bandwidth mmwave coverage.

There have been numerous studies published that show the probability of Line of Sight between a hub antenna and a residential antenna. The results of one such study are shown below in Figure 3. The data illustrates that beyond 200m from the hub site, there is very little probability of LOS in a rural environment. In Figure 4, the data presents a case that increasing the height of the hub site antenna helps improve LOS as one might expect, but the overall probability of LOS to a residence is limited.

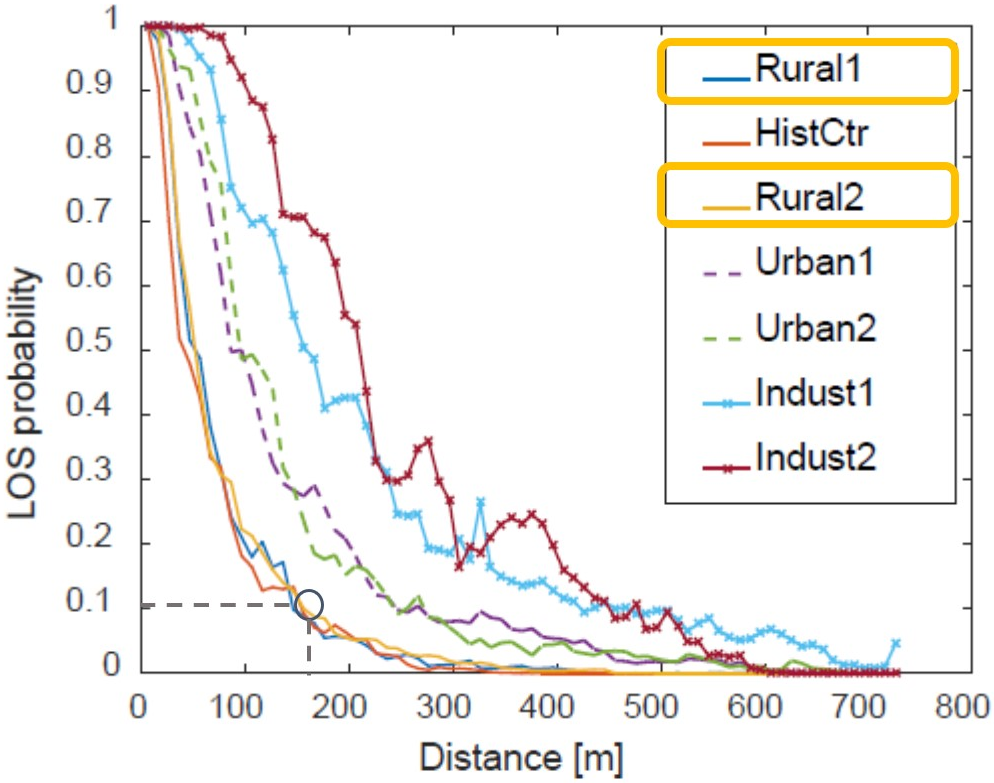
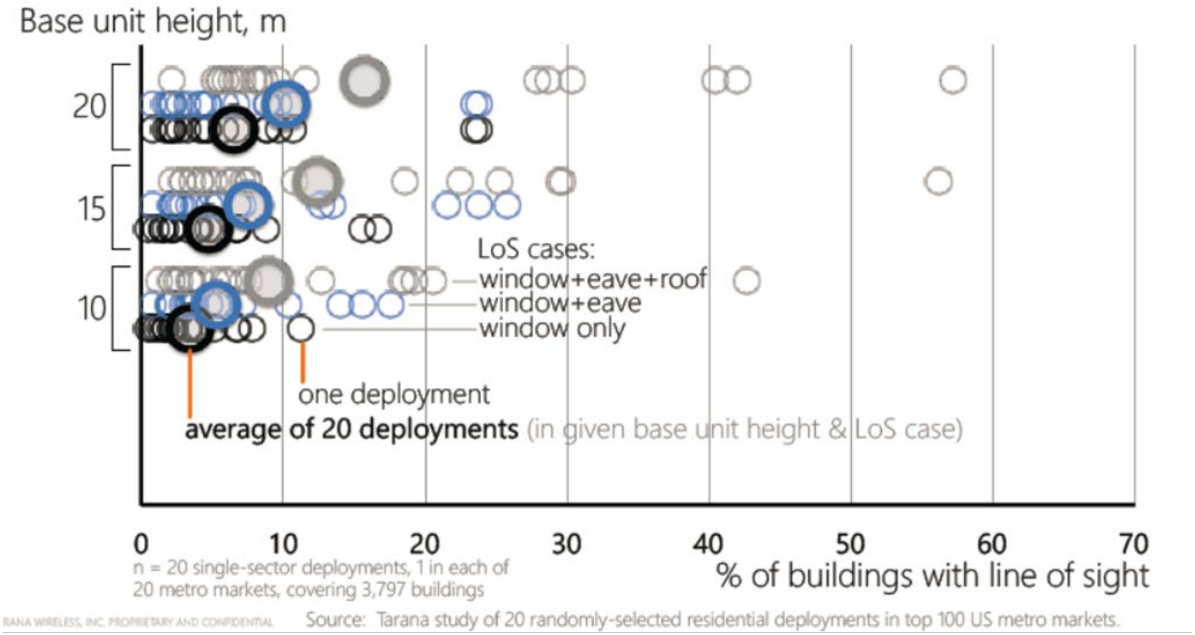


