Comments Regarding Amateur Radio use of the 77 GHz Band

By Barry Malowanchuk P. Eng, Amateur Radio Station VE4MA/W7, March 23, 2015

Introduction

I must preface this discussion by stating that although I am a Canadian citizen, licensed as a radio amateur in Canada, I operate under reciprocal license provisions in the state of Arizona for approximately 5 (five) months every year.

This FCC request for comments is somewhat of a "Déjà vu" of the request some years ago concerning the original consideration of the 76-77 GHz spectrum. As a Professional Engineer I have a responsibility to represent the public interests in my work and this professionalism does carry over into my personal life. At the earlier time I recognized that this undertaking is of a potentially massive impact to public safety worldwide, and it's difficult for me to defend exclusive use of this spectrum for amateur radio use.

My use of the 77 GHz band follows from a long chain of events where equipment was built and operated on increasingly higher amateur frequencies, starting at 432 MHz in 1966, and reaching 47 GHz in 2005. Living in the middle of Canada there were few stations to communicate with locally and propagation to Minneapolis (the nearest major city) only occurred briefly during summer months. In order to take advantage of my time and monetary investment in the equipment, I pursued bouncing my radio signals off of the moon. This required the use of the best technology and by paying careful attention to details. All of the assigned frequency bands have been conquered including 432 , 902 & 1296 MHz, 2.3, 3.4, 5.7 and 10 GHz. Notably the first 24 GHz and 47 GHz moon bounce communications was accomplished in 2001 and 2005 using a 2.4 m dish with approximately 30 MW ERP on both frequencies.

The radio technology required for 77 GHz imposed a considerable hurdle but with the slow acquisition of used millimeter wave components (often at significant cost) and a passion to move forward shared with many close amateur radio friends, I have been able to create high performance equipment for 77 GHz.

77 GHz Activities at VE4MA

The 77GHz activity in Canada has been non-existent until recently. In 2010 I completed 2 (two) complete stations capable of SSB, FM and Morse code transmissions and using 1 (one) ft dish antennas. One of the stations made use of a prototype low noise amplifiers on loan from a USA amateur to evaluate in connection with an effort to develop a 77 GHz moon bounce station (see Figure 1). These stations were used to establish the first 77 GHz amateur communications in Canada, and was timed to avoid having this accomplished by visiting amateur radio operators from the East Coast of the USA. The equipment was used on the last warm day in October and a maximum distance of only 5 km was covered across farm fields with no elevated launch positions and limited by trees used for wind breaks in the fields.. Although the equipment was shown to be capable of covering much larger distances, this has still not occurred but the equipment has been improved to both use high gain low noise amplifiers bi-directionally with output powers of near 5 mW and approximately a 5 dB noise figures. The frequency used was 78192 MHz as this was established by a consensus of amateurs in North America and it provides lower propagation losses than operating down at 75.5 GHz.

77 GHz Moon Bounce

The 77 GHz work was always targeted towards a possible moon bounce attempt. Al W5LUA and I had been working on our own systems which were receive only at 78.192 GHz. In 2009 Tom Williams WA1MBA began working on affordable ham priced low noise amplifiers. We needed high gain LNAs with low noise figures to overcome the relatively high noise figures of our mixers so that we could hear weak signals from the moon. I was able to minimize the mixer noise figure by using a fundamental mixer rather than a harmonic mixer. With the low noise amplifiers a noise figure of near 4 dB was achieved. Cooling of the amplifier with dry ice provided a further reduction down to near 3 dB!

Figure 1 2 x 78 GHz Transceivers

Figure 2 2.4 m dish 77 GHz Sun Noise

As a follow-up to work done for 47 GHz moon bounce where a 2.4 m offset parabola was resurfaced with “kitchen” aluminum foil, this and several smaller 1.2 and 0.9 m reflectors were evaluated at 77 GHz using noise from the sun (see Figure 2). Unfortunately the sun with its ~0.5 degree subtended angle is no longer a point source reflector and thus could not be used for optimization.

