Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Use of Spectrum Bands Above 24 GHz for Mobile Mobile Radio Services	)	**GN Docket No. 14-177**
	)	
Amendments of the Commission's Rules Regarding The 37.0-38.6 GHz and 38.6-40.0 GHz Bands	)	**ET Docket No. 95-183 (terminated)**
	)	
Implementation of Section 309(j) of the Communications Act – Competitive Bidding, 37.0-38.6 GHz and 38.6-40.0 GHz Bands	)	**PP Docket No. 93-253**
	)	
Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules For the 42.3-43.5 GHz Band	)	**RM-11664**

To: The Commission

COMMENTS OF ARRL, THE NATIONAL ASSOCIATION FOR AMATEUR RADIO

ARRL, the national association for Amateur Radio, formally known as the American Radio Relay League, Incorporated (ARRL), by counsel, hereby respectfully submits its comments in response to the *Notice of Inquiry*, FCC 14-154, 29 FCC Rcd. 13020, released October 17, 2014 (the Notice).[1] The Notice generally examines the potential for the provision of mobile radio services in frequency bands above 24 GHz. Specifically, the Commission states an intention to examine the use of millimeter wave (mmW) bands for mobile use, thus to develop

[1] Pursuant to a Public Notice, *Wireless Telecommunications Bureau and Office of Engineering and Technology Extend Period to File Comments and Reply Comments in Response to Notice of Inquiry on Use of Spectrum Bands Above 24 GHz for Mobile Radio Services*, DA 14-1703, released November 25, 2014, the Commission extended the comment date in this proceeding to January 25, 2015 and the Reply Comment date to February 17, 2015 in response to a request by the Satellite Industry Association. Accordingly, these comments are timely filed.

technical standards for Fifth Generation (5G) mobile services.[2] So, the Commission asks what frequency bands above 24.0 GHz would be most suitable for this purpose and a series of other, related questions. The goal is to develop a record on mobile service rules, sharing criteria and a licensing framework for mobile services in some of those bands. In the interests of the Amateur Radio Service in maintaining reasonable access to the present mmW allocations at and above 24 GHz, within which to conduct experiments in radio propagation and to contribute to the development of high speed broadband networks and other communications technologies in that frequency range, ARRL states as follows:

I. Introduction and Background

1. Amateur Radio licensees have for a very long time had access to specific, limited segments of certain mmW bands. These segments have been beneficially deployed in fulfillment of the purposes outlined for the Service in 47 C.F.R. §97.1.[3] The mmW bands allocated to the Amateur Service include the following bands (specified in gigahertz):

Wavelength	**ITU Region 1**	**ITU Region 2**	**ITU Region 3**
1.2 cm	24.00-24.25	24.00-24.25	24.00-24.25
6 mm	47.0-47.2	47.0-47.2	47.0-47.2
4 mm	76-81	76-81	76-81
2.5 mm	122.25-123.00	122.25-123.00	122.25-123.00
2 mm	134-141	134-141	134-141
1 mm	241-250	241-250	241-250
	Above 275	Above 275	Above 275

[2] It is understood that the Commission is considering mobile use of the bands above 24 GHz not for stand-alone mobile services, but rather as supplementary channels to deliver ultra-high data rates in specific places. The mmW bands would thus be utilized as one component of near-term commercial mobile service packages that continue to use lower bands to ensure ubiquitous coverage and continuous system-wide coordination, as part of a 5G network that will permit substantially exceed the capacity of existing mobile technologies.

[3] That rule section sets forth the expectations of the Commission for the Amateur Radio Service, including the continuation and extension of the amateur's proven ability to contribute to the advancement of the radio art; to allow advancement of skills in the communications and technical phases of the art; and to expand the reservoir of trained operators, technicians and electronics experts.

