Development of Wideband Dual Polarized of Microstrip Antennas for Microwave Remote Sensing

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***Abstract*— A novel wideband dual polarized L-band antenna for NASA's microwave remote sensing applications has been designed, fabricated, and validated. The novel antenna structure consists of a rectangular microstrip antenna excited by capacitive coupled four probes. One of the linear polarizations is obtained by feeding two diagonally opposite probes with equal but out of phase signals. Other orthogonal polarization is obtained by feeding other remaining probes with equal but out of phase signals. The novel structure provides the band width in excess of 500 MHz (with the center frequency of 1.3 GHz) and the cross polarization below -40 dB. For validation purpose, two prototype antennas were fabricated and tested. The test results collected show relatively good agreement with simulation results. For achieving wider band width, it is required to use, in our design, the probes with diameter larger than conventional coaxial connector. A novel feed structure using larger size cylindrical via is designed. The new feed structure design is fabricated and validated before its integration with the antenna.**

Keywords- microstrip; L-band antenna; microwave; NASA.

I. INTRODUCTION

Microwave radars/radiometers are often used by NASA and other agencies for remote sensing of the Earth science parameters. The spatial and temporal resolutions obtainable with the microwave radars/radiometer observation depend upon their frequency bandwidth. It is always desirable for high spatial resolution to have radar operating at much higher bandwidth. The current antenna technology offers antenna with 20-50 MHz bandwidth. We proposed to develop a wideband (40%, 500MHz), dual polarized L-band array antenna for the next generation of microwave remote sensing radars and radiometers. The novel wideband antenna configuration will enable the scientists to observe the Earth science parameters with less than meter spatial resolution. In addition, the dual polarization capability with very low cross-polarization coupling (< -50 dB) will allow to measure the Stokes parameters with enhanced accuracy/sensitivity (-50 dB). Accurate measurement of the Stokes parameters will yield better estimates of permafrost and biomass which are critical parameters for development of Earth's carbon cycle model. It has been reported that dual polarization capability will provide biomass estimation with RMSE error of ~ 120 Mg/ha. 500 MHz bandwidth will allow achieving resolution in the range of 50 x 50 cm.

Researchers use different techniques and technology to design and fabricate an antenna. Microstrip has been one of the most popular microwave transmission lines in antenna. However, coplanar waveguide transmission lines have also been used in microwave transmission line as well. They are often selected over high frequency transmission line option such as stripline. John Coonrod has reported differences between microstrip and coplanar waveguide transmission lines to find the best performance applications [1]. Also, antenna size is always something that must be related to the wavelength and thus the frequency. Higher frequencies can utilize smaller antennas. However, the size of the antenna depends to the radiation resistance, the antenna feeding impedance, and radiation pattern [2]. Neil Chamberlain [3] has reported a method to fabricate a single-layer antenna that has application in military and commercial environments. He used a large-diameter center post as its supporting structure that allows for fabrication of a sufficiently rigid antenna element that can survive launch loads.

In this work, we present a procedure to design wideband dual polarized L-band antenna element and its microstrip feed line structure. We also describe a procedure used to fabricate and test these microwave components using the laboratory facility available at Microwave Instrument Technology Branch of NASA Goddard Space Flight Center (NASA-GSFC) in Maryland.

