Computer modeling of the parabolic dish antenna with a special feed for left and right-hand circular polarization

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***Abstract*—**This paper deals with a computer model and the simulation results of the parabolic dish antenna. At first, design of the feed antenna used for illumination of the dish is described and its parameters are modeled and optimized using two EM field solvers based on the finite elements method. Finally, the feed antenna is put together with the parabolic dish reflector and the whole system is simulated to obtain radiation pattern and estimated gain.

***Keywords*—**Antenna simulation, Circular polarization, Parabolic antenna.

I. Introduction

THE presented antenna is intended for use for experimental communication using radio wave reflection from the Moon surface. Circular polarization is used for this experimental communication in order to eliminate influence of the Faraday rotation [1]. Since the sense of rotation of the circular polarization changes in opposite when the wave is reflected, it is necessary to use left-hand circular polarization (LHCP) for receiver and right-hand circular polarization (RHCP) for transmitter. This effect can be achieved using a horn feed with a septum polarizer [2][3]. However the dish antenna (1,9 m diameter) is intended for use on the wavelength 23 cm (frequency 1296 MHz), thus this solution results in large physical dimensions of the horn. This cause decreasing of antenna efficiency, since large feed structure shields significant area of the aperture of the dish. For this reason, a feed antenna on principle of radiating circular slot with a switched excitation was designed. Final structure was optimized using a computer model in CST Microwave Studio.

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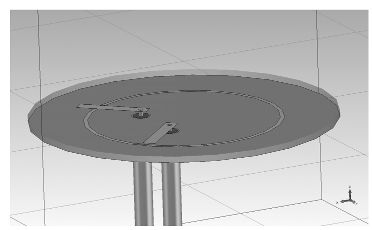
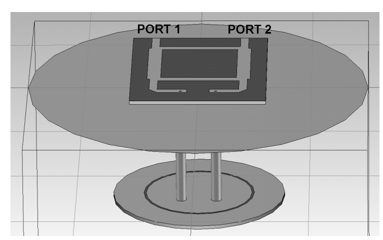
The time domain solver was used for simulation of the complete dish antenna. The feed antenna structure was also modeled in frequency domain using Ansoft HFSS simulator.

II. Slot loop antenna with circular polarization

The primary antenna is based on a circular slot in a metal plate, that is excited by two microstrip probes rotated by 90 degrees and fed by a signal with 90 degrees phase shift. Detailed view of the slot with probes is depicted in fig. 1a. The slot length is approximately one wavelength at the working frequency. The slot is etched in metallization of Arlon 25N dielectric substrate (thickness 1.5 mm with relative permittivity 3.28).



(a)



(b)

Fig. 1. Detail of the slot loop fed by two probes (a). The feeding network using 90 degree microstrip hybrid coupler (b).

To achieve the 90 degrees phase shift of the excitation signal, a microstrip hybrid coupler was designed (fig. 1b). The coupler is placed on the bottom side of antenna reflector and is connected with radiator by a semi-rigid coaxial transmission line. In receiving configuration first port is connected to a receiver and second port is terminated by a 50 Ohm load. In transmitting configuration first port is terminated and second port is connected to a transmitter. In final version of the antenna, the switching will be performed by a microwave coaxial relay.

In order to achieve good dish antenna efficiency, the feed antenna radiating pattern must satisfy certain criteria to achieve good reflector illumination [4]. The best compromise between the spillover and illumination efficiency is to keep edge taper of radiation pattern of the feed antenna between 10 and 13 dB [5]. To satisfy this condition, one director and modified reflector has to be used. The director was designed in the same way as the radiator (a slot in the metallization of the dielectric substrate) and it is held in front of the radiator by a dielectric rod. The reflector has raised edges in order to minimize sidelobes. Complete model of the feed antenna is depicted in fig. 2.