In addition to the foregoing, internationally, per footnote RR 5.561A, the Amateur and Amateur-Satellite services have a secondary allocation at 81.0-81.5 GHz. Each of these allocations are shared, to a greater or lesser extent, and the Amateur Service has in each case conducted its operations in the bands successfully and compatibly with the sharing partners in each band. For example, the 24.00-24.05 GHz segment of the band 24.00-24.25 GHz band (which is just above the radioastronomy allocation at 23.6-24.0 GHz) is available in the United States for Part 18 ISM[4] operation, and the segment 24.05-24.25 GHz is shared on a secondary basis with Government radiolocation (which uses the band extensively on a primary basis, principally for military purposes). This sharing arrangement works remarkably well; Amateur spectrum usage, though different, is generally compatible with military and governmental use. The National Telecommunications & Information Administration (NTIA) has confirmed that compatibility.[5]

2. At 24.0-24.05 GHz, the Amateur Service provides a compatible buffer between potentially incompatible adjacent band uses: Radioastronomy below 24.0 GHz and Radiolocation above 24.05 GHz. The same circumstance appertains in the Amateur Radio primary allocation at 47.0-47.2 GHz. Both the 24.0-24.25 GHz and 47.0-47.2 GHz bands are significantly and regularly used by Amateur Radio operators for communications on point-to-point, line of sight paths, testing and pushing the limits of propagation and atmospheric absorption characteristics above 24 GHz. Radio amateurs commonly utilize antennas with

[4] Industrial, Scientific and Medical devices.

[5] In the *Spectrum Allocation Final Report* of NTIA (February 1995) released in response to Title VI of the Omnibus Budget Reconciliation Act of 1993, NTIA stated at Appendix B of that Report that: "The amateur radio service has successfully coexisted with Federal fixed, mobile and radiolocation services (i.e. radar) for nearly fifty years. As indicated in many of the public comments on the Preliminary Report and the FCC NOI, this sharing has been successful for both Federal and amateur spectrum users. This success is primarily due to the fact that much of the Federal spectrum usage is located away from populated areas, minimizing potential interference as well as the amateurs' ability to utilize the guard bands placed between different types of Federal services. . . . Recently, amateurs have indicated that there are practical problems sharing spectrum with commercial services that have a relatively high transmitter power, a high number of stations in heavily populated areas, and/or high duty cycle[s] . . . ."

narrow beamwidths on mmW allocations at high elevations to communicate over point-to-point paths of varying distances, some of which are substantial. By maximizing antenna efficiency, receiver design and facilities siting, radio amateurs have demonstrated the capabilities, and contributed to the development of mmW spectrum on a consistent basis. Attached hereto as Exhibit A is a list maintained by ARRL of the claimed distance records for Amateur Radio two-way, point-to-point communications by band over time in North America alone. It is notable that of these records, two at 75 GHz were established as recently as June of 2014. The amount of propagation research worldwide by Amateur Radio operators in the mmW bands is on the increase.[6] In other mmW bands such as 77-81 GHz, compatible sharing with automotive radars is possible because of geographic separation, limited propagation characteristics of the latter permitting frequency re-use, and because of the type of Amateur Radio operations conducted in the band.

3. The instant proceeding constitutes the second time in the past 20 years that the Commission has broadly examined the development of the mmW bands. In November of 1995, the Commission released a Notice of Proposed Rule Making in ET Docket 94-124[7] which proposed to open for commercial development and use a portion of the mmW bands above 40 GHz. Initially proposed were: (1) the allocation of 16 GHz of spectrum on a shared basis with existing and future government users; and (2) the allocation of 2 GHz between 40.2-42.5 GHz for non-government uses. The plan was to permit the development of short-range wireless radio systems with high-bandwidth, high data transfer rate capabilities. Purposes envisioned by the

[6] For example, the Australian communications distance record for communications at 78 GHz as of December, 2013 (between Amateur Stations VK3XPD and VK3ZQB was 32 kilometers. On May 15, 2014 Amateur station VK3XPD located at Mt. William in Western Victoria made two-way digital and analog voice (SSB) communication with VK3HZ at Melbourne's Mt Dandenong Observatory, a path of 139.8 kilometers. This effort not only broke a record for SSB distance, but established an initial digital record on that band, which was officially confirmed.

[7] *Amendment of Parts 2 and 15 of the Commission's Rules to Permit Use of Radio Frequencies Above 40 GHz for New Radio Applications,* Notice of Proposed Rule Making, 9 FCC Rcd. 7078 (1994).

proposal included National Information Infrastructure applications, educational and medical short-range applications including remote wireless access, and non-communications applications such as vehicular radar systems and highway guidance systems.