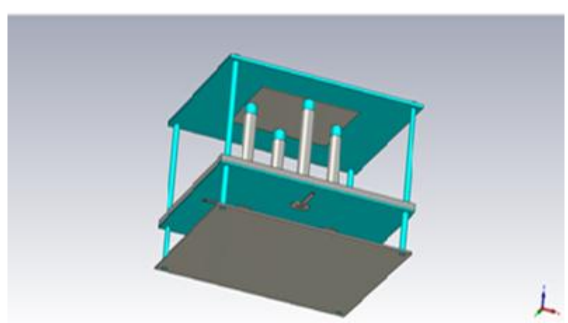

Figure 1. The computer model of L-band antenna

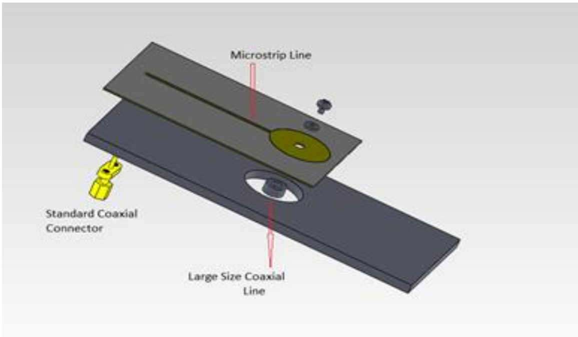

Figure 2. Transition for standard coaxial connector to large size coaxial line

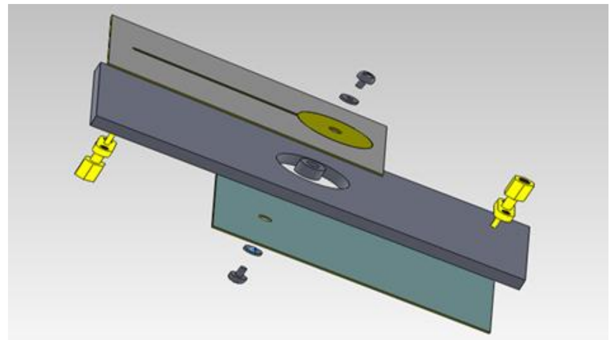

Figure 3. Microstrip feed line using larger size coaxial section

II. DESIGN METHODOLOGY

Two tasks need to be fulfilled to design and build microstrip antenna. Fist task starts with design of microstrip feed line using large size coaxial line. Fig. 1 shows the wideband dual polarized L-band antenna structure to be modeled. Our electromagnetic simulation of this antenna showed that for wideband operation, the four probes need to be of diameter much larger than the diameters of central conductor of a standard coaxial connector. Hence, a perfectly matched transition (as shown in Fig. 2) is required to connect conventional small size coaxial connector to a large size coaxial line. The desired transition has to transfer 100 % of power between the standard coaxial inputs to the larger size coaxial output. However, to test such a transition we would require unconventional large size coaxial connectors. To overcome this difficulty, we used back-to-back transitions (shown in Fig. 2), which results in a structure shown in Fig. 3, and which only require standard coaxial connectors to test the power transfer through a large size coaxial line section. The transition shown in Fig. 3 consists of metal plate of size 43.18 x 17.78 x1.27 cm (17 x 7 x 0.5 inches). On each side of the metal plate a dielectric substrate with dielectric constant of 2.94 and thickness 0.1mm were glued to the metal plate. On the top and bottom surface of these composite layers, a microstrip line having characteristic impedance of 50 Ohms was etched out to form 50 Ohms microstrip lines.

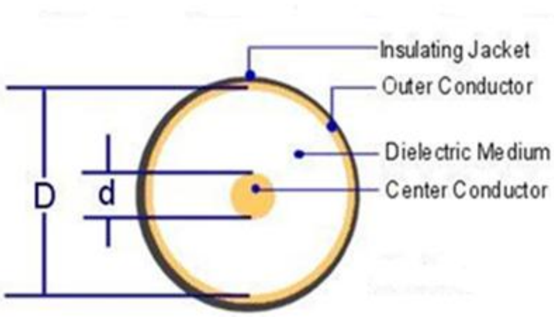

Figure 4. Cross section of coaxial line section

The width of the microstrip lines were calculated using [4]

$$Z_0 = \left(\frac{87}{\sqrt{\varepsilon_r + 1.41}}\right)\ln\left(\frac{5.98h}{0.8w + t}\right) \text{ ohms} \qquad (1)$$

In (1), Z_0 = 50Ω is the characteristic impedance, ε_r= 2.94 is dielectric constant of the insulator, h= 0.8 mm is thickness of the dielectric insulator, and t= 0.08 mm is thickness of the copper strip. The width, w, of the microstrip using (1) is found to be 1.7 mm which was rounded to 2.00 mm. The coaxial line section used in the proposed transition has a cross section as shown in Fig 4.

In order to design the larger size coaxial line with characteristic impedance of 50 Ohms, (2) for a coaxial line was used to estimate inner and outer diameter of coaxial line section [5].

$$Z_0 = \left(\frac{138}{\sqrt{\varepsilon_r}}\right)\log\left(\frac{D}{d}\right) \quad \text{ohms} \qquad (2)$$

