Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of		
Use of the 5.850-5.925 GHz Band	)	ET Docket No. 19-138

COMMENTS OF AREDN
IN RESPONSE TO FURTHER NOTICE OF PROPOSED RULEMAKING

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SUMMARY

The Amateur Radio Emergency Data Network (AREDN), through counsel, respectfully submits these Comments in response to para. 179 of the Further Notice of Proposed Rulemaking, which proposes that outdoor access points in the U-NII-4 band be allowed to transmit at a power of 36 dBm. This is the same power that has been approved in the U-NII-5 band with automatic frequency coordination (AFC) and the U-NII-3 band.

Using AREDN intellectual property, amateur radio licensees have constructed fixed data networks with broadband speeds of up to 144 Mbps in the 5.9 GHz Band. Some of the AREDN-enabled networks would rival the microwave networks in the 6 GHz band that the Commission is protecting from interference from unlicensed operation. AREDN-enabled fixed data networks are similarly situated to Fixed Service microwave operations. The AREDN-enabled networks should receive protection through AFC similar to what the Commission requires for outdoor unlicensed operation in the 6 GHz Band.

Under Section 301 of the Communications Act, the FCC may not authorize an unlicensed service that causes harmful interference to a licensed service. In determining the power level for unlicensed operation in the 5.9 GHz Band, the FCC necessarily will make a determination about whether the unlicensed operation causes harmful interference to licensed operations. AREDN presents herein interference analysis demonstrating that unsupervised unlicensed operation may transmit at no more than -42.1 dBm (61.7 nanowatts). In order for unlicensed operation to transmit at commercially feasible power in the 5.9 GHz Band, AREDN-enabled networks will need to be protected by AFC.

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Amateur Radio Emergency Data Network (AREDN), through counsel, respectfully submits these Comments in response to the Further Notice of Proposed Rulemaking (*Further NPRM*).[1] On May 3, 2021, AREDN submitted its Petition for Reconsideration urging that the Order in this proceeding be rescinded because it falls outside authority delegated to the FCC. The relief that is requested in these Comments is requested in the alternative, if it is determined that the Commission has authority to issue the Order. AREDN's first preference is that the Order be vacated.

The *Further NPRM* seeks comment on its proposal to allow "unlicensed operation of U-NII-4 access point device . . . a radiated power of 23 dBm/MHz or 36 dBm radiated power for all bandwidths."[2] This is the same power as in the U-NII-5 band (with AFC) and the U-NII-3 band.

In summary, under Section 301 of the Communications Act,[3] unsupervised unlicensed operation should have a transmit power limit of -42.1 dBm (61.7 nanowatts).

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[1] *In the Matter of Use of the 5.850-5.925 GHz Band*, First Report and Order, Further Notice of Proposed Rulemaking and Order of Proposed Modification, ET Docket No. 19-138 (Nov. 20, 2020) (the *Further NPRM*). The *Further NPRM* was summarized in the Federal Register, 86 Fed. Reg. 23323 (May 3, 2021), with comments due June 2, 2021.
[2] *Further NPRM* para. 179.
[3] 47 U.S.C. § 301. Section 301 prohibits radio transmission without a Commission license. The U.S. Court of Appeals held that unlicensed operation may be authorized

Alternatively, consistent with the Commission's action in the 6 GHz proceeding,[4] unlicensed operation should utilize automated frequency coordination (AFC) to protect AREDN's fixed, point-to-point, high-speed data networks from harmful interference. Under Section 301, in order for unlicensed operation to operate at commercially viable power in the 5.9 GHz Band, AFC should be implemented.

I. Background – FCC proceedings

A. The 5.9 GHz proceeding

The Order[5] devotes two paragraphs to amateur operations.[6] In pertinent part, the Order states, "We believe that U-NII devices operating in the U-NII-4 band will not cause harmful interference to amateur operations because of the relatively low power with which U-NII devices will operate as compared to amateur stations, which are permitted to operate with as much as 1.5 kW (62 dBm) peak envelope power."[7]

This statement does not make a determination about AREDN's fixed, point-to-point, high-speed data systems. As the Order noted, no specific technical analysis was submitted, and the AREDN fixed high-speed data networks are different from traditional amateur radio. The Further NPRM seeks comment on the appropriate power level for unlicensed devices in the lower part of the U-NII-4 band.[8] In deciding the power level, the Commission will make a Section 301 determination about whether the authorized

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only where it does not interfere with a licensed service. *American Radio Relay League, Inc. v. FCC,* 124 F.3d 227, 234-35 (D.C. Cir. 2008).

[4] *In the Matter of Unlicensed Use of the 6 GHz Band*, ET Docket No. 18-295, GN Docket No. 17-183, Report and Order and Further Notice of Proposed Rulemaking (2020).

[5] First Report and Order, *supra* n1 (the "Order").

[6] *Id.* at paras. 92-93.

[7] *Id.* at para. 93 (citing 47 C.F.R. § 97.313(b)).

[8] *Supra* n2.

power level would cause interference to licensed services. In these Comments, AREDN presents evidence that responds to the request for comment on the appropriate power level, and addresses the requirement of Section 301.

B. The 6 GHz proceeding

In August 2017, the Commission issued a Notice of Inquiry (NOI) about flexible use of mid-band spectrum.[9] The NOI noted that Commission licensing records reflect that more than 27,000 fixed service (FS) licenses are issued for point-to-point operations in the 5.925 to 6.425 GHz band.[10]

In October 2017, the Fixed Wireless Communications Coalition (FWCC) submitted comments stating that "[t]o avoid causing interference to the fixed service, unconstrained unlicensed transmitters would need a power limit in the vicinity of -80 to -60 dBm. Taking terrain and ground clutter into account might raise this by a few tens of dB at most."[11] FWCC Comments went on to say that "[i]t follows that non-interfering unlicensed operation in the fixed service bands, at commercially useful power levels, will need some sort of active frequency coordination, such as geolocation with database lookup."[12]

In January 2018, Apple Inc., Broadcom Corporation, *et al.* submitted an engineering report by RKF Engineering solutions.[13] The transmittal letter stated: "RKF's

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[9] *In the Matter of Expanding Flexible Use of Mid-Band Spectrum Between 3.7 and 24 GHz*, GN Docket No. 17-183, Notice of Inquiry (Aug. 3, 2017) (the NOI).
[10] *Id.* at para. 25.
[11] Comments of the Fixed Wireless Communications Coalition, GN Docket No. 17-183 (Oct. 2, 2017) 11.
[12] *Id.*
[13] Letter from Paul Margie, counsel to Apple Inc., Broadcom Corporation, et al. to Marlene Dortch, Secretary, FCC (Jan. 26, 2018).

findings are clear: unlicensed services can successfully coexist with the primary services present in the 6 GHz band."[14] The RKF study relied on average clutter (noise) calculations resulting from indoor and indirect transmissions from unlicensed devices.

In March 2018, FWCC submitted a rebuttal study by George Kizer that pointed out errors and omissions of the RKF study, which had ignored co-channel, line-of-sight propagation.[15] FWCC was joined by others who extensively criticized the RKF study.[16] The National Spectrum Management Association (NSMA) said that, in its experience, "receiver interference is typically a relatively infrequent line of sight case rather than an "average" clutter dominated result."[17] NSMA calculated conditions under which unmanaged RLAN operation would be unlikely to interfere with fixed microwave operations. According to NSMA, for RLANs with no height restrictions (FCC rules subsequently provided no height restriction), the transmit power limit is -59.9 dBm.[18] This is very close to the -60 dBm upper power limit stated by FWCC.[19]

Another key concern was the inability to detect interfering unlicensed devices. FWCC quoted AT&T, which said the following:

> Compounding the difficulty of sharing, to a microwave link, interference caused by a mobile is indistinguishable from atmospheric or environmental fade. Even very weak signals will create interference, which will reduce the effectiveness of the link's

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[14] *Id.*
[15] Letter from Chen-li Yiu and Mitchell Lazarus, counsel to FWCC, to Marlene Dortch, Secretary, FCC (Mar. 13, 2018) 10.
[16] Letter from Susan H. Crandall, Associate General Counsel, Intelsat Corporation & Gerry Oberst, President, SES Americom, Inc., to Marlene H. Dortch, Secretary, FCC (Feb. 23, 2018); Letters from Stacey G. Black, Vice President, AT&T Services, Inc., to Marlene H. Dortch, Secretary, FCC (Mar. 26 and 27, 2018); Letter from Dave Meyer, Board Member and Former President, National Spectrum Management Association, to Marlene H. Dortch, Secretary, FCC (Mar. 27, 2018).
[17] Letter from Dave Meyer, *supra* n16, at 3 (citing ITU-R Recommendation F.1706).
[18] *Id.* at 4-6.
[19] *Supra* n11.

engineered fade depth. . . . In fact, mobiles operating 3 km from a victim point-to-point receiver will need to have at least 46.5 dB of terrain obstruction loss and antenna discrimination to avoid interference to the link—and that margin increases to 66.5 dB for mobiles within 300 m of the victim receiver.

Because interference caused by mobiles will look to the microwave systems like fade, and because these links are not engineered to monitor for this type of interference, there also will be no ability for the microwave licensee to identify that interference is occurring—they will simply find that statistically the performance of their path decreases. Even if a device was malfunctioning or being operated in a malicious manner, the microwave licensee would never be able to identify the source of the interference—the itinerant nature of most unlicensed activity, even if it was identified as causing interference, means that the device may never be located, since it may be transmitting only intermittently and is likely to be in motion. These fears are compounded when the potential exists for additive interference from a large number of devices, as most unlicensed technologies intend.[20]

The Internet of Things is a giant itinerant unlicensed operation, as AT&T described in its Comments. FWCC similarly told the FCC that the "FS operator cannot detect interference until after the link fails [] even then [the FS operator] cannot tell if failure was due to deep fade, RLAN interference, or something else."[21]

After further discussions, in June 2018, Apple Inc., Broadcom Corp., *et al.*, essentially agreed to FWCC's demand and requested that the FCC issue a Notice of Proposed Rulemaking providing for location-based automated frequency coordination.[22] In October 2018, the Commission issued the 6 GHz Notice of Proposed Rulemaking that proposed to require location-based automatic frequency coordination (AFC).[23] In October 2020, the Commission issued the 6 GHz Report and Order that allows, in the U-

[20] Comments of AT&T Services, Inc., *Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz*, GN Docket No. 17-183 (Oct. 2, 2017) 16-17.
[21] Letter of Cheng-yi Liu, counsel to FWCC, to Marlene H. Dortch, Secretary, FCC (July 17, 2018) at page 16 of *ex parte* presentation.
[22] Letter from Paul Margie, counsel to Apple Inc., Broadcom Corporation, et al. to Marlene Dortch, Secretary, FCC (Jun. 15, 2018).
[23] *Unlicensed Use of the 6 GHz Band*, ET Docket No. 18-295, Notice of Proposed Rulemaking (Oct. 24, 2018) para. 17.

NII-5 and U-NII-7 bands, outdoor use of unlicensed devices at standard power (36 dBm EIRP), with location-based AFC.[24] This is the same power level that the Further NPRM proposes for the U-NII-4 band (5.9 GHz) and is permitted in the U-NII-3 band.

II. AREDN's Point-to-point Systems are Similarly Situated to Microwave Networks

A. What AREDN does

AREDN networks provide communications services to public safety agencies in emergencies, like a forest fire, and for public events, like the Marine Corps Marathon. AREDN is different from traditional ham radio because it provides a way for amateur radio operators to create high-speed data networks.[25]

A core function of amateur radio has been to relay messages between public safety agencies in an emergency. For example, a forest fire might cover several counties, and ham operators would relay messages between officials of different counties to coordinate the fire-fighting effort. Traditionally, amateur radio operators relied on voice transmissions for these communications. A typical message-passing scenario involved a public safety official conveying a message to an amateur radio operator who would write or type it onto a standard ICS-213 form. The message would then be relayed by voice over radio to another operator who would write or type it onto another ICS-213 form at the receiving end. The form would typically be hand delivered to the recipient (*e.g.*, a public safety official in another county) who would read and sign the form. Any

[24] *Unlicensed Use of the 6 GHz Band*, ET Docket No. 18-295, Report and Order and Further Notice of Proposed Rulemaking (Apr. 24, 2020) paras. 20-86.
[25] The following description is excerpted from the AREDN website, https://arednmesh.readthedocs.io/en/stable/arednGettingStarted/aredn_overview.html. This website provides more fulsome documentation of the AREDN network.

acknowledgement or reply would then be handled through the same process from the receiving end back to the originator.

However, public safety and emergency response personnel are accustomed to communicating with email, text and audio-video communication. Ham operators meet these preferences by sending digital data between devices over an AREDN-enabled, high-speed data network. During an emergency, an AREDN network serves as the transport mechanism to substitute for applications like email, chat, voice, document sharing, video conferencing, and many other useful programs. A licensed amateur radio operator controls each radio station. Depending on the implementation, this digital data network can operate at near-Internet speeds with many miles between network nodes.[26]

In order to participate in an AREDN network, the amateur radio licensee buys his own radio equipment from the manufacturer or vendor. AREDN Inc. provides, free of charge, firmware and software that the ham licensee can download to enable his radio to join an AREDN mesh network. The licensee then configures his radio, obtains the site and places the radio into operation under his control. AREDN networks are non-commercial and charge the agencies they support no fees.

Unlike most other licensed services, the amateur radio service does not permit commercial operation. Thus, amateur radios are purchased out of the personal funds of amateur licensees, who generally have modest or middle class means. AREDN has leveraged Wi-Fi economies of scale by establishing firmware and standards that work for Wi-Fi equipment. An all-in cost for an AREDN node usually is around $250. This is

[26] *See* https://arednmesh.readthedocs.io/en/stable/arednNetworkDesign/network_topology.html for typical network topology.

something that most amateur licensees can afford. More exotic equipment (see, *e.g.*, Cases E1, E2 and F, below) that operates at higher power or has other special features would be outside of the COTS (commercial, off-the-shelf) paradigm. Once the price level rises much above about $250, the average amateur licensee is priced out of the market. Thus, there is an important economic component to the Commission's assumption, *see* Order para. 93, that the power level can simply be raised. In order to maintain the network effect of a number of ham operators contributing to build an AREDN network, the price needs to be kept affordable – a few ham operators can afford more expensive equipment, but to get widespread participation that generates a network effect in an AREDN network, the price needs to be kept reasonable. If the Commission really expects higher power amateur operation, it should revisit the requirement of non-commercial operation and allow ham operators to recoup the cost of the radios.

The primary goal of the AREDN project is to empower licensed amateur radio operators to deploy high-speed data networks when and where they might be needed, as a service both to the hobby and the community. This is especially important where traditional utility services (electricity, phone lines or Internet services) become unavailable. Then, an off-grid amateur radio emergency data network may be a lifeline.

AREDN amateur radio networks can be fixed point-to-point and point-to-multipoint networks with permanent nodes mounted at various sites.[27] Or, they can be *ad hoc* networks, temporarily constructed and placed into operation for a special event or

[27] *See* Declaration of Orville Beach attached as Exhibit 2 hereto (Southern California Mesh Network) and Declaration of Brett Popovich attached as Exhibit 3 (Willamette Valley Mesh Network).

rescue and recovery in a disaster area.[28] Or, they can be a combination, with a permanent backbone but expandable to new locations to cover events or disasters.

B. AREDN fixed networks

Attached hereto as Exhibit 1 are screenshots of maps showing the 5.9 GHz nodes (in orange) and major 5.9 GHz RF links (green and yellow) of AREDN-enabled, fixed, high-speed data networks in Southern California, San Francisco and Willamette Valley, Oregon. The Southern California network stretches from Ojai to Indio, California, and from Santa Clarita to Oceanside. As indicated by the link report (Declaration of Orville Beach, Exhibit 2), this network has 101 links operating in the 5.9 GHz Band that are more than five miles long. The longest of these is 61 miles in distance. The following websites display real time maps of these networks: https://mapping.kg6wxc.net/meshmap (Southern California), http://meshmap.sfwem.net/map_display.php#12/37.7828/-122.3877 (San Francisco) and https://willamettevalleymesh.net/meshmap/ (Willamette Valley).

In the real-time maps at the above websites, when one clicks on a node, an information box pops up. This box displays the responsible FCC amateur license for that node, latitude and longitude of the fixed radio/receiver, SSID, channel, bandwidth, other operational information and transmit/receive links along with identification of the node at the other end of each link, and distance and bearing. The layers function in the legend to the left-hand side of the screen enables one to isolate the different components of the mesh map.

[28] *See* Declaration of Mark Braunstein attached as Exhibit 4 (Marine Corps Marathon) and Declaration of Gene Harrison attached as Exhibit 5 (disaster response).

For point-to-point links, these networks use directional antennas to focus their signals. For point-to-multipoint, 90- or 120-degree sector panels are utilized to service slices of the surrounding area. These networks satisfy the Commission's definition of a fixed service: "A radio communications service between specified fixed points."[29]

In addition to 5.9 GHz, these networks also have 900 MHz, 2.4 GHz and 3.5 GHz nodes. The 900 MHz band is barely used in these networks, and the 3.5 GHz nodes are being phased out per the Commission's reallocation of that spectrum. Because of interference from unlicensed operation, the 2.4 GHz nodes mostly are connected by landline (DTD – device-to-device, and tunneling indicated on the maps). Interference from unlicensed operation at 2.4 GHz prevents use of that band and is discussed below.

The RF workhorse of these networks is the 5.9 GHz band. If the 5.9 GHz band were to become unusable due to interference from unlicensed operations, like the 900 MHz and 2.4 GHz bands, it would severely cut back these networks. The networks could primarily become landline networks. This would defeat the purpose of the networks, which is to provide an off-infrastructure, independent means of communicating in the event of an emergency.

These networks are designed with redundancy in order to be resilient, reliable and available in a catastrophe. As stated above, the purpose of the networks is to provide emergency communications services when conventional cellular and landline networks are disabled. For example, Oregon had catastrophic forest fires around Labor Day 2020 that disabled conventional communications networks, and ice storms over Valentines Day 2021 that knocked out electric power service for more than eight days. Many of the

[29] 47 CFR § 101.3.

nodes of the Willamette Valley Mesh Network went down during these catastrophes. Nevertheless, the network was sufficiently resilient that it continued to provide communication services to government emergency response administrations.

AREDN-enabled mesh networks occupy a unique niche in emergency response and disaster recovery.[30] They are IP-based and can do essentially anything the Internet can do, but without the Internet. No other communications service provides equivalent high-speed data (broadband) over an off-infrastructure and off-grid platform. This makes AREDN-enabled networks uniquely able to assist emergency response in a disaster area. AREDN nodes are flexible, scalable, interoperable and are self-organizing, self-healing and self-managing. They will automatically form a mesh network anywhere when dropped into a disaster area or brought by agencies from different parts of the country. The AREDN nodes then deliver broadband service at speeds up to 144 Mbps. This enables video (both video of the disaster area and video conferencing), voice, text, document transfer and other features of broadband service. Of course, the ability to reach 144 Mbps depends heavily on fade margin, or signal-to-noise ratio (SNR), which is a key point of these Comments.

The Commission and other federal agencies, such as NTIA and DHS, have addressed some public safety interoperability problems with the National Interoperability Channels and authorities.[31] This program is good as far as it goes. The limitation is that "[o]nly narrowband emissions are to be used on the Federal Interoperability Channels."[32]

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[30] *See* Declaration of Gene Harrison, Exhibit 4.
[31] *See* National Interoperability Field Operations Guide, U.S. Department of Homeland Security Emergency Communications Division, Version 1.6.1A (Jan 6, 2019) https://www.cisa.gov/sites/default/files/publications/NIFOG%20Ver%201.6.1A.pdf.
[32] *Id.* at 19.

In a way, the National Interoperability Channels are like old-school ham radio – it's just voice. Essentially, this simple analog FM voice mode is the national standard for interoperability and coordination across the entire Nation. In great contrast, in the field, AREDN mesh networks can operate over 20 megahertz channels and deliver true broadband in an emergency. As an alternative, the highly engineered, long-distance backbone links of AREDN fixed networks often use 10 megahertz channels. Both of these flexible modes deliver broadband services. Loss of use of the 5.9 GHz band due to harmful interference from unlicensed operation would result in loss of a unique and valuable resource for disaster and emergency response.

A small number of unlicensed devices could cause harmful interference to some of the links of these AREDN networks and, in many cases, the network would simply route traffic around the broken links and continue to function. However, if the interference severed a backbone or a link in a remote area, the network would not be able to route around. As described by Mark Braunstein[33] and Brett Popovich,[34] once a large number of unlicensed devices saturate the band, as they have at 900 MHz and 2.4 GHz, it is impossible to establish *any* link. Large numbers of unlicensed devices are projected for the 5.9 GHz Band.[35] The Commission has no way to ensure that just a few unlicensed devices operate unsupervised. It is all or nothing – either the AREDN networks are fully protected at 5.9 GHz, or they will be swamped by unlicensed operation.

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[33] Declaration of Mark Braunstein, Exhibit 4, page 3.
[34] Declaration of Brett Popovich, Exhibit 3, para. 9.
[35] Technology companies projected nearly one billion unlicensed devices in the near future. *Supra* n21 at page 4 of *ex parte* presentation ("RLAN Group seeks to deploy 958,000,000 unlicensed RLANs").

