Amateur Radio on Manned Space Vehicles: Improving Amateur Radio's Future Through Enhanced Space Frequencies

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Abstract

Since 1983, Amateur Radio has had frequent or continuous presence on space vehicles with astronauts and cosmonauts on-board. To date, tens of thousands of amateur radio operators and their guests have communicated with astronauts and cosmonauts in space. Despite the outstanding success of this facet of amateur radio, it has been plagued with a significant problem-many parts of the world, including most of the U.S., cannot reliably receive the 2 meter signals from the spaceborne crew members due to severe frequency interference. This problem is even worse for our amateur radio colleagues in space. This paper intends to describe the problem that astronauts and cosmonauts in space and terrestrial amateur radio operators endure to achieve contact success. It also provides some high-level recommendations to relieve this problem in the future.

Introduction

Amateur radio on human-operated space vehicles started in 1983 when U.S. astronaut Owen Garriott, W5LFL, was granted permission by NASA to fly a 2 meter hand-held transceiver on the Space Shuttle Columbia. Since that first mission on STS-9, the Shuttle Amateur Radio Experiment (SAREX) has flown 24 times on all of NASA's Space Shuttle fleet. In 1986 the Russian Space Station Mir was launched. Shortly thereafter, amateur radio was installed on Mir. This was accomplished through joint cooperation by the German Space Amateur Funk Experiment (SAFEX) team, the Russian Mir Amateur Radio Experiment (MAREX) team and the U.S. Mir International amateur Radio Experiment (MIREX) team. Since these humble beginnings 14 years ago, amateur radio has become a mainstay on all Russian and U.S. space platforms and will continue this tradition permanently on the International Space Station (ISS).

On Earth, remote scientific and research outposts like Antarctica have used amateur radio to provide psychological solace for the members of the research team and educational opportunities for student groups. Like their Earth-bound researchers, the Shuttle and Mir astronauts and cosmonauts use amateur radio as a spontaneous communication tool to permit random communication with people on the ground and pre-scheduled contacts with their friends and family. Early on, the international teams who coordinate the SAREX, MIREX, SAFEX and MAREX programs recognized the high visibility and tremendous appeal this new facet of amateur radio offers the general community. As a result, all these teams have implemented educational programs using communications between astronauts and cosmonauts as a means to pique student's interest amateur radio, science and technology. These programs have been tremendously successful. They provide our international youth a stimulating pathway to begin the amateur radio hobby and provide an amateur radio experience to whole communities that is positive and remembered for a lifetime. These positive experiences are vital for the future of amateur radio. Today's student hams represent amateur radio's future. Moreover, the positive experience to the community is vital in an era when antenna covenants and radio frequency interference issues threaten the viability of ham radio's future.

When crew-operated amateur radio in space began in 1983, it was very difficult to select frequencies that would be compatible in all parts of the world. The 2-meter bandplan in IARU (International Amateur Radio Union) Region 2 (North and South America) is very different from what is used in Region 1 (Europe, Middle East and Africa) or in Region 3 (Asia and Australia). This problem has gotten significantly worse over the past 14 years due to the popularity of packet radio in the U.S. and the significant worldwide influx of new radio amateurs that have flooded the 2 meter band. Crowded frequencies requires frequency sharing and strict frequency coordination. These methods have worked reasonably well for most terrestrial-based hams; however, they have not for those who wish to communicate with the astronauts and cosmonauts. From an astronaut's perspective, this frequency problem makes the worst DX pileup look like child's play. The orbiting crews are, many times, quite frustrated with the inability to communicate with their fellow hams because of unwanted frequency interference. The following sections describe the problems that the space communicators (hams on the ground and the crew on-board) face everyday and some potential solutions to the problem.

Communicating With Space Vehicles— Similarities and Differences with Traditional VHF Communications

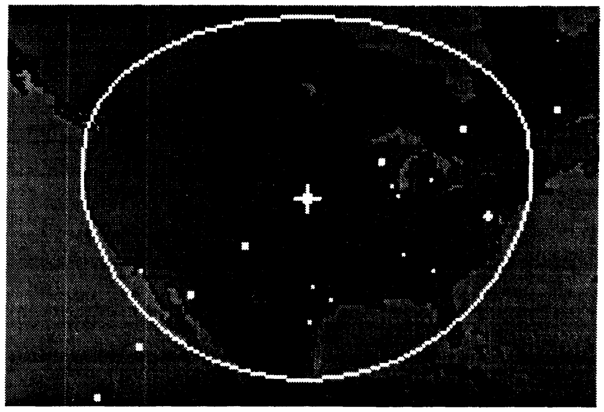
Before we delve into the question of frequencies, let's first understand how space travel effects amateur radio communications. There are three significant effects that space communicators experience which are vastly different from what a VHF or UHF ham radio operator traditionally experiences. These include 1) a significant change in station visibility, 2) the requirement to compensate for the Doppler effect and 3) the extremely long path length of the signals which results in weak signal communications.