“The Big obstacle” to 77 GHz moon bounce is the lack of a high power transmitter with an output of 50 Watts or more. Fortunately I was able to acquire a used EIO Klystron tube which originally provided 70 Watts output at 78.160 GHz (see Figure 3). I was able to get the original data sheet and work began on testing the tube and creating an appropriate power supply. Unfortunately the tube was ultimately found to have become gassy and the cathode poisoned, rendering it unusable. The cost of rebuilding this tube is on the order of $100k so clearly out of a hobby budget. Other EIO klystrons have since appeared on the used market but not at a hobby price. It is however likely that these tubes are also not longer serviceable.

Figure 3 70 W 78 GHz Klystron tube

Sergei RW3BP in Moscow, who is an old friend from earlier 24 GHz and 47 GHz moon bounce work, reported the first lunar echoes on 77 GHz (see a video dialog of the extraordinary work done at https://www.youtube.com/watch?v=2En_W2EaJFw). Sergei was using a 2.4m offset fed dish and a 60 watt pulse rated travelling wave tube. Figure 3 documents the first lunar echoes as received by Sergei on Feb 17, 2013. The series of 3 long horizontal lines denote the transmitted signal and the 3 short faint lines in between the long horizontal lines denote the received lunar echoes. The actual frequency of operation chosen by Sergei was 77.184 GHz as determined by the frequency at which Sergei achieved the highest power with his TWT. This TWT was originally designed for pulse service and the cathode structure only permits very short (~0.1 second) transmissions. Even at this the cathode of the TWT sustains damage and the output power from the tube is highly variable from time to time.

On June 12, 2013, Sergei RW3BP conducted a test transmission and Al W5LUA was able to successfully receive the EME signals from Sergei. We used a program that was written by a Russian friend of Sergei's that allows us to integrate received signals over long time periods. The software monitors the received signal over a 10 minute time period and through long term integration, a signal to noise enhancement of approximately 10 dB is obtained over real time transmissions and the transmitted signal is reproduced at the receiving end. A moon tracking computer program allows the dish (with an approximate 0.15 degree beam width) to automatically track the location of the moon. The same software does automatic Doppler frequency control for my Flex-1500 Software Defined Radio.

