

ECE4011/ECE 4012 Project Summary

Project Title	2.4 GHz Phased Array System for Lunar Extravehicular Activity (EVA) Communications
Team Members (names and majors)	Sarah Deitke
	Baris Gurses
	Lucas Wray
Advisor / Section	Dr. Greg Durgin / Section L7A
Semester	Spring 2020 Intermediate (ECE 4012)
Project Abstract (250-300 words)	<p>A recent surge in interest in crewed lunar exploration has brought with it a slew of unmet technological challenges critical to mission performance. In the decades since Apollo, bandwidth demands in space communications have steadily increased as more data from more sensors has become the norm. Future human extravehicular activities (EVAs) on the lunar surface will almost certainly be faced with similar challenges. Unlike the relatively simple data demands of the Apollo EVAs (voice, simple life support telemetry), the data of NASA's proposed Artemis missions might include high-definition video and commands/data for multiple peripherals located in the field. The inclusion of a 2.4 GHz Wi-Fi comm system has been proposed by NASA, which would improve baud rates by a factor of 200 versus the conventional VHF systems (used for Apollo EVAs and ISS spacewalks). However, a major hindrance associated with this Wi-Fi system is its limited range, which directly constrains the operational radius for exploration.</p> <p>Our group developed a lander-mounted communications system prototype to improve operational range for missions. The design utilized a cluster of linear arrays to direct radiation—and thus maximize gain—in the direction of astronauts on the surface. These arrays were fabricated on single boards containing patch antennas and Butler matrix feed networks for beamforming. Iterations of the design incorporated findings from environmental simulations in both HFSS and Excel. Once a final design was reached, the necessary boards were fabricated and populated. Measurements and simulation characterized the system's radiation properties and range capabilities. Overall, the prototype aimed to solve the problem of high-speed EVA comms at longer ranges while following a spaceflight-conscious approach: free of failure-prone mechanical actuators and low in power consumption.</p>

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List codes and standards that significantly affect your project. Briefly describe how they influenced your design.	Since the phased array's design were heavily governed by its frequency of operation, IEEE wireless communication standards were influential in our design. NASA's new lunar campaign, named Artemis, outlines a plan to utilize Wi-Fi links between the lunar module and other mobile equipment (EVA suits, lunar rover, etc.). Therefore, we designed our phased array to operate in the WLAN (Wireless Local Area Network) frequencies, more specifically 2.4 GHz frequency. Therefore, IEEE 802.11 standards for Wi-Fi communications were our most significant resource. Specifically, IEEE 802.11b/g/n/ax standards influenced our design choices since these specific standards govern the 2.4 GHz Wi-Fi communications. Additionally, all of the components needed to be certified for space applications by the EEE-INST-001 and EEE-INST-002 standards specified by NASA.
List at least two significant realistic design constraints that applied to your project. Briefly describe how they affected your design.	A combination of cosmic noise limitations and available off-the-shelf products limits the frequency bands of communication to a range to 50 MHz – 10 GHz. Because of this, we chose to communicate at a 2.4 GHz frequency. This is a popular communications band for Wi-Fi enabled devices which will be incorporated in many other pieces of hardware in the overall lunar comm system. In antenna engineering, there is always a constraint between greater beam width or greater directivity. Therefore, in order to obtain a greater range of communication with astronauts as they travel away from the lander, very precise electrical steering was required. Our limitations in implementing realistic electrical steering indicated how directive we could design the beam and the range of communication we could expect from the antenna.
Briefly explain two significant trade-offs considered in your design, including options considered and the solution chosen.	The first trade-off in our design stemmed from phased array architectures. Phased arrays require multiple antennas, each with its own feeding network. This increased the size, weight, and consumed power of the system, critical criteria for space missions. To tackle this, we considered utilizing more efficient feeding networks such as Butler matrices or Rotman lenses, and we decided on Butler matrices due to their more straightforward and efficient design. The second trade-off in our design was due to the directionality of phased arrays. Although phased arrays utilize beam steering to cover all directions, PCBs, on which the antennas were printed, block and narrow the antennas' radiation to one half of the azimuthal plane and taper the radiation intensity as it gets close to 0° and 180°. To alleviate this issue, we decided to utilize three PCBs placed 120° apart from each other to cover all 360° on the azimuthal plane.
Briefly describe the computing aspects of your projects, specifically identifying hardware-software tradeoffs, interfaces, and/or interactions. <i>Complete if applicable; required if team includes CmpE majors.</i>	Our group used a combination of HFSS (High Frequency Structure Simulator) and Excel to complete the computing aspects of our design. HFSS was used to make observations about the far field radiation patterns and connection designs between the antenna and feed. Excel was used to compute the link equation of the system on the lunar surface. This design project utilized electrical steering rather than mechanical steering of the antenna to optimize the hardware-software tradeoffs and interactions. By minimizing hardware, this design is less expensive to fly.

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<p>Leadership Roles (ECE4011 & Forecasted for ECE4012) (NOTE: ECE4012 requires definition of additional leadership roles including:</p> <ol style="list-style-type: none"> 1. Webmaster 2. Expo coordinator 3. Documentation 	<p>Sarah Deitke – Webmaster, Antenna/Propagation Environment Simulation Lead, PCB Fabrication Lead Baris Gurses – Expo Coordinator, Feed Network Systems Lead Lucas Wray – Documentation Coordinator, Antenna Design Lead, PCB Layout Lead</p>
<p>International Program: Global Issues (Less than one page) (Only teams with one or more International Program participants need to complete this section)</p>	N/A