The AREDN fixed, high-speed data networks are not identical to the licensed microwave operations in the U-NII-5 and U-NII-7 bands. For example, AREDN networks transmit and receive on the same channel utilizing time division duplex, where microwave networks use frequency division. The AREDN networks are highly adaptable and will redirect traffic around a broken link or incorporate a new node that appears with the proper SSID, channel and bandwidth, while microwave networks are not so adaptable.

Nevertheless, the two types of networks perform similar services and have the same function – to rapidly transport large amounts of data from one fixed point to another fixed point. The AREDN and licensed microwave fixed networks are similarly situated and should receive similar protection from harmful interference of unlicensed devices.

III. Interference From Unlicensed Devices

As noted above, under Section 301 of the Communications Act, unlicensed operation may not be approved at configurations or power levels that would cause harmful interference to a licensed service.[36]

A. Measuring standard

In the 6 GHz proceeding, the Commission required use of the -6 dB interference to noise power (I/N ratio) for determining exclusion zones to protect against unlicensed operation.[37] The Commission declined to use the carrier to interference (C/I) ratio because it would require knowledge of the microwave link, including the received signal strength, and this information is not available to unlicensed operators via ULS.[38]

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[36] *Supra* n3.
[37] 6 GHz Report and Order, *supra*, n24 at paras. 70-71.
[38] *Id.*

AREDN subscribes to the industry standard of keeping the interference 6 dB below the system noise floor. These Comments report calculations of the signal to interference ratio, which includes information about the received signal strength and characteristics of the microwave system being utilized. We do so in order to give a more complete picture of the interference scenarios and because the information is readily available to us. The correction factors reported herein are what is needed in each case to bring the interference to 6 dB below the system noise floor. We recognize that an AFC system would use the I/N metric instead of the signal to interference ratio. The results presented below and at Exhibit 6 are the same as if I/N were calculated.

B. AREDN equipment

Although there is some variation in radios and antennas chosen by amateur licensees when connecting to the AREDN mesh, the following are representative configurations.

Typical antennas are parabolas of about 16-24 inches in diameter. A representative antenna used for point-to-point links would be the Ubiquiti RocketDish RD-5G30 Dish antenna, which has dimensions of 25.6 x 25.6 x 11.97 inches and gain of 30 dBi at 5.9 GHz. A representative antenna for point-to-multipoint links would be the Ubiquiti airMAX AM-5G19-120 Sector antenna, which has dimensions of 27.45 x 5.32 x 2.87 inches and gain of 19 dBi.

For end-point applications, a representative device would be the Ubiquiti NanoBeam NBE-M5-19 Radio with integrated Dish antenna which, as utilized by AREDN, has output power of 26dBm and receiver sensitivity of -94dBm. A representative radio used with the above two dish antennas would be the Ubiquiti M5

Rocket, with bandwidths of 5, 10 and 20 megahertz, output power of 27 dBm and receiver sensitivity of -94 dBm.

These antennas and radios use dual-polarization to increase throughput and enhance diversity. The emissions are time division duplex (different from TDMA), and transmit and receive on the same frequency using the same antenna. Once configured to an engineered system design, the AREDN devices employ preset, fixed channel assignments and channel widths. They themselves are not adaptive, and cannot auto-negotiate channels or bandwidths.

C. Power limits for unsupervised unlicensed operation

The table below sets out the limits on interferer power that would be required under various scenarios to bring the interference down to 6 dB below the system noise floor. Please refer to Exhibit 6 to these Comments for the detailed calculations. AREDN networks have link bandwidths of 20, 10 or 5 MHz. The most common is 10 MHz.

Limits on Interferer Power

Case Example	Power Limit 20 MHz BW (dBm)	Power Limit 10 MHz BW (dBm)	Power Limit 5 MHz BW (dBm)
A1: Long Point-to-Point (AT&T)	-22.1	-25.1	-28.1
A2: Long Point-to-Point Backbone	-16.1	-19.1 (Case A3)	-22.1
B1: Point-to-Multipoint Distribution	-5.6	-8.6	-11.6
B2: Point-to-Multipoint Distribution	14	11	8
C: Multipoint-to-Multipoint Mesh	-16.1	-19.1	-22.1
D: Close Multipoint-to-Multipoint Mesh	-36.1	-39.1	-42.1
E1: High Power Multipoint-to-Multipoint Mesh	2.9	-0.1	-3.1
E2: High Power Multipoint-to-Multipoint Mesh	-37.1	-40.1	-43.1
F: Very High Power Multipoint-to-Multipoint Mesh	2.9	-0.1	-3.1

D. Interference scenarios

This section briefly explains the interference scenarios (each a "Case"). The Cases address different parts of an AREDN-enabled network.

Case A1 uses a scenario that is similar to that posited by AT&T in the 6 GHz proceeding.[39] The purpose of this first calculation is to allow the Commission to compare an AREDN network to what AT&T described. In AT&T's example, the interferer transmits a lower power than is proposed to be allowed. A real-world scenario would be where the interferer is operating at the power proposed by the rules in the Further NPRM (36 dBm). The remaining calculations address unlicensed operation at 36 dBm.

Case A2 is a realistic scenario of unlicensed interference with an AREDN backbone link of 30 kilometers in length. The unlicensed interferer is assumed to be three kilometers away from the AREDN receiver and transmitting at the authorized power of 36 dBm.

Case B1 is where an AREDN node uses a sector antenna to transmit point-to-multipoint within the 120-degree sector. Case B2 is a variation on Case B1.

Case C represents the mesh part of the network, with a link length of 3 kilometers, and the interferer is assumed to be 300 meters away from the desired receiver. Case D also represents the mesh part of the network, with a link length of 3 kilometers, but the interferer is assumed to be just 30 meters away from the desired receiver.

[39] Comments of AT&T Services, Inc., *Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz*, GN Docket No. 17-183 (Oct. 2, 2017) n20.

Case E1, Case E2 and Case F respond to the Commission's implicit statement in the Order that amateur radio has room to raise its power level,[40] thereby implying that there should be no trouble with interference from unlicensed devices. Please note that Cases E1, E2 and F are totally unrealistic with current equipment for the AREDN fixed, point-to-point and point-to-multipoint networks. Expensive, custom equipment would be needed that is beyond the budget of all but a very few ham operators. Indeed, we were unable to locate a feasible UHF transmitter at 62 dBm (1500 Watts) at any price. The posited power levels for Cases E1 and E2 (50 dBm or 100 Watts) and Case F (62 dBm or 1500 Watts) are atypical to say the least. Nevertheless, we offer the theoretical results of Cases E1, E2 and F, in order to dispel the myth that high power cures all.

E. Maximum permitted power for unsupervised unlicensed operation

Under Section 301 of the Communications Act, the Commission must determine the configuration and maximum power that unsupervised unlicensed devices could have without causing harmful interference to the AREDN networks. The proponents of unlicensed operation bear the burden of proof of showing that they will not cause harmful interference.

Case D: Close Multipoint-to-Multipoint Mesh, requires that the unsupervised unlicensed device operate at -42.1 dBm (61.7 nanowatts) at 5 MHz bandwidth, which is the lowest power limit of the interference cases studied. We are excluding Case E2: High Power Multipoint-to-Multipoint Mesh at -43.1 dBm. This is because Case E2 is not a

[40] Order para. 93 ("We believe that U-NII devices operating in the U-NII-4 band will not cause harmful interference to amateur operations because of the relatively low power with which U-NII devices will operate as compared to amateur stations, which are permitted to operate with as much as 1.5 kW (62dBm) peak envelope power").

realistic scenario and is presented here merely to show that a theoretical high-power transmission does not solve interference. All the cases would require substantial reduction in power from the 36 dBm for unlicensed devices that has been proposed. Even the most optimistic case (Case B2 at 14 dBm (25.1 milliwatts) at 20 MHz bandwidth) would require a reduction in power that probably is not commercially feasible for unlicensed operators.

Thus, for purpose of the Commission's Section 301 determination, unsupervised unlicensed devices should have a transmit power limit of -42.1 dBm (61.7 nanowatts).[41] However, the real takeaway is not a particular number, like -42.1 dBm. Rather, the main point is that the FCC would violate Section 301 by authorizing unlicensed devices to transmit at the proposed power level of 36 dBm without protecting AREDN networks from harmful interference. AREDN should be protected by location-based AFC.

F. Experience of AREDN operators in 2.4 GHz

The above calculations are borne out by the practical experience of AREDN operators trying to use spectrum that is allocated to both Part 15 (unlicensed operations) and Part 97 (amateur radio). The AREDN users attest to the fact that the part of the 2.4 GHz band that is allocated to Part 15 is largely unusable because of interference from unlicensed operation. As the Commission knows, Wi-Fi channels 1 through 11 at 2.4 GHz are shared by ham and unlicensed, while 2.4 GHz channel -2 is ham only.

[41] By comparison, AREDN's transmit power limit of -42.1 dBm is more tolerant than the -60 dBm arrived at by representatives of fixed service licensees in the 6 GHz proceeding, see *supra* nn11, 19. Nevertheless, this power level is far below what is commercially feasible for unlicensed operation.

Mark Braunstein said the following about interference testing prior to AREDN support of the Marine Corps Marathon:

> To determine the impact of interference on AREDN equipment, the terminals were operated at both WiFi Channel 1 (i.e., Part 15 operation) and at Channel -2. A snapshot of the interference environment showed that AREDN equipment would be severely interference-limited in trying to support longer-range links. When operated at Channel -2, however, no interference was noted, and throughput increased noticeably.[42]

Similarly, Orville Beach reported that only 13 of the 2.4 GHz links longer than five miles are left in the Southern California Mesh Network.[43] This is out of a total of 1248 links in that network. By comparison, 101 links longer than five miles operate over the 5.9 GHz Band.[44]

Brett Popovich noted the following about the Willamette Valley Mesh Network:

> Almost all of the RF links in our network are at 5.9 GHz. We tried to get the 2.4 GHz and 900 MHz nodes to link and operate over radio spectrum. We were unsuccessful for almost all of these nodes. For example, we tried to establish a one-kilometer RF link over 2.4 GHz. This is a relatively short link for us. We could get a signal but it would not remain connected. If we raised the power, we still would not have a consistent connection. The problem for both 2.4 GHz and 900 Mhz is interference near the receivers on our mesh network. Both of these spectrum bands are saturated with unlicensed users that cause interference. **The 900 MHz and 2.4 GHz bands should have been the first choice for our long links because they have better propagation. But they are unusable because they are saturated.**[45]

The real-world experience of these radio operators in the field demonstrate that AREDN networks need protection from unlicensed operation if the latter is to be authorized for the 5.9 GHz Band.

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[42] Declaration of Mark Braunstein, Exhibit 4, page 3.
[43] Declaration of Orville Beach, Exhibit 2, para. 9.
[44] *Id.* at para. 6.
[45] Declaration of Brett Popovich, Exhibit 3, para. 9 (emphasis added).

IV. A Double Standard Should Not Be Employed

A. FCC treated FS licensees differently

The FCC could have told the 6 GHz Fixed Service (FS) licensees what it told Amateur Radio: your licensed power levels far exceed those of unlicensed operation, so you should have no trouble with U-NII devices.[46] Many FS licensees are licensed for power levels that far exceed that of Amateur Radio.[47] So, the FCC certainly could have said this to the microwave licensees.

Similarly, the Commission could have reminded the FS licensees that, because they are primary or co-primary licensees, they are entitled to protection, whereas U-NII devices operate under Part 15 rules on the conditions of not causing harmful interference and accepting any interference from an authorized radio station. The Order also said this to Amateur Radio,[48] albeit without the benefit of information about AREDN's fixed point-to-point and point-to-multipoint networks.

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[46] *See* Order para. 93.

[47] There are many fixed point-to-point licensees authorized to transmit over frequencies in the U-NII-5 or U-NII-7 band at much higher power than amateur radio, including the following (to cite just a few): KFM89 at 69.6 dBm EIRP, KCK69 at 72.3 dBm, KBH73 at 67.5 dBm, KCG66 at 76.1 dBm to 79.6 dBm. Signal strength doubles every 3 dBm. KFM89 is authorized for 69.6 dBm EIRP, while amateur radio has a maximum authorization of 62 dBm PEP. The difference between 69.6 dBm and 62 dBm represents more than twice doubling or more than four times the power. The difference actually is even more pronounced. EIRP (the standard for microwave licensees) is an average power measure, meaning actual power can fluctuate above the limit, so long as the average is at the limit. By contrast, PEP (peak envelope power), which is the limit for amateur radio, represents the crest of the modulation, or an absolute limit on peak power. This has the effect of reducing the permissible power for PEP by about 10 dBm, in order to avoid modulating above the peak power limit.

[48] Order para. 93.

Instead, in the 6 GHz proceeding, the parties and the Commission took to heart the technical showings of George Kizer[49] that co-channel operation of unlicensed devices in the main beam of the point-to-point receiver will cause harmful interference, even from kilometers away. The tremendous discrepancy in authorized power, between licensed and unlicensed operation, is irrelevant where an unlicensed device has line of sight to the main beam of the desired receiver.

Similarly, the parties and the Commission credited the Comments of AT&T Services, quoted above, that a point-to-point operator will not know that it is suffering harmful interference from an unlicensed device.[50] The operator will simply find that statistically the performance of the path decreases. The Part 15 rule about not causing interference is of no help a point-to-point operator who does not know of the existence of the unlicensed interferer. The Commission essentially acknowledged this point in the 6 GHz proceeding by stating that "[r]eduction in fade margin is equivalent to increase in nominal noise floor due to interference."[51]

If applied to AREDN fixed point-to-point and point-to-multipoint networks, the above statements from the Order would constitute a double standard. The AREDN networks are similarly situated to the licensed microwave networks that are receiving AFC protection. AREDN networks should receive the same.

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[49] *Supra* n15.
[50] *Supra* n20.
[51] *Unlicensed Use of the 6 GHz Band*, ET Docket No. 18-295, Notice of Proposed Rulemaking (Oct. 24, 2018) at 17 n102.

B. Relief requested

Section 301 requires relief similar to what the microwave licensees received: centralized, location-based automatic frequency coordination for existing and future AREDN fixed networks. Protecting future fixed networks is important, as the AREDN project is new and has a lot of growth ahead.

Co-channel unlicensed operation must not be allowed within a radius of AREDN fixed nodes. The same applies to adjacent channel unlicensed operation where the bandwidth is so wide that it intrudes into the channel that AREDN is using (*e.g.*, 40-, 80- and 160-megahertz bandwidths). This effectively is co-channel. The databases supporting AREDN's real-time maps (see map links above, *supra* 9) would replace ULS for purpose of AFC, and serve as the database of latitude and longitude location for fixed nodes, as well as the channel, bandwidth and bearing of the signal.

AREDN requests that 47 C.F.R. § 15.407 be applied in its entirety to unlicensed operation in the 5.9 GHz Band, including subsection k (Automated Frequency Coordination (AFC) System). AREDN further requests that this rule be modified to protect amateur radio fixed systems in the 5.9 GHz Band and pull location and path information from current and future AREDN real-time websites instead of ULS AREDN requests that this rule be otherwise modified as appropriate to make it applicable to the 5.9 GHz Band.

Respectfully submitted,

AMATEUR RADIO EMERGENCY DATA NETWORK

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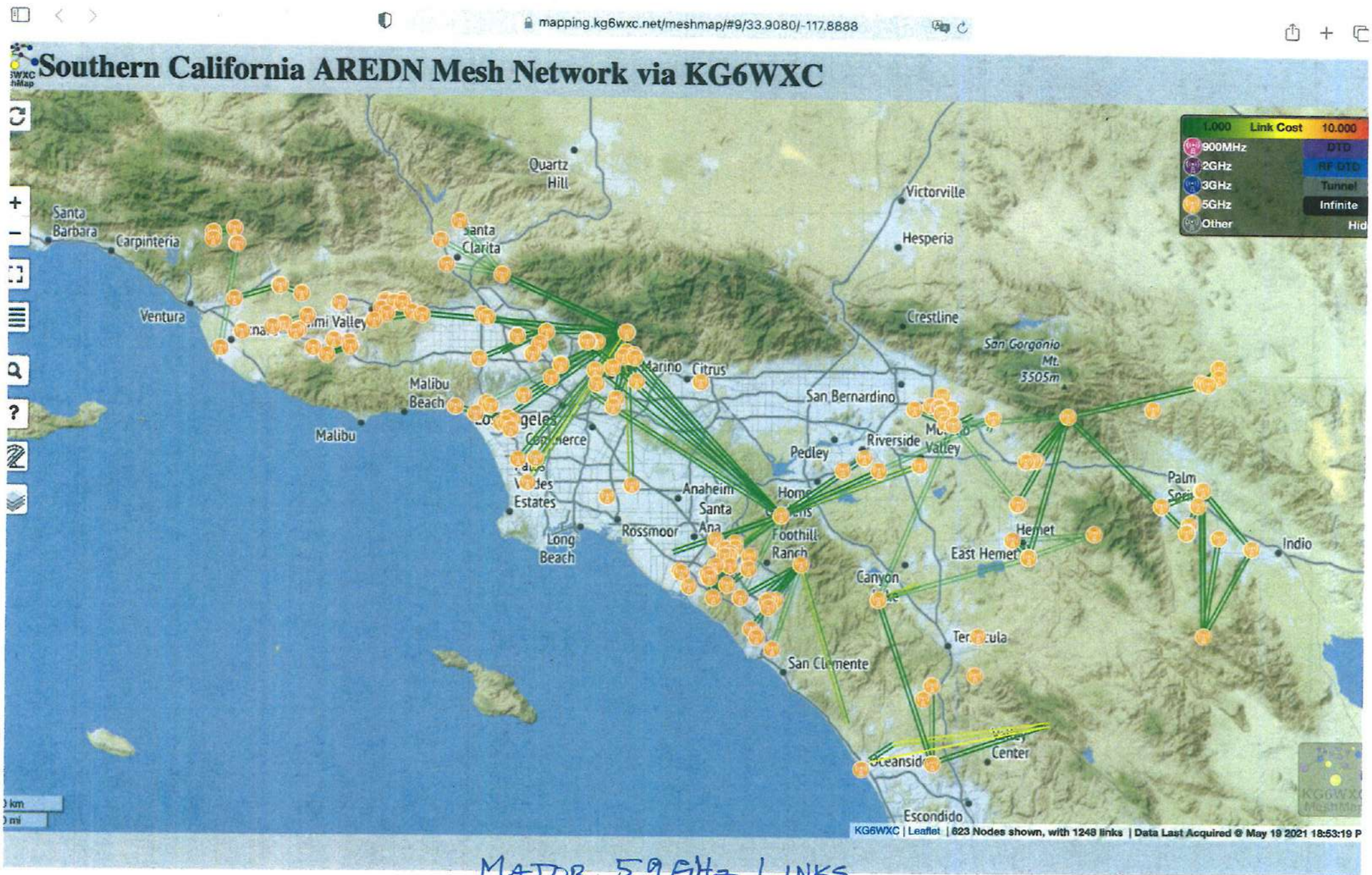
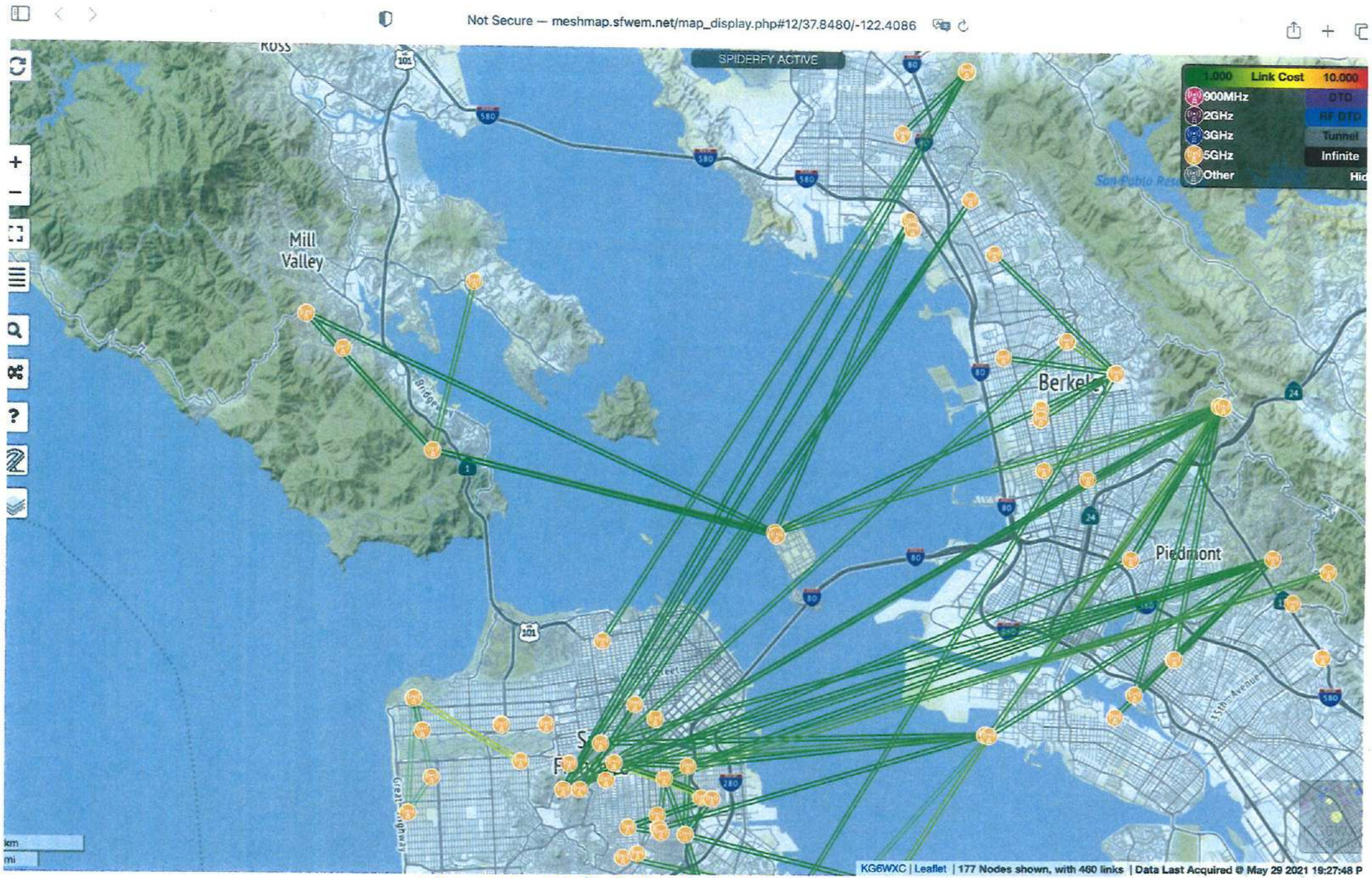
EXHIBIT 1

