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Considerations Taken in Developing the Frequency Assignment Guidelines for Communications in the Mars Region Provided in SFCG Recommendation 22-1

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Abstract

In the 23rd Annual SFCG meeting in San Diego, CA, the SFCG created SFCG Action Item No. 23/10 to provide a readable summary of the work done by the Mars Interim Working Group (MIWG). The SFCG created the MIWG to develop a frequency plan for future Mars missions. The working group has produced a number of documents resulting in a recommendation, SFCG Rec 22-1 [1], titled Frequency Assignment Guidelines for Communications in Mars Region, including a frequency plan for the Mars Region. This document is prepared in response to the SFCG Action Item to provide an overview of the considerations taken when selecting the frequencies and to point out where detailed information of the considerations can be found.

1 Introduction

The Mars Interim Working Group (MIWG) was created by the SFCG during the 20th annual meeting to recommend a frequency plan for use by future Mars missions for communication and navigation in the Mars region. Since its creation, the IWG had made significant progress and presented its work at each of the subsequent SFCG annual meetings, culminating with a recommended frequency plan for the Mars region in the 23rd SFCG annual meeting, SFCG Rec. 22-1.

The MIWG considered numerous issues for selecting frequency bands for use in the Mars region. The issues were technical and forward-looking. The technical issues included technology maturity, link performance, compatibility between various links around Mars, sharing of the equipment with direct-to-earth (DTE) and direct-from-earth (DFE) links, and in-flight testing. The MIWG looked at current and planned missions for their communications and navigation requirements, as well as at the needs of potential future

missions. The working group also looked at the potential interference to passive observations, particularly the quiet zone in the shielded area of the Moon.

There are several types of links identified in the SFCG Rec. 22-1 around Mars: space-to-Earth, Earth-to-space, orbit-to-surface, surface-to-orbit, surface-to-surface, and orbit-to-orbit. The users around Mars are divided into surface users and orbiting users with orbiting users also act as relay satellites. The surface users can be landers, rovers, balloons, or low-flying airplanes. The surface users communicate with the earth stations either directly through DTE/DFE links or through relay satellites. The connectivity of different types of users around the Mars region can be found in MIWG-6 [6].

This document is intended to provide an overview of the issues that were considered in drafting the frequency plan in SFCG Rec. 22-1 and to point out where additional information regarding these issues can be found in the MIWG documents.

2 Considerations for SFCG Rec. 22-1

When assigning frequency bands for users around Mars, the MIWG considered several factors which are described in this section.

2.1 Bandwidth Availability

Due to the large distance from Earth, there is little restriction on frequency assignments around Mars. With the exception of the direct links with Earth, which are provided in the existing allocations to SRS, there is ample bandwidth for communications within the Mars region. The MIWG has recommended ample bandwidth and multiple bands to each of the different links around Mars.

2.2 Existing, Planned, and Future Mars Missions

When devising the frequency plan, the MIWG looked at the communications and navigation needs of the current and planned missions as well future Mars missions [7]. It looked at the data volume for different classes of missions as well as relay orbiters at different Mars orbits, including low-altitude polar orbits and areostationary orbits [8]. The MIWG also looked at the frequency needs for Mars local high-rate links [3]. The working group examined issues such as hardware availability, performance, coverage, propagation, and evolution of the Mars network for different frequency bands in supporting high-rate links around Mars.

2.3 Link Performance

The MIWG looked at the link performance at different frequencies for different links around Mars. In the current UHF relay system, both the transmitter and the receiver use a low-gain antenna (LGA). In such LGA-LGA links, a lower frequency band minimizes the propagation loss, hence UHF is preferred. In the future where directional high-gain antenna (HGA) is deployed, if a link includes a LGA and an HGA, propagation loss is not affected by the choice of frequency. If a link contains two HGAs, the higher frequency would be preferred as propagation loss decreases as the frequency increases. MIWG-2 [2] discusses the trade-off of different antenna combinations for different frequency bands and for different links. The use of directional HGA requires the antenna

to be able to point. Issues such as antenna pointing and coverage/footprint are also addressed in MIWG-2.

