A PATCH ANTENNA CONCEPT FOR THE LUNAR-ORBITING DAPPER SPACECRAFT

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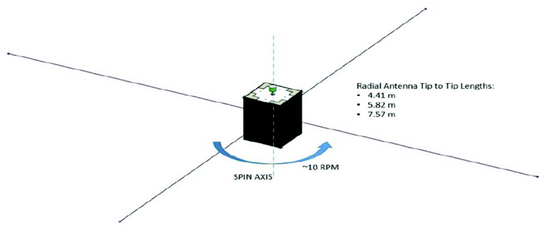
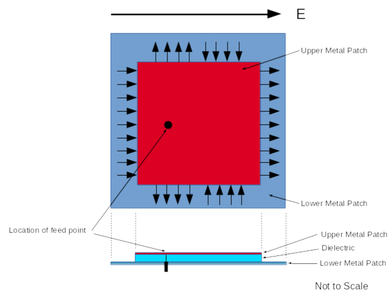
Purpose

The primary motivation for developing a new antenna is to mitigate the complex beam structure associated with using thin wire designs at frequencies where the physical length of the wires is longer than a half wavelength.



Basic Patch Antenna

The antenna is a layered structure consisting of a lower metal plate that forms a ground plane, a non-conductive (dielectric) layer, and a metal plate at the top. In this case, the layers are square but could take on other shapes. The terminal is formed by attaching an unbalanced transmission line such as a coaxial cable to the structure with the ground bonded to the ground plane with the center conductor that protrudes through the dielectric and attached to the top plate.

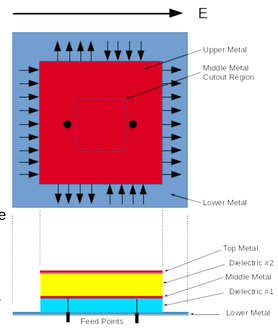


Stacked Patch Antenna

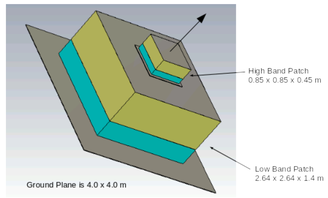
Due to the relatively high Q of this resonator, the basic patch operates over a narrow bandwidth, typically about 3% or less, which results in skewing of the beam off boresight and a reduction in the real part of the terminal impedance for frequencies near the edges of this bandwidth.

The skewing can be corrected by using a pair of feed points placed symmetrically about the center line and fed 180 degrees out of phase. The bandwidth can be increased by increasing the thickness of the dielectric and adding another resonator stacked on top that is tuned to a higher frequency.

In this configuration, the middle plate has a cut-out in the center (dashed region) to enhance the coupling between the lower and upper cavities.



Modeling the Patch Antenna

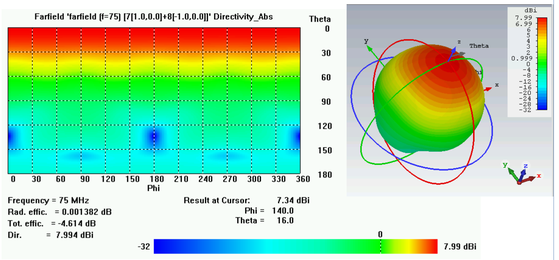


The stacked configuration was optimized for the two DAPPER bands (15-30 MHz and 60-110 MHz) using CST EM Studio. A rendering of the model is shown. However, only the high frequency patch was adopted for DAPPER – the wire monopoles will be used for the low band.

For the high frequency antenna, the bottom dielectric material (ε_r= 6) is 0.15m thick and the upper dielectric (ε_r ~ 1) is 0.3m thick, yielding a total height of 0.45m.

Modeling the Patch Antenna

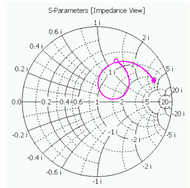
A representative beam pattern of the patch antenna at 75 MHz is shown in both two and three dimensional formats as simulated by CST EM. The weak dependence of the beam pattern on frequency is an important characteristic for DAPPER.

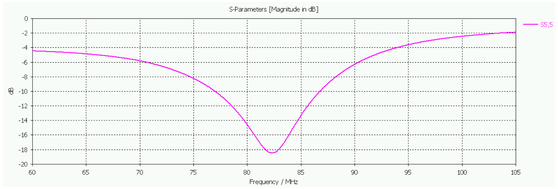


Modeling the Patch Antenna

Reflection coefficient at the terminals of the patch antenna for a 50 ohm system shown on a Smith Chart and magnitude in dB.

The efficiency of the antenna is greater then 10% across the band and approaches 90% near the resonant frequency.

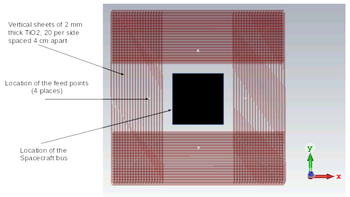




Fabrication of the Patch Antenna

One challenge associated with the construction of the antenna is the realization of a non-conductive material having a relative dielectric constant of approximately 6.0.

Polymers such as polyvinylidenefloride (PVDF) Can be used but these have a mass density of around 1,750 kg/m3, yielding a block of this size much too massive for spaceflight.



One approach to circumventing this problem is to fabricate the non-conductive (ε_r= 6) material using thin sheets of a very high dielectric material such as titanium dioxide (TiO2) that has an ε_r~80-100 laminated together with sheets of foam material (ε_r~1) such that the *effective* dielectric constant of the laminated block is approximately 6.

This process and others are currently under development.

Conclusions

- A new antenna has been adopted for the DAPPER spacecraft to cover the 60-110 MHz band.
- The basic design concept is completed.
- The detailed design and prototype development are currently underway.
- A study is underway to determine how best to fabricate a light weight dielectric material having a dielectric constant of approximately 6.

Acknowledgment

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