TO
COMMENTS OF AREDN
IN RESPONSE TO FURTHER NOTICE OF PROPOSED RULEMAKING

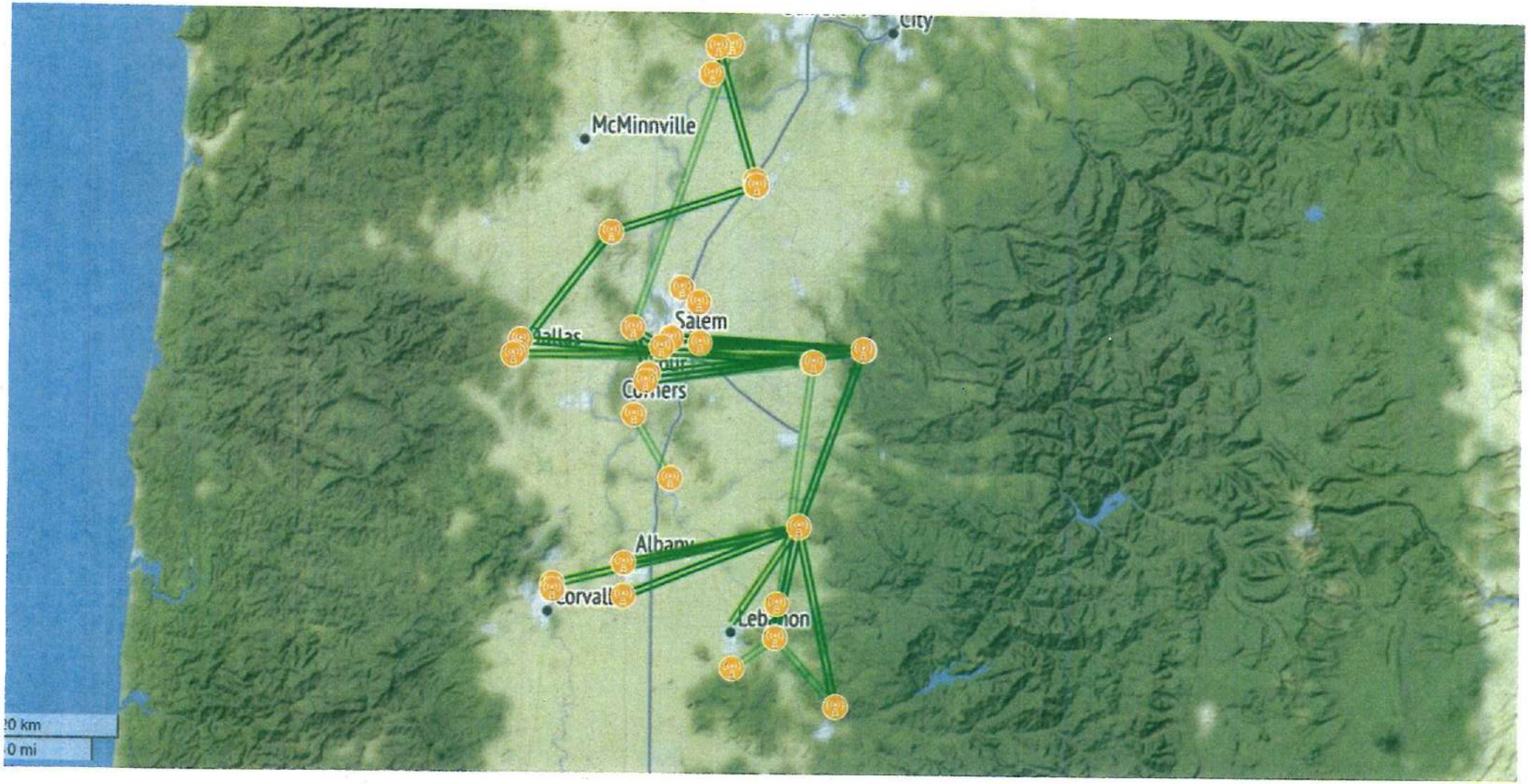
Maps of major 5.9 GHz links of AREDN mesh networks of Southern California, San Francisco and Willamette Valley, Oregon



MAJOR 5.9 GHz LINKS
SOUTHERN CALIFORNIA MESH NETWORK



MAJOR 5.9 GHz LINKS
SAN FRANCISCO MESH NETWORK



MAJOR 5.9 GHz LINKS
WILLAMETTE VALLEY MESH NETWORK

EXHIBIT 2

TO
COMMENTS OF AREDN
IN RESPONSE TO FURTHER NOTICE OF PROPOSED RULEMAKING

Declaration of Orville Beach
Link report of 5.9 GHz links longer than five miles in Southern California Mesh Network
Video stills of fires taken by Southern California Mesh Network

DECLARATION OF ORVILLE BEACH

1. I, Orville Beach, declare under penalty of perjury that the following is true and correct to my information, knowledge and belief.

2. My name is Orville Beach, with address of 3008 Waukegan Ave., Simi Valley, CA 93063. I am the licensee of W6BI in the Amateur Radio Service.

3. This Declaration is in opposition to the introduction, into the 5.850-5.925 GHz band (5.9 GHz band), of unlicensed operations and cellular vehicle-to-everything (C-V2X).

4. I am a user and implementer of the AREDN solution to establish high-speed data networks. I own and operate several nodes in the Southern California Mesh Network. The nodes that I own and operate are located in and around Simi Valley, California. The Southern California Mesh Network is a large network covering all of the Los Angeles basin, west into Ventura County and into surrounding mountains. The website that provides a real-time map for this network is found at https://mapping.kg6wxc.net/meshmap .

5. My direct experience is with the portion of this network in Ventura and western Los Angeles counties. In preparing for this Declaration, I also inspected printouts and the database of the Southern California Mesh Network map.

6. Based on printouts received from a network administrator, attached is a report of the links greater than five miles long in the 5.9 GHz band in the Southern California Mesh Network. The attached report lists 101 such links with the longest at 61 miles. In addition to the attached, there are another approximately 53 links in the 5.9 GHz band that are shorter than five miles. These exclude device-to-device links (two nodes in the same location typically connected by Ethernet cable) and "tunneled" links (two nodes connected via the Internet).

7. The AREDN ham network provides enhanced (*i.e.*, faster) digital communications in support of the public safety agencies that ARES and ACES support. ARES stands for Amateur Radio Emergency Service, and ACES stands for Auxiliary Communications Service – amateur radio

operators that are unpaid county employees. In our immediate area, ARES and ACES support the Ventura County Red Cross, Simi Valley Police Department and Simi Valley Hospital. Other agencies are supported in other parts of the network. As we have the opportunity, we continue to install 5.9 GHz band equipment in ACS/ARES-supported sites.

8. In addition to supporting local public health and safety agencies with communication services, we also maintain cameras in the canyons around Simi Valley. We have recorded, and broadcast the live video of developing brush fires. We intend to expand this remote camera coverage. This is important because a brush fire can start in a remote area, where there is no commercial or governmental presence, and not be noticed until after it grows into a dangerous fire. Attached are photos of some of the fires we broadcast. The foregoing is a description of what we do in the Simi Valley portion of the Southern California Mesh Network. Other ham licensees will have provided similar public services elsewhere in the network.

9. There is only one usable Part 97 channel (amateur allocation) in the 2.4 GHz band; this is channel -2, which is the second channel down from the Part 15 (unlicensed operation) spectrum. Even channel -2 suffers from out-of-band interference from Part 15 users. The Southern California Mesh Network has some legacy operations at 2.4 GHz channel -2. There are only 13 2.4 GHz links in Southern California left longer than 5 miles. No new user access points are being deployed anywhere in the 2.4 GHz band due to this interference.

10. If the new FCC rules are allowed to go into effect, we fear that the 5.9 GHz band will become like the 2.4 GHz band. The 2.4 GHz band has too much interference to establish a link of any distance. If unlicensed operations were to come into the 5.9 GHz band, we probably will have to shorten links at 5.9 GHz, add new nodes and new sites, spend more money and possibly reduce service. If we had to operate the Southern California Mesh Network entirely in the 2.4 GHz band, we probably would have to double or triple the number of sites and nodes and, even then, many links would not be possible. We would not be able to provide the service we now provide. We fear the same will happen in the 5.9 GHz band if unlicensed operation comes to the 5.9 GHz band.

Orville Beach

Orville Beach

Southern California AREDN Amateur Radio 5 GHz links > 5 miles

No.	Node 1	Node 1 Lat	Node 1 Lon	Node 2	Node 2 Lat	Node 2 Lon	Link Distance
1	AE6XE-PleasantsPk-P2P-Yucaipa	33.797813	-117.623661	AI6BX-4-RM5-XW-SW	34.029016	-117.027561	60.72
2	AI6BX-1-RM5-XW-Elsinore	34.013976	-117.138539	K6AH-ELBBRED	33.60223	-117.344149	49.57
3	Ai6HJ-RD5G34	33.869755	-118.338288	K6ECG-LA-MtWilson-SE	34.224	-118.061	46.95
4	K6ECG-LA-MtWilson-SW	34.224	-118.065	AI6HJ-Rocket	33.869745	-118.338288	46.75
5	AI6BX-10-PBE-M5-SMP-ELS	33.214284	-117.187579	K6AH-ELBBSM	33.602896	-117.343769	45.58
6	K6AH-SN5GDL95	34.037	-116.814	WA6MZW-CCCove2Snow	33.76615	-116.47352	43.53
7	K6ECG-LA-MtWilson-SW	34.224	-118.065	KDOLH-M5PB-74-248-139	33.9255	-118.36618	43.26
8	K6ECG-LA-MtWilson-SW	34.224	-118.065	KM6RNG-M5NB-184-178-95	33.9282759907141	-118.317624746665	40.28
9	K6ECG-LA-MtWilson-SW	34.224	-118.065	KM6RNG-LA-M5R-90-134-150-197	33.9285	-118.31708	40.23
10	K6ECG-LA-MtWilson-SW	34.224	-118.065	KI6NAZ-MikroTIK-5HPnD	33.866371	-118.04561	39.81
11	AE6XE-PleasantsPk-P2P-Yucaipa	33.797813	-117.623661	KE6AAP-1-PBM5	33.91875	-117.23304	38.49
12	AI6BX-7-RM5-SNOW-SW	34.03784	-116.8142	W6COH-RM5-XW-SnowPeak	33.705047	-116.922073	38.32
13	KE6BXT-EDOM-M5RXW-P2P	33.86667	-116.43512	KE6BXT-TORO-M5R120	33.523334	-116.42544	38.19
14	KE6BXT-TORO-M5R120	33.523334	-116.42544	WA6MZW-LGH5-22-Edom2Toro	33.86611	-116.431259	38.12
15	K6PVR-VC-SouthMtn-SE-Sector-5G	34.325231	-119.042	K6PVR-VC-SimiEast-2G	34.258	-118.642	37.5
16	K6AH-SN5GDL95	34.037	-116.814	N6GKB-Node1	34.1146	-116.4196	37.34
17	K6BFG-LA-MgcMtn-NW-Sector	34.353747	-118.416685	K6ECG-LA-MtWilson-SE	34.224	-118.061	35.72
18	K6ECG-LA-MtWilson-SW	34.224	-118.065	K6BFG-LA-MgcMtn-NW-Sector	34.353747	-118.416685	35.38
19	KO5HR-HP-Hatz-LHG-XL	34.075985	-118.353112	K6ECG-LA-MtWilson-SW	34.224	-118.065	31.21
20	W6FL-1	33.905476	-117.347299	AE6XE-PleasantsPk-P2P-Yucaipa	33.797813	-117.623661	28.19
21	KG6WXC-VC-RF-5G	34.180768	-119.207158	K6PVR-VC-Sulphur-to-Oxnard-5G	34.419591	-119.1614	26.89
22	AI6BX-1-RM5-XW-SE	34.013797	-117.138558	W6COH-PBE-M5-400-DanielPk	33.830328	-116.953969	26.58
23	AE6XE-PleasantsPk-P2P-Yucaipa	33.797813	-117.623661	K9LMR-Riverside-PleasantsPeak	33.935331	-117.388171	26.58
24	K6KEN-DanielPk-PBM400	33.830327	-116.953854	AI6BX-7-RM5-SNOW-SW	34.03784	-116.8142	26.43
25	KE6BXT-TORO-M5R120	33.523334	-116.42544	WM6Q-LHG5XL22-PD2Toro	33.7539	-116.383	25.94
26	AE6XE-PleasantsPk-P2P-LagunaWoods	33.797813	-117.623661	W6LY-RM5-RDish-LWV-PP	33.605175	-117.734814	23.76
27	K6ECG-LA-MtWilson-SW	34.224	-118.065	K6OAT-RocketM5	34.11727	-118.275544	22.72
28	KB6JAG-PBE-M5-400	33.745912	-116.968783	W6COH-RM5-XW-PineCove	33.76155	-116.73734	21.47
29	N6FQ-RM-SMP	33.400259	-117.191226	AI6BX-10-RM5-XW-SMP-RED	33.214277	-117.187535	20.68
30	K6CCC-ROCM5-2-GLENDALE	34.1472	-118.2486	K6ECG-LA-MtWilson-SW	34.224	-118.065	18.92
31	K6PVR-LA-Verdugo-W-Sector-5G	34.222146	-118.289626	K6ZIF-LHG5mesh-01	34.1587	-118.4788	18.78
32	K6BFG-LA-MgcMtn-NW-Sector	34.353747	-118.416685	K6BFG-BGI-LH5	34.4345804	-118.5898952	18.26
33	AE6XE-Saddleback-RM5	33.683336	-117.563946	W6LY-RM5-RDish-LWV-SB	33.605175	-117.734814	18.05
34	KE6BXT-PleasantsPk-M5R-SW	33.797813	-117.623661	W4HAC-PB5-TUS	33.7392388	-117.8050582	17.99
35	K6BFG-LA-MgcMtn-NW-Sector	34.353747	-118.416685	K6BFG-LA-QTH-LHG5XL	34.4790371	-118.5357322	17.7
36	K6ECG-LA-MtWilson-SW	34.224	-118.065	KA6TZM-3-north	34.06937	-118.09149	17.37
37	K6PVR-LA-Verdugo-W-Sector-5G	34.222146	-118.289626	W6RWN-LA-SFV-5G	34.26189	-118.470918	17.24
38	KE6BXT-PleasantsPk-M5R-SW	33.797813	-117.623661	KE6GYD-PBE-M5-400ISO-QTH	33.701019	-117.766907	17.07
39	KM6ICT-QTH-400-ISO	33.9292892637573	-116.933631151915	AI6BX-7-RM5-SNOW-SW	34.03784	-116.8142	16.34
40	K7LHC-Cross	34.551542	-114.194444	K9LMR-Mojave-CrossmanPeak	34.533712	-114.368448	16.06
41	K6PVR-LA-Verdugo-W-Sector-5G	34.222146	-118.289626	KF6NMZ-168-9-183	34.254857	-118.45838	15.93
42	K6ECG-LA-MtWilson-SW	34.224	-118.065	W2JCL-NBM5-184-178-134	34.1018	-118.146	15.5
43	K6CCR-BHSO	34.01577	-118.383251	N6HWW-03-90272	34.04827	-118.5461	15.44
44	AI6BX-7-RM5-SNOW-SW	34.03784	-116.8142	N6AJB-PB-M5-400	33.9346	-116.9237	15.29
45	K6PVR-VC-SouthMtn-SE-Sector-5G	34.325231	-119.042	K6PVR-VC-Sulphur-ResourceServer	34.41559	-119.16144	14.87
46	W6QN-NBM5-1	33.718968	-117.752232	KE6BXT-PleasantsPk-M5R-SW	33.797813	-117.623661	14.77
47	K6AMD-LH5-XL-01	34.378571	-118.572998	K6BFG-LA-MgcMtn-NW-Sector	34.353747	-118.416685	14.61
48	wb6lqp-101	34.05	-118.1	WM3SH-RKM5S-SW120-SM12-AM5G19	34.170584	-118.043246	14.39
49	K7LHC-Cross	34.551542	-114.194444	K7LHC-R5-FS2	34.50672222	-114.34083333	14.31
50	KJ6UUS-QTH-PBM5	33.933026	-116.902471	K6AH-SN5GDL95	34.037	-116.814	14.15

