Earth-Moon Distance Measurement

Low-Cost 1.296 GHz EME System and Feed Antenna

Students

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Introduction: Bouncing electromagnetic signals off the Moon enables a variety of experiments, most notably the measurement of the Earth-Moon distance. While such experiments were historically limited to highly specialized facilities, modern RF components have made Earth-Moon-Earth (EME) setups feasible even for modest budgets. This thesis investigates a low-cost EME distance measurement at 1.296 GHz, based on time-of-flight and a 1.8 m diameter parabolic dish antenna installed on one of the buildings of OST Rapperswil. The selected frequency provides a practical compromise between antenna gain, system losses, and achievable transmit (TX) power for a dish this size.

Approach / Technology: Achieving a detectable EME signal with the limited antenna gain requires high TX power. Since commercial high-power amplifiers from reputable brands were beyond the project budget, a 140 W power amplifier (PA) acquired from a radio amateur was used, driven by a medium-power pre-amplifier.

Signal generation and detection were realized using a USRP. Different signals were evaluated with respect to ranging accuracy and implementation effort. Continuous-wave (CW) transmission was used to verify system functionality and to observe Doppler effects. For distance measurement, an advanced signal form, optimized for timing accuracy as well as recognizability by amateur radio operators, was employed. This enabled estimation of the Earth-Moon distance via cross-correlation of the received signal with the known transmitted sequence.

To protect the receiver (RX) during high-power transmission, TX/RX isolation was implemented using mechanical RF relays. Out-of-band emissions were reduced by placing a high-power circulator after the power amplifier. On the receiver side, a low-noise amplifier (LNA) was positioned close to the antenna to minimize the system noise figure.

A dedicated feed antenna was designed for the existing parabolic dish. Several antenna concepts were evaluated, and a mechanically robust patch antenna fabricated from aluminium sheets was selected for its weather resistance and suitable illumination of the dish aperture while minimizing spillover. The feed antenna was simulated in Ansys HFSS and validated by measurements, performed using a drone-based measurement setup developed in a separate student project. A gain of 26.5 dBi was measured, which is close to the calculated maximum of about 27.8 dBi.

Conclusion: A complete low-budget EME system was successfully implemented and verified to operate as intended. While the realized TX power proved insufficient for a conclusive Earth-Moon distance measurement, the results clearly identify the link budget as the limiting factor. Increasing the available RF power or using a larger parabolic dish would likely enable successful distance measurements.

Fig. 1: The EME measurement setup including USRP, TX amplifiers, circulator, power supplies, and dish control.
Own presentment

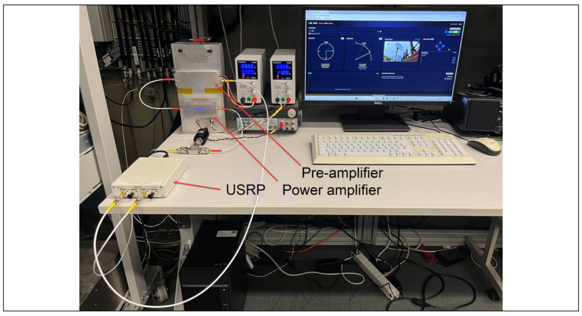


Fig. 2: Simulated and measured S11 of the designed feed antenna at 1.296 GHz.
Own presentment

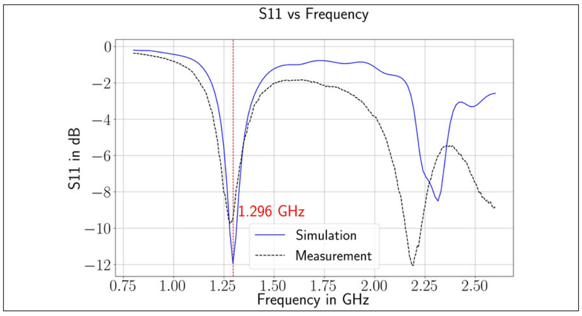
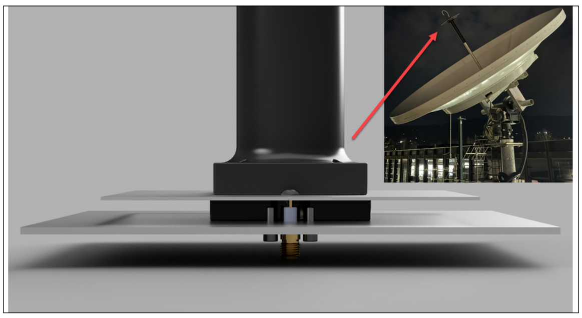


Fig. 3: Rendering of the aluminum patch feed antenna and its installation on the dish.
Own presentment



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