<u>Space Vehicle Visibilitv</u>

VHF QSOs are predominantly accomplished using "ground-wave" (as compared to "sky-wave") communications techniques. Therefore, the contacts are usually line of sight. The higher your antenna, the further you can communicate. If you are driving in your car and operate simplex with another car, your communications "circle" is about 1-2 miles. If you increase your effective antenna height using a repeater, your communications "circle" increases to 15-30 miles or more. Space vehicles literally take the "repeater" idea to new heights. Figure 1 illustrates this effect quite clearly for the Russian space station Mir. As shown, the visibility circle encompasses the entire continental U.S. at times. The white dots that traverse from the bottom left of the picture to the upper right represent the motion of the center of this visibility circle every two minutes. Thus, the center of the visibility circle moves from around New Mexico to Wisconsin in about 6 minutes.

Figure 1 provides a graphical representation of several points that are crucial to understand the frequency issues

1. Vehicles in space see very large parts of the world, providing a great communications device
2. Space vehicles move quite fast over a terrestrial ham's station. Shuttle and Mir provide a maximum of an 8-10 minute communications opportunity for a ham during an orbital pass.
3. Due to their vantage point, space stations have "big ears." In other words, radio transmissions not intended for the astronauts or cosmonauts that occur on the space station uplink frequency will cause interference on the space station.
4. There are no borders in space. Figure 1 clearly illustrates that at one point in the orbit, Mexico, the U.S. and Canada can all communicate with Mir at the same time.



Space Station Mir Visibility Circle
During a North America Pass
Figure 1

<u>Doppler Effects</u>

The Doppler effect is the change in frequency that is observed by an individual when an object travels towards or away from that observer. When you stand near the track of a fast moving train, the whistle is high pitched as it approaches and becomes lower pitch when it passes by. Space stations move at 7.5 km/sec; so the Doppler effect is much more pronounced. A ground observer will see the Mir or Shuttle 2-meter downlink frequency increase up to a 3.5 kHz from its nominal frequency as the vehicle approaches. At closest approach, the downlink will be centered at the nominal frequency. As the vehicle moves away from the ground station, the observer will see up to a 3.5 kHz decrease in frequency from the nominal due to Doppler.

Doppler becomes important because it means that space vehicles need a wider channel separation as compared to ground-based activity. Currently, the FM channel spacing in the U.S. is either 15 kHz or 20 kHz. To guarantee interference does not occur with space vehicles, an additional 5- 10 kHz of separation is required on 2 meters due to the Doppler effect.

Long path length

Most VHF line-of-sight contacts are conducted with point-to-point path lengths no longer than 30 miles. Contrast this path length with 300 miles at closest approach for Mir and Shuttle. As figure l depicts, the Shuttle and Mir range circle is about 2500 miles in diameter (the width of the continental U.S.) This very long line-of-sight path length puts communications with these space faring vehicles in the weak signal category.

Despite these observations, there are times when hams on the ground have copied both Mir and Shuttle using handhelds tranceivers. While this reception is quite exciting for the ground-based ham, it rarely lasts for more than 30 seconds to one minute. Also, it usually occurs only when the space station attitude is favorable and while the vehicle is making its closest approach to the ground station.

To have a meaningful (>l minute) conversation with the orbiting crew requires the use of receiver pre-amps and circularly polarized gained antennas. Strong terrestrial signals close to the Shuttle or Mir downlink will make reliable communication with the space station untenable due to the spillover of signals through the pre-amp or due to ground station receiver desensitization. This issue is quite apparent on Mir where the current space station downlink (145.80 MHz) is within 10 kHz of the APRS frequency (145.79 MHz). Strong terrestrial FM operations adjacent to weak signal space operations is detrimental to effective space communications.

Astronaut and Cosmonaut Experience

Many of the astronauts and cosmonauts who are hams are not your "dyed in the wool" radio amateurs. They are accustomed to using radios for space communications, but have rarely experienced a ham radio DX pileup or severe QRM. When faced with continual interference from voice repeaters, blasts from packet radio stations and stray voice snipets from simplex operators, the orbiting crew soon grows weary of ham radio as an effective communications medium. It is also very difficult for the orbit crew to change frequencies as they pass from one territory to the next. What are needed are clear uplink channels to the crew members and a set of frequencies that will not require the space crews to switch frequencies from one part of the globe to another.