In (2), the D represents the diameter of the hole in

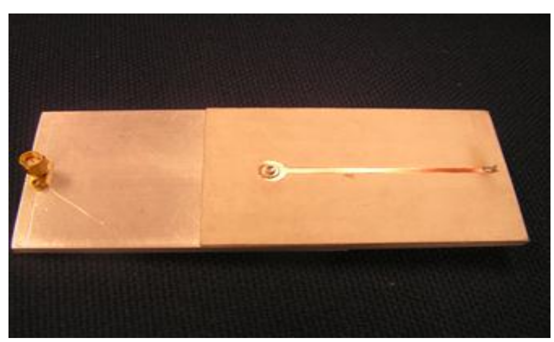

Figure 5. Photo of fabricated transition

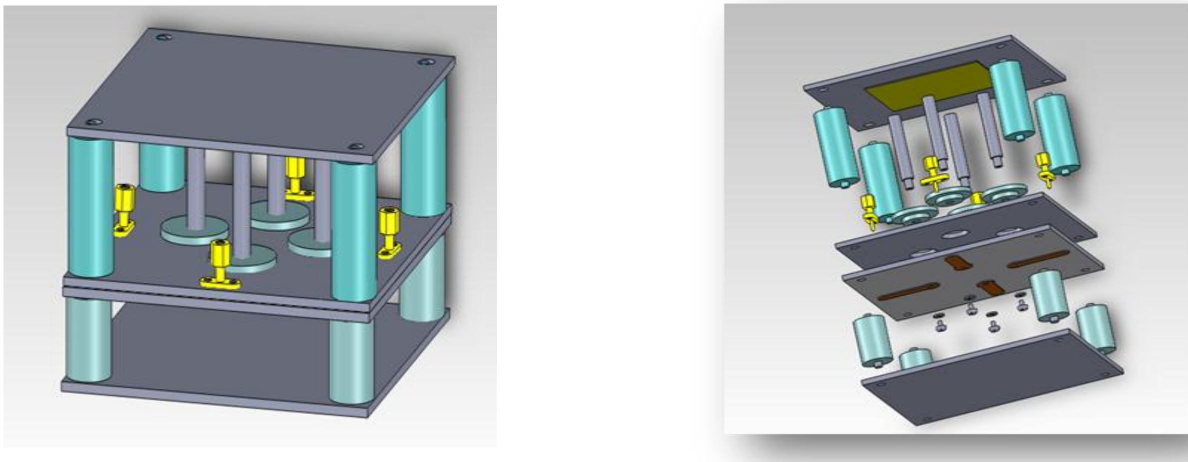

Figure 6. CAD model of different components of a L-band antenna

the aluminum plate, and the d represents the diameter of the center conductor pin located at the center of the hole. The ratio of D/d can be calculated with assuming the value of Z_0 is 50 ohms and $\varepsilon_r = 1$ for value of air dielectric.

Using the dimensions obtained by these two equations, the transition was fabricated using fabrication facilities available at Microwave Instrument Technology Branch of NASA-GSFC. A photo of fabricated transition is shown in Fig. 5.

The second task starts with design of wideband dual polarized L-band antenna. The simulation model of the proposed L-band antenna is shown in Fig. 1. The critical parameters that control the antenna performance are (1) diameter of probe, (2) rectangular patch size, (3) height of patch from the ground, (4) separation of probes from center. Using the CST Microwave Studio electromagnetic simulation model, the antenna performance was optimized with respect to above parameters [6].

Commercial SolidWorks Computer Aided Design (CAD) software is utilized to draw and design antenna components for fabrication purpose. The geometry of the desired model is given in Fig. 6.

The two different types of L-band antennas were fabricated and tested. The first antenna had a thick substrate, while second antenna had a thin substrate. The L-band antenna consisted of four layers including an aluminum plate at the base, substrate with copper strip in the middle, aluminum ground plate attached to top of the middle substrate, and substrate with copper radiation patch at top. Four radiation poles are connected through ground plate and substrate to four copper transmitting strip lines. The commercial CST Microwave Studio software was used to obtain the desired specifications of the dimensions of the L-band antenna. The antenna was fabricated to the specified dimensions and it is shown in Fig. 7.