4. The Commission in Docket 94-124, among other things allocated the bands 47.2-48.2 GHz for commercial licensed use, and adopted flexible licensing rules to permit licensed operations on an area-wide basis. The Commission also developed a band plan for the 36-51 GHz band in a separate docket at the same time.[8] It also established rules for unlicensed operation in the 59-64 GHz band. Finally, in a Third Report and Order in Docket 94-124 in 1998, the Commission firmed up the allocation of the band 76-77 GHz for vehicular radar collision avoidance systems, and created a co-primary Amateur Radio allocation at 77.5-78 GHz.[9] Since that time, the entirety of the band 76-81 GHz has been the subject of worldwide development and deployment of advanced vehicular radar systems and a test ground for autonomous automotive system development on a compatible, shared basis with the Amateur Service. [10]

5. In the 1995-1998 dockets dealing with commercial development of the mmW bands, however, there was little consideration of future land mobile communications systems. The focus then was on radiolocation, satellite and fixed operations. Nevertheless, the Commission wisely chose to adopt flexible rules for both licensed and unlicensed operations, thus to encourage the commercial deployment of the mmW bands according to technical developments rather than the

[8] *Notice of Proposed Rule Making*, IB Docket No. 97-95, FCC 97-85, released March 24, 1997.
[9] In the *Third Report and Order* in Docket 94-124, FCC 98-150, released July 15, 1998, the Commission affirmed the value of Amateur Radio mmW experimentation: "The Commission believes that upgrading the status of the Amateur Radio Services to co-primary in the 77.5-78 GHz band is needed to ensure that future amateur station access to spectrum near 77 GHz is maintained without the threat of preemption by higher priority services….The Commission believes that this allocation is needed if we are to continue to foster amateur operator experimentation using millimeter wave technology…"
[10] See, e.g. WRC-15, Agenda Item 1.18. See also RM-11666, filed by Robert Bosch, LLC proposing the amendment of Part 15 of the Commission's rules to permit operation of automotive short-range radar facilities in the 77-81 GHz band.

regulatory paradigms of the moment. As the Commission put it with respect to 47 GHz in particular in the *Second Report and Order* in Docket 94-124: "as a 'frontier' band located in the frequencies above 40 GHz that are yet to be opened for commercial development, the exact nature of the services to emerge from the development of the 47 GHz band cannot be predicted in the comments." The Commission is urged to continue this flexibility in planning the deployment of the mmW bands for mobile services. Technology which facilitates compatible sharing should be the determinant.

II. The Commission Should Utilize Existing Mobile Allocations in the mmW Bands Above 24 GHz Which Can be Internationally Harmonized.

6. The Commission has properly focused its current mmW inquiry on further development of the mmW frequency bands which are already allocated to the mobile service. With one exception, the frequency bands considered in Section III.B. of the Notice[11] are already allocated to the mobile service in the United States Table of Frequency Allocations[12] and the international table of frequency allocations in the ITU *Radio Regulations*.[13] The exception is the proposed use of 24.25-24.45 GHz and 25.05-25.25 GHz, in which there is no mobile allocation in ITU Regions 1 and 2 but there is a co-primary mobile allocation in Region 3. There are ample domestic allocations to the mobile service above 24 GHz, and utilization of these allocations should be maximized before reallocation of other mmW spectrum for mobile deployment is considered. In addition to the candidate bands between 24 and 86 GHz specifically discussed in the Notice, the Commission "seek[s] comment and discussion on bands above 95 GHz that commenters believe would be suitable candidates for mobile services."[14] ARRL suggests that

[11] Notice, ¶¶ 46-87
[12] 47 C.F.R. § 2.106.
[13] RR Article 5.
[14] See, the Notice, at ¶50, where the Commission invites comments on the suitability of the Local Multipoint Distribution Service (LMDS) bands, the 39 GHz band, the 37/42 GHz bands, the 60 GHz band, the 70/80 GHz bands, and the 24 GHz band for advanced mobile services, and invites comment on any other bands above 24 GHz

the numerous bands allocated to the mobile service above 95 GHz are a suitable and sufficient range of additional candidate bands for mobile 5G development and deployment.

