Technical Review Paper Evaluation Form

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Lunar Communications Networks and Applications

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September 30, 2019

1 Introduction

NASA is going back to the Moon in 2024, and improved communications systems are a demand that will not be considered lightly! Considerable advances in antenna and internet-of-things technologies have been made since the Apollo era. It is of critical importance that these technologies be integrated into the Artemis missions to improve the communications abilities of hardware and humans on the Moon. The following technical review focuses on the lunar comm network: its history, environment, and future.

2 Lunar Comm

2.1 History

Historically, the Apollo lunar module had an extravehicular activity (EVA) Antenna that communicated over VHF (Very High Frequency). This antenna had an omni-directional radiation pattern and was used for communications between the lunar module and the EVA crew. It had two VHF antennas with omni-directional communications between the lunar module and the command service module. The lunar module also contained an S band steerable antenna that was unidirectional, auto-tracking, and crew manually pointed for communications between the lunar module and the ground and space network. Furthermore, it had an S band inflight forward antenna and an S band inflight after antenna. Only one was used at a time for communications between the lunar module and the ground and space network. Finally, there was an S band erectable antenna that was setup during an EVA as the primary communications link between the lunar module and the ground and space network [1,2].

During the Apollo missions, audio was both transmitted and received over 296.8 MHz between the lunar module and the command service module. A backup frequency channel designed was at 259.7 MHz, and this could behave in both duplex operations and simplex operations. The data rate between the lunar module and the command service module was 1.6 kbps. The lunar module could transmit to the astronauts over 296.8 MHz. The second astronaut transmitted voice and data to the first astronaut over 279.0 MHz, and the first astronaut served as a return link to the lunar module at 259.7 MHz with both voices [1,2]. The lunar rover also communicated over VHF to both astronauts. In summary, all on Moon lunar comm was done in VHF bands.

2.2 Lunar Environment

There are many environmental design factors to consider when implementing an RF network on the Moon. The Artemis program aspires to land its first manned mission on the Moon's South Pole [3]. It has been shown from lunar samples collected at the central part of the visible side of the Moon that the real component of the dielectric permittivity varies with frequency. As frequency reaches the GHz and higher ranges, dielectric permittivity decreases due to losses associated with conductivity and polarization of the regolith [4]. It is also significant to note that the dielectric properties of the lunar poles may also have different behavior due to the combination of ice and regolith only found there. Electric permittivity is estimated at 3.0537 at the CE-3 landing site [5]. Cosmic noise is also a dominant factor in lunar comm networks. The bands between 100 MHz to 1 GHz see greater levels of galactic and solar noise than the 1 GHz to 10 GHz [6]. From regolith properties and cosmic noise, it can be seen that comm over Wi-Gig, Wi-Fi and LTE bands are important because they are the most effective in the lunar environment.

An additional factor worth noting is losing line of sight due to the Moon's rugged terrain. While NASA has not yet selected a landing location within the south pole, it can be anticipated that signal range may be impaired by terrain.

3 Future Lunar Technology

3.1 Network Architecture Building Blocks

The following design constraints are vital to the next lunar comm network architecture: minimize avionics SWaP (size weight and power) in the Flight Vehicle, modularity of architecture and design, minimize costs, minimize risks, minimize logistics and maintenance, support heterogeneity, strive for "commonality". Through these expectations, there is an emphasis on developing a standards-based autonomous, self-organizing, self-healing wireless network for future lunar missions. Nodes functioning over Wi-Gig, Wi-Fi, and LTE will create "collections of meshes with frequent cross-links" [7]. Wireless local area networks (LANs), sensor networks, low-power or passive (no power) sensors, and minimized wiring will be integrated wherever possible. The intent of this is based on an expectation that the architecture will require minimum crew time. Additionally, future exploration missions are expected to be multiple vehicles with multiple network sources. Multiple hardware vendors will be contributing to these vehicles, once again emphasizing the importance of modularity and a multi-node network.

3.2 Commercial Lunar Technology Applications

Off the shelf solutions exist for these low-power and passive sensors mentioned above. For example, low power laser range sensors, a device commonly used on rover-type robots can be purchased on earth for as little as $40 [9]. After space rating this low-power hardware, it would be ready to implement on larger systems like future lunar landers. Providing the infrastructure to support a range of low-power space rated sensors would enable humans to use more off the shelf solutions in the design of larger lunar systems.

As alluded to previously, multi node networks are significant to future lunar exploration. A preliminary study on telerobotics for lunar missions was conducted with three astronauts on the international space station. These astronauts were given a software package to run on their computers. Using this, it was found the astronauts could remotely control the telemetry of robots stationed in NASA's robotics research, development, and test facility [10]. From this proof of concept, it is concluded that crew have the ability to remotely operate surface robots (i.e. lunar landers) from inside a flight vehicle (i.e. lunar lander).

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