Figure 3. Probability of LOS over Distance between Tx and Rx. Source: Study by Computer Networks and Communications, Dept. of Computer Science, University of Erlangen, Germany.



Source: Tarana Wireless

Figure 4. LOS Probability vs hub antenna height and residential antenna location

Additional Challenges

Identifying Locations for Wireless Hubs

Finding suitable locations for wireless hub antennas is another challenge with which rural wireless service providers are faced. Utility poles may not exist, are too short to extend above tree line, and/or do not have power or vertical space for equipment.

Traditional monopole or lattice towers in rural areas are typically spaced for lower frequency, mobility coverage, usually 2-5 miles. This spacing is insufficient for residential coverage using mmwave radios, which would have a range of no more than a few hundred meters.

Backhaul

Wireless hubs would need multi-gig backhaul in order to accommodate 1+ Gig residential speeds. Cellular monopole and lattice towers would normally have that level of bandwidth available, but as noted above, rural towers would not have the dense spacing required to offer residential fixed service at such levels, particularly at mmwave frequencies.

Market Examples

The following examples depict the challenges in providing high capacity service using mmwave radio technology in typical rural residential markets.

Example A – Carroll County, GA

This market, like many in the southeast, in characterized by tall, dense deciduous and coniferous trees. The trees are much taller than the typical single-story homes in the market making LOS to local towers unlikely. Even if small cells were placed on utility poles, the tree density would limit the range of the small cell to just a few homes at mmwave frequencies.

Example B – Nacogdoches County, TX

While the deciduous tree population is not as dense as in the Georgia example, the mature trees in this Texas market are still much taller than the average single-story home making LOS a challenge. Note that even the tops of the utility poles are still below the height of the trees. Mmwave radios, in either a PMP or mesh configuration, would not be able to provide consistent, high capacity coverage.

As a further example of the challenges with mmwave residential service, the image above shows the local Nacogdoches water tower, the only tall structure in the neighborhood. Assuming that mmwave radios could be placed on the water tower, LOS would be limited to no more than a dozen homes around the tower. Dense tree coverage would block most rooftops beyond a couple hundred meters.

Example C – Charlotte County, FL

The picture above shows a typical Florida residential area. The terrain is very flat, and the trees are sparser than in the previous two examples. Even still, the trees are generally taller than the average single-story homes, making rooftop to rooftop mesh connectivity or utility pole to rooftop PMP connectivity a challenge. Hub antennas placed on typical cellular monopole or lattice towers would have a reasonable probability of LOS to a given rooftop, but as in most residential areas, there are no such towers in the neighborhood.

This image shows a sample 60 GHz PMP coverage design for the Charlotte County street-view neighborhood above. The area of interest is only 2x2 miles, but given the limited range of 60 GHz, particularly in a heavy rain region like Florida, the network would require over 30 hub locations to provide maximum probability of LOS coverage. Apart from the capital costs, this design illustrates two key challenges with mmwave fixed wireless in residential areas – 1) where to find 30 hub locations that are above the local clutter and 2) how to get multi-gig backhaul to each of the hub locations.