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COMPACT L- & C-BAND SAR ANTENNA

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Abstract—A compact three-layer shared-aperture dual-band dual-polarised sub-array operating in L/C-band is designed for application in synthetic aperture radar (SAR). Square, aperture-coupled patches in the C-band and a square, perforated L-band patch are combined on the top layer. They are fed from behind the ground plane by a combined feed system. Combined layers of patches and feed layers results in a highly compact antenna suitable for low weight applications such as space borne synthetic aperture radars (SAR).

1. INTRODUCTION

Microstrip antennas have undergone tremendous growth during recent years. Single layer, regular shaped geometry is no longer able to provide solutions to ever more complex, critical and demanding applications of the future. Synthetic aperture radar (SAR) is one such application, which is constantly pushing the limits of microstrip antenna. Typical SAR antennas must have dual-polarization capability, low cross-polarization, high efficiency, low mass and small volume. Recent SAR systems also require beam scanning incorporated into the antenna. This places