Summary

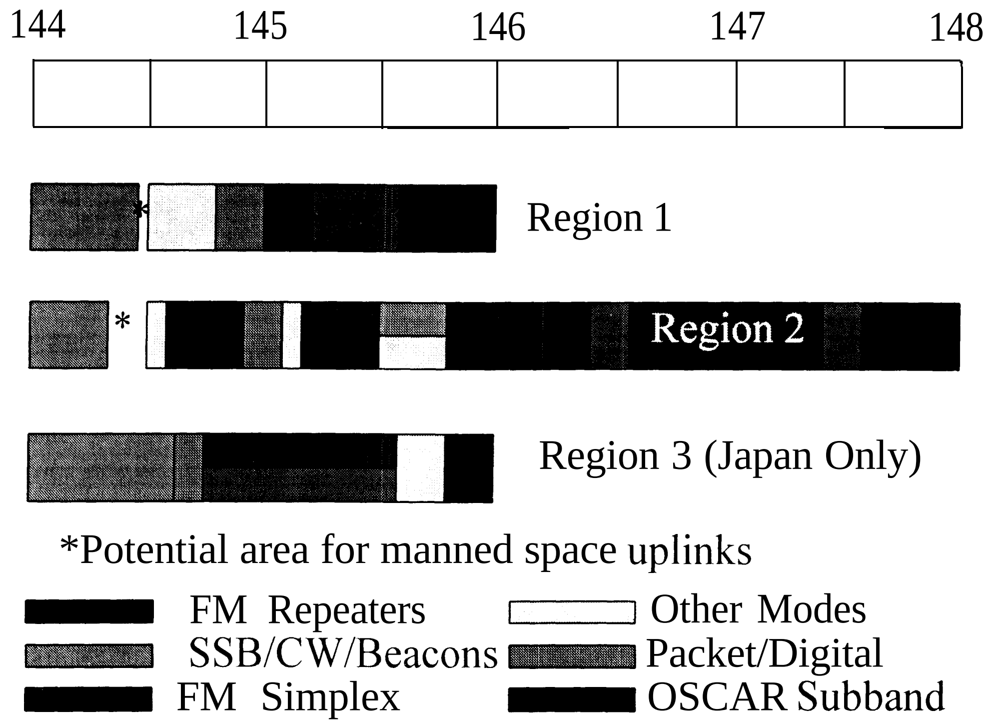
In summary, to effectively communicate with Shuttle, Mir and ISS crews using VHF requires:

1. Clear uplink and downlink frequencies.
2. A minimal channel separation from other activities on 2 meters of'at least 20 kHz with 25-30 kHz being preferable. This separation will cover the Doppler shifts as well as the weak signal concerns.
3. Frequencies that can be used throughout the U.S. since the space station's visibility encompasses the entire U.S. for periods of time.
4. Frequencies that can be used world wide since the space station overlaps several countries at the same time.

Frequencies in Space--What's the Problem??

Right now, frequency interference for manned space vehicles is a tremendous problem on 2-meters. The three IARU regions (Region 1, Region 2, and Region 3) each have differing bandplans. See figure 2. As shown, in many parts of the world the two meter band is only 2 MHz wide (144- 146). Since frequencies at VHF and above are primarily used for line of sight communications, these frequencies have been traditionally coordinated at the local level with no concern for global coordination. This means that many countries within an XARU region each have differing bandplans or "gentleman's agreements". This issue is even worse in the U.S. where "local coordination" occurs at the city, territory (e.g. Southern California, Mid-Atlantic, etc.) or state. In space, this "local coordination" becomes a problem because line of sight communications on the Space Shuttle and Mir (and eventually the International Space Station) overlap several cities, countries or continents simultaneously. This causes interference in space and on the Earth and a violation of these gentlemen's agreements. To date, the 2 meter band represents the most challenging coordination effort because it is the most used amateur radio band and it is currently the primary band for SAREX and Mir.

Until last year, the Mir crew used 145.55 MHz simplex as the amateur radio 2-meter frequency for voice and packet. This frequency was also used as a downlink frequency for SAREX. Many international organizations, especially the European community, have asked that Mir and SAREX move from the 145.55 MHz frequency since it is a popular simplex frequency. See figure 2.



2 meter (144 MHz-148 MHz) Bandplans for IARU regions 1,2, & 3
Figure 2

The Mir crew are currently using 145.80 (downlink) and 145.20 (uplink) for voice and packet. These changes were made by the Russian MAREX team and the German SAFEX team to conform with some of the manned space frequency recommendations that came out of the 1996 Region 1 (Europe, Africa and Middle East) IARU conference in Tel Aviv, Israel. It should be noted that these frequency recommendations have not been approved by the other two IARU regions. While this specific frequency recommendation may work well in parts of Europe, it violates many of the bandplans utilized in Region 2 and Region 3. In particular, 145.20 is absolutely untenable in the U.S. since over 140 repeaters in this country use this frequency or frequencies within 10 kHz of this frequency. Therefore, since the changeover, many U.S. radio amateurs who have attempted to contact Mir have been cited by other local radio amateurs for not following the Region 2 bandplan. This change has also resulted in considerable repeater-generated QRM on-board Mir. This complaint has been lodged by the astronauts and cosmonauts who use the radio on Mir.