Southern California AREDN Amateur Radio 5 GHz links > 5 miles

51	KE6BXT-MVCH-M5R-248	33.596636	-117.659674	AE6XE-Saddleback-RM5	33.683336	-117.563946	13.09
52	K7LHC-Cross	34.551542	-114.194444	N8MJM-NBM5-LakeHavasuCity	34.47996	-114.30462	12.86
53	N6IPD-IDEC-RM5-SignalPk-Relay-Sector	33.60455	-117.810967	K6BAT-PBE-M5-400-QTH	33.708941	-117.763965	12.4
54	K7TJH-PB1	34.524126	-114.325105	K7LHC-Cross	34.551542	-114.194444	12.35
55	K6PVR-VC-SouthMtn-W-Sector-5G	34.325231	-119.039967	AI6VX-VC-EVTA	34.29316	-119.16835	12.32
56	KE6BXT-MVNPM-M5NB-132-28-248	33.601422	-117.651628	AE6XE-Saddleback-RM5	33.683336	-117.563946	12.2
57	WB6RLC-PwrBeamM5xw-Cove2Edom	33.765629	-116.47717	KJ6DQR-M5Rocket-Edom2PS-CC	33.86631	-116.431059	11.98
58	N6IPD-IDEC-PBE-M5-400-PHS	33.672541	-117.713155	N6IPD-IDEC-RM5-SignalPk-Relay-Sector	33.60455	-117.810967	11.8
59	WA6MZW-LGH5-Dish-EdomToCCCove	33.86631	-116.432009	WA6MZW-LGH5-22Dish-Cove2Edom	33.76625	-116.47352	11.77
60	KJ6DQR-RocketM5Omni	33.76812	-116.475067	KJ6DQR-M5Rocket-Edom2PS-CC	33.86631	-116.431059	11.65
61	WA6MZW-LGH5-Dish-EdomToCCCove	33.86631	-116.432009	KJ6DQR-PowerBeam400-M5XW-QTH	33.768221	-116.475066	11.61
62	KJ6DQR-M5Rocket-Edom2PS-CC	33.86631	-116.431059	KO6B-LGH5-18-HyattPS2Edom	33.826466	-116.547209	11.61
63	N6IPD-IDEC-RM5-SignalPk-Relay-Sector	33.60455	-117.810967	KE6GYD-IDEC-PBE-M5-400ISO-QTH	33.7011	-117.766617	11.49
64	N6IPD-IDEC-RM5-SignalPk-Relay-Sector	33.60455	-117.810967	N6IPD-IDEC-PBE-M5-400-IHS	33.70261	-117.781384	11.24
65	K7LHC-Cross	34.551542	-114.194444	K0TAN-PB1	34.480878	-114.282017	11.23
66	K6PVR-VC-RasnowPk-N-Sector-5G	34.165282	-118.90905	K6PVR-VC-Camarillo-Hills-SW-5G	34.2551	-118.9633	11.16
67	W6VAH-NB-M5-LLVA	34.050157	-117.249463	AI6BX-1-RM5-XW-NW	34.014063	-117.138505	10.98
68	N6IPD-IDEC-RM5-Quail-Relay-Sector	33.636257	-117.772566	N6IPD-IDEC-PBE-M5-400-NHS	33.733162	-117.751803	10.95
69	KA6ECT-PAS-NE-RM5-GPS-42-127-62	34.1346414	-118.1534574	WM3SH-NGM5-WSW8-SM26-QTH2HMH	34.170694	-118.043253	10.9
70	K6PVR-VC-SimiEast-5G	34.26	-118.642	KJ6GEU-VC-QTH-5G	34.2741606	-118.7562166	10.61
71	KJ6DQR-M5Rocket-Edom2PS-CC	33.86631	-116.431059	KJ6FYY-RocketM5Omni-CC-Shop	33.784166	-116.467538	9.74
72	K7LHC-Cross	34.551542	-114.194444	W7DXJ-PB1	34.49258333	-114.2725	9.7
73	K6PVR-VC-Camarillo-Hills-SW-5G	34.2551	-118.9633	W6JWP-QTH-Camarillo-NanoBridgeM5	34.230688	-119.061413	9.42
74	K6CCC-ROCM5-1-GLENDALE	34.14707	-118.248731	K6PVR-LA-Verdugo-S-Sector-5G	34.224146	-118.289626	9.36
75	N6IPD-IDEC-NBM5-OSF-Shed	33.677855	-117.764596	N6IPD-IDEC-RM5-SignalPk-Relay-Sector	33.60455	-117.810967	9.21
76	N6IPD-IDEC-PBE-M5-400-BHS	33.717771	-117.782299	N6IPD-IDEC-RM5-Quail-Relay-Sector	33.636257	-117.772566	9.11
77	AI6BX-RM5-Sector-LLVA	34.050162	-117.249457	KM6AJP-NS-M5-XW	34.018506	-117.160407	8.93
78	AI6BX-1-RM5-XW-NW	34.014063	-117.138505	KK6WJU-NB-M5-QTH	34.083067	-117.172436	8.29
79	WM3SH-RKM5S-S120-SM11-BAILEY	34.178252	-118.06577	W6ORG-5	34.1101	-118.0336	8.14
80	W6JPL-M5R-Mesa	34.20391	-118.175973	KA6ECT-NBM5-JPL-60-241-34	34.1346414	-118.1536574	7.97
81	W6LY-RM5-RDish-LWV-SB	33.605175	-117.734814	KE6BXT-QTH-hAP-Tun226	33.58396	-117.654	7.85
82	W6BI-VC-SVPD-NSM5	34.2883	-118.7194	K6PVR-VC-SimiEast-5G	34.26	-118.642	7.78
83	W6EOC-9-PBM5-RdlsEOC-1	34.059493	-117.201765	AI6BX-1-RM5-XW-NW	34.014063	-117.138505	7.71
84	N6IMF-1	34.2127	-118.371398	K6PVR-LA-Verdugo-W-Sector-5G	34.222146	-118.289626	7.59
85	W6BI-VC-QTH-5G	34.29	-118.7158	K6PVR-VC-SimiEast-5G	34.26	-118.642	7.56
86	AI6BX-RM5-Sector-LLVA	34.050162	-117.249457	AI6BX-6-NB-M5-PV	34.043447	-117.171654	7.21
87	AJ6GZ-1-PBM5-WEST	34.041466	-117.172435	AI6BX-RM5-Sector-LLVA	34.050162	-117.249457	7.16
88	K6PVR-VC-RasnowPk-N-Sector-5G	34.165282	-118.90905	K3CAQ-VC-PB1-Portable	34.195653	-118.843682	6.9
89	K6PVR-VC-RasnowPk-N-Sector-5G	34.165282	-118.90905	AF6XT-VC-ThousandOaks-AirGrid	34.183887	-118.841145	6.58
90	WD6EBY-5G-Link---Ojai-Black-to-Reeves	34.432115	-119.230364	N6FL-VC-Reeves-Rd-to-Black-Mtn-Link-5G	34.456905	-119.1678	6.36
91	K6PVR-VC-SimiEast-5G	34.26	-118.642	WB2YXY-VC-5G	34.294	-118.6972	6.33
92	K6PVR-VC-Camarillo-Hills-SW-5G	34.2551	-118.9633	KE6NYT-HM-DISH	34.236	-119.028	6.31
93	K6PVR-VC-SouthMtn-SE-Sector-5G	34.325231	-119.042	WB6IWT-VC-QTH-5G	34.306667	-118.97857	6.18
94	AI6BX-8-PBE-M5-P2P-HC	34.055928	-117.178868	AI6BX-1-RM5-XW-NW	34.014063	-117.138505	5.96
95	KM6IAU-PaxtonHill-Node2	34.1532	-116.3895	KK6WCX-Base-Node0	34.118645	-116.437255	5.84
96	N6IPD-IDEC-RM5-Quail-Relay-Sector	33.636257	-117.772566	N6IPD-IDEC-PBE-M5-400-WHS	33.67923	-117.806713	5.73
97	KM6FQ-LHG5XL	34.285917	-118.695772	K6PVR-VC-SimiEast-5G	34.26	-118.642	5.72
98	W6OEU-VC-OJ-QTH-PB-5G	34.44764	-119.227866	N6FL-VC-Ojai-East-5G	34.456905	-119.1674	5.64
99	KM6IAU-PaxtonHill-Node2	34.1532	-116.3895	W6BZY-Node1	34.116042	-116.4296943	5.55
100	N6IPD-IDEC-PBE-M5-400-UHS	33.651296	-117.823565	N6IPD-IDEC-RM5-SignalPk-Relay-Sector	33.60455	-117.810967	5.33
101	KM6IAU-PaxtonHill-Node2	34.1532	-116.3895	N6GKB-Node2	34.1147	-116.4196	5.1


11-09-2018 09:38:05
SimiNorthCam


ulphurMtn
59:10 / 1:43:42

EXHIBIT 3

TO
COMMENTS OF AREDN
IN RESPONSE TO FURTHER NOTICE OF PROPOSED RULEMAKING

Declaration of Brett Popovich
Link report of major 5.9 GHz links in the Willamette Valley Mesh Network

DECLARATION OF BRETT POPOVICH

I, Brett Popovich, declare under penalty of perjury that the following is true and correct to my knowledge, information and belief.

1. My name is Brett Popovich, with address of 8557 Saghalie Drive S., Salem, OR 97306. I am the licensee of KG7GDB, a license in the Amateur Radio Service.

2. This Declaration is in opposition to the introduction, into the 5.850-5.925 GHz band (5.9 GHz Band), of unlicensed operations and cellular vehicle-to-everything (C-V2X).

3. I am a user and implementer of the AREDN solution to establish a high-speed data mesh network.

4. I am one of the network administrators of the Willamette Valley Mesh Network. The website for our network is located at https://willamettevalleymesh.net.

5. We have been developing the Willamette Valley Mesh Network since April 2019. Each of the amateur licensees in our network has a background or interest in emergency management. We started by connecting the separate emergency response communications systems in our respective counties. We have built on that by continuing to extend and densify the network. We migrated to the AREDN protocols because we were frustrated with the slowness of the old Winlink radio email that some of us were using. Amateur radio using AREDN gives a very large improvement over Winlink. In an emergency, the agencies that we support can email and text each other at Internet speeds using our network, even when the Internet is down. We are almost entirely self-funded, and we received a few donations of used equipment.

6. We support ARES (amateur radio emergency service) and local emergency management agencies. We provide communications in an emergency between and among the following adjacent Oregon counties: Marion, Polk, Yamhill, Linn, Lane, Benton and Clackamas Counties. We provide the communications infrastructure for different public safety and emergency management agencies in these counties to talk with each other in these counties. This is especially important in an emergency where cellular and

landline telephone networks may be disabled or, if functioning, are saturated by heavy calling by the public.

7. We had two emergencies recently. The Labor Day 2020 forest fires in Oregon were catastrophic, and the Valentines Day 2021 ice storms knocked out electric power for more than eight days. Our network survived both events and contributed to the emergency response to both. The Cascadia Earthquake is the really big event that we are preparing for but hope will not happen.

8. Attached is a map of the 5.9 GHz Band RF links of our network, as well as a link report of the longer links. These were current as of mid-May, 2021. We continue to grow the network. For example, the longest link listed in the attached link report has a length of 33 miles. However, we are currently working on a new 41-mile link.

9. In addition to the 5.9 GHz nodes shown on the attached map, we also have a smaller number of 2.4 GHz and 900 MHz nodes. These spectrum bands are shared with unlicensed users. Almost all of our 2.4 GHz and 900 MHz nodes are connected to our network by tunneling via landline data and telephone lines. Our preference is to have all of our links operate over radio frequencies. Our goal is to operate by radio frequency (RF) independent of public networks in an emergency. Almost all of the RF links in our network are at 5.9 GHz. We tried to get the 2.4 GHz and 900 MHz nodes to link and operate over radio spectrum. We were unsuccessful for almost all of these nodes. For example, we tried to establish a one-kilometer RF link over 2.4 GHz. This is a relatively short link for us. We could get a signal but it would not remain connected. If we raised the power, we still would not have a consistent connection. The problem for both 2.4 GHz and 900 Mhz is interference near the receivers on our mesh network. Both of these spectrum bands are saturated with unlicensed users that cause interference. The 900 MHz and 2.4 GHz bands should have been the first choice for our long links because they have better propagation. But they are unusable because they are saturated.

10. Because we are self-funded, we cannot pay rent for transmitter sites. This makes it difficult to get sites. Other wireless operations, like cellular telephone operators and wireless Internet service providers, pay rent and get sites readily. The expectation from site owners is that we should pay too. We have encountered at least one situation where we were not able to place a

node on a rooftop because another wireless operation demanded that no other antennas go on the rooftop.

11. The spectrum is much cleaner at 5.9 GHz because the users cooperate with each other. Coordination among users is more important to maintaining clean spectrum than the absolute number of users. By cooperating with each other, we avoid interfering with each other and are good neighbors.

12. A network the size of the Willamette Valley Mesh Network requires considerable internal planning, as well as coordination with other licensees. For transmitters operating at a shared site, we need a separation of at least two channels in order to avoid self-interference and to avoid interfering with another licensee. The frequency assignment has to come together with site acquisition in order to have a functioning network.

13. By contrast, at 2.4 GHz and 900 MHz, where the amateur radio allocation is shared with unlicensed users, with one exception, we do not know who the other users are. In these bands, unlicensed users appear unpredictably and move around. The unlicensed users have no understanding of frequency coordination or cooperation with other radio operators. They transmit on the channels that were programmed into their devices. Consequently, the spectrum at 900 MHz and 2.4 GHz is crowded, chaotic and unusable for our purposes. As stated above, raising the power level does not solve the problem for us. There will be interference whenever an unlicensed device is transmitting co-channel and is located near our receiver. It does not matter how strong our signal is, there will be interference.

14. If the new FCC rules are made effective, we fear that the 5.9 GHz Band will become like the 900 MHz and 2.4 GHz bands. Unlicensed users will flood into the 5.9 GHz Band. There will be little or no frequency coordination with unlicensed users. The 5.9 GHz Band will become crowded and chaotic, like the other spectrum allocated to unlicensed use.

15. If the new FCC rules become effective, the Willamette Valley Mesh Network probably would have to go from a long-range network to short-range. We probably would need to double or triple the number of sites with shorter links between sites in order to provide the same coverage. We probably would not be able to obtain that many new sites for free. Our frequency coordination plan probably would be disrupted. We probably would not be able to maintain a two-channel separation between links. As a result, we

probably would drop links. This would result in considerably greater expense for us, and we probably would have to reduce the services that we provide to emergency response agencies.

Brett Popovich

AREDN Willamette Valley Mesh

Sorted by 5.9 GHz link

Site	Amateur License	Transmitter/ Identifier	Latitude	Longitude	Channel	Linked To	Device/ Identifier	Link Distance Miles
9	K7LWV	LHG-XL	44.9161	-123.3320	174	WA7ABU	PB400M5-XW-529T	33
16	WA7ABU	PB400-M5-XW-	44.9265	-122.6566	174	K7LWV	LHG-XL	33
1	AH6LE	Chehalem RPTR	45.3393	-122.9160	174	N7TB	ROCK-M5-XW-OMN	28
10	N7TB	ROCK-M5-XW-OMN	44.9530	-123.1020	174	AH6LE	Chehalem RPTR	28
7	W7RGM	PBM5-XW-42EF	44.9360	-123.3190	172	WA7ABU	PB400-VP-0CCD	28
17	WA7ABU	PB400-PB400-VP-0(	44.9085	-122.7549	172	W7RGM	PB-M5-XW-42F	28
17	WA7ABU	PB400-PB400-VP-0(	44.9085	-122.7549	172	K7LWV	SXTsq-5G	28
9	K7LWV	SXTsq-5G	44.9164	-123.3330	172	WA7ABU	PB400-VP-0CCD	28
8	W7PLK	EOC-LHG5XL	44.9190	-123.3270	172	WA7ABU	PB400-VP-0CCD	28
17	WA7ABU	PB400-PB400-VP-0(	44.9085	-122.7549	172	W7PLK	EOC-LHG5XL	28
16	WA7ABU	PBM5-VP-99F4	44.9085	-122.7539	184	W7VA	M5-NanoB-K7ENW	26
28	W7VA	M5-NanoB-K7ENW	44.5314	-122.8208	184	WA7ABU	PBM5-VP-99F4	26
23	K7CVO	GSRMC-PB-M5-620	44.6030	-123.2524	184	K7ENW	RodgersMtn-M5	24
26	K7ENW	RodgersMtn-M5	44.6832	-122.7790	184	K7CVO	GSRMC-PB-M5-620	24
16	K7ATV	ROCK-m5-xw-7AD3	44.9256	-122.6547	177	KKCAT	NANOM5-MEOW	21
18	KK7CAT	NANOM5-MEOW	44.8911	-123.0721	177	K7ATV	ROCK-m5-xw-7AD3	21

12	W7BDB	ROCKET-OMNI-TBlc	44.9400	-123.0800	177	K7ATV	ROCK-m5-xw-7AD3	18
16	K7ATV	ROCK-m5-xw-7AD3	44.9256	-122.6547	177	W7BDB	ROCKET-OMNI-TBlc	18
26	K7ENW	XW-PB400-F1-77	44.6820	-122.7780	172	WA7ABU	PB400-2scio-9064	18
16	WA7ABU	PB400-2scio9064	44.9265	-122.6575	172	K7ENW	XW-PB400-F1-77	18
25	K7LBC	M5-WHO	44.5873	-123.1147	184	K7ENW	RodgersMtn-M5	18
26	K7ENW	RodgersMtn-M5	44.6832	-122.7790	184	K7LBC	M5-WHO	18
26	K7ENW	RodgersMtn-M5	44.6832	-122.7790	184	KG7BZ	MarksRidge-M5	18
30	KG7BZ	Marks-Ridge-M5	44.4346	-122.7034	184	K7ENW	RodgersMtn-M5	18
22	K7AGH	AlbanyGenHospital	44.6317	-123.1164	184	K7ENW	RodgersMtn-M5	17
26	K7ENW	RodgersMtn-M5	44.6832	-122.7790	184	K7AGH	AlbanyGenHospital	17
15	KB7PPM	PB400-XW-93F9	44.9346	-122.9732	174	WA7ABU	PB400-M5-XW-	16
16	WA7ABU	PB400-M5-XW-	44.9265	-122.6566	174	KB7PPM	PB400-XW-93F9	16
2	K9RCP	CRMT-Sector	45.3371	-122.9436	180	KJ7TAD	NSM5-FS21a-5B2C	14
5	KJ7TAD	NSM5-FS21a-5B2C	45.1495	-122.8658	180	K9RCP	CRMT-DISH	14
5	KJ7TAD	NSM5-FS21b-57898	45.1495	-122.8668	183	K7RTL	ROCKM5B-XW-489[illegible]	14
6	K7RTL	ROCK-M5B-XW-498	45.0830	-123.1456	183	KJ7TAD	NSM5-FS21b-5789	14
6	K7RTL	ROCK-M5A-XW-5A5	45.0829	-123.1456	175	W7PLK	EOC-RckM5	14
8	W7PLK	EOC-RckM5	44.9188	-123.3272	175	K7RTL	ROCKM5A-XW-5A5[illegible]	14

26	K7ENW	RodgersMtn-M5	44.6832	-122.7790	184	W7VA	M5-NanoB-K7ENW	11
28	W7VA	M5-NanoB-K7ENW	44.5314	-122.8208	184	K7ENW	RodgersMtn-M5	11
28	W7VA	M5-NanoB-KG7BV	44.5311	-122.8209	173	KG7BZ	M5-NanoB-W7VA	9
30	KG7BZ	M5-NanoB-W7VA	44.4343	-122.7037	173	W7VA	M5-NanoB-KG7BV	9
20	KG7GDB	NSM5-MOBILE-D56	44.8341	-123.0990	182	KG7AHP	PBE-M5-400	7
21	KG7AHP	PBE-M5-400	44.7466	-123.0265	182	KG7GDB	NSM5-MOBILE-D56	7
28	W7VA	M5-NanoB-Lebanor	44.5307	-122.8210	149	WY7MAE	M5-Nano-Lebanon	5
29	W7MAE	M5-Nano-Lebanon	44.4875	-122.9053	149	W7VA	M5-NanoB-Lebanor	5
10	N7TB	ROCK-M5-XW-OMN	44.9530	-123.1020	174	K17FWH	NANO1	4
18	K17FWH	Nano1	44.8921	-123.0721	174	N7TB	ROCK-M5-XW-OMN	4
10	N7TB	ROCK-M5-XW-OMN	44.9530	-123.1020	174	K7RTL	PB400-QTH-EAEB	3
11	K7RTL	PB400-QTH-EAEB	44.9270	-123.0470	174	N7TB	ROCK-M5-XW-OMN	3
27	KA7GFU	NanoB-M5	44.5765	-122.8200	184	W7VA	M5-NanoB-K7ENW	3
28	W7VA	M5-NanoB-K7ENW	44.5314	-122.8208	184	KA7GFU	NanoB-M5	3

EXHIBIT 4

TO
COMMENTS OF AREDN
IN RESPONSE TO FURTHER NOTICE OF PROPOSED RULEMAKING

Declaration of Mark Braunstein

DECLARATION OF MARK BRAUNSTEIN

I, Mark Braunstein, declare under penalty of perjury that the following is true and correct to my knowledge, information, and belief.

My name is Mark Braunstein, and my address is 14345 Brookmere Drive, Centreville, VA 20120. I am licensed as an Amateur Extra Class operator (WA4KFZ) in the Amateur Radio Service. I am an experimenter and volunteer for amateur-radio related activities. Through my local club, I provide training assistance for those interested in obtaining an amateur radio license and serve as a Volunteer Examiner. Amateur radio has been an integral and rewarding part of my life. As a young boy, I was first licensed in 1970. My early experience with amateur radio proved to be invaluable, first becoming an Electronics Technician in the US Coast Guard and eventually obtaining a BSEE in Electrical Engineering. For me, amateur radio was the "seed" of what today we call a STEM education. I encourage newly licensed amateurs to treat our radio spectrum as their "wireless sandbox" and learn about radio technology to their fullest.

As an amateur radio operator who volunteers in public service activities, I am writing in opposition to the unlicensed use of spectrum in the 5.850-5.925GHz spectrum and am deeply concerned about the interference that would be produced by the introduction of unlicensed devices and C-V2X systems as currently proposed.

I have volunteered with the Marine Corps Marathon as an amateur radio operator since approximately 2011, utilizing my capabilities to support medical communications. I now coordinate AREDN activities for the marathon.

Amateur radio operators serve a unique function for the marathon, working in conjunction with Navy Corpsman and Marine Corps personnel to provide voice and data communications within the medical command structure. In addition to working with military personnel, we also work in tandem with medical students who volunteer to learn how to operate in a mass casualty scenario. In fact, the medical response planning for the marathon is treated, by the Marine Corps Marathon Office, as a "planned mass casualty event."

The Marine Corps Marathon Office uses amateur radio communications as a means of operating "off infrastructure." Since the race encompasses both Washington, DC and Arlington, VA there is concern that any major incident could result in the cellphone or commercial WiFi networks becoming severely

overloaded. Amateur radio operations work as an integral part of the unified command structure, coordinating and relaying information to the various law enforcement and EMS services assigned to the racecourse.

For medical communications, amateur radio operations utilize ad-hoc network equipment in what could be described as a "tactical" configuration. Medical and aid station equipment is set up the morning of the race and secured in the evening. Both generator and battery backup systems are deployed at each station. Temporary repeater and AREDN sector node systems are set up on rooftops a few weeks prior to the race.

Amateur radio operators perform communications and data entry into the runner database. The database contains information that links the runner's bib number to their name, medical history, and emergency contacts. The database is updated in real-time when a runner requires medical intervention. Treatment can range from simple cuts and scrapes to more serious conditions such as dehydration and heat stroke. Runners who require medical care are stabilized by the Corpsman and transported to nearby hospitals. The runner database contains all the up-to-date information on the individual and is followed up by Marine Corps Marathon personnel, post-race, to close out any medical incidents.

Initially, amateur radio operators relied on the use of 9600bps packet radio for exchanging information into and out of the runner database. Later, to improve data throughput, Icom DSTAR ID-1 radios were utilized to provide data transmissions at 128kbps.

The Marine Corps Marathon Office, in 2018/2019, updated their database configuration and now utilize a vendor that **only** offers a cloud-based solution. Tests conducted by amateurs with the ID-1 equipment showed that the bandwidth necessary to operate with this new database configuration **could not be met with 128kbps equipment.** On top of that, the ID-1 equipment is now obsolete and only recently has a similar unit been offered on the market by Icom at considerable expense.

With the increased need for bandwidth, amateur radio operators turned to AREDN equipment as a means of providing a "wider pipe" capable of working with the new database. AREDN equipment was selected since it is cost effective (about the cost of a typical amateur radio VHF/UHF handheld) and readily meets the maximum permissible exposure (MPE) requirements for both controlled and uncontrolled environments. Data rates using AREDN are easily an order of

magnitude (and in some cases two orders of magnitude) faster than the previous ID-1 equipment.