7. Part of the rationale for the above recommendation is the Commission's own (correct) assertion at Paragraph 48 of the Notice that "…in a global economy there will often be a need for single devices to operate seamlessly throughout more than one, or perhaps even throughout many different countries. Further, global harmonization of regulatory and technical requirements will promote global economies of scale in equipment manufacturing." This makes inherent good sense, and the fact is that those entities developing standards and equipment for 5G networks are doing so on a global scale.[15] ARRL urged the same concept in comments filed in July of 1995 in response to the Commission's proposal[16] to harmonize the United States' regulations concerning commercial development and use of the bands above 40 GHz with the *European Table of Frequency Allocations and Utilisations"* for the band 3400 MHz to 105 GHz. That table was developed by the European Radiocommunications Committee (ERC) of the European Conference of Postal and Telecommunications Administrations (CEPT). In its comments[17], ARRL stated that:

> The League generally supports the concept of international harmonization of millimeter-wave bands, since equipment that is useful worldwide for these allocations will generally be more available for amateurs, and allow worldwide amateur communications in allocations similar throughout the world… Harmonization of microwave bands and millimeter-wave bands allows and fosters

---

that are not included in that list but might be appropriate. It seeks comment and discussion on bands above 95 GHz that commenters believe would be suitable candidates for mobile services.

[15] At paragraph 47 of the Notice, the Commission notes that:

> "Various international organizations and standards bodies, including 3GPP, 5GNOW, and METIS have launched 5G-oriented research and development programs. (footnote omitted). These organizations are made up of various different vendors, operators, and academic organizations.[15] We recognize that these entities will play a significant role in determining the technical requirements and standards for 5G systems and technologies, including the use of mmW bands for mobile wireless services. A common goal cited by these organizations is to build consensus and contribute to standardization of future mobile and wireless communications."

[16] See the *Public Notice*, DA 95-1415, released June 23, 1994.

[17] Comments of ARRL, filed July 28, 1995, Docket 94-124.

> the sharing of scientific findings of radio amateur experimenters regarding propagation studies, circuitry and antenna designs.

8. More to the point, however, international harmonization of mobile allocations in the mmW bands and utilization of the ample current mobile allocations above 24 GHz will contribute to avoiding incompatibility between incumbent services and new 5G mobile services. There has been found to be a general lack of compatibility between Amateur and Amateur-Satellite operations on the one hand and services, systems or stations with high signal densities, such as high density land mobile systems. According to Recommendation ITU-R M.1044-2 (1994-1998-2003), developed in response to Question ITU-R 48/8, which pertains to Frequency sharing criteria in the amateur and amateur-satellite services, ITU-R recommended, among other things, that: (1) the amateur and amateur-satellite services may share, subject to suitable sharing criteria, with the radiolocation service, the fixed service, mobile services where traffic density is low, some meteorological aids and certain satellite services with low power flux-densities; and (2) that the amateur and amateur-satellite services should not share with safety, distress and operational traffic of the aeronautical or maritime mobile services for safety of life reasons. Any additional sharing with the amateur and amateur-satellite services should not introduce services, systems or stations with high signal densities, such as high density land mobile systems.

9. Thus, the Notice appropriately asks questions focused on assessing sharing, compatibility, and coexistence of new mobile services with incumbent services. Of the seven questions the Commission poses in Section III.A. of the Notice, ARRL views three as particularly relevant:

> (5) What characteristics of the technology are relevant to the manner in which mobile services in the mmW bands might coexist without impact on incumbent services that occupy the relevant frequency bands?
>
> (6) Are there frequency bands contemplated for mobile use that are being considered for alternative uses and, if so, what might those alternative uses be? To

> what extent are such uses compatible or incompatible with the kinds of mobile wireless technologies being explored in this NOI?
>
> (7) What technical and operational characteristics as well as interference mitigation techniques of the anticipated technologies for these bands need to be considered in assessing sharing and compatibility with in-band and adjacent band incumbent services? Are there other technical considerations the Commission should examine in enabling deployment of mobile services in bands above 24 GHz?[18]

The Notice, at paragraph 46, notes that most of the candidate bands above 24 GHz are already shared and, most likely, will continue to be shared by other services. It concludes, therefore, that it is important to determine whether or not those services are compatible with advanced mobile service in the mmW bands. Similarly, in selecting the most suitable bands above 24 GHz for mobile services, the Commission states that it is obligated to determine whether advanced mobile operations in a given band are consistent with encouragement of efficient use of spectrum, as well as promoting innovation, investment, and the global competitiveness of the United States. Using these goals as a metric, ARRL would suggest that the mmW bands allocated to the Amateur Service are inappropriate for shared 5G mobile service. Amateur experimental operation in the mmW bands above 24 GHz is, as discussed above, largely itinerant, temporary fixed operation using exceptionally sensitive receivers and high gain, narrow beamwidth antennas in bands typically shared with other incumbent services. Terrestrial operation is point-to-point almost exclusively. This type of operation is difficult to coordinate with mobile operation. Inter-service coordination is a relatively simple matter where both services utilize fixed or temporary fixed point-to-point operation and narrow beamwidth antennas. [19] The same is not true where the sharing in this frequency range is with ubiquitous, omnidirectional or MIMO

[18] Notice, at ¶17.