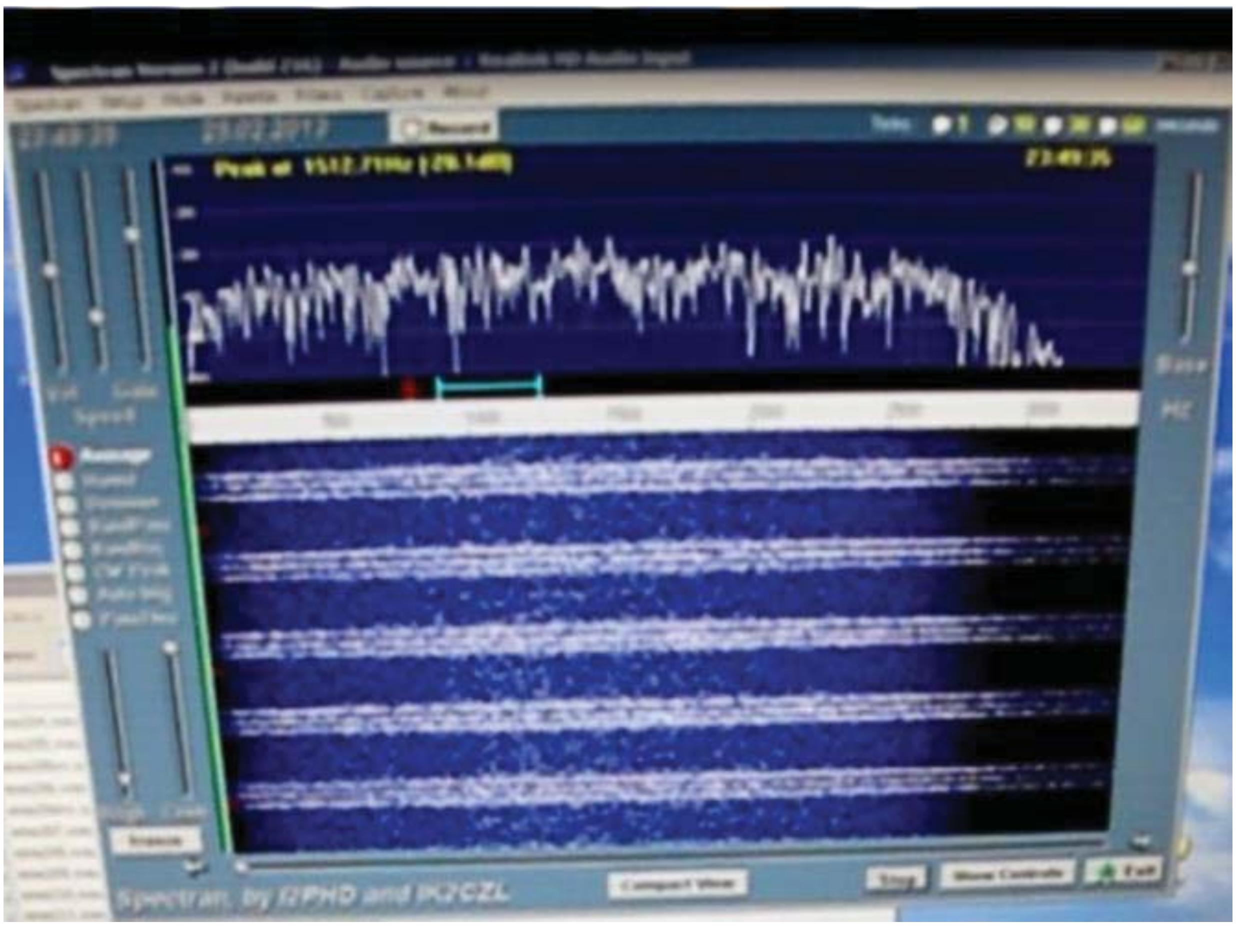

Figure 4 77 GHz Lunar Echoes Received by RW3BP

For the software to recover the transmitted signal, the frequency must remain stable within 100 Hz for the 10 minute transmission period, while the Doppler shift (maximum of 125 KHz) is changing at approximately 210 Hz per minute. The moon reflected 77 GHz signal from RW3BP decoded by W5LUA is shown in Figure 5. In order for the basic receiver to be precisely on frequency and hold it so, the local oscillators had to be phase locked to a stable source, which was a GPS locked 10 MHz reference in our case.

Unfortunately I was unsuccessful in receiving Sergei's signal which was due to a malfunctioning of the Doppler correction program at my end.

Despite failures with high power tubes, the desire to make the first 2 way contact in the 77 GHz amateur radio band via the moon continues.