Starting in 2015, AREDN equipment in the 2.4GHz spectrum was tested to determine how well it would perform during the race. The equipment was located at the Iwo Jima Memorial and provided connectivity between medical tents approximately 0.25 miles apart. To determine the impact of interference on AREDN equipment, the terminals were operated at both WiFi Channel 1 (i.e., Part 15 operation) and at Channel −2. **A snapshot of the interference environment showed that AREDN equipment would be severely interference-limited in trying to support longer-range links.** When operated at Channel −2, however, no interference was noted, and throughput increased noticeably. This measurement is discussed in a presentation from 2017 in this video:

https://www.youtube.com/watch?v=n2vAcQvYx4o&t=17s
AREDN Mesh and the Marine Corps Marathon (MCM)
[2017 test showing channel 1 test interference.]

Due to interference alone, the only way AREDN equipment can provide adequate long-range performance is by operating in "quiet" radio spectrum.

While the initial test at 2.4GHz at Channel −2 was successful, the bandwidth is restricted to only a single 10MHz channel in a tactical configuration with minimal antenna separation. The use of a single channel precludes using co-located AREDN equipment to perform bridging operations (referred to as device-to-device or DtD in AREDN) in support of the mesh networking architecture. Such bridging configurations are commonly used to work around obstructions such as buildings, trees, bridges, etc.

To fully utilize the capabilities of AREDN, the participating amateur radio operators decided to add a 5.9GHz capability along side the 2.4GHz systems. This allowed operators with older AREDN gear to continue to operate while introducing newer, higher bandwidth equipment to our portfolio. Operating at 5.9GHz, with multiple channels, also allowed in-band bridging configurations to be supported.

In 2018, a combined 2.4GHz and 5.9GHz link was tested between the medical tents spanning from the finish line to the Rosslyn Metro station. The success of this test led us to perform a course-wide test in 2019. This test utilized two sector antenna systems, operating at 2.4GHz and 5.9GHz, covering most of the racecourse along the National Mall. At the last minute, a third sector system was

added on the roof of the Smithsonian Museum of American History. The test was successful and showed that we could provide high bandwidth connectivity for the medical and aid stations along the racecourse. A summary presentation of the 2019 operation is discussed in this video:

https://www.youtube.com/watch?v=ytHhjwusK_8
AREDN Mesh 2020 Frostfest
[Presentation of AREDN 2.4/5.9GHz at 2019 MCM]

If AREDN equipment is forced to compete with a "sea" of unlicensed devices, the interference environment would most likely preclude operation over long distances such as those required for the marathon. It is precisely because of the low interference environment that AREDN equipment can be utilized at both 2.4GHz and 5.9GHz. With the recent FCC decision to revamp the 5.9GHz spectrum allocations, and to allow C-V2X equipment operation, we once again are concerned about having to contend with a sea of interferers.

Presently, the amateur radio community does not know how AREDN equipment would perform in a saturated C-V2X environment. In September 2020, AREDN operators associated with the Marine Corps Marathon supported a measurement study performed at the behest of the Department of Transportation (DOT). Off-air AREDN signals, with network traffic being passed, were recorded by US Army (ATEC, Aberdeen Proving Grounds) personnel using their advanced signal collection and recording systems. These wideband recordings were handed over to the Institute of Telecommunication Sciences (ITS) for analysis to determine the impact to both AREDN and C-V2X systems. This analysis work is currently being performed by ITS in Boulder, CO.

If AREDN equipment is to continue providing off-infrastructure support to the Marine Corps Marathon, the interference environment will need to remain tightly controlled. For this reason, I oppose the restructuring of the 5.850-5.925GHz spectrum until such time that amateur radio operations are given due consideration.

Mark Braunstein

May 30, 2021

EXHIBIT 5

TO
COMMENTS OF AREDN
IN RESPONSE TO FURTHER NOTICE OF PROPOSED RULEMAKING

Declaration of Gene Harrison

DECLARATION OF GENE HARRISON

I, Gene Harrison, declare under penalty of perjury that the following is true and correct to my knowledge, information and belief.

1 My name is Gene Harrison, with address of P.O. Box 1584, Leesburg, VA 20177. I am the licensee of N3EV, a license in the Amateur Radio Service.

2 This Declaration is in opposition to the FCC's First Report and Order that introduces unlicensed operations into the 5.850-5.925 GHz band (5.9 GHz Band).

3 I am a user of the 5.9 GHz spectrum and an implementer of the AREDN mesh solution to establish high-speed data mesh networks. My special emphasis is on crafting rapidly deployable and survivable emergency communications systems for life-saving responses to local and National disasters and critical incidents.

4 My experience and qualifications are as follows.

4.a Since 2015, I have been retired, and I continue to serve as a pro-bono mentor and consultant to multiple public safety and charitable public service organizations. Over my entire professional career, I have served our Nation and it's military, government, industry, and volunteer communities.

4.b For 31 years, from 1984 to 2015, I was at The MITRE Corporation, where I was a subject matter expert in "Emergency Communications & Wireless". At MITRE I held the position of Lead Engineer and supported almost every US Military Service and multiple Government Agencies, developed many pragmatic & innovative solutions, and received numerous commendations and performance awards.

4.c My informal specialties included "practical tactical solutions" for survivable and rapidly deployable C4ISR systems. As just one relevant example, I have been awarded US Patent 10305945, "Providing Survivable Calling and Conferencing" (unclassified) which is already being implemented within certain USG Agencies.

4.d I was selected and recruited to MITRE to solve a critical national survivability problem, with an urgent need for viable & reliable emergency communications. As a pivotal enabling solution, I developed the High Frequency Radio Automatic Link Establishment system (HF-ALE). I authored the unprecedented ALE criteria which were enthusiastically

approved and incorporated in Military Standard MIL-STD-188-141A, plus the corresponding Federal Telecommunications Standard FED-STD-1045.

4.e Our HF-ALE system has been widely recognized as the first integrated & synergistic implementation of combined digital signaling, adaptive protocols, computer controlled radios, and (early) artificial intelligence. Presently our U.S. HF-ALE has been accepted and broadly implemented globally as the de-facto world standard for automated HF communications.

4.f I received a Bachelor of Science Degree in Electrical Engineering, from the Virginia Polytechnic Institute and State University (Virginia Tech), and also a Master's Degree in Telecommunications and Computers, from The George Washington University.

4.g My graduate research project "HALE-Comm - A Rapidly Deployable, Broadband Wireless, Emergency Communications System" presented a unique opportunity that, if implemented, could have restored critical life-saving communications across the post-Katrina disaster region in only days, instead of months or years.

4.h I am experienced with emergency operations and missions, and I have been a lifelong first-responder, volunteering in multiple organizations, such as:

h.i Loudoun County Volunteer Rescue Squad (Advanced Life Support EMT-C & EMT Instructor);

h.ii Loudoun County Fire & Rescue Commission (Technical Representative to the Washington Region Council of Governments Committee on Emergency Medical Services Communications)

h.iii Appalachian Search And Rescue Conference (Co-Founder, President and Training & Communications Officers);

h.iv National Cave Rescue Commission (Co-Founder, and first Eastern Region Coordinator):

h.v US Air Force Auxiliary, Civil Air Patrol (Mission Pilot, Ground & Air Mission Directors, and Communications Engineer);

h.vi Maryland & Mid-Atlantic Wilderness Rescue Squad (d.b.a. Austere Medical Professionals) (Director and Communications Officer); and the

h.vii DHS SHARES IWG (Interoperability Working Group), one of the longest running and most successful US Government emergency communications interoperability programs (Co-Creator and continuing participant).

5 SUMMARY OF KEY POINTS:

5.a The present Amateur Radio Service incumbents of the 5.9 GHz band, and especially the AREDN mesh systems, have been fully compliant with the spirit and letter of the FCC Part 97 guidance, in full accord with the

fundamental goals of the Service, especially emergency communications, technology advancement, and Public Good.

5.b The 5.9 GHz band is a unique and valuable resource, which provides an almost optimal "sweet spot" for propagation, bandwidth, high performance waveforms, and effective data communications capabilities. There is no reasonably equivalent band remaining in the ARS.

5.c The AREDN mesh system itself has achieved amazing successes in advancement of practical tactical technologies, especially valuable to rapidly deployable and emergency response communications capabilities that are applicable across almost the entire Government, Military, Industry, and Public Safety communities.

5.d Existing and valuable systems, such as AREDN mesh, which are already delivering actual benefit to our Nation and in the Public Good, and essentially zero taxpayer dollars, will be crippled, and highly likely will be destroyed.

5.e The Amateur Radio Service has no reasonably equivalent spectrum available to replace the unique and beneficial performance and capabilities of the 5.9 GHz, and the loss of this small piece of spectrum is literally irreplaceable and will cause permanent damage to ARS capabilities and developments.

6 Unless some effective and reliable protective measures are applied, the introduction of unlicensed devices will likely destroy the viability and utility of the 5.9 GHz spectrum for essentially all other users, including the ARS. In practice and effect, the unlicensed system will constitute a massive, Nationwide, jamming system that will drive out all other systems and users.

7 OVERVIEW:

7.a In my professional opinion, as both an operational mission responder and emergency communications engineer, the AREDN mesh network at 5.9 GHz is clearly one of the very best emergency response communications systems available.

7.b Within the urgently needed combination and synergy of it's unique functional capabilities, the AREDN mesh network at 5.9 GHz is overall arguably superior on many levels to almost anything the U.S. military, FEMA (Federal Emergency Management Administration) or state emergency response administrations are able to provide. They may aspire to, but evidently have failed to actually produce, a similar capability communications system to operate in the chaotic hours and days during and after a disaster or other severe incident.

7.c In the remainder of this Declaration, I will explain the reasons for my assessments and recommendations. We will start by addressing the vital

operational mission needs of emergency responders in the Public and National interest, then the spectral advantages and underlying physics of this unique band, and then the revolutionary emergence of advanced protocols for flexible and survivable communications almost ideally suited for this band and those vital operational mission needs.

7.d We follow with additional affirmative evidence and clarifications to address other key and relevant issues and opportunities. We then address the significant concerns with, and severe impacts from, the threat of unlicensed systems in this band.

8 AREDN, 5.9 GHZ, AND DEPLOYABLE EMERGENCY OPERATIONS:

8.a What is the relationship between AREDN, and the 5.9 GHz band, to rapidly deployable responses and flexible emergency communications?

8.b Based on a half century of observations and lessons learned, we respectfully assert several key points and hard facts:

8.c Even the most powerful Nation on Earth can have a significant portion of it's homeland essentially blasted back into the stone age, and Katrina is just one of too many tragic examples.

8.d Virtually every responding or mitigating organization and effort is absolutely dependent on communications for coordination, collaboration, situational awareness, and other essential functions.

8.e Those vital communications capabilities absolutely must provide reliability, availability, resilience, survivability, flexibility, capacity, and range and coverage, both within the impacted and operational areas, plus extensions beyond to the rest of the Nation and planet as needed.

8.f These communications must also provide suitable and sufficient services and support for all necessary information and media (voice, data, imagery, video, etc) with easy and prompt sharing among all necessary participants and levels, geographically and organizationally.

8.g Given these critical operational mission requirements, experience informs us that there is usually little, and ofttimes no, surviving infrastructure or resources, and the only assets available are the ones the responders themselves bring.

8.h What <u>can't</u> we do? It is impossible to predict when and where any crises or disasters may occur, or which threats or needs emerge, or which or how many responding entities will or might participate, or where or with whom they will need to communicate.

8.i What <u>can</u> we do: We can do our best to estimate the most frequent, and likely, incidents, including where, and who & what might be involved.

8.j Therefore, we are clearly compelled to create, implement, provide, and preplan the essential communications systems using interoperable standards and protocols and procedures, and as much as feasible.

8.k In addition, due to the dynamic movement of the responding users, with sudden and intermittent connectivity and uncertain coverages, all of those communications implementations must be inherently standardized and interoperable, and they must be autonomous & cooperative, self-organizing, self-configuring, self-routing, self-restoring, and accomplish this all automatically, with minimal human oversight or intervention.

8.l In short, they must simply work, even if there are no surviving operators or managers. Of equal importance, if any data path exists, information should and must be able to flow between any participating entities.

8.m Traditionally, these verified and valid operational mission needs and essential functional capabilities have been inadequately addressed, and they are often considered somewhere between impracticable and impossible. Many hundreds of millions of taxpayer dollars have been expended in pursuit of such capabilities, with insufficient success.

9 WHAT SOLUTIONS DOES AREDN AND 5.9 GHZ BAND OFFER?

9.a The AREDN mesh system at 5.9 GHz is already providing the solutions, through independent and volunteer efforts, and in full accordance with the FCC objectives and justifications for the Amateur Radio Service. We are grateful to report that the ARC Community has essentially already developed the technologies to accomplish many of these essential functional capabilities. We realize that many readers may be unaware that there is already an ongoing evolution, which is notionally an ARC National Emergency Communications Information Infrastructure. In fact, it already exists as a working demonstration project, and it is growing into a viable National and global capability. It is composed of most importantly the AREDN mesh protocols and software, and it's most vital spectrum is the 5.9 GHz band.

9.b Essentially, the ARDEN mesh systems in the 5.9 GHz band must be allowed to survive and prosper, and from a pragmatic and Public Good basis, they should be encouraged and supported. Then eventually, these valuable capabilities may be leveraged and exploited in other available and suitable bands, by government, military, industry, and other user communities.

9.c Meanwhile, by leveraging pro-active mutual aid agreements, and in full accordance with the wise intents and guidance of the Communications Act and the FCC Rules, the ARS will be able to promptly accompany, support,

and enhance all responders and participants during disaster and other emergent incidents.

9.d Eventually, we hope that these valuable capabilities may be leveraged and exploited in the many other suitable bands, by government, military, industry, and other user communities. But unfortunately it will take many years, significant political and regulatory changes, daunting changes in cultures and bureaucracies, and certainly many billions of taxpayer dollars. Meanwhile, the Hams are just doing it!

10 WHAT EMERGENCY COMMUNICATIONS DOES AREDN OFFER AT 5.9 GHZ?

10.a What are these vital emergency communications, and how does AREDN mesh and the 5.9 GHz band enable them?

10.b As an overview of mission essential functional capabilities, virtually every emergency response entity needs to communicate with each other and the outside world, and they need to utilize multiple media, including but not limited to voice telephony, data transfer, imagery, video and others. This includes many emergency response and situational awareness needs, such as dynamic & flexible voice collaboration & video teleconferencing, imagery such as broken levees or failing bridges, interactive mapping and planning, coordination of medical care, resource allocation and distribution, safety and tracking of personnel and equipment, and many more..

10.c As a critical requirement for interoperability and commonality, all of these widely diverse media and needs are presently supported by the global digital information standard, the internet protocol (IP),

10.d Returning to the unique advantages of 5.9 GHz and AREDN mesh system, many of the potentially competing systems and alternate spectrum and waveforms are demonstrably unable to adequately satisfy the acknowledged operational mission needs. This is often due to limitations to one or few media, or inadequate waveforms, or insufficient capacity, or limited data throughput, or inflexible or proprietary waveforms, or inadequate connectivity or coverage, and many other unacceptable deficiencies.

10.e We are grateful to firmly assert that the 5.9 GHz band, when enhanced by the AREDN mesh technology and reliable interface equipment, has already been demonstrated to be almost optimal to transport this diverse IP based traffic, and to effectively and efficiently leverage this spectrum for these life-saving operational mission needs.

11 WHY IS THE 5.9 GHZ BAND A UNIQUE "SWEET SPOT" FOR EMERGENCY COMMUNICATIONS?

11.a Many have noted that the 5.9 GHz band fortuitously provides an excellent, and relatively rare, spectrum "sweet spot" which well satisfies these daunting and vital operational mission requirements. It is said that "nobody can beat physics", and in this scenario, physics is our "best friend!"

11.b This band offers both capacity and propagation range, both well matched to the essential performance characteristics. Yet these characteristics also promote spectral efficiency by frequency reuse and other techniques.

11.c The digital waveforms employed in the 5.9 GHz band are capable of providing sufficient capacity to carry voice, data, video and other media via standard IP-based traffic. High performance commercial grade equipment is readily available and adaptable at very modest costs, and they can provide throughputs of tens or hundreds of Mbps and beyond.

11.d However, if you shift down the spectrum chart into lower bands, such as 2.4 GHz to 900 MHz, there is not enough spectral or waveform capacity to support the higher data rates and traffic loading, such as necessary for video et al, and appropriate equipment is inadequate or unavailable.

11.e And if you shift up the spectrum chart into the higher bands, such as 10 GHz, there may be more bandwidth and capacity, but the propagation range or penetration, and coverage may be insufficient to adequately service a disaster area, unless quite small.

11.f Therefore, we must respectfully yet strongly urge the retention and protection of the Amateur Radio Service 5.9 GHz band, as it is the last remaining bastion of optimal spectrum for amateur radio communication of these vital services, in both fixed and rapidly deployable emergency response operations.

12 HOW DOES AREDN AT 5.9 GHZ ENABLE SURVIVABLE AND DEPLOYABLE COMMUNICATIONS?

12.a AREDN is the Amateur Radio Emergency Data Network. (Please see AREDNmesh.org for more information.) It is a revolution in advanced digital communications technologies, sponsored by volunteer Amateur Radio Operators. The AREDN mesh project is an amazingly successful effort to create a highly flexible and survivable data infrastructure that could augment or even substitute for the internet or similar systems, especially in emergencies or other incidents when such internet services were destroyed or unavailable.

12.b The AREDN Team pragmatically leveraged high quality commercial wireless data devices, commonly employed by WISP (wireless internet services provider) vendors, and modified the firmware to add a unique mesh networking capability.

12.c The AREDN Team significantly upgraded the firmware to enable mesh type network data exchanges. It is based on OLSR (Optimized Link State Routing), which is a "pro-active" protocol created for rapidly changing mobile ad hoc networks. (Please see IETF RFC3626 et al.). This OLSR has dramatic advantages over the "traditional" internet protocols, with fixed nodes and mostly static connections.

12.d With the enhanced AREDN mesh system, network links may be point-to-point, one-to-many, any-to-any, or whatever is available, even if engineered or temporary & fortuitous. It also equally supports fixed stations, mobile units, backbone infrastructures, and almost any other node.

12.e If one participating node fails, moves out of network coverage, or otherwise goes offline, other nodes automatically route traffic around the node that disappeared. There are usually multiple likely paths, so the system automatically picks the path with the "best" available performance (fastest, most available capacity, lowest latency, etc). When that path fails or degrades, the system already has in mind the next best path(s) as prompt alternative(s).

12.f Thus AREDN mesh enables creation of standardized and interoperable, yet extremely dynamic, networks and nodes, and these networks are inherently autonomous & cooperative, self-organizing, self-configuring, self-routing, self-restoring, and all automatically, with minimal human oversight or intervention. They are also very tolerant of unexpected links & participants, and intermittent connections.

12.g In short, if any data path exists between participating entities, then information can flow between them.

12.h The AREDN Team was also able to modify the frequency range of the commercial equipment to enable authorized Amateur Radio licensees to properly employ frequencies allocated for amateur radio, in full accordance with existing FCC Part 97 criteria.

12.iThe AREDN mesh system is unique. There are some other reportedly "mesh" systems that claim to provide similar capabilities. However, overall they are essentially not equivalent or even viable alternatives. The typical deficiencies include, closed or proprietary networks, operations only in undesirable or non-optimal frequency bands, effective services impaired by equipment or regulatory constraints, expensive or unsuitable equipment which are in-feasible financially or in the operational environments, and

numerous other problems. Some implement non-interoperable waveforms or protocols. Some employ a "standard" but it may be modified with "features" to prevent fair competition or cripple actual interoperability.

13 HOW DOES AREDN AT 5.9 GHZ ENABLE ALL RESPONDERS TO COMMUNICATE WITH EACH OTHER?

13.a As briefly noted above, in an emergency response situation or some unexpected and remote incident, communication among all deployed responders and participants is critical. It is remarkable that the fundamental needlines for communications among almost all such likely participants are quite similar across almost all emergency and similar distressed scenarios and responding entities, including natural or man-made disasters, crises, search & rescue, wildfire fighting, humanitarian, military, exploration, expedition, and many others.

13.b To clarify, we identify the most common six needlines of communication (of various media and flavors), and then we characterize and organize them as follows, and generally in a notional order of priority for operational coordination and survivability, and also approximate ranges and coverages. They are:

b.i Within each deployed Team (such as for essential autonomy and viability).

b.ii With and among other similar deployed Teams (for collaboration & coordination).

b.iii With other deployed organizations and assets.

b.iv With surviving or existing local organizations and assets, if any (for local knowledge & mutual aid).

b.v With deployed or existing nodes outside of the deployed operational area (such as staging areas and regional coordination).

b.vi The "Reachback" to the Team(s) base & organization (for support & relief, etc. aka "ET, phone home!").

14 HOW DOES AREDN AT 5.9 GHZ SATISFY ALL OF THESE ESSENTIAL OPERATIONAL NEEDLINES, WITH ALL OF THE VITAL MEDIA, ACROSS ALL OF THE COVERAGE AREAS REQUIRED?

14.a It should be noted that each of the above needlines have varying modes and media. For example, the most common at i) and ii) are most commonly simple voice exchanges, typically using handheld and mobile VHF/UHF radios. The following needlines, such as v) and vi) would likely employ IP-based wireless data transport, for VoIP, data, imagery, video, and others.

14.b To stress several key points, there have been NO systems that can support ALL of those various needlines (need propagation & connectivity) and also ALL the necessary media (need supporting waveforms, with capacity and bandwidth).