[19] The Commission specifically inquires about the suitability of mmW bands for backhaul for mobile broadband systems. Backhaul is more likely to utilize a traditional point-to-point path, and while it may utilize a substantial amount of spectrum, it may not have as many sharing and compatibility implications as would medium or small cell broadband use in the mobile service.

operations, because prior or real-time coordination in that context is inherently and significantly complex, if not impossible. Though the Commission notes substantial recent improvements in antenna technology, which ARRL acknowledges, the inherent complexity and difficulty of shared fixed, point-to-point terrestrial Amateur operation with high-density, ubiquitous mobile operation remains as an obstacle to the present time.

10. Authorization or allocation of new high-density mobile service technologies on a shared basis with incumbent licensees, regardless of the nature of those incumbent services requires proof of concept and testing in advance.[20] Ideally, that testing would occur both in controlled and real world environments prior to deployment. The Commission, acting jointly with NTIA, recently conducted an inquiry into characteristics required in a "model city" for such real world testing and is in the process of evaluating comments received in response to that inquiry.[21] Specifically, the Commission and NTIA proposed the establishment of a public-private partnership to facilitate the creation of an urban test city (model city) that would support rapid experimentation and development of policies, underlying technologies, and system capabilities for advanced, dynamic spectrum sharing. The concept resulted from the July 2012 recommendations of the President's Council of Advisors on Science and Technology (PCAST) to the President on issues relating to further sharing of government-held spectrum.[22] This report (the "PCAST Report") concluded that clearing and reallocation of federal spectrum is no longer a sustainable basis for spectrum policy due to the high cost, lengthy time to and disruption to the

[20] ARRL has consistently, for years, urged that the justifications for domestic spectrum allocation decisions include technical compatibility studies *ab initio* as opposed to the now-typical, exclusive reliance on public interest allegations and unsubstantiated predictions of compatibility found in petitions for rule making proposing allocation changes.
[21] See, the *Public Notice* , DA 14-981, 79 Fed. Reg. 41262 *et seq.*, released July 11, 2014 in Docket 14-99.
[22] See Report to the President: Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth, at 49-50 (July 2012), available at http://go.usa.gov/k27R (PCAST Report).

federal mission.[23] Based on this finding, the PCAST Report called for a new spectrum architecture premised on (compatible) spectrum sharing rather than exclusive use. One of the PCAST Report's recommendations was to create an urban test city in a major U.S city to support realistic, rapid experimentation in spectrum management technology and practice. The Commission asked for comments "on ways to establish, fund, and conduct the Model City program".

11. The model city concept is appropriate for and should be a necessary final step in the development of sharing techniques to permit mmW spectrum access by mobile services for 5G systems. The participation of the private sector and the general public in developing sharing methodologies should not be limited to the model city stage. It should involve joint, public-private development and analysis of sharing techniques, followed by joint, public-private testing of these technologies in a controlled environment, culminating, if warranted, by live, rigorous, proof of concept testing in an appropriate model city or cities. After proof of concept in a controlled environment, the city or cities for real world testing should be chosen on a case by case basis to ensure all interested in-band and adjacent band services are represented. The participation of representatives of incumbent radio services must be included (regardless of allocation status) if a proposed allocation in a band being studied already accommodates incumbents. Finally, the model city testing process cannot include artificial constraints or limitations that would taint the deployment testing process. For example, public and private land use restrictions cannot preclude any radio service's participation in real world testing, and to the extent those restrictions exist in a candidate model city, they should be preempted. Otherwise, the model city choice is unsuitable.

III. Conclusions.

[23] *Id.* at vi.