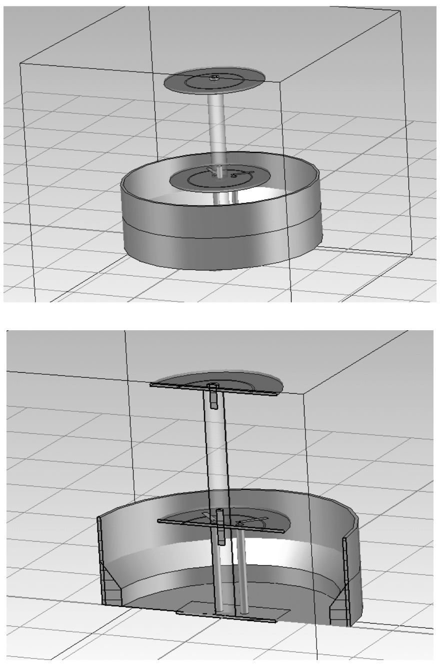


Fig. 2. Complete feed antenna (full view and transversal cut).

III. MODELING OF THE FEED ANTENNA USING FINITE ELEMENT METHOD

Two FEM (Finite Element Method) solvers were used for optimization and analysis of the structure - CST MWS time domain solver and Ansoft HFSS frequency domain solver. The time domain solver is more suitable for calculation in larger bandwidth and it consumes less memory than the frequency domain solver. On the other hand, the frequency domain solver with adaptive meshing produces accurate solution without need of complex settings. For this reason, the frequency domain solver was used to confirm proper setting of the time domain solver mesh parameters. This was achieved by comparing calculated s-parameters. Finally, the time domain solver was used for simulation of the feed with the dish.

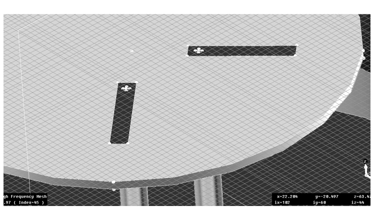


Fig. 4. Discretization in the proximity of excitation microstrips (CST MWS time domain solver).

The Ansoft HFSS solver uses adaptive hexahedral meshing, which is based on iterative mesh refinement. The difference in s-parameters between two solutions is monitored and the mesh is refined in regions with significant error [6]. This results in dense mesh in regions with high EM field intensity, as shown in fig. 3.

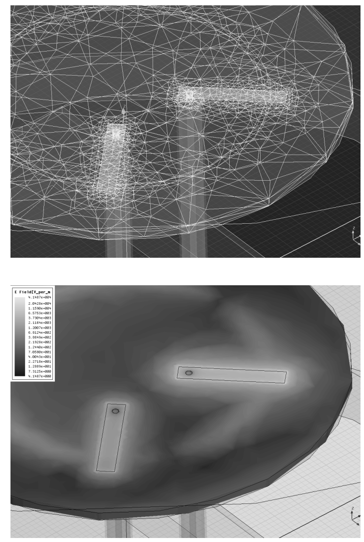


Fig. 3. Detail of discretization and calculated electric field in the proximity of excitation microstrips (Ansoft HFSS frequency domain solver).

On the other hand, the CST MWS time domain solver uses hexahedral mesh and the finite integration method (FI-Method) in conjunction with the Perfect Boundary Approximation [7]. The mesh is generated by the automatic mesh generator. However the generator parameters must be correctly set by the user, or the adaptive mesh refinement can be optionally used as well . The mesh used in model is shown in fig. 4. The return loss of the feed antenna calculated by both solvers is compared in fig. 5. The results show relatively good agreement, so we can assume that solvers are configured properly.

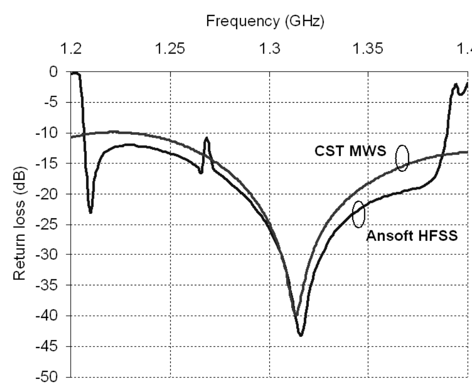


Fig. 5. Comparison of calculated return loss using Ansoft HFSS and CST MWS solver.

As can be seen in fig. 5, the minimum of the return loss is not exactly at working frequency. This is a compromise between impedance matching and optimal shape of radiation pattern, caused by the distance between the radiator, reflector and director. However, the return loss is still lower than -20 dB at working frequency.

The simulated shape of the antenna directivity pattern is shown in fig. 6. Directivity is normalized, so that 0 dB represents maximum of radiation. For the given parameters of the parabolic dish, it was calculated that the edge taper (as mentioned in previous section) should occur at the angle 64 degrees from the axis. It can be observed from fig. 6, that the edge taper is optimized to -11 dB at the given angle.