14.c Traditionally, a collection of otherwise non-interoperable equipment, on different bands and odd waveforms, must be deployed and leveraged to accomplish the overall necessary communications. Often exchanges of information among them requires manual intervention, with very limited automation.

14.d The good news is that there is now a very capable equivalent integrated system that can essentially support all of those needlines, and all of these media! Specifically, the 5.9 GHz band, in synergy with the AREDN mesh. The AREDN mesh infrastructure, when proliferated across any given operational area, and with Reachback trunks or gateways at various nodes into the internet, or even government, military, or other organizational intranets, can clearly support all of the connectivity. The 5.9 GHz band itself also easily supports all of the needed IP-based transport for all of the needed media, with of course any needed adapters for non-IP devices.

14.e In summary, the synergistic combination of 5.9 GHz and AREDN mesh provides a highly capable, and evidently the only, total solution to all of those rapidly deployable emergency communications needlines. And yes, they are critically dependent on the unimpaired availability of the 5.9 GHz band.

15 HOW CAN THE 5.9GHZ BAND BE LEVERAGED BY THE AREDN SYSTEM FOR EMERGENCY RESPONDERS IN DISASTERS?

15.a From the standpoint of rapidly deployable emergency response operational mission requirements, the AREDN mesh network is virtually ideal for the common, standardized, interoperable, and essentially universal information infrastructure to satisfy these needs, and it is clearly far superior to almost any available alternative or equivalent solution.

15.b In actual practice, many different first-responders and assets are deployed by multiple different agencies and services at multiple different levels of capability or responsibilities, from multiple different geographic areas, with almost random routes, means, and arrivals, and they all descend on a given disaster area or incident event. (IF you were thinking chaos, you were right!)

15.c As noted above, these first-responders need to communicate with each other and with the outside world. Traditionally, interoperability of all kinds

and at all levels has been a major problem in this type of very chaotic situation. As a too familiar and very basic example, firefighters from one part of the country may bring their own radios (case i), but they often simply can not talk to the radios of paramedics from another part of the country (case ii), even though they may share the very same frequency band, and standard analog voice modes, and even same models and manufacturers. [Yes, we applaud the excellent Nationwide Interoperability Channels (CFR 47 _90.20(i)), but they only support simple analog FM voice, and data modes are still lacking.]

15.d If the responding entities are unable on an elementary level to simply talk voice to each other, what hope do they have of sharing all the other essential modes and media, such as conferencing, data, mapping & planning, imagery, video, and so many more?

15.e The key point here is that the AREDN mesh system is automatically functional and is capable of reliably providing interoperable services for all participating entities at every level, over virtually all phases of deployment (from before the first alert to well after final demobilization). For those critical and chaotic early phases of a response, minimal prior coordination is needed.

15.f As a general pro-active measure, each potential participant should be equipped with modest basic and deployable AREDN mesh nodes, Of course, they must also already be interfaced (if needed) to whatever organic systems and communications that the entity brings.

15.g Effective participation in the collective AREDN mesh system can be initiated promptly upon arriving within the coverage range of any participating AREDN mesh nodes. In addition, optional system entry and access may also be achieved by auxiliary connections while hundreds or thousands of miles away, by regional or global links, and even tunnels via any available internet or intranet like services.

15.h In concept, system entry and access is about as simple as a responder bringing their own PC (or their system), plus a handy LAN cable, and looking for an available RJ-45 jack to plug into. Even better, in practice the AREDN mesh system usually skips the wires, and it provides immediate services wirelessly as soon as responders arrive within range. As a bonus, every arriving participant with nodes enhances and expands the capacity and extends the coverage of the collective system.

15.iThe AREDN mesh nodes from different organizations will automatically seek each other, automatically recognize each other automatically establish link(s) to form a flexible and resilient mesh network, and automatically coordinate to route the needed data services. In short, AREDN mesh nodes

are "smart" and will automatically collaborate to transport vital traffic in the most efficient and effective manner.

15.j Of course, the communications requirements of any incident response is likely to grow, as more responders arrive, or during later phases or evolving scenarios, and other common challenges. Again by design, the AREDN mesh system is highly scaleable and flexible, and it can expand it's capacity and coverage by promptly incorporating additional nodes, frequencies, gateways, subnet optimizations, and many other techniques.

16 HOW CAN 5.9 GHZ AND AREDN PROVIDE SURVIVABLE ACCESS TO THE INTERNET AND OTHER REACH-BACK?

16.a In a disaster situation, access to the internet is usually nonexistent, or at least saturated and dysfunctional. By pragmatic design, these capabilities are already embedded in the AREDN mesh system. In short, participants no longer need to compete for the internet, and instead they simply access the local AREDN mesh system.

16.b In essence, only one participating node needs to be connected to the internet, and it can serve as a "gateway" to provide services for any or all of the other nodes within that collective system. The primary requirement is that some viable path must exist between the user nodes and the gateway.

16.c The AREDN mesh system also supports multiple gateways for increased capacity, redundancy & reliability. The user nodes follow the same basic methodology to select the best available gateway node. This automatically manages the overall data loading in a consistent and efficient manner. Of course, if an arriving responder is equipped with their own Reachback capability (case vi)), they can easily share that capability with other participating user nodes.

16.d As a bonus, consider use of DMR (Digital Mobile Radio), reportedly the fastest growing digital voice (& data!) radio mode. DMR systems are inherently IP-based, and not only interoperate wirelessly in the RF spectrum, they may also leverage a flexible backbone infrastructure through terrestrial or satellite or other IP based systems. Today, wireless DMR repeater and other systems are already seamlessly communicating nationally and globally via the internet, but also through regional AREDN mesh systems.

17 HOW CAN AREDN AT 5.9 GHZ ENABLE DEPLOYED RESPONDERS TO ACCESS THE PSTN AND CELLULAR SYSTEMS?

17.a As above, in a disaster the public switched telephone network (PSTN) and the cellular telephone system may be destroyed, or at least severely dysfunctional. If somehow some has survived, it is usually saturated, with

marginal services, long delays for connections, failed or dropped calls, and even forced use of unintelligible low rate vocoders. As is expected, essentially everyone is trying to use the cell phone to call out of, or even within, the disaster area.

17.b As a specific example, the annual Marine Corps Marathon, in the Washington D.C. region, involves about 30,000 runners, perhaps 70,000 spectators, and at least 10,000 coordinators and support. Yes, a sudden and massive service loading of over 100,000 users! Traditionally, every year each cellphone vendor brings multiple COWs (Cellular On Wheels) to augment their system capacity, and very consistently, every year they are again saturated and cellular services suffer.

17.c At this point, we must frankly point out that nobody is proposing to replace the cellular telephone system or even address their capacity and performance issues. Let us focus on what is feasible and practical, with specific support to the small but vital community of emergency responders, event managers, and essential participants. And specifically, how we can provide equivalent cellphone services reliably and independently.

17.d For the MCM, the AREDN mesh at 5.9 GHz has already been demonstrated to provide high quality telephone services of several types, to support incident management and other pressing needs.

17.e One pragmatic implementation is an independent and autonomous VoIP telephone system incorporated into the AREDN mesh system, and employing an industry accepted Asterisk switch running on a small Raspberry-pi server. Multiple VoIP telephones, and even VoIP software running on computers or cellphones, are able to call and conference among the responders who have adopted this modest yet effective approach. This easily supports local operations, and it is totally isolated within the dedicated systems, which carry the majority of the mission traffic. In addition, it is also capable of calls to and from the PSTN if desired, when the switch is furnished a suitable outside PSTN line, as a telephone gateway.

18 HOW CAN AREDN AND 5.9 GHZ ENABLE EMERGENCY RESPONDERS TO ACCESS GLOBAL SATCOM AND REACH-BACK?

18.a Again, in a disaster the local fixed satellite ground stations may be destroyed, and if somehow surviving, they are usually saturated.

18.b In most cases, the implementation of SATCOM is via transportable terminals, similar to COWs. There will also be a proliferation of small terminals, such as BGAN etc, or handheld units, such as IRIDIUM or GLOBALSAT, etc.

18.c All of these SATCOM systems suffer from several common and familiar deficiencies. In general, there are insufficient assets to adequately support the needs of a major disaster area. There are not enough space elements, and they do not have enough capacity. There are not enough SATCOM bands, and in a small geographic area, frequency reuse is severely restricted.

18.d To aggravate the situation, much of the traffic originating in an incident area is actually intended for other elements also within the same area. Yes, frequently users are signaling about 45,000 miles (round trip to geosynchronous orbit), to chat with each other while only a mile apart! Therefore, much of the SATCOM capacity, otherwise available for Reachback is wasted on essentially local communications that could easily be offloaded to any local communications systems, if available and sufficient.

18.e Furthermore, only the military owns their own SATCOM, and even DHS, FEMA and the Red Cross are compelled to employ commercial assets. Since they are also competing with not only each other, but also many other commercial users, some of which have dedicated and guaranteed capacity, the availability, reliability, and capacity of the SATCOM is severely compromised.

18.f However, if the responders are able to exchange their local and regional traffic on a reliable and flexible system like AREDN mesh, then the majority of the SATCOM loading could be released, which would enable more effective and efficient use of those scarce resources.

19 WHAT ARE THE MAJOR THREATS TO THE AREDN MESH SYSTEMS AND THE ARS BY ALLOWING UNLICENSED OPERATIONS INTO THE 5.9 GHZ BAND?

19.a In my experience and reasonably informed judgment, the obvious interference from unlicensed or other radio systems will certainly impact emergency response operations, and almost all implementations and applications in the many different communities and their needs.

19.b As has been strongly asserted and supported above, the 5.9 GHz band has unique properties that are a fortuitous "sweet spot" for the implementation of both routine and certainly emergency communications systems, and especially the highly capable AREDN mesh technologies. This band provides an excellent balance of media transport capability, capacity, and propagation and coverage. No other (remaining) available ARS band offers such an optimal solution.

19.c Preservation of access to, and protection of, this band is vital, as it is the only remaining band in the ARS that offers these unique capabilities.

19.d The available equipment employed by ARS users, especially for the unique AREDN mesh systems, are very low power and very spectral efficient, often employing only a small fraction of a Watt of RF power. Yet this is sufficient for creation of extremely capable and effective emergency communications networks. These criteria are in full compliance with wise FCC mandates on spectral use, including employment of minimal power and bandwidth necessary to achieve reliable links and effective communications.

19.e Without reiterating the detailed technical engineering analyses and assessments already presented by other commenters, we will below present additional concerns and factors.

20 WHAT HAVE WE DISCOVERED IN RESEARCH INTO THESE U-NII UNLICENSED DEVICES?

20.a We understand that U-NII devices will be installed almost everywhere that internet and related services are desired, which is literally everywhere. This includes not only access points but also a wide variety of associated devices. This may include buildings, vehicles, pedestrians, infrastructures, and other participants. We have found projections to deploy almost a billion devices, and they, or similar devices, will certainly proliferate well beyond present estimates.

20.b In short, we can confidently expect U-NII devices to be massively distributed across almost the entire Nation, and very highly concentrated in urban and suburban areas. Even rural areas will be impacted.

20.c The cited U-NII RF power levels we found were about 36 dBmi EIRP in a 20 MHz bandwidth, and likely will be higher in practice and time. These devices have RF characteristics that are similar to AREDN mesh systems, and U-NII is clearly a direct competitor for this spectrum.

20.d Briefings from the implementers estimate that they expect U-NII device densities as high as hundreds or thousands of radios within only kilometers, which obviously generates massive signal densities, and critically greater than practical AREDN mesh signaling.

21 WHAT IS THE CLEARLY PRESENT HARM TO EXISTING 5.9 GHZ INCUMBENTS, INCLUDING AREDN SYSTEMS, IF UNLICENSED DEVICES ARE INTRODUCED INTO THE 5.9 GHZ BAND?

21.a In short, there will certainly be wide spread and significant harm to virtually all present and future spectrum users in the 5.9 GHz band,

including their essential communications systems and vital operational missions (except notionally the unlicensed devices themselves!).

21.b Overall, introduction of almost any form of unlicensed operations into the 5.9 GHz band will severely disrupt virtually all of the above described beneficial operational missions and dramatically degrade the many known and demonstrated capabilities. It is highly likely to in fact destroy the viability of those licensed systems.

21.c To be very specific, these unlicensed devices will likely induce the collapse of the excellent AREDN mesh systems, and the loss of their unique capabilities and resources.

21.d Unlike the present modest, compliant and licensed spectrum users in this ARS 5.9 GHz band, these unlicensed devices will essentially be unaccountable and likely untraceable, and they will be able to interfere with licensed services without restraint or limit. It is unlikely that the FCC will have the staff, funding or motivation to track down or investigate legitimate interference incidents.

21.e It will also cripple the development of advanced and vital technologies such as AREDN mesh that offer significant benefits to the Public Good, as well as contributions to public safety and other user communities. Even commercial interests can benefit from the development and evolution of these demonstrated flexible, reliable, and survivable innovations.

21.f Sensitive AREDN mesh and similar receivers will likely be disabled, and possibly damaged, by interfering unlicensed emissions. Even with well engineered links, no receiver can succeed or survive when it has multiple, or even many hundreds, of strong close-by emitters swamping it's input. An obvious case would be a deployable node that is attached to a U-NII equipped emergency response vehicle, and it could be jammed by every such vehicle in the local traffic, including it's own! It's still physics, and proximity usually beats any distant transmitter.

21.g As an additional and compounding concern, consider the adverse impact of just one thousand unlicensed devices within a short range of an AREDN mesh or any other receiver. Even in a relatively simple case of being perceived as noise, those 1000 interfering emitters would roughly be about 30 dB more powerful than just a single one, simply by massive RF energy density.

21.h In that regard, some commenters have claimed that the ARS is authorized much higher power levels (up to 62dBm or 1500 Watts RF) in this band, so why couldn't the ARS stations simply increase their transmit

power to compensate for the increased harmful interference? This approach is unacceptable on many levels.

h.i First, such high power equipment in the 5.9 GHz band is either unavailable or prohibitively expensive.

h.ii Second, personnel operating in proximity to such strong emissions will certainly exceed the current radiation exposure mandates.

h.iii Third, the FCC Rules mandate that the minimum practical power be used, sufficient to achieve reliable communications, and the AREDN mesh systems have proven that a Watt or a fraction is effective.

h.iv Furthermore, many deployable and emergency response AREDN mesh nodes are necessarily small and light, with limited battery power, and thus unable to leverage such excessive power.

21.i We should recall that, as a general rule, interfering signals that are markedly different from a receivers intended signal will usually be perceived as an increase in the noise level, and that receiver digs the desired signal out of the noise. However, the more destructive alternative is for the interferer (or jammer) to use a similar signal structure, which makes it far more difficult for the receiver to differentiate. Unfortunately, the U-NII unlicensed devices reportedly use such a similar signal to the AREDN mesh systems, with the obvious impacts.

21.j Based on the documents we have been able to acquire, it is clear that the unlicensed devices themselves reportedly ignore any other type of devices and therefore are incapable (or unwilling) of fairly sharing spectrum by agility and avoidance. They will simply broadcast with impunity, and with freedom from responsibility for their actions and damage.

22 SUMMARY OF KEY POINTS:

22.a The present Amateur Radio Service incumbents of the 5.9 GHz band, and especially the AREDN mesh systems, have been fully compliant with the spirit and letter of the FCC Part 97 guidance, in full accord with the fundamental goals of the Service, especially emergency communications, technology advancement, and Public Good.

22.b The 5.9 GHz band is a unique and valuable resource, which provides an almost optimal "sweet spot" for propagation, bandwidth, high performance waveforms, and effective data communications capabilities. There is no reasonably equivalent band remaining in the ARS.

22.c The AREDN mesh system itself has achieved amazing successes in advancement of practical tactical technologies, especially valuable to rapidly deployable and emergency response communications capabilities that are

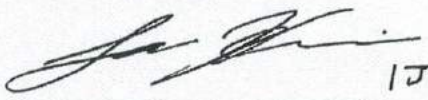
applicable across almost the entire Government, Military, Industry, and Public Safety communities.

22.d Existing and valuable systems, such as AREDN mesh, which are already delivering actual benefit to our Nation and in the Public Good, and essentially zero taxpayer dollars, will be crippled, and highly likely will be destroyed.

22.e The Amateur Radio Service has no reasonably equivalent spectrum available to replace the unique and beneficial performance and capabilities of the 5.9 GHz, and the loss of this small piece of spectrum is literally irreplaceable and will cause permanent damage to ARS capabilities and developments.

22.f Unless some effective and reliable protective measures are applied, the introduction of unlicensed devices will likely destroy the viability and utility of the 5.9 GHz spectrum for essentially all other users, including the ARS. In practice and effect, the unlicensed system will constitute a massive, Nationwide, jamming system that will drive out all other systems and users.

In summary, we respectfully yet strongly urge the preservation and protection of the 5.9 GHz band for the Amateur Radio Service, and the denial of the use of unlicensed devices in this band.



1JUN2021

Gene Harrison

AREDN Link Interference Performance Analyses

Gene Harrison – N3EV
Mark Braunstein – WA4KFZ

1 June 2021 - Version 3.2

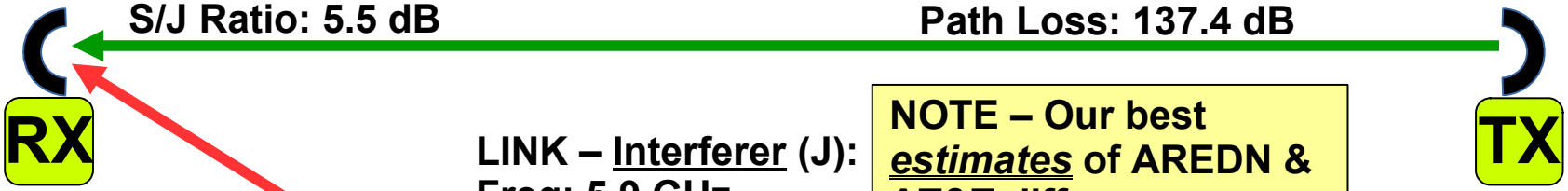
Link Interference Performance Analyses Parameters

- Assess interference impacts on AREDN Mesh high rate data communications in the 5.9 GHz band
- Primary threats from potential unlicensed RF systems
  - Interferers – U-NII-4 with maximum EIRP 36 dBmi [47 CFR 15.407(a)(3)]
- Address potential mitigation and avoidance methods
- Selected cases:
  - A: Long point-to-point “backbone” (AT&T & AREDN)
  - B: Wide area point-to-multipoint “distribution” (Looking both ways)
  - C: Local area multipoint-to-multipoint “mesh”
  - D: Local area multipoint-to-multipoint “mesh” – close interferers
  - E: High power multipoint-to-multipoint “mesh”
  - F: Very high power multipoint-to-multipoint “mesh”
  - G: “Backbone” with multiple interferers
- Consider relative levels of RF energy levels...
  - Link signal (S) vs Interferer (J) vs Noise floor (NF) & Receiver Sensitivity (RS)
- Industry standard best practices
  - For required high quality data links, design link fade margin (FM) at least 30 dB
  - For sufficient performance, keep interference at least 6 dB below receiver NF (-6dB J/N)
  - Or 10 dB below Receiver Sensitivity (RS) (considers Minimum Signal-to-Noise (SNR))

A1: Long Point-to-Point (*AT&T*)

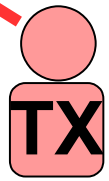
RECEIVER INPUTS:
Link Signal (S): -38.4 dBm
Interference (J): -43.9 dBm
S/J Ratio: 5.5 dB

LINK – Primary (S):
Freq: 5.9 GHz (BW *30* MHz)
Distance: 30.0 km
Path Loss: 137.4 dB



Mfr: TBD
Model: TBD
Ant Gain: *38* dBi
TX: *24* dBm
RX Sens: -92 dBm
Feed Loss: 0.5 dB
Role: Link Destination

LINK – Interferer (J):
Freq: 5.9 GHz
Distance: 3.0 km
Path Loss: 117.4 dB



Mfr: Unlicensed
Model: Unknown
Ant Gain: 0 dBi
TX: 36 dBm (EIRP)
RX Sens: Unknown
Feed Loss: 0.0 dB
Role: Interferer

NOTE – Our best *estimates* of AREDN & AT&T differences:
BW 20 MHz vs *30*
RS -94 dBm vs -*92*
Ant 10-30 dBi vs *38*
TX ~27 dBm vs *24*
Limit -104 dBm vs -*102*

Mfr: TBD
Model: TBD
Ant Gain: *38* dBi
TX: *24* dBm
RX Sens: -92 dBm
Feed Loss: 0.5 dB
Role: Link Source

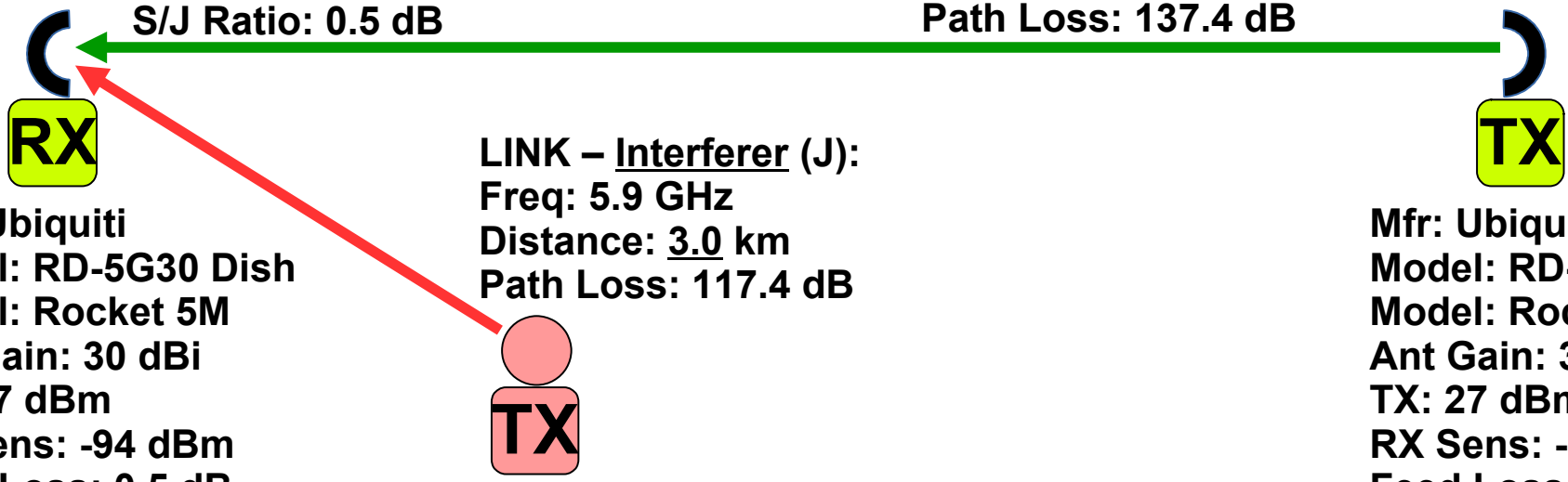
LINK ASSESSMENTS:
RX Link Signal (S): -38.4 dBm
RX Sensitivity (RS): -92 dBm
RX Noise Floor (NF): -*96* dBm
Maximum feasible FM: 31.6 dB (No J)
Set Interference Margin: NF/J 6dB
J Max Allowed (NF): (-6dB J/N) = -*102* dBm
LEVEL LIMIT
RX Interference (J): -43.9 dBm
Received Positive S/J Ratio: 5.5 dB
Need to Correct Interferer Power: -58.1 dB (~NF)
Thus Non-Interfering Interferer: -22.1 dBm TX

CONCLUSIONS:
- Link is virtually jammed!
- FM = S/J = 5.5dB
- Reduce Interferer by -58.1dB to achieve -102dBm (6dB under NF)
- Set interferer to -22.1dBm TX
- Then FM up to 31.6 dB (GOOD!)