12. The Commission is appropriately concerned in this proceeding with the technical compatibility between incumbent services in the mmW bands and proposed high-density, wide bandwidth 5G mobile services that might be introduced in this band. Radio amateurs have pioneered operation in this frequency range and have contributed to the science that leads the Commission to conclude that new technological developments may permit incorporation of 5G mobile systems in the mmW bands, as components of mobile systems using lower frequency allocations. In planning for this deployment, however, the Commission should first look to mobile allocations and should attempt to harmonize these allocations internationally. As well, there must be flexible regulatory structures in place that allow technology to determine the proper sharing criteria and deployment criteria, instead of spectrum use and assignment regulations. Intermixture of mobile and fixed or temporary fixed services should be avoided where possible to avoid conflicts and to facilitate real time and advance private sector coordination. Finally, there should be in each case both advance proof-of-concept testing and real world testing in an environment such as the model city program that the Commission and NTIA have recently jointly endorsed.

Now, therefore, the foregoing considered, ARRL, the national association for Amateur

Radio respectfully requests that the Commission address proposed mobile 5G deployment in the mmW bands in accordance with the recommendations contained herein, and not otherwise.

Respectfully submitted,

ARRL, the national association for Amateur Radio

225 Main Street
Newington, CT 06111-1494

By: Christopher D. Imlay
Christopher D. Imlay
Its General Counsel

Booth, Freret & Imlay, LLC
14356 Cape May Road
Silver Spring, MD 20904-6011
(301) 384-5525

January 15, 2015

EXHIBIT A

Claimed North American Distance Records for mmW Bands Achieved by Radio Amateurs (as of June 4, 2014)

Propagation Mode	Distance (km)	Stations (Maidenhead Grid Locator System geographic coordinates listed in parentheses)	Two-way Amateur Radio Contact Date
24 GHz			
Rain Scatter	283	KM0T (EN13vc) - W0ZQ/0 (EN35ab)	31-Dec-2005
Rain Scatter	218	KM0T (EN13vc) - W0ZQ/0 (EN15wb)	02-Apr-2006
Rain Scatter	195	KD7TS (CN87ui) - W7SZ (CN85uo)	28-Sept-2007
Rain Scatter	119	KM0T (EN13vc) - N0DQS (EN22ge)	26-Aug-2003
Tropo (C)	543	W5LUA (EM13qc) - WW2R/5 (EM41hc)	07-Sept-2002
Tropo (C)	526	WB6CWN/6 (DM04ms) - AD6FP/6 (CM88ws)	21-Aug-2010
Tropo (C)	412	KC6QHP/6 (DM04ms) - AD6FP/6 (CM98qf)	22-Aug-2010
Tropo (C)	375	K6GZA/6 (CM97hm) - AD6FP/6 (DM04ms)	16-Sept-2000
Tropo (C)	375	AD6FP/6 (CM97hm) - W6QI/6 (DM04ms)	20-Aug-2005
Tropo (C)	313	W6QI/6 (DM04ms) - AD6FP/6 (DM07dm)	21-Aug-2005
Tropo (C)	311	N1JEZ/1 (FN44ig) - KA1OJ/1 (FN41ll)	19-Aug-2012
Tropo (C)	290	KB8VAO/6 (DM04ms) - W6QI/6 (DM07gi)	20-Sept-2004
Tropo (C)	285	N1JEZ/1 (FN44ig) - KA1OJ/1 (FN51av)	17-Sept-2006
Tropo (C)	266	WA6EXV (DM06wl) - K6OW (DM14kf)	05-Jul-1997
Tropo (C)	257	KK6TG (CM98mr) - WB7ABP (CN80on)	12-Sept-1992
47 GHz			
Tropo (C)	343	W6QI/6 (DM04ms) - AD6FP/6 (DM07bs)	30-Oct-2005
Tropo (C)	246	W0EOM/6 (CM97ei) - KF6KVG/6 (DM06ms)	09-Feb-2003
Tropo (C)	232	KB8VAO/6 (CM96qi) - AD6FP/6 (DM04ms)	18-Sept-2004
Tropo (C)	205	N1JEZ/1 (FN44ig) - WA1MBA/1 (FN42bl)	03-Jul-2005
Tropo (C)	174	W3IY/4 (FN10ff) - W4SW/4 (FM08us)	14-Nov-2001