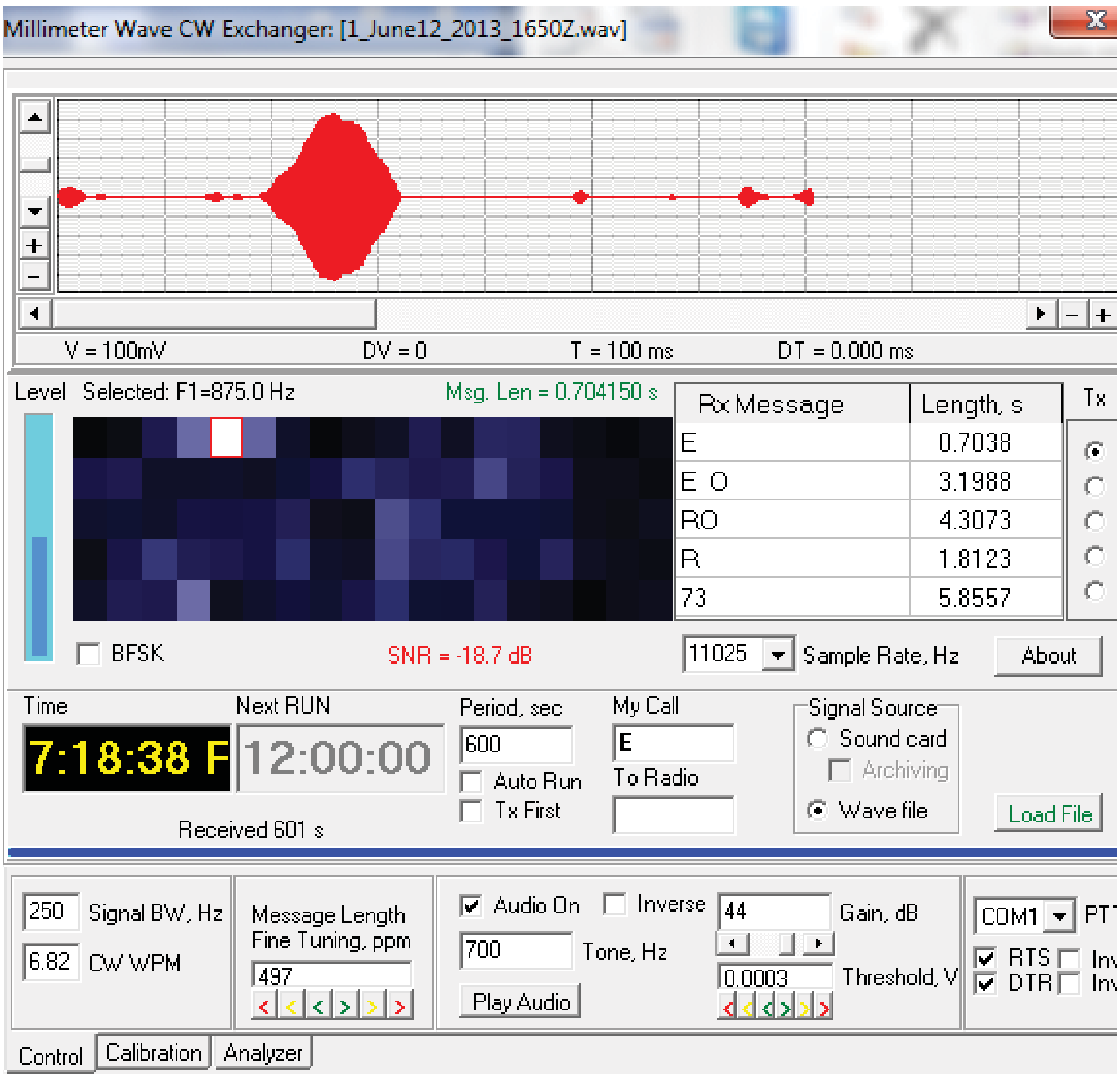

Figure 5 RW3BP Decoded 77 GHz Signal at W5LUA

Future Work

With the availability of the 2 (two) terrestrial stations there are plans to try to extend the longest distances covered by taking advantage of high rise building rooftops in the Winnipeg area since there are no mountains of any consequence within 400 km. Since I am a winter resident of Arizona there are plans to take advantage of the dry climate and high elevation locations to cover some very long distances. Further equipment upgrades are planned to increase transmit powers to 100 mW from 5 mW and that should allow non –line of sight paths to be explored. Tropospheric ducting has been observed on 24 GHz but it is not known at what frequency the radio waves begin to act only as optical rays.

This has been a multi-year project that has cost me 7 (seven) thousand dollars of investment not including the cost of test equipment used to test and align these systems. Of course there has been "many" hundreds of hours expended in the quest. Clearly any change in the operating frequency will have significant cost implications in money and time. With the frequency constraints of the transmitter tubes, continued work towards "77 GHz" moon bounce may not even be possible.

Specific Comments to FCC 15-16 by Paragraph

1. **"**Evaluating the compatibility of incumbent operations, including that of amateur radio, with radar applications in the 77-81 GHz band."

There has been no analysis of compatibility between the two services. There does not yet appear to be defined standards for the proposed systems, which would appear to make this analysis impossible. It is noted however in the 79 GHz EU Newsletter that in November 2013 Technical Characteristics for the SRR systems was submitted to the ITU.

7. "Developers of these technologies claim that the existing 1 gigahertz bandwidth used by LRR is insufficient to develop high-resolution short-range vehicular radars (SRR) that can implement safety features such as collision warning, lane departure warning, lane change assistance, blind-spot detection, and pedestrian protection."

While this is understandable it is noted that there is demonstrated incompatibility between the LRR and the SRR systems, no matter what modulation format is used. See Items 8 & 26.