A2: Long Point-to-Point "Backbone"

RECEIVER INPUTS:
Link Signal (S): -51.4 dBm
Interference (J): -51.9 dBm
S/J Ratio: 0.5 dB

LINK – Primary (S):
Freq: 5.9 GHz (BW 20 MHz)
Distance: 30.0 km
Path Loss: 137.4 dB



LINK – Interferer (J):
Freq: 5.9 GHz
Distance: 3.0 km
Path Loss: 117.4 dB

Mfr: Ubiquiti
Model: RD-5G30 Dish
Model: Rocket 5M
Ant Gain: 30 dBi
TX: 27 dBm
RX Sens: -94 dBm
Feed Loss: 0.5 dB
Role: Link Destination

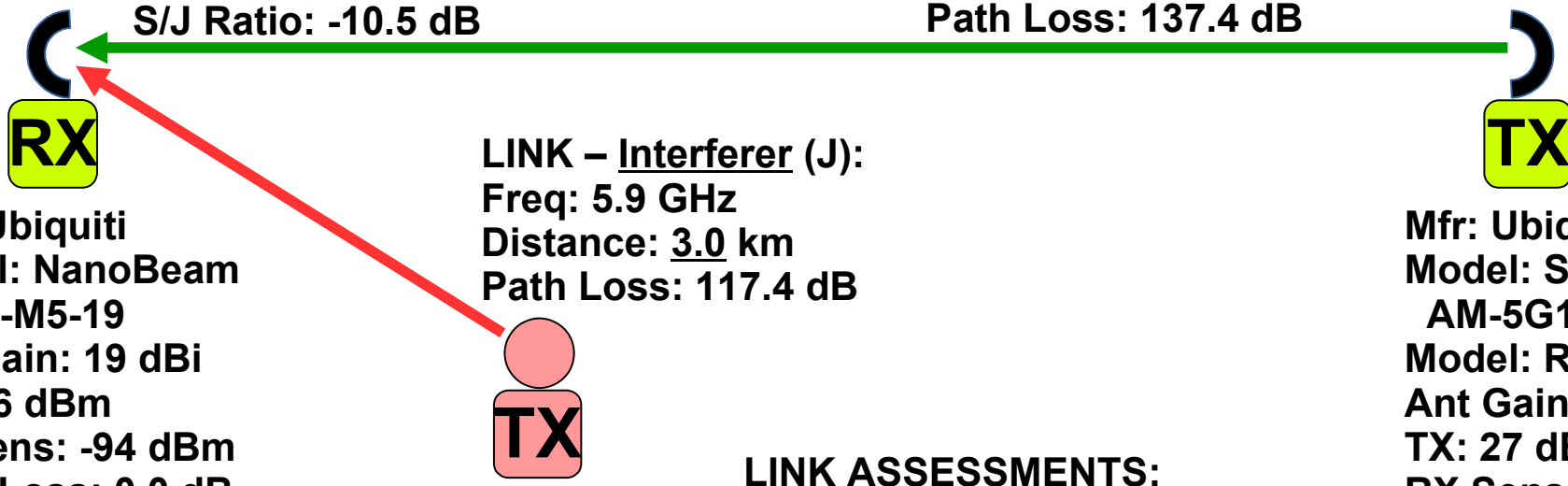
Mfr: Unlicensed
Model: Unknown
Ant Gain: 0 dBi
TX: 36 dBm (EIRP)
RX Sens: Unknown
Feed Loss: 0.0 dB
Role: Interferer

Mfr: Ubiquiti
Model: RD-5G30 Dish
Model: Rocket 5M
Ant Gain: 30 dBi
TX: 27 dBm
RX Sens: -94 dBm
Feed Loss: 0.5 dB
Role: Link Source

LINK ASSESSMENTS:
RX Link Signal (S): -51.4 dBm
Required Fade Margin (FM): 30 dB
RX Signal minimum: -81.4 dBm
RX Sensitivity (RS): -94 dBm
RX Noise Floor (NF): -98 dBm
Maximum feasible FM: 42.6 dB (No J)
Set Interference Margin: NF/J 6dB or RS/J 10dB
Interference J Max Allowed (FM): -91.4dBm
J Max Allowed (NF): (-6dB J/N) = -104 dBm
LEVEL LIMIT
RX Interference (J): -51.9 dBm
Received Positive S/J Ratio: 0.5 dB
Loss of Required FM: 29.5 dB
Loss of Desired FM: 35.5 dB
Need to Correct Interferer Power: -52.1 dB (~NF)
Thus Non-Interfering Interferer: -16.1 dBm TX

CONCLUSIONS:
- Link is clearly jammed!
- FM = S/J = 0.5dB
- Reduce Interferer by -52.1dB to achieve -104dBm (6dB under NF)
- Set interferer to -16.1dBm TX
- Then FM = 30dB (GOOD!)

B1: Point-to-Multipoint "Distribution"



RECEIVER INPUTS:
Link Signal (S): -72.9 dBm
Interference (J): -62.4 dBm
S/J Ratio: -10.5 dB

LINK – Primary (S):
Freq: 5.9 GHz (BW 20 MHz)
Distance: 30.0 km
Path Loss: 137.4 dB

LINK – Interferer (J):
Freq: 5.9 GHz
Distance: 3.0 km
Path Loss: 117.4 dB

Mfr: Ubiquiti
Model: NanoBeam NBE-M5-19
Ant Gain: 19 dBi
TX: 26 dBm
RX Sens: -94 dBm
Feed Loss: 0.0 dB
Role: End-point User

Mfr: Unlicensed
Model: Unknown
Ant Gain: 0 dBi
TX: 36 dBm (EIRP)
RX Sens: Unknown
Feed Loss: 0.0 dB
Role: Interferer

Mfr: Ubiquiti
Model: Sector AM-5G19-120
Model: Rocket 5M
Ant Gain: 19 dBi
TX: 27 dBm
RX Sens: -94 dBm
Feed Loss: 0.5 dB
Role: Multipoint Hub

LINK ASSESSMENTS:
RX Link Signal (S): -72.9 dBm
Required Fade Margin (FM): 30 dB
RX Signal minimum: -102.9 dBm
RX Sensitivity (RS): -94 dBm
RX Noise Floor (NF): -98 dBm
Maximum feasible FM: 21.1 dB (No J)
Set Interference Margin: NF/J 6dB or RS/J 10dB
Interference J Max Allowed (FM): -112.9dBm
J Max Allowed (NF): (-6dB J/N) = -104 dBm
RX Interference (J): -62.4 dBm
Received NEGATIVE S/J Ratio: -10.5 dB
Loss of Required FM: 19.5 dB
Loss of Desired FM: 25.5 dB
Need to Correct Interferer Power: -41.6 dB (~NF)
Thus Non-Interfering Interferer: -5.6 dBm TX

LEVEL LIMIT

CONCLUSIONS:
- Link is very marginal.
- FM = S/J = 10.5dB
- Reduce Interferer by -41.6dB to achieve -104dBm (6dB under NF)
- Set interferer to -5.6dBm TX
- Then FM = 27.1dB (~GOOD!)

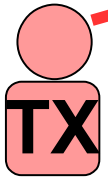
B2: Point-to-Multipoint "Distribution"

LINK – Primary (S):
Freq: 5.9 GHz (BW 20 MHz)
Distance: 30.0 km
Path Loss: 137.4 dB

RECEIVER INPUTS:
Link Signal (S): -73.9 dBm
Interference (J): -82 dBm
S/J Ratio: 8.1 dB

Mfr: Ubiquiti
Model: NanoBeam NBE-M5-19
Ant Gain: 19 dBi
TX: 26 dBm
RX Sens: -94 dBm
Feed Loss: 0.0 dB
Role: End-point User

LINK – Interferer (J):
Freq: 5.9 GHz
Distance: 27.0 km
Path Loss: 136.5 dB



Mfr: Unlicensed
Model: Unknown
Ant Gain: 0 dBi
TX: 36 dBm (EIRP)
RX Sens: Unknown
Feed Loss: 0.0 dB
Role: Interferer

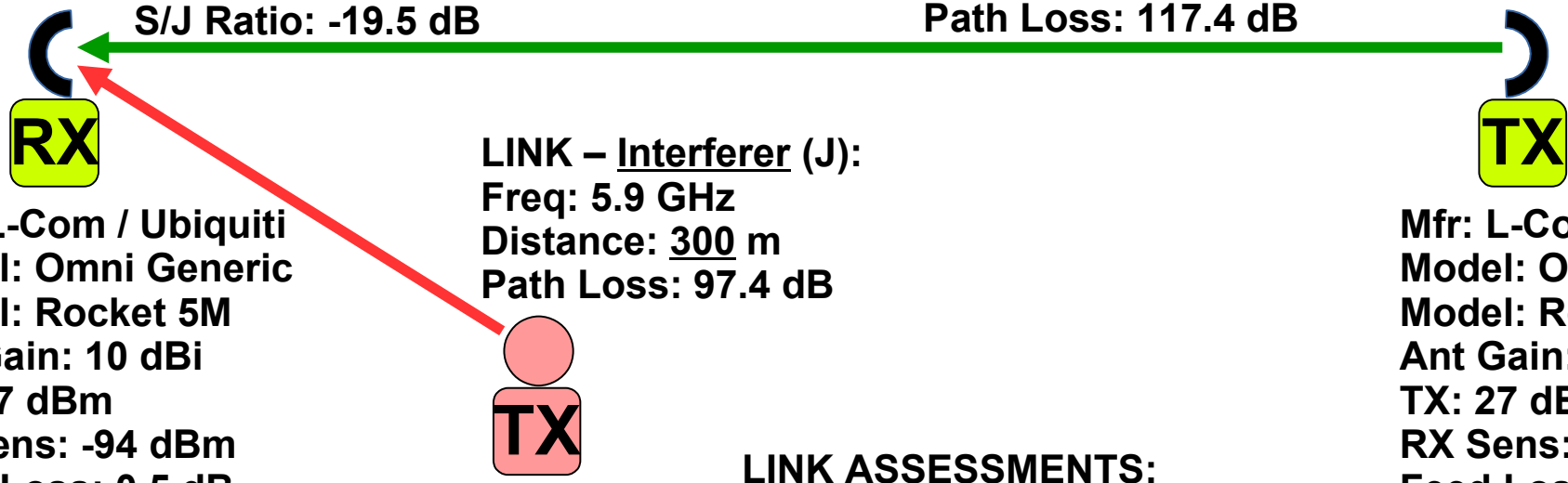
Mfr: Ubiquiti
Model: Sector AM-5G19-120
Model: Rocket 5M
Ant Gain: 19 dBi
TX: 27 dBm
RX Sens: -94 dBm
Feed Loss: 0.5 dB
Role: Multipoint Hub

LINK ASSESSMENTS:
RX Link Signal (S): -73.9 dBm
Required Fade Margin (FM): 30 dB
RX Signal minimum: -103.9 dBm
RX Sensitivity (RS): -94 dBm
RX Noise Floor (NF): -98 dBm
Maximum feasible FM: 20.1 dB (No J)
Set Interference Margin: NF/J 6dB or RS/J 10dB
Interference J Max Allowed (FM): -113.9dBm
J Max Allowed (NF): (-6dB J/N) = -104 dBm
RX Interference (J): -82 dBm
Received Positive S/J Ratio: 8.1 dB
Loss of Required FM: 21.9 dB
Loss of Desired FM: 27.9 dB
Need to Correct Interferer Power: -22 dB (~NF)
Thus Non-Interfering Interferer: 14 dBm TX

LEVEL LIMIT

CONCLUSIONS:
- Link is very marginal.
- FM = S/J = 8.1dB
- Reduce Interferer by -22dB to achieve -104dBm (6dB under NF)
- Set interferer to 14dBm TX
- Then FM = 20.1dB (~OK)

C: Multipoint-to-Multipoint "Mesh"

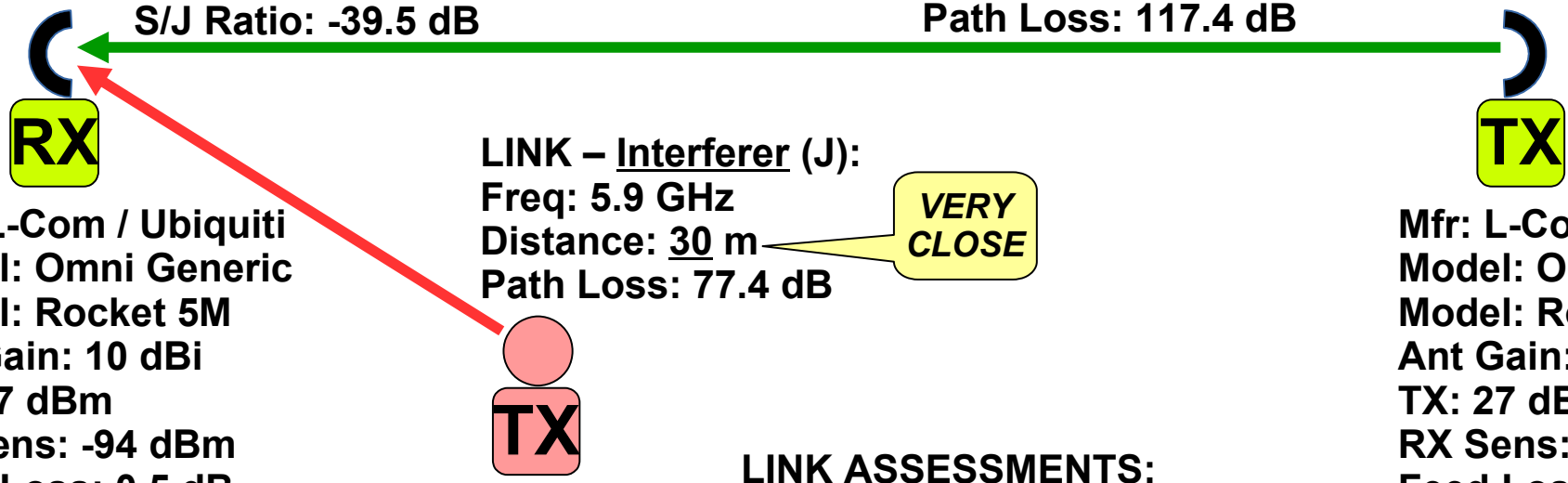


LINK ASSESSMENTS:
RX Link Signal (S): -71.4 dBm
Required Fade Margin (FM): 30 dB
RX Signal minimum: -101.4 dBm
RX Sensitivity (RS): -94 dBm
RX Noise Floor (NF): -98 dBm
Maximum feasible FM: 22.6 dB (No J)
Set Interference Margin: NF/J 6dB or RS/J 10dB
Interference J Max Allowed (FM): -111.4dBm
J Max Allowed (NF): (-6dB J/N) = -104 dBm
RX Interference (J): -51.9 dBm
Received NEGATIVE S/J Ratio: -19.5 dB
Loss of Required FM: 49.5 dB
Loss of Desired FM: 55.5 dB
Need to Correct Interferer Power: -52.1 dB (~NF)
Thus Non-Interfering Interferer: -16.1 dBm TX

LEVEL LIMIT

CONCLUSIONS:
- Link is totally jammed!
- Reduce Interferer by -52.1dB to achieve -104dBm (6dB under NF)
- Set interferer to -16.1dBm TX
- Then FM = 22.6dB (~OK)

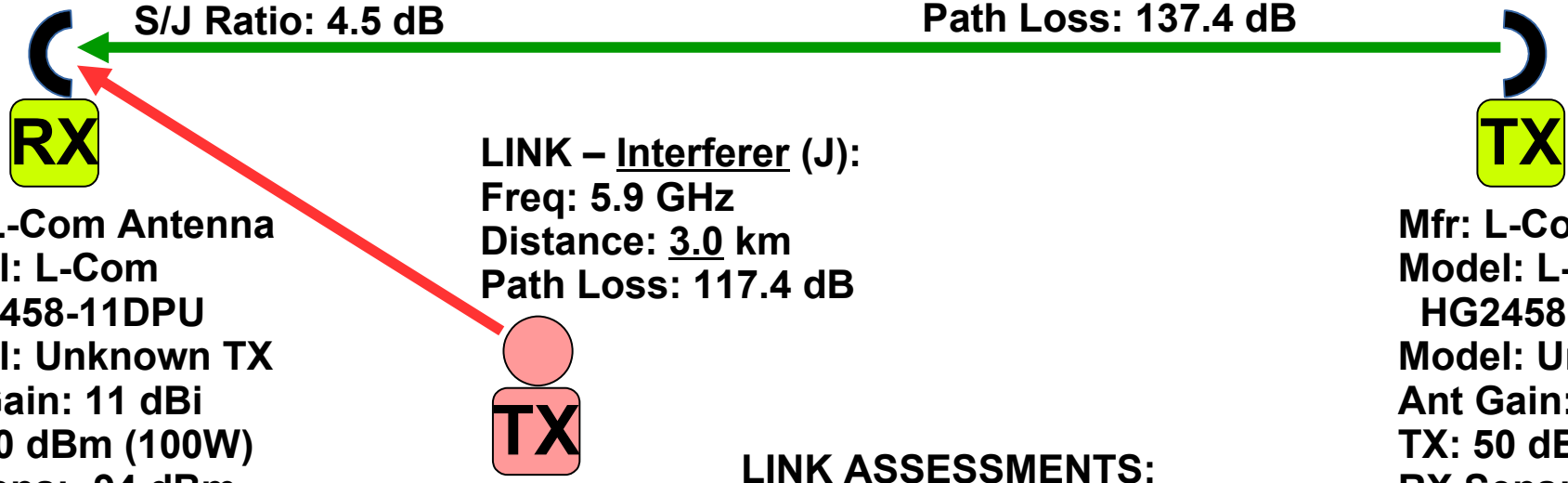
D: Close Mpoint-to-Mpoint "Mesh"



LINK ASSESSMENTS:
RX Link Signal (S): -71.4 dBm
Required Fade Margin (FM): 30 dB
RX Signal minimum: -101.4 dBm
RX Sensitivity (RS): -94 dBm
RX Noise Floor (NF): -98 dBm
Maximum feasible FM: 22.6 dB (No J)
Set Interference Margin: NF/J 6dB or RS/J 10dB
Interference J Max Allowed (FM): -111.4dBm
J Max Allowed (NF): (-6dB J/N) = -104 dBm
LEVEL LIMIT
RX Interference (J): -31.9 dBm
Received NEGATIVE S/J Ratio: -39.5 dB
Loss of Required FM: 69.9 dB
Loss of Desired FM: 75.9 dB
Need to Correct Interferer Power: -72.1 dB (~NF)
Thus Non-Interfering Interferer: -36.1 dBm TX

CONCLUSIONS:
- Link is totally jammed!
- Reduce Interferer by -72.1dB to achieve -104dBm (6dB under NF)
- Set interferer to -36.1dBm TX
- Then FM = 22.6dB (~OK)

E1: High Power Mpoint-to-Mpoint "Mesh"