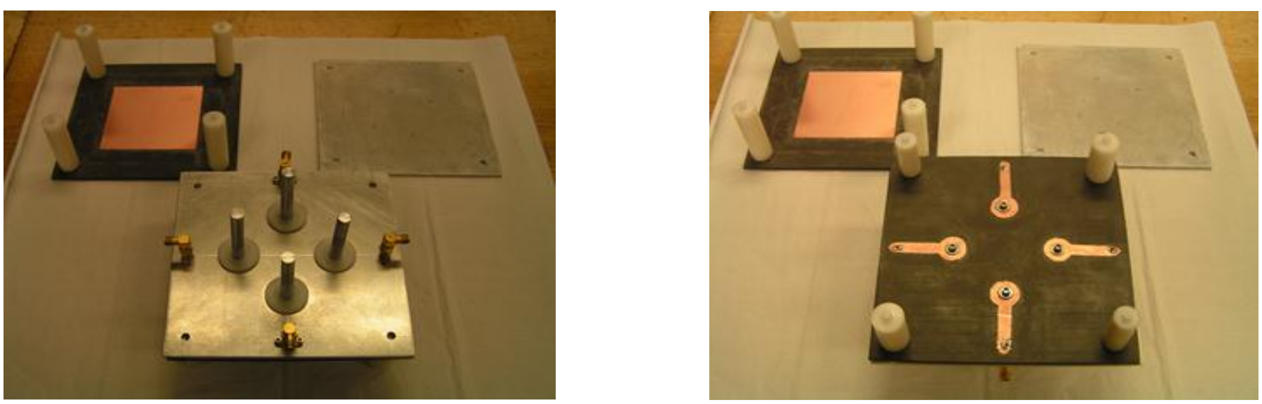

Figure 7. Components of fabricated antenna

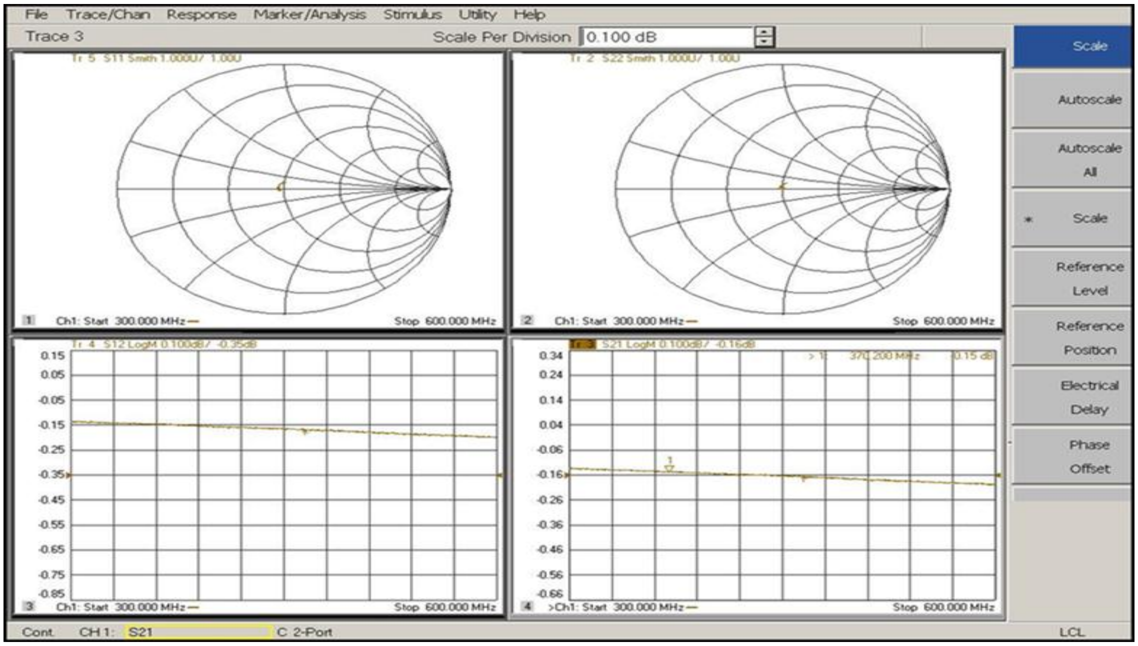

Figure 8. Microstrip test results

The second antenna has same specifications except using different substrate to compare the results.

III. RESULTS

The microstrip and two L-band antennas were tested and reported as following. The fabricated microstrip model shown in Fig. 5 was tested with the PNA analyzer to validate the design specification. The graphs in the results section indicate that the microstrip met the desired design. The results shown in Fig. 8 confirm that there was very low return loss (low S11 and S22) at both ports. The top two smith charts within the graph both represent return loss in ports one and two. The S11 and S22 curves are very minimal and tight to the center as expected. The bottom charts both represent transfer of power through the design structure from one port to the other. The results show about -0.13db of loss of power between the ports one and two. Note that these transitions were fabricated and tested for frequency range of 0.3-0.6 GHz as shown in Fig. 8. An identical approach was used to design a transition for the L-band.

Two samples of antenna shown in Fig. 7 were fabricated and measured. It was found that both samples gave identical performance within the experimental tolerances.

First the L-band dual polarized antenna with thick substrate was tested for its input Voltage Standing Wave Ratio (VSWR) and its impedance matching performance outside the anechoic chamber. It was also tested for its radiation performance inside the electro- magnetic anechoic chamber room. Anechoic means no echoes which imply the room is free of reflections which gives accurate measurements. The antenna has four ports and to perform measurements two ports were terminated into matched load and other two were excited through a 3dB hybrid coupler. Fig. 9 shows input VSWR when two of four ports were excited through a 3dB hybrid coupler and other two ports were terminated into matched loads. Fig. 9 shows both measured and simulated results obtained using CST Microwave Studio software. A good agreement between calculated and measured VSWR is observed. Desired results are lower than -10 db's for entire desired band showing a good impedance match for the antenna.