26, 27, 28. "It asserts that a common band between the two systems is not feasible, and that we should identify alternate spectrum for SRR use. They contend that greater bandwidth leads to better range separation and object discrimination. The SRR applications will have a lower transmit power density level than that for LRR applications and therefore will have low likelihood for causing any potential interference."

First of all, the proposed systems are for public safety so that high performance of these systems is better for the public good. The SRR systems will certainly have shorter range and less energy radiated with less possibility of interference. In order to avoid interference from similar systems on other vehicles, one of the techniques likely to be employed is frequency hopping, and by having extra bandwidth the systems should be able to respond quickly with high resolution even with possible interference. Understandably that there will be an increase in the noise floor in this spectrum but the impact should be felt only for a short distance.

30. "Bosch and Continental further note that the 2015 World Radio Communication Conference is expected to adopt an allocation to support the operation of vehicular radars in the 76-81 GHz range on a worldwide basis".

Noted and understood. Reference 66 is also noted.

31. "We believe that new proposed radar operations will be compatible with incumbent operations in the 76-81 GHz band. As a general matter, the same technical principles that already allow successful shared operation in the 76-77 GHz band should apply in the larger 76-81 GHz range."

So this says "Compatible with incumbent operations in 76-81 GHz just as it is in 76-77 GHz" but from 16. "the Commission stated that it continues to believe that vehicular radars should be able to share the band with fixed radars operating at the same levels and **noted that there were no conclusive test results indicating that there would be incompatibility issues between the two types of radars.**

Further from 21. **"**The Commission has previously considered compatibility issues for amateur operations with vehicular radar and FOD detection radar operations. **In light of concerns about interference between amateur operations and vehicular radars, the Commission imposed (and, more recently, maintained) a suspension of the amateur-satellite service allocation in the 76-77 GHz band."** So does this mean that if we suspend amateur service allocations in 77-81 GHz there will be no problems?....is this compatibility ?

34. "In its petition, Bosch states that it expects no interference issues between Amateur Radio operation and vehicular radar operations at 77-81 GHz.….Are there any additional interference or compatibility studies that may exist on the subject? Our goal is to adopt rules that address amateur use, including amateur satellite use, within the 76-81 GHz band in a comprehensive and consistent manner."

Certainly **No** joint compatibility studies have been conducted. The Commission has already dealt with this for 76-77 GHz…by eliminating amateur operation….so is that the intention for 77-81 GHz? See more below!

37. "and because the nature of the millimeter wave band makes it possible for LRR and SSR vehicular radars to share use of the band."

And this is why the LRR and SSR must have separate spectrum to avoid interference. So this is "sharing the use of the band"???

38. "We do not propose to distinguish between SRR and LRR operations in our rules, but instead rely on the market to determine the appropriate portions of the 76-81 GHz band for particular types of vehicular radar applications."

It has already been stated that there is incompatibility between LRR and SRR radars and they need to be separated in frequency. Further that SSR needs 4 GHz of spectrum to be able to provide the quality of service required. The LRR needs have been established clearly over the past years and are sufficient. So why not identify this in the rules? The Commission has chosen to eliminate amateur operations from 76-77 GHz, so does this not imply that by default amateur operations would be eliminated from 77-81 GHz??

60. "*Amateur radio use*. In conjunction with our efforts to develop a comprehensive policy for use of the 76-81 GHz band, we seek comment on how we should structure future amateur 4 mm band use."

Noted see below!

61. "Given the continuing lack of technical sharing criteria or any other evidence of compatibility, should we extend the 76-77 GHz amateur suspension to the entire 76-81 GHz band?"

I do not understand why there is a continuing lack of technical sharing? The proponent for this reorganization should be prepared to come forward with firm technical details on what it proposes for equipment and be prepared to entertain compatibility testing. This could be facilitated through the ARRL, the national voice for amateur radio.

62. "Bosch, in its petition, states that it "is unconvinced, after several meetings with technical staff of ARRL, the national association for Amateur Radio, that there is any significant incompatibility between Amateur Radio and SRR operation at 79 GHz." "However, Bosch also notes that European regulators previously determined "that the use of SRR within the band 77-81 may be incompatible with the Radio Amateur Service," but also concluded that amateur users could be accommodated in the 75.5-76 GHz band (which is not currently available in the U.S.)."