The use of 145.80 as a manned space downlink is also a major problem. The primary issue in the U.S. is that this downlink is very near the APRS frequency of 145.79. The primary rationale behind the use of 145.80 as a downlink frequency is that it is right at the edge of the weak signal OSCAR sub-band. This frequency choice is considered to be an excellent compromise as a "guard" between the weak signal satellite users and the terrestrial VHF hams. As stated previously, the Mir and Shuttle downlinks are considered weak signal FM operations. The AMSAT international community would like to keep FM manned space downlinks at or near the OSCAR sub-band edge to minimize interference with CW/SSB weak signal satellites like AMSAT-OSCAR 10 and eventually Phase 3D.

The 145.80/145.20 pair used to be a repeater frequency pair in Europe. It should be noted that the European VHF societies mounted a great campaign over many years to move repeaters off this frequency pair. This was accomplished because 145.80 is right on the band edge of the OSCAR sub-band and these repeaters were interfering with satellite operations. Now that the 145.80 frequency is clear, the European VHF society believes using this frequency is an excellent choice for Mir, Shuttle, and ISS in Europe and will provide and effective way of keeping VHF repeaters in Europe from re-establishing this frequency pair.

In reviewing figure 2, one might arrive at a solution to move the manned space activity into the OSCAR subband (145.80- 146). While the Mir, Shuttle and ISS downlinks are considered weak FM signals, uplinks from terrestrial based hams clearly are not. The AMSAT international community is extremely concerned that high powered uplinks in the weak signal OSCAR sub-band will cause severe interference to OSCAR-l 0 and eventually to the sensitive receive systems on Phase 3D. The compromise is to use frequencies on the sub-band edge (145.80) or close to the sub-band edge for downlinks and move the high powered uplinks to an area well away from the OSCAR sub-band. As shown in figure 2, the asterisk (*) portion of the Region 1 and Region 2 bandplan provides an excellent area for potential manned space uplinks. A portion of this area in Region 2 includes the frequency 144.39. This may be an excellent frequency to move the APRS activities since part of Region 2 (Canada) uses this frequency for APRS now. A combined movement of APRS and the establishment of dedicated, world-wide 2-meter frequencies for Mir, SAREX and ISS will provide an unprecedented level of collaboration and compromise in amateur radio at the national and international level.

Manned Space Frequency Suggestions

The following manned space frequency suggestions have been presented to the AMSAT-NA/ARRL team as well as several IARU consultants in the US and Europe. These seem to solve the manned space frequency problems described in this paper and represent the best compromise between the satellite users and the VHF community.

Manned Space Frequency Suggestions:

1) Worldwide 2-meter Downlink Frequencies for Mir, Shuttle, and ISS:

   145.80, 145.8125* and 145.990* MHz

   *Backups or alternatives to primary 145.80 frequency

2) Worldwide 2-meter Uplink Frequencies for Mir, Shuttle, and ISS:

   144.490, 144.470 and 144.450 MHz

3) If a 600 kHz split pair is desired for Region 1 (Europe, Middle East, and Africa), the following is suggested:

Downlink	145.80
Uplink	145.20

4) The AMSAT-NA VP. for Manned Space Programs will work with the IARU, the ARRL and the U.S. Digital community in an effort to globally coordinate the above frequencies for manned space operations. Global coordination of all non confidential manned space frequencies for 15 meters, 10 meters and 70 cm is highly recommended and should be initiated as soon as possible.

Note that the above split mode frequency recommendations do not preclude simplex operations, if required. F'or simplex operations, the team will use frequencies which will minimize frequency contention such as 144.49 and 144.47, and 144.45.

Conclusions

Communicating with astronauts and cosmonauts is an exciting and challenging facet of amateur radio. Currently the orbiting crews and the ground-based radio amateur endure significant frequency interference issues to achieve success. These frequency problems have limited the growth and success of this communication medium. Moreover, the full potential of this facet of amateur radio to infuse new blood into the hobby through educational opportunities for students and its positive experience to the community has been somewhat stunted due to these frequency problems. Several suggestions have been made to improve the frequency issue on the Mir and the Shuttle. Let's take this opportunity to develop a compromise solution that benefits all and guarantees a strong future for amateur radio. Once accomplished, we can proceed with the design of the amateur radio station on the International Space Station with renewed vigor; knowing that it will soon become the ultimate station for experimenters, DXers and amateur radio educational outreach.