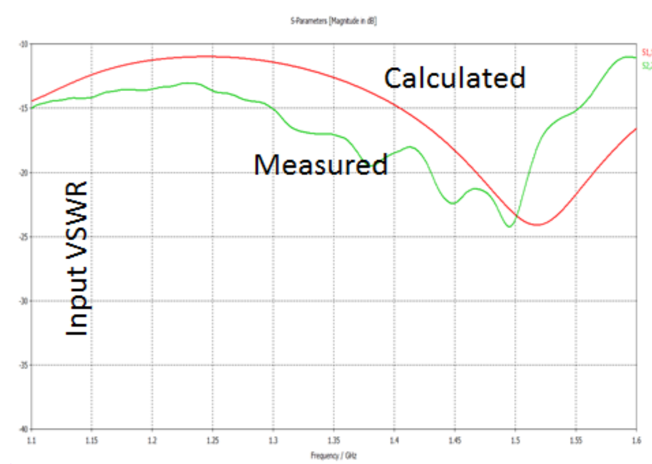

Figure 9. L-band antenna (First model Port1)

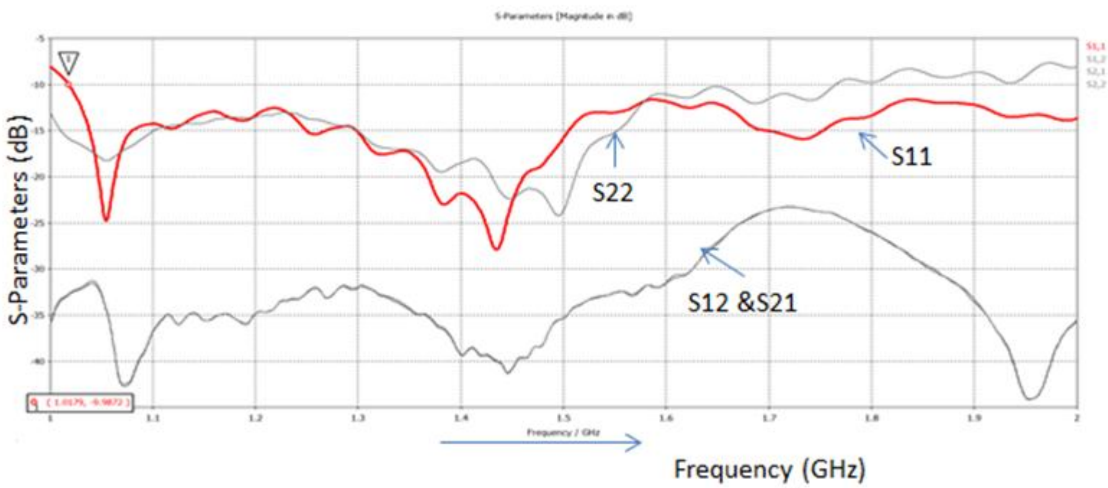

Figure 10. L-band antenna (Second model ports 1, 2)

The next step was to test L-band dual polarized antenna with thin substrate. To configure the four port antenna into a dual polarized two port antenna, pair of two diagonally opposite probes is fed through hybrid couplers. This feeding arrangement converts the four port antenna into two port antenna. S-parameters (S11, S21, S12, and S22) of the dual polarized antenna were measured and shown in Fig. 10. The curves for S11 and S22 show that the antenna is impedance matched over the frequency band covering 1.0 – 1.7 GHz band. The curves for S12 and S21 show that the cross coupling between the two linear polarization is below -30 dB.

IV. CONCLUSION AND FUTURE WORK

In this project, the performance of fabricated microstrip antenna has been evaluated. Both measured and calculated results are presented and found to be in a good agreement. The SolidWorks CAD commercial software is utilized to visualize components for fabrication process. The model has been fabricated in a traditional machine shop and tested several times to collect data from the PNA Analyzer. Despite working with traditional method for fabricating microstrip and antenna, good agreement was achieved between the simulated and measured results. This project was involved extensive research, design, fabrication, constant testing, and troubleshooting. The wideband L-band designed and tested in this work is planned to be used in a large L-band array antenna for NASA’s remote sensing.

ACKNOWLEDGMENT

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