Compact, Lightweight Dual-Frequency Microstrip Antenna Feed for Future Soil Moisture and Sea Surface Salinity Missions

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Abstract— **The development of a compact, lightweight, dual-frequency antenna feed for future soil moisture and sea surface salinity (SSS) missions is described. The design is based on the microstrip stacked-patch array (MSPA) to be used to feed a large lightweight deployable rotating mesh antenna for spaceborne L-band (~1 GHz) passive and active sensing systems. The design features will also enable applications to airborne sensors operating on small aircrafts. This paper describes the design of stacked patch elements, 16-element array configuration and power-divider beam forming network. The test results from the fabrication of stacked patches and power divider were also described.**

I. INTRODUCTION

The development of a compact dual-frequency antenna feed for future soil moisture and sea surface salinity (SSS) missions is described. Soil moisture and SSS are high priority measurements for the study of global water cycle and hence climate changes. In response to these measurement needs, two missions, Aquarius (sea surface salinity) and Hydros (soil moisture), were selected recently for the third NASA Earth System Science Pathfinder (ESSP) program. Both mission concepts use the offset parabolic antenna designs with conical feed horns for integrated radar and radiometer operations at L-band (~1 GHz) frequency. The Hydros mission proposes a 6-m diameter lightweight deployable rotating antenna [1], while the Aquarius mission plans a 3-m diameter pushbroom antenna with three conical feedhorns. Future high-resolution systems operating at low microwave frequencies (L-band) will require large reflectors with multiple feeds [4,5]. These feeds must be compact and lightweight, with dual-frequency capability for passive and active sensing [1,3], which is the motivation for this development program.

The microstrip stacked-patch array will be a factor of 3 lighter, and a factor of 10 shorter, than the conical feedhorn design traditionally used to illuminate reflector antennas. The key feature is the stacked-patch design with two resonant frequencies at 1.26 and 1.41 GHz for L-band radar and radiometer operations. This is a three-year technology development, which was started in November 2002. The first task is to obtain an optimal design for a single microstrip stacked patch to achieve desired resonant frequencies and minimum return loss. The second task conducted in FY04 will be to develop the MSPA, including the array of stacked patches and power divider for beam forming. The third task planned for FY05 is to measure the insertion loss and stability of the MSPA with a cold sky radiometric calibration technique. This paper presents theoretical and measured performance of the microstrip stacked-patches and the design and testing of power dividers.

II. DUAL-FREQUENCY MICROSTRIP STACKED-PATCH ANTENNA

Traditionally, feedhorns are used to illuminate reflector antennas. The major drawback of feedhorns is that they are heavy and occupy a large volume. An alternative approach is a microstrip patch array feed. Microstrip patches are low profile, lighter, and take up much less volume than a conventional feedhorn.

During our phase 1 activities conducted in 2003, we completed the conceptual demonstration of the stacked patch design for dual frequency (1.26 and 1.41 GHz) and dual linear polarization applications. The geometry of the preliminary stacked-patch design is shown in Figure 1 for one element. The stacked patch resonates at each of the desired frequencies to achieve dual-frequency capabilities.

The patches are thin Copper/Kapton layers bonded to Astro-Quartz layers. Three Copper/Kapton/Astro-Quartz layers are built to function as the upper patch, lower patch and ground plane. The lower radar patches sit on a honeycomb dielectric (Korex) structure above a conducting ground plane. The honeycomb structure is filled mostly with air and therefore introduces only a small loss at L-band frequencies. On the top of the radar patches will be another honeycomb dielectric structure to support the radiometer patches. The Copper/Kapton/Astro-Quartz layers and the Korex honeycomb layers will be drilled to allow attachment of the feed wires to the lower patch (radar) and the upper patch (radiometer). The lower patch will be fed through the ground plane, while the feed conductor for the upper patch will be brought through the center of the stacked patch and bent to feed the upper layer from the top. The layout illustrates the operation of single polarization. For dual-polarization operation, another pair of coax conductors is installed (Fig. 2). The size of patches, thickness of honeycomb structures, and location of the patch feeds are