2.4 Sharing Hardware

Most Mars surface elements (landers, rovers, etc.) are expected to have the capability to communicate directly with Earth as well as with an orbiting relay satellite or with another surface element. Similarly, a surface element having the capability to communicate with a relay orbiter may also have the need to communicate with another surface element on Mars. In the interest of reducing spacecraft cost and mass, the MIWG considered selecting frequency bands that would allow sharing of communication hardware between various links. For example, SFCG Rec. 22-1 examines use of 8400-8500 MHz for the surface-to-orbit link, where 8400-8450 MHz is allocated for SRS, deep space, downlink. This allows the surface users to use a modified version of the DTE transmitter with extended frequency capabilities to forward telemetry to a relay satellite carrying a corresponding receiver in the 8450-8500 MHz band. Use of the 8400-8450 MHz for the surface-to-orbit link is also allowed by SFCG Rec. 22-1, but only in the near term when the users are few. As another example, the recommendation allows the use of the 390-405 and 405-450 MHz bands for surface-to-surface communication, and for links between a surface element and an orbiter. Hence the same hardware used to forward telemetry (via a relay satellite) back to Earth can also be used to pass information among different surface users. One potential problem of using the SRS frequency for local links is the interference issue. To solve that problem, the MIWG allows the bands adjacent to the DTE/DFE bands to be used for local Mars links [2][3], enabling sharing or reuse of a relative simple extension of the DTE/DFE equipment. This would benefit future Mars missions in terms of cost and mass savings and at the same time ensure compatibility between the DTE/DFE links and the local links.

2.5 Compatibility with Existing Infrastructure

It is critical that the frequency plan is compatible with existing Mar relay infrastructure. The existing relay orbiters around Mars, such as Mars Odyssey and Mars Express, already carry CCSDS-compliant relay radios as described in MIWG-4 [4]. Since these orbiters are expected to continue to provide relay services and since it is critical for new surface users that rely on relay services to have redundant relay orbiters, the frequency plan of the SFCG 22-1 has to be compatible with the existing infrastructure. This is one of the reasons that the 390-405 and 405-450 MHz bands are recommended as one of the low-rate relay link frequencies.

2.6 Technology Maturities

Technology maturity is one of the factors considered by the MIWG in selecting frequency bands for various Mars local links. In assessing the applicability of a frequency band and its technology maturity for a Mars local link, the MIWG considered using the frequency bands as they are being used in the Earth environment. This would ensure technology maturity and availability of space-qualified equipment. For example, the MIWG examined the use of S-band and Ku-band which are used around Earth for satellite services. Because of the large propagation losses due to the large range between

Mars and Earth, using these frequencies around Mars is compatible with the users around Earth.

2.7 In-Flight Tests

It is often desirable to test the on-board relay equipment long before the spacecraft arrives at Mars. This is especially important for a relay orbiter. In-flight testing allows the mission planners to find out the performance of the relay equipment before it arrives at Mars, and plan accordingly. More importantly, it allows mission planners to determine whether the equipment will be available for the following Mars missions that are currently being designed or built.

Conducting in-flight testing can raise a number of issues. One of these issues is that the frequency used for relay links in the Mars region, i.e. 390-405 MHz and 405-450 MHz bands, are not allocated for the SRS. MIWG-5 [5] suggests RF in-flight testing with narrow band CW signals transmitted at selected frequencies from an Earth station, on a non-interference basis to existing users, to verify the RF performance of antenna and microwave equipment. MIWG-5 also examines the capabilities of the next generations of relay equipment and suggests a possible solution for the future. It includes use of on-board self-testing to verify receiver processor capabilities at the required data rates. It also includes use of frequency agile relay equipment to verify RF performance at test frequencies offset from the operating frequencies.