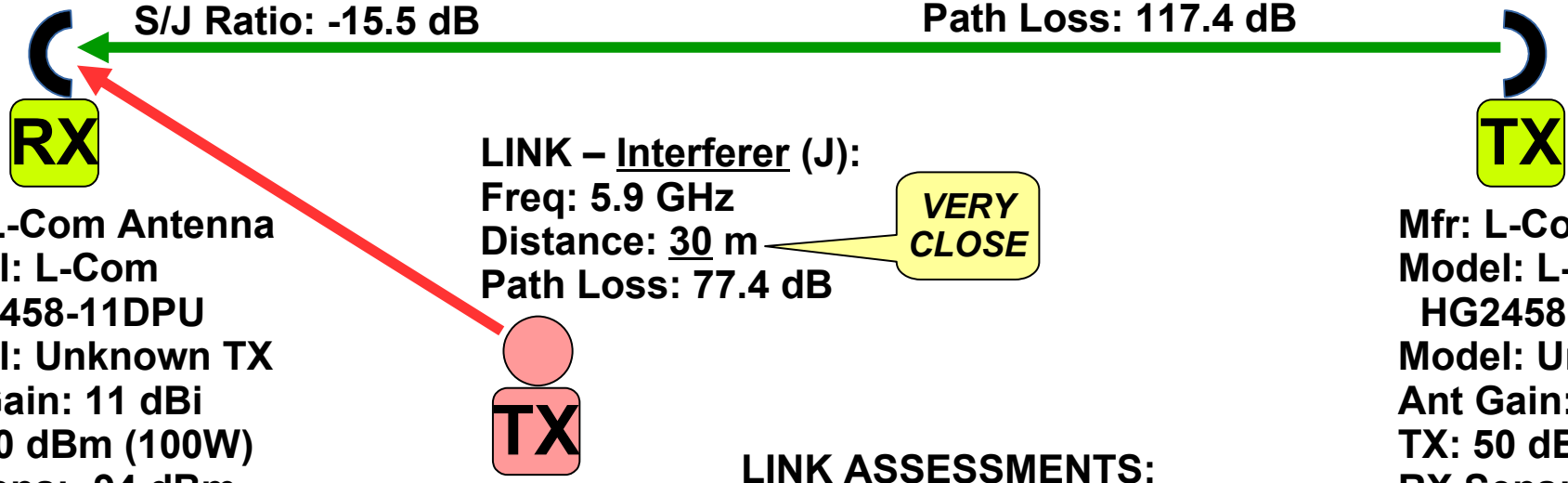


LINK ASSESSMENTS:
RX Link Signal (S): -66.4 dBm
Required Fade Margin (FM): 30 dB
RX Signal minimum: -96.4 dBm
RX Sensitivity (RS): -94 dBm
RX Noise Floor (NF): -98 dBm
Maximum feasible FM: 27.6 dB (No J)
Set Interference Margin: NF/J 6dB or RS/J 10dB
Interference J Max Allowed (FM): -106.4dBm
J Max Allowed (NF): (-6dB J/N) = -104 dBm
RX Interference (J): -70.9 dBm
Received Positive S/J Ratio: 4.5 dB
Loss of Required FM: 25.5 dB
Loss of Desired FM: 31.5 dB
Need to Correct Interferer Power: -33.1 dB (~NF)
Thus Non-Interfering Interferer: 2.9 dBm TX

LEVEL LIMIT

CONCLUSIONS:
- Even with 100W Link TX Power
- Link is virtually jammed!
- Reduce Interferer by -33.1dB to achieve -104dBm (6dB under NF)
- Set interferer to 2.9dBm TX
- Then FM = 27.6dB (~GOOD!)

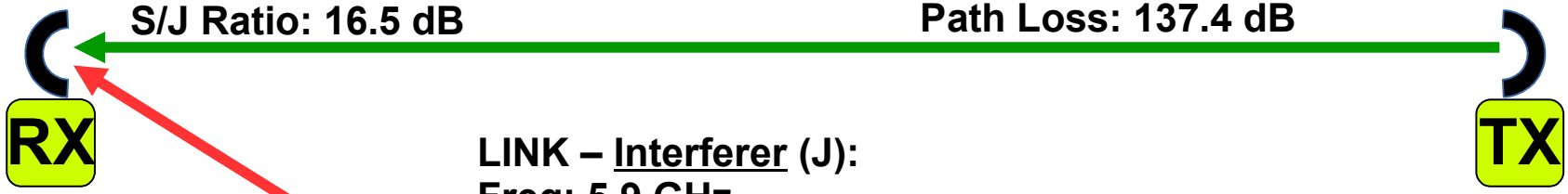
E2: High Power Mpoint-to-Mpoint "Mesh"



LINK ASSESSMENTS:
RX Link Signal (S): -46.4 dBm
Required Fade Margin (FM): 30 dB
RX Signal minimum: -76.4 dBm
RX Sensitivity (RS): -94 dBm
RX Noise Floor (NF): -98 dBm
Maximum feasible FM: 47.6 dB (No J)
Set Interference Margin: NF/J 6dB or RS/J 10dB
Interference J Max Allowed (FM): -86.4dBm
J Max Allowed (NF): (-6dB J/N) = -104 dBm
LEVEL LIMIT
RX Interference (J): -30.9 dBm
Received NEGATIVE S/J Ratio: -15.5 dB
Loss of Required FM: 45.5 dB
Loss of Desired FM: 51.5 dB
Need to Correct Interferer Power: -73.1 dB (~NF)
Thus Non-Interfering Interferer: -37.1 dBm TX

CONCLUSIONS:
- Even with 100W Link TX Power
- Link is totally jammed!
- Reduce Interferer by -73.1dB to achieve -104dBm (6dB under NF)
- Set interferer to -37.1dBm TX
- Then FM = 30dB (~GOOD!)

F: Very High Power Mpt-to-Mpt "Mesh"



RECEIVER INPUTS:
Link Signal (S): -54.4 dBm
Interference (J): -70.9 dBm
S/J Ratio: 16.5 dB

LINK – Primary (S):
Freq: 5.9 GHz (BW 20 MHz)
Distance: 30.0 km
Path Loss: 137.4 dB

LINK – Interferer (J):
Freq: 5.9 GHz
Distance: 3.0 km
Path Loss: 117.4 dB

Mfr: Unknown Ant.
Model: Unknown TX
Ant Gain: 11 dBi
TX: 62 dBm (1500W)
RX Sens: -94 dBm
Feed Loss: 0.5 dB
Role: Mesh User

Mfr: Unlicensed
Model: Unknown
Ant Gain: 0 dBi
TX: 36 dBm (EIRP)
RX Sens: Unknown
Feed Loss: 0.0 dB
Role: Interferer

Mfr: Unknown Ant.
Model: Unknown TX
Ant Gain: 11 dBi
TX: 62 dBm (1500W)
RX Sens: -94 dBm
Feed Loss: 0.5 dB
Role: Mesh Hub

LINK ASSESSMENTS:
RX Link Signal (S): -54.4 dBm
Required Fade Margin (FM): 30 dB
RX Signal minimum: -84.4 dBm
RX Sensitivity (RS): -94 dBm
RX Noise Floor (NF): -98 dBm
Maximum feasible FM: 39.6 dB (No J)
Set Interference Margin: NF/J 6dB or RS/J 10dB
Interference J Max Allowed (FM): -94.4dBm
J Max Allowed (NF): (-6dB J/N) = -104 dBm
RX Interference (J): -70.9 dBm
Received Positive S/J Ratio: 16.5 dB
Loss of Required FM: 13.5 dB
Loss of Desired FM: 19.5 dB
Need to Correct Interferer Power: -33.1 dB (~NF)
Thus Non-Interfering Interferer: 2.9 dBm TX

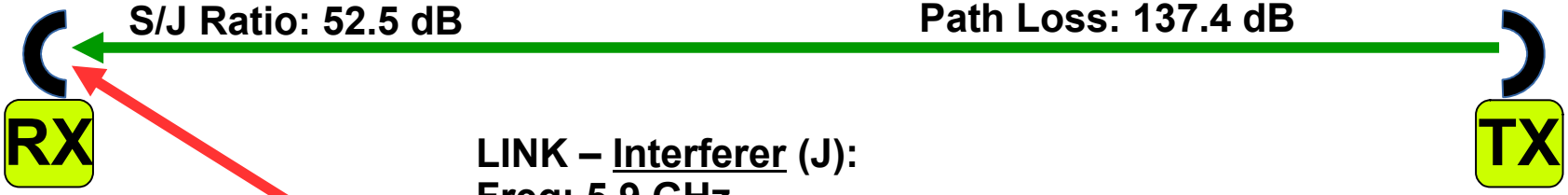
LEVEL LIMIT

CONCLUSIONS:
- Even with 1500W Link TX Power
- Link is marginal but usable.
- Reduce Interferer by -33.1dB to achieve -104dBm (6dB under NF)
- Set interferer to 2.9dBm TX
- Then FM = 30dB (~GOOD!)

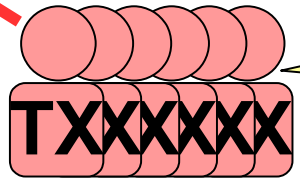
G: “Backbone” with Multiple Interferers

RECEIVER INPUTS:
Link Signal (S): -51.4 dBm
Interference (J): -103.9 dBm
S/J Ratio: 52.5 dB

LINK – Primary (S):
Freq: 5.9 GHz (BW 20 MHz)
Distance: 30.0 km
Path Loss: 137.4 dB



LINK – Interferer (J):
Freq: 5.9 GHz
Distance: 3.0 km
Path Loss: 117.4 dB



MULTIPLE INTERFERERS 1 TO N

Mfr: Ubiquiti
Model: RD-5G30 Dish
Model: Rocket 5M
Ant Gain: 30 dBi
TX: 27 dBm
RX Sens: -94 dBm
Feed Loss: 0.5 dB
Role: Link Destination

Mfr: Ubiquiti
Model: RD-5G30 Dish
Model: Rocket 5M
Ant Gain: 30 dBi
TX: 27 dBm
RX Sens: -94 dBm
Feed Loss: 0.5 dB
Role: Link Source

Mfr: Unlicensed
Model: Unknown
Ant Gain: 0 dBi
TX: -16 dBm (EIRP)
RX Sens: Unknown
Feed Loss: 0.0 dB
Role: Interferer

Total Interference increases with log of added N units:
$J_{(\text{Total Increase})} = [10 \log_{10}(N)]$ dB

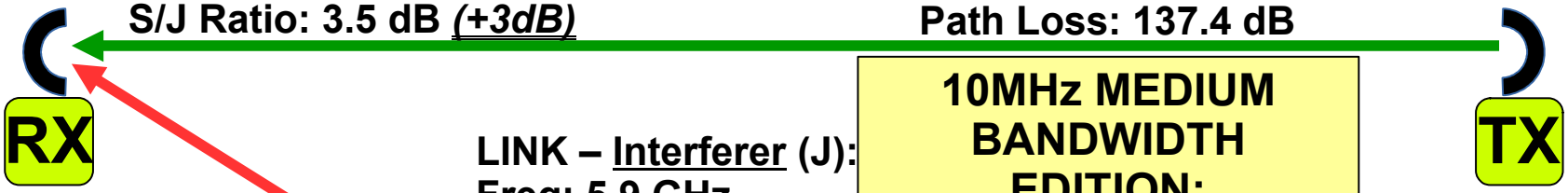
LINK ASSESSMENTS:
RX Link Signal (S): -51.4 dBm
Required Fade Margin (FM): 30 dB
RX Signal minimum: -81.4 dBm
RX Sensitivity (RS): -94 dBm
RX Noise Floor (NF): -98 dBm
Set Interference Margin: NF/J 6dB or RS/J 10dB
Interference J Max Allowed (FM): -91.4dBm
J Max Allowed (NF): (-6dB J/N) = -104 dBm
LEVEL LIMIT
RX Interference (J): -103.9 dBm
Received Positive S/J Ratio: 52.5 dB
Loss of Required FM: -12.6 dB (lots extra)
Loss of Desired FM: -6.6 dB (lots extra)
A2 Corrected Interferer Power: -52.0 dB (~NF)
Single Non-Interfering Interferer: -16.0 dBm TX

CONCLUSIONS: Starting at N=1
- Link is OK until more interferers...
- Set each interferer to -16.1dBm TX
- 10 interferers = RS -94dBm
- 200 interferers = FM Sig min -81dBm
- 2000 reduces S/J to ~20dB
- 2000 at 300m >> interference = signal

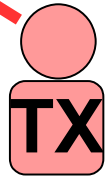
A3: *10MHz* Long Point-to-Point

RECEIVER INPUTS:
Link Signal (S): -51.4 dBm *(same)*
Interference (J): -54.9 dBm *(-3dB)*
S/J Ratio: 3.5 dB *(+3dB)*

LINK – Primary (S):
Freq: 5.9 GHz (BW *10* MHz)
Distance: 30.0 km
Path Loss: 137.4 dB



LINK – Interferer (J):
Freq: 5.9 GHz
Distance: 3.0 km
Path Loss: 117.4 dB



10MHz MEDIUM BANDWIDTH EDITION:
BW: *10*MHz / 20MHz
J EIRP: *33*dBmi / 36
RS: -*97*dBm / -94
RX NF: -*101*dBm / -98
J Limit: -*107*dBm/-104

Mfr: Ubiquiti
Model: RD-5G30 Dish
Model: Rocket 5M
Ant Gain: 30 dBi
TX: 27 dBm
RX Sens: -*97* dBm
Feed Loss: 0.5 dB
Role: Link Destination

Mfr: Unlicensed
Model: Unknown
Ant Gain: 0 dBi
TX: *33* dBm (EIRP)
RX Sens: Unknown
Feed Loss: 0.0 dB
Role: Interferer

Mfr: Ubiquiti
Model: RD-5G30 Dish
Model: Rocket 5M
Ant Gain: 30 dBi
TX: 27 dBm
RX Sens: -*97* dBm
Feed Loss: 0.5 dB
Role: Link Source

LINK ASSESSMENTS:
RX Link Signal (S): -51.4 dBm
Required Fade Margin (FM): 30 dB
RX Signal minimum: -81.4 dBm
RX Sensitivity (RS): -*97* dBm
RX Noise Floor (NF): -*101* dBm
Maximum feasible FM: *45.6* dB (No J)
Set Interference Margin: NF/J 6dB or RS/J 10dB
Interference J Max Allowed (FM): -91.4dBm
J Max Allowed (NF): (-6dB J/N) = -*107* dBm
RX Interference (J): -*54.9* dBm
Received Positive S/J Ratio: *3.5* dB
Loss of Required FM: 29.5 dB
Loss of Desired FM: 35.5 dB
Need to Correct Interferer Power: -*52.1* dB (~NF)
Thus Non-Interfering Interferer: -*19.1* dBm TX

LEVEL LIMIT

CONCLUSIONS:
- Link is clearly jammed!
- FM = S/J = 0.5dB
- Reduce Interferer -*52.1*dB *(same)* to achieve -*107*dBm (6dB under NF)
- Set interferer to -*19.1*dBm TX
- Then FM up to *45.6*dB (GOOD!)

Limits on Interferer Power (J)

Case Example	Required Interferer J Power Limit 20 MHz BW	Required Interferer J Power Limit 10 MHz BW	Required Interferer J Power Limit 5 MHz BW
A1: Long Point-to-Point (AT&T)	-22.1 dBm	-25.1 dBm	-28.1 dBm
A2: Long Point-to-Point "Backbone"	-16.1 dBm	-19.1 dBm (Example Case A3)	-22.1 dBm
B1: Point-to-Multipoint "Distribution"	-5.6 dBm	-8.6 dBm	-11.6 dBm
B2: Point-to-Multipoint "Distribution"	14 dBm	11 dBm	8 dBm
C: Multipoint-to-Multipoint "Mesh"	-16.1 dBm	-19.1 dBm	-22.1 dBm
D: Close Mpoint-to-Mpoint "Mesh"	-36.1 dBm	-39.1 dBm	-42.1 dBm
E1: High Power Mpoint-to-Mpoint "Mesh"	2.9 dBm	-0.1 dBm	-3.1 dBm
E2: High Power Mpoint-to-Mpoint "Mesh"	-37.1 dBm	-40.1 dBm	-43.1 dBm
F: Very High Power Mpt-to-Mpt "Mesh"	2.9 dBm	-0.1 dBm	-3.1 dBm

Impacts of Multiple Interferers

- Multiple interferers will certainly combine their energy to increase the total received interference power by 10 $\log_{10}$ (N) dB.
- To maintain the effect of a single unlicensed device with a limited power lever, all of those devices in view must collective adjust each of their transmit powers downwards, in the inverse of the above formula, in order to properly maintain the same effective interference level.
- The expected widely proliferated and dispersed interfering unlicensed emitters will dramatically impact AREDN Mesh systems. Quantities as high as a billion are projected.
- Even worse, highly concentrated unlicensed emitters, such as in suburban or urban areas, or at major events or incidents, will likely totally prevent AREDN operations or cripple viability
- Please see following Table, based on Case G.
- For clarity, in a “real world” scenario, this situation would be far more complicated.
- There would be multiple devices in the field of view of the RX site, with their antennas at various random ranges, from very close (worst cases) to far away along the link path. Simple examples are Cases B1 & B2.
- Potentially, you would be looking at many tens of thousands of interfering units at these many various ranges.
- This means that the total interference would in practice much faster than the simple scenarios presented herein.

Impacts of Multiple Interferers

Interferers N	Combined Power TX dBm	Combined Power RX dBm	Elevation ABOVE NF Margin dB
1	-16	-104	0
2	-13	-101	*3*
4	-10	-97	*6*
10	-6	-94	*10*
20	-3	-91	*13*
100	+4	-84	*20*
200	+7	-81	*23*
1000	+14	-74	*30*
2000	+17	-71	*33*

This example is based on Case A2:
BW: 20 MHz
J EIRP: 36dBmi
RS: -94 dBm
RX NF: -98dBm
J Limit: -104 dBm

MULTIPLE INTERFERER POWERS EQUAL RECEIVER SENSITIVITY

LINK IS SIMPLY OVER POWERED BY INTERFERENCE

Path Performance vs Fade Margin

- Receiver path performance is a direct function of path fade margin (FM).
- Fade margin is limited by the combined power level of receiver front end noise and any external interference, given by the formula below.
- $RFM = \{ 10 \text{ Log}_{10} [10^{N/10} + 10^{J/10}] \} - N$
  - RFM = Reduction in Fade Margin (dB)
  - N = Receiver Front End Noise (dBm)
  - J = External interference (dBm)
- If we relate J to power relative to N, we can set N=0 and J as the dB level of power relative to N.
- Using this approach gives the following chart showing impact of interference power as follows:
- [Relative Interference Power (dB) = Interference (dBm) – Receiver Noise (dBm)]
  - Please see following Table.

Path Performance vs Fade Margin

Relative Interference Power (dB)	Decrease in Fade Margin (dB)
-10	0.4
-6	1.0
-2.3	2.0
0	3.0
1.8	4.0
3.3	5.0
9.5	10.0
14.9	15.0
20.0	20.0
25.0	25.0
30.0	30.0
40.0	40.0

EVEN IF WE ORIGINALLY HAD A 30 dB FADE MARGIN, IT'S GONE NOW!

Conclusions & Recommendations

- The AREDN Mesh system is, by excellent engineering and good system design, very sensitive to the desired on-channel signals for high performance data communications.
- Unfortunately, and like any similar system, AREDN is therefore also very susceptible to almost any co-channel noise, and especially similar mode data signaling from interfering emitters.
- Even a single interfering unit within the view of an AREDN node has a high potential to severely degrade the communications link.
- As a minimum, even a much weaker interferer may still degrade the available fade margin on the link path.
- The problem is greatly magnified by adding multiple interfering emitters within the link receiver view. If multiple interfering devices are in view of a impacted receiver, then they collectively must each be reduced in power by the inverse of the 10 log10(N) rate.
- Even more challenging is the potential proximity of any interfering emitter(s). Proximity is highly likely in almost any practical scenario, and it essentially leverages the interference by many orders of magnitude!
- In summary, we recommend that interfering emitters be significantly limited in power levels, and be geographically isolated from any AREDN nodes.
- Note- Even if most or all AREDN fixed node locations are available for protection, such a database is still insufficient for protection of the rapidly deployable emergency communications AREDN systems, which must operate anytime, anyplace, and cannot be promptly tabulated.

References

- The AREDN MESH Project
  - www.AREDNmesh.org
- Ubiquiti Networks
  - www.ubnt.com
- L-Com Inc.
  - www.L-Com.com
- NOKIA, Automated Frequency Co-Ordinator (AFC) for U-NII-5 and U-NII-7 Band, Buddhikot & Moout, 8 April 2019
  - ecfsapi.fcc.gov/file/1041057063639/Nokia-6GHz_AFC-Concepts-Apr2019.pdf
- MikroTik (SIA Mikrotīkls)
  - www.mikrotik.com
- Unlicensed National Information Infrastructure (U-NII), Wikipedia
  - en.wikipedia.org/wiki/Unlicensed_National_Information_Infrastructure
- RFS World Category A Antennas
  - SBC6-W60DD2 - CompactLine Antenna, Ultra High Performance, Dual Polarized, 6 ft
  - www.rfsworld.com
- Fixed Wireless Communications Coalition, Inc. (FWCC) Kizer Study, 13 March 13
  - fwcc.us

Questions??

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