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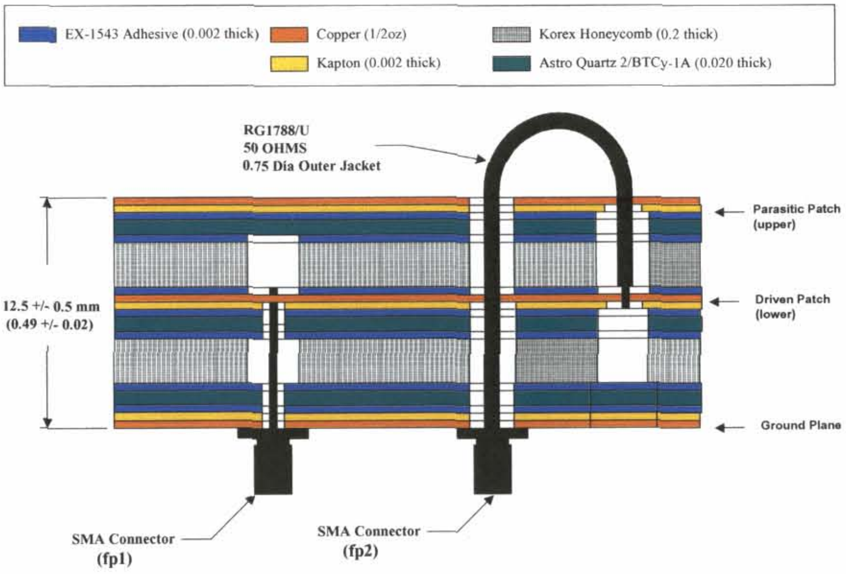


Figure 1. Detailed layout of the stacked-patch element.

design parameters for two resonant frequencies at 1.26 and 1.41 GHz.

To test the fabrication process and verify the design tool, a single-element stacked patch was build. The physical dimension of the fabricated unit was derived from the computer design simulation performed at the University of California, Los Angeles (UCLA). Figure 2 provides the front, side and back views of a fabricated stacked patch with the dimension shown in Figure 3. The return loss measurements of this fabrication show two resonant frequencies at 1.26 and 1.48 GHz for both vertical and horizontal polarization ports (Figure 3). The measurements lend support to the use of stacked patch for L-band radar and radiometer applications at L-band. However, the design parameter is being adjusted to place the upper resonant frequency in the frequency band allocated for radio astronomy centered at 1.413 GHz.

III. ARRAY DESIGN

We investigated three array configurations for the demonstration of an array of stacked patches. A seven-element stacked patch array with elements forming a hexagonal pattern is most suitable for applications to the Aquarius and Hydros missions. However, a sixteen-element array with a 4x4 rectangular configuration (Fig. 4) is more suitable for applications to airborne and ground demonstration of the stacked-patch array.