I share the Bosch opinion as I am unconvinced of any significant incompatibility; however I have NO information as to the technical specifications of the SRR equipment.

63."To the extent that commenters believe that amateur operators can continue to use the millimeter band, we seek comment on what additional rule modifications we would have to adopt to realize successful shared use of the entire band. For example, our existing service rules would permit amateur operators to transmit with significantly higher power than other proposed operations."

I do not believe that any rule modifications are required, again given that the technical specifications of LRR and SRR equipment and the impact of possible interference to the radar is unknown. If the radars are to co-exist with each other, the narrow band emissions of amateur systems should not present an additional challenge. Normal amateur power levels are not significantly greater than what I believe the LRR systems would use (<5 mW). However with the advancement of 77 GHz technology, greater transmitter powers ~100 mW are going to be used by some amateurs in the near future. But taking into account to somewhat remote locations used for amateur operations, and the very high directivity of amateur antennas (~1 degree beamwidth) the likelihood of interference is small.

For amateur moon bounce operation at extreme power levels (~70 W transmitters) with very large antennas (1.8 -2.4 m or larger), the antennas are almost exclusively used at elevation angles greater than 30 degrees in order to avoid atmospheric losses, and with the very low sidelobe antenna performance, interference to ground based systems is unlikely. This is not unlike the FOD radar system which have high power transmitters but whose antennas are focused down at the ground and away from public vehicles. The FOD radars may however use wideband modulation techniques to enhance the resolution of target objects, whereas amateur moon bounce signals are very narrowband (<3 kHz).

With the proximity and explosive growth in use of new Gigabit Ethernet microwave radios in the spectrum starting at 81 GHz, do the specifications for the SRR systems include some immunity from strong wideband systems in the adjacent spectrum? I note that one supplier alone supplied 10,000 such units in 2014 and 23, 000 are already deployed across the world. These radios will likely use higher power (~100 mW) in order to give the largest possible system gain.

64. "Bosch recommends an amateur allocation at 75.5-76 GHz, arguing that such an allocation would permit reaccommodation of any displaced Amateur Radio operators as the result of aggregate noise from SRRs in the 79 GHz band, and harmonize the United States Amateur allocation with that in ITU Region 1 and in other areas of the world. We seek comment on allocating the 75.5-76 GHz band to the amateur service if we were to remove the amateur allocation, including amateur satellite, in the 76-81 GHz band."

I have always believed that amateurs should have a primary world-wide allocation at 75.5 -76 GHz. I am not familiar with the reasons why this was not possible in the USA, but now would be an appropriate point in time to reconsider that decision. Even with a secondary allocation at 75.5 -76 GHz I believe that amateur operation can co-exist very well with existing users.

If the amateur allocation is removed from 76-81 GHz I would expect compensation as I have a considerable investment in 77-78 GHz equipment that does not translate directly to a new frequency without considerable cost / effort and this would preclude any possible moon bounce operations.

Even with an amateur allocation at 75.5 -76 GHz, I believe that the truly experimental long distance work that is possible with operating moon bounce or terrestrially closer to 81 G where the path loss is lower, should be permitted on a secondary basis in the77-81 GHz band. The experimenters involved with this work are amateurs in name only!

As discussed elsewhere with the low power of SSR's, the most common use of remotely located amateur operating sites, and very higher gain antennas elevated well above the horizon, I do not anticipate a significant impact on amateur operations, even those with the extremely low noise floor receivers. Where the interfering signal levels might be strong, amateur receivers are capable of handling this but it depends on the modulation format of the interferer. There was a suggestion in the 79 GHz Project material that frequency hopping was a likely modulation format, and this probably offers the best possible solution for minimizing interference between all users of the spectrum.

Even with the use of frequency hopping if the signals are strong enough there can be issues with dynamic range in receivers. This has been the case with band sharing at 5.8 GHz where the Wi-Fi equipment is of much higher power and much closer proximity to amateur installation. Amateur operation at 5.8 GHz is most often conducted from less remote locations than at 77 GHz, and of course very long distance communications is easily achieved in this part of the microwave spectrum.