2.8 Protection of the Shielded-Zone of the Moon

The ITU-R RA.478-4 recommends that special attenuation be paid to emissions into the shield zone of the Moon (SZM) from deep-space platforms or transmitters near or on the Moon. The UHF frequencies used for Mars local communications are part of the frequencies of interest to radioastronomy at SZM. The MIWG concluded that UHF communication systems operating in the Mars environment will generally not interfere with radioastronomy observations in the SZM due to the large distance between Mars and the Moon. The MIWG recognized that in-flight testing of UHF equipment if performed at a small spacecraft-to-Moon distance can violate the protection criteria of the SZM such that in-flight tests of Mars communications equipment should be conducted with the protection of the SZM in mind. The MIWG also suggested that the UHF relay radio equipment developed for the Mars environment not be deployed in the SZM.

2.9 Interference with Other Spacecraft around Mars and Self-Interference

In selecting frequencies for different types of links around Mars, the MIWG examined the potential interference problems among the different spacecraft around Mars and self-interference within the same spacecraft. The interference problems arises when the same frequency bands are used for different types of Mars links so that the same equipment can be used for more than one type of link to conserve spacecraft mass and cost. The MIWG has recommended frequency bands with the intent of minimizing these interference problems while preventing interference to or from the DTE/DFE links.

An example of an inter-spacecraft interference is when an orbiter transmits to another orbiter at the 435-450 MHz band, the signal can interfere with a surface receiver

communicating with an orbiter at the same frequency. A similar interference scenario occurs when a surface-to-surface link at 390-405 MHz takes place near a surface-to-orbit link at the same band simultaneously. When potential inter-spacecraft interference exists, coordination is necessary.

The problem of self-interference occurs when a spacecraft transmits at the same band at the same time a receiver on the same spacecraft is receiving. The transmit signal, which is typically much stronger than a receive signal, can be coupled into the receiver and interfere with the receiver operation or even damage the receiver RF front-end equipment. As an example, the 8400-8450 MHz band which is allocated by ITU for SRS (deep-space) downlinking to earth stations is recommended by the MIWG for surface-to-orbiter links in the Mars region. If an orbiter transmits to Earth at the same time it receives from a surface user in the same band, the receiver will be interfered and perhaps damaged. The same is true as the 390-405 MHz and 435-450 MHz bands, which are recommended for surface-to-orbit and orbit-to-surface links, respectively, are also set aside for orbiter-to-orbiter links. The receiver of an orbiter can, hence, be interfered or damaged if there the transmitter on the same spacecraft is communicating at the same frequency at the same time. In the cases where self-interference may occur, coordination will be necessary.

3 Conclusion

The SFCG MIWG has specified a frequency plan for the Mars region, a set of frequency assignment guidelines contained in SFCG Recommendation 22-1. This frequency plan provides ample bandwidths and multiple choices of frequency for various links. It also identified various issues associated with usage of some of these frequency bands and recommended solutions for these issues. This frequency plan provides a platform for missions from different agencies to operate compatibly. The considerations that went into developing the frequency plan, as described in the recommendation, have been presented here.

4 References

The following documents are available at the SFCG Website: www.sfcgonline.org.

[1] MIWG-1, SFCG 22-1 Recommendation, October 2002

[2] MIWG-2, Notes on Mars Local Link Frequencies Recommended, October 2002

[3] MIWG-3, Frequencies for Mars Local High Rate Link, April 2003

[4] MIWG-4, Frequencies in the CCSDS Proximity-1 Standard, April 2003

[5] MIWG-5, In-Flight Testing of Onboard UHF Equipment, September 2002

[6] MIWG-6, Connectivity Required to Support Mars Missions, April 2003

[7] MIWG-7, Mars Missions: Already in Flight or Committed to Launch, and Future Possibilities, April 2003

[8] MIWG-8, Strategies for Telecommunications and Navigation in Support of Mars Exploration, October 2000

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