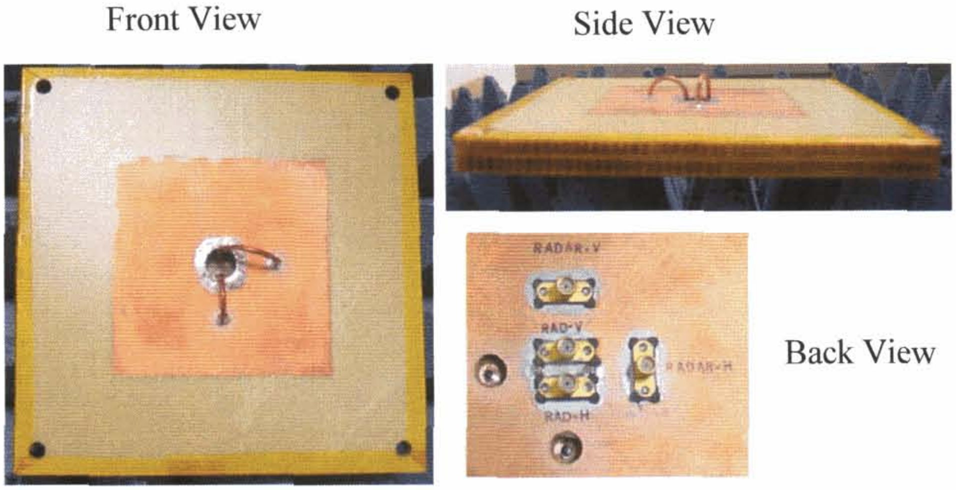


Figure 2. Front, side and back views of the stacked-patch antenna

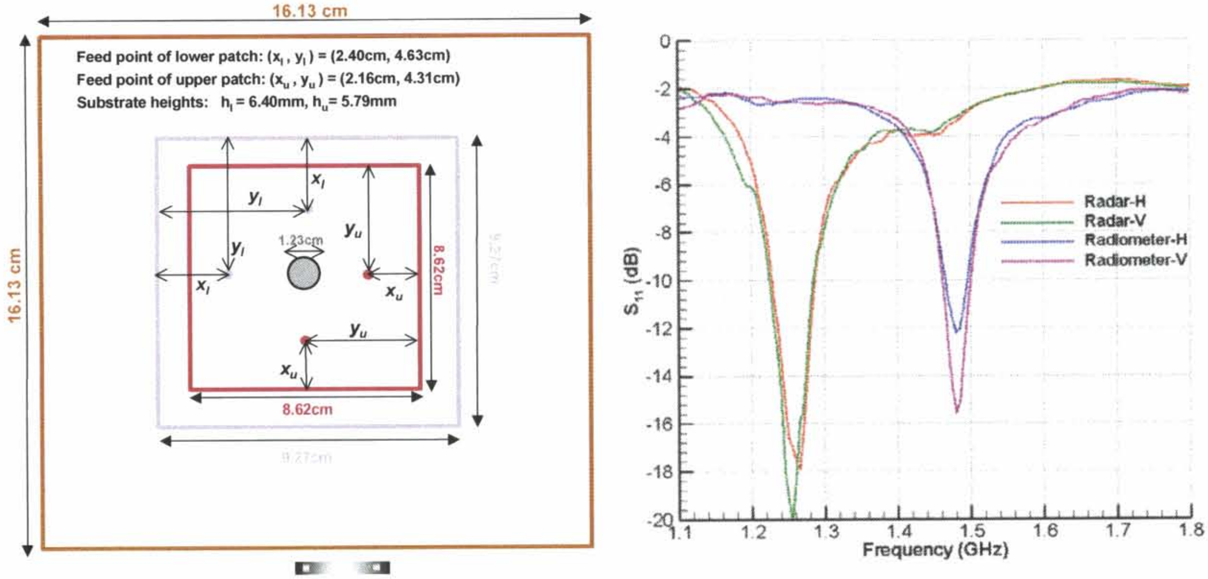
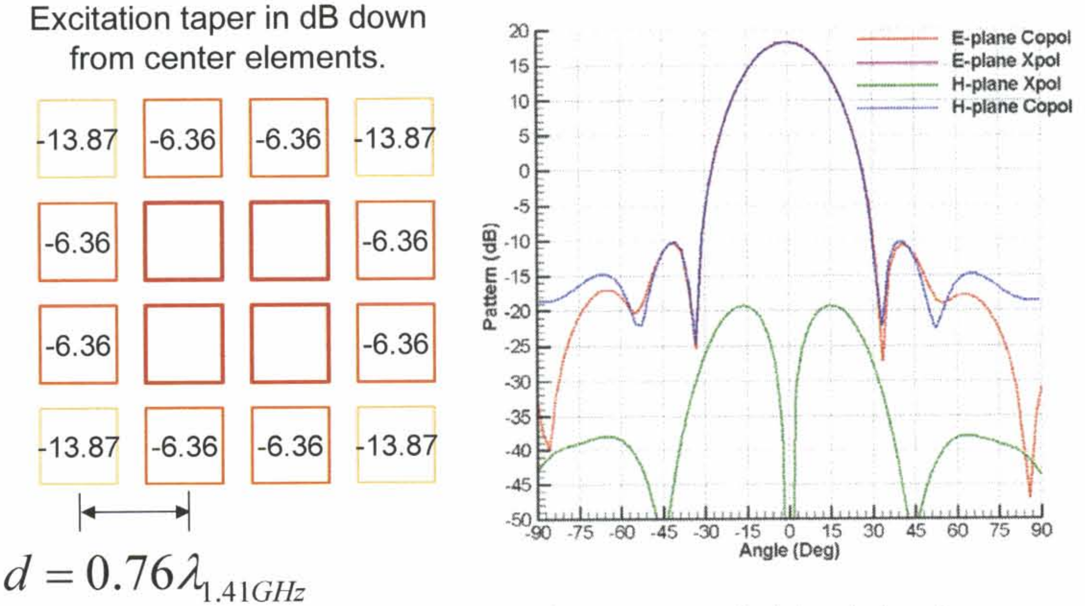