Tropo (C)	120	NU7Z (CN87ms) - KD7TS (CN96aw)	04-Oct-2003
75 GHz			
LOS	289	AD6IW (CN90fl) - KF6KVG (CM97av)	23-June-2014
LOS	289	AD6IW (CN90fl) - K6GZA (CM97av)	23-June-2014
LOS	177	AD6FP/6 (CM88qp) - KF6KVG/6 (CM97ad)	01-Mar-2002
LOS	177	W0EOM/6 (CM88qp) - KF6KVG/6 (CM97ad)	01-Mar-2002
LOS	110	K2AD (EM96ur) - W2SZ (FM07fm)	20-May-1999
LOS	60	W2SZ (FM07fm) - WA4RTS (FM08ia)	01-May-1999
120 GHz			
LOS	30	WA1ZMS/4 (FM07fm) - W4WWQ/4 (FM07ji)	02-Apr-2003
LOS	24.8	KF6KVG/6 (CM87wj) - W0EOM/6 (CM97cj)	29-Mar-2003
LOS	20.7	W4WWQ/4 (FM07hj) - WA1ZMS/4 (FM07fl)	11-Mar-2003
LOS	1.1	WA1MBA (FN32ri) - WB2BYW (FN32rj)	11-Jul-1994
122 GHz			
LOS	114	WA1ZMS/4 (EM96ur) - W4WWQ/4 (FM07fm)	18-Jan-2005
LOS	24.8	W0EOM/6 (CM97cj) - KF6KVG/6 (CM87xh)	27-Aug-2004
LOS	1	N1JEZ/1 (FN34ha) - KT1J (FN34ha)	23-Aug-2008
134 GHz			
LOS	114.4	WA1ZMS/4 (EM96ur) - W4WWQ/4 (FM07fm)	26-Feb-2006
142 GHz			
LOS	79.7	W2SZ/4 (FM07fm) - WA1ZMS/4 (EM96wx)	12-Jan-2003
LOS	61.6	W2SZ/4 (FM07fm) - WA4RTS/4 (FM08ib)	01-Jan-2001
LOS	34	WA1ZMS (FM05fm) - WA4RTS (FM05ji)	06-Nov-2000
LOS	11.7	KF6KVG (CM87uk) - W0EOM (CM87wj)	19-Oct-1999
241 GHz			

LOS	114	WA1ZMS/4 (FM07fm) - W4WWQ/4 (EM96ur)	21-Jan-2008
LOS	79.7	WA1ZMS/4 (EM96wx) - W2SZ/4 (FM07fm)	17-Feb-2004
LOS	61.8	W2SZ/4 (FM07fm) - W4WWQ/4 (EM97xe)	03-Dec-2003
LOS	11.4	WA1ZMS/4 (FM07ln) - W4WWQ/4 (FM07jn)	11-Mar-2002
LOS	7.3	WA1ZMS (FM07jj) - W4WWQ (FM07ji)	23-Feb-2002
Micrometer Radio			
322 GHz	1.4	WA1ZMS/4 (FM07ji) - W4WWQ/4 (FM07ji)	04-Mar-2003
322 GHz	0.5	WA1ZMS/4 (FM07ji) - W4WWQ/4 (FM07ji)	01-Mar-2002
322 GHz	0.05	W2SZ (FM07ji) - WA4RTS (FM07ji)	15-Dec-2001
403 GHz	1.42	WA1ZMS/4 (FM07ji) - W4WWQ/4 (FM07ji)	21-Dec-2004
403 GHz	0.52	WA1ZMS/4 (FM07ji) - W4WWQ/4 (FM07ji)	11-Apr-2003
Light			
474 THz	192.6	WB7VVD (DM34hb) - KC7AED (DM43iq)	21-Sept-1997
474 THz	81.6	XE2AT (DL81vq) - XE2ZB (DL80vx)	25-Aug-2005
678 THz	248	WA7LYI (DM34tf) - KY7B (DM42ok)	08-Jun-1991

Notes
Frequency bands include Micrometer Radio (300 to 3000 GHz) and Light (3 to 30,000 THz).
Propagation modes are tropospheric refraction and ducting (including line-of-sight paths), divided into in three categories: Tropo (A) (tropospheric modes across the Atlantic, Caribbean, and Gulf of Mexico); Tropo (C) (tropospheric modes across continental North America; Tropo (P) (tropospheric modes across the Pacific); Aurora (auroral scatter); Auroral E (auroral E); Sporadic E (sporadic E); FAI (E-layer field-

aligned irregularities; IFS (ionospheric forward scatter); Meteors (meteor scatter); TE (transequatorial field-aligned irregularities); and Rain scatter (precipitation scatter).
Distance calculations are based on the centers of 6-place grid locators, as calculated by BD (the W9IP bearing and distance program). Distances shorter than 100 km my be calculated using more precise methods.
Call signs are those used to make the contacts.