Simulated axial ratio is lower than 1.5 dB within angle ±50 degrees.

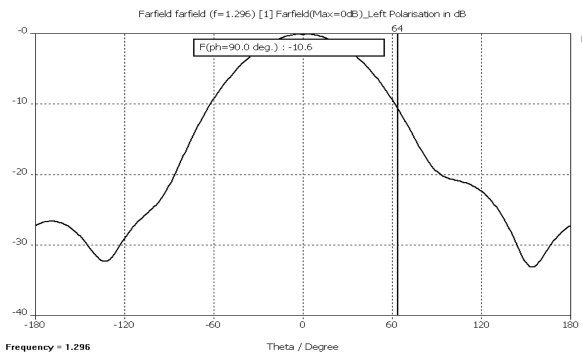


Fig. 6. Simulated shape of antenna directivity pattern.

IV. Modeling of the Parabolic Dish Antenna

After the design of the feed antenna, the whole system consisting of the feed antenna and the dish was modeled (see

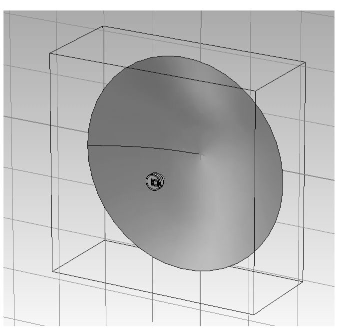
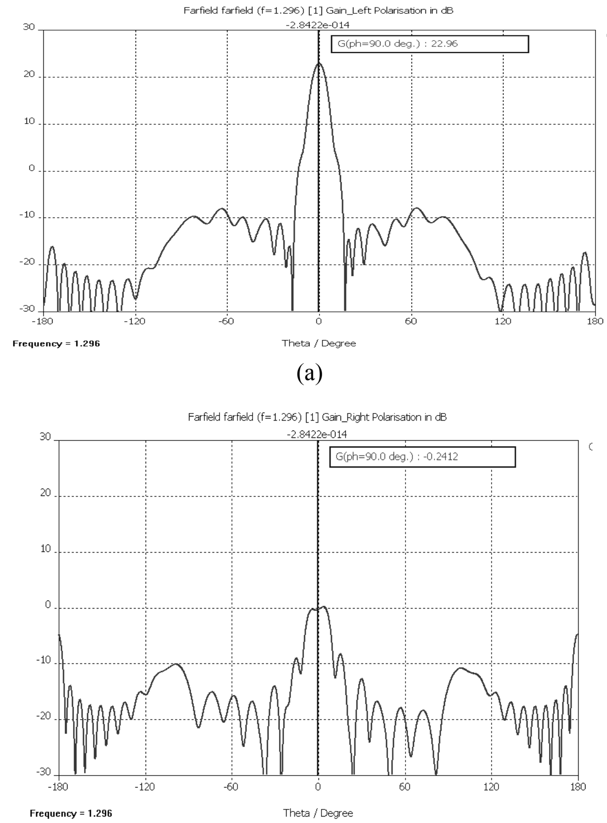


Fig. 7. Complete antenna system prepared for simulation in CST MWS.

fig. 7). We have considered diameter of the dish 1900 mm and *f*/*D* ratio 0,4. Then the focus is located in distance 760 mm from the center of the dish. The feed antenna is positioned so that its calculated phase center is located in the focus of the dish. For simulation was used CST MWS time domain solver. The used simulation setup results in about 70 millions finite elements.

The results of the simulation are depicted in fig. 8. The feed antenna was set for LHCP. The resulting maximal gain is 23 dB and 3 dB beamwidth is 8 degrees (fig. 8a). For RHCP, the maximal gain is 0 dB (fig. 8b), i.e. the isolation between LHCP and RHCP is 23 dB.



(a)

(b)

Fig. 8. Simulated gain of the dish antenna for LHCP (a) and RHCP (b).

V. Conclusion

In the next step, the feed antenna will be fabricated and measured. The RX/TX switching relay will be installed and the feed will be assembled with the dish. Finally, the antenna will be used for experimental Earth-Moon-Earth communication.

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