Figure 3. Schematics (left) and return loss measurements (right) of a stacked-patch antenna.


Excitation taper in dB down from center elements.

-13.87	-6.36	-6.36	-13.87
-6.36			-6.36
-6.36			-6.36
-13.87	-6.36	-6.36	-13.87

$$d = 0.76\lambda_{1.41GHz}$$

Figure 4. Configuration, excitation taper, and antenna pattern of a 4x4 stacked-patch array

The key design parameters of the 4x4 array are the spacing between adjacent elements and the excitation amplitude for each element. The right panel of Fig. 4 illustrates the theoretical antenna pattern at 1.41 GHz for 0.76-wavelength spacing between radiometer patches. The four center patches are uniformly excited. With respect to the excitation level of four center patches, the four corner patches are excited at –13.87 dB and the 8 patches on the edges are excited at –6.36 dB. The array beamwidth is estimated to be about 20 degrees and the calculated beam efficiency is greater than 99%, exceeding a nominal requirement of 95% for radiometer applications.

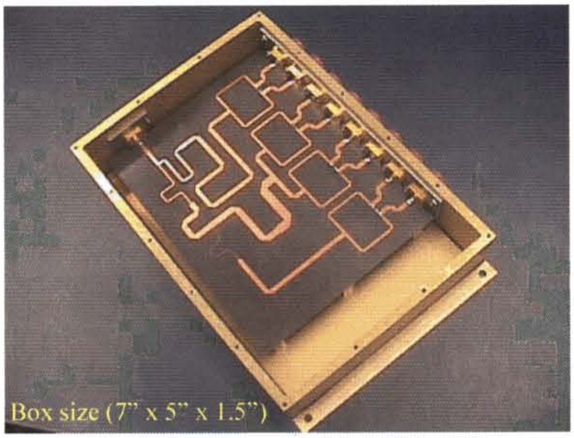


Figure 5. Picture of the proto-type 1-to-8 power divider

IV. POWER DIVIDER

To realize the optimized excitations for array elements, the 1-to-16 power divider based on printed circuit board (PCB) is being investigated. We have tested the design tool for a 1-to-8 power divider with –6 dB taper for the edge element and –14 dB taper for the corner element. A 1-to-8 power divider was fabricated and tested for insertion loss through each output port. The taper design agrees with the measurement to within 0.2 dB for the –6dB taper and 0.4 dB for the –14 dB taper. The net insertion loss of the power divider was –0.28±0.05 dB for eight repeated measurements. This indicates that the microstrip stacked-patch array can achieve comparable insertion loss to the conical feedhorn together with the orthomode transducer for polarization splitting. We have completed the design and fabrication of a 1-to-16 PCB power divider. Testing is being performed to evaluate the performance of the full-size power divider.

V. SUMMARY

The concept of microstrip stacked-patch design to support dual-frequency, dual-polarization applications for L-band radar and radiometer was demonstrated with the design, fabrication and testing of a single-element stacked patch. The design parameters are being modified to obtain desired radiometer and radar frequencies at L-band. In addition, we have completed an array optimization to reach desired antenna beamwidth and antenna beam efficiency. The excitation for each element was determined and used to design a PCB-based power divider for beam forming. A proto-type 1-to-8 power divider was developed with the insertion loss measured to be about 0.3 dB, comparable to the performance of a conical feed integrated with an orthomode transducer. The design of a 1-to-16 power divider was completed, and its performance is being verified through fabrication and testing. We expect to complete the array design and fabrication within a few months.

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