Spectrum Management for Lunar and Mars Space Initiatives

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Abstract

This submission will examine anticipated electromagnetic spectrum requirements for space communications over the next quarter-century in planning lunar and Martian spacecraft transit, navigation, orbiting, docking, and landing missions. Missions, goals, and requirements will be identified, including those necessary for Earth-based ground network antennas. Six nations/organizations are planning lunar or Martian space missions which will require collaboration to ensure that sufficient spectrum is identified and that there will be compatibility among all spacecraft, modules, capsules, probes, and relay satellites. The timeframe for introduction of missions will be proposed. Technical requirements for protocols, hardware compatibility and perhaps also interoperability among these nations/organizations will be postulated.

1. Summary

Six nations or organizations are headed to the moon or to Mars in coming years. Consequently, it is necessary for them to plan and to develop a coordinated set of agreements or understandings so that operations are completely compatible and particularly that no electromagnetic interference can occur. Communications with astronauts in space must be continuous for these missions. Additionally, economical benefits are possible through close planning and coordination. The International Space Station, planned and operated between the Russian Federation and the United States, with other partners, is an excellent model in demonstrating the benefits of cooperation in space.

In the United States, certain space-related architecture can be foreseen until about the year 2030. Space missions, goals, and requirements can be identified. Ground network antennas used for space communications can be optimized. In the case of moon exploration and establishment of a permanent base there, related architecture and spectrum can be foreseen through the year 2015. There are space communications issues that must be addressed. Data rates and technologies must be agreed. The agenda for the 2011 Radio Regulations world radiocommunication treaty conference of the International Telecommunication Union, the United Nations specialized agency for telecommunications, will include addressing new spectrum allocations to ensure that adequate bandwidth to accommodate needed data rates, is available in the foreseen timeframe for all space endeavors.

Six agencies are discussing lunar and Martian protocols on space communications compatibility and interoperability:

- Russian Federation (RFSA)
- Peoples Republic of China (CNSA)
- India (ISRO)
- Japan (JAXA)
- European Union (ESA)
- United States (NASA)

An explanation of the top-level space communications architecture that may be applicable to these agencies will be given in this paper. Following that will be an explanation of other levels of network, security, spectrum, and navigation architecture. Issues identified so far include of (1) no lunar backside communications capability, (2) limited lunar pole coverage, (3) faster data rates with associated spectrum bandwidth needed for information and telemetry transfer, (4) precise navigation/timing needs, and (5) additional spectrum links that are foreseen.

Recently, the U.S. National Aeronautics and Space Administration (NASA) has been working with the RFSA, CNSA, ISRO, JAXA, and ESA to particularly advance communication and navigation concepts for system compatibility, and interoperability for missions to the moon and to Mars. NASA hopes to find consolidated positions and consensus on these issues.

Network architecture: Newly-required systems are to be integrated with legacy networks and extensive use should be made of programmable communication devices (software-defined radios) to allow reconfiguration and upgrade as technologies and missions evolve. Software-defined radio is a radio that includes a transmitter in which the operating parameters of frequency range, modulation type or maximum output power (either radiated or conducted) can be altered by making a change in software without making any changes to hardware components that affect the radio frequency emissions.

Security architecture: Provision is to be made of selectable data-protection services for users needing them. Confidentiality and authentication must be included. Mission planners should have freedom to select security provided by the infrastructure or to uniquely develop security programs.

Spectrum architecture: Communication and navigation spectrum adopted by treaty in the Radio Regulations of the International Telecommunication Union is to be used. Additionally needed spectrum allocations and sharing protection should be pursued. Appropriate coordination of spectrum must occur with international agencies. Compatibility and interoperability with other space-fairing users is sought.

Navigation architecture: Conventional radiometric tracking is to be supported, relying on GPS for missions from low-Earth orbit to geostationary-Earth orbit. A common time reference should be supported and distributed to users.

Space communication and navigation requirements include:

- Connectivity to exploration and science program vehicles
- Knowing spacecraft position precisely
- Transferring mission data
- Vehicle telemetry
- Voice commands

Using these requirements, the lunar architecture is evolved based on an assumed human base at the South Pole of the moon. Two moon-circling relay satellites orbit to support both South and North Pole missions. A second plane of relay satellites is added to increase coverage at both the South and North Poles and provide complete coverage. Orbital planes are inclined to support global, far-side and equatorial missions. The final configuration visualized is six relay satellites with two in inclined circular orbits. The advantage is global coverage that is more evenly distributed than for polar orbits and is better suited to support exploration at lower latitudes of the moon.

Space communications networks are three types, viz., (1) the space network (SN) consisting of a system of Earth relay satellites covering low-Earth orbit, noting that relay satellites simplify the number of terminals; (2) the deep space network (DSN) consisting of three installations near Madrid, Canberra, and Goldstone with large antennas for missions into deep space (beyond 2×10^6 kilometers); and (3) the ground network (GN) consisting of a system of Earth-based ground stations principally used for communicating with Earth-orbit satellites.

Insofar as Earth antenna arrays are concerned, arrays (26, 32, and 38 GHz) can be built into virtual large aperture antennas for high data rates as proven by the European Galileo system. Arrays can be scalable in small increments as space programs develop. The array locations are presumed at the deep space sites for continuous coverage. Sub-arrays can be formed to support separate missions. Arrays provide graceful degradation in the event of failure. A 12 meter diameter appears optimum for communications and for an international common parts/maintenance protocol.

For near-Earth and near-lunar communications, the S-band (2025-2110 MHz for uplinks, and 2200-2290 MHz for downlinks) is used by the Telecommunications Data Relay Satellite System (TDRSS). The ground network is used for continuous coverage from launch to low-Earth orbit and then to 30,000 kilometers with TDRSS. Beyond 30,000 kilometers, the ground network alone can provide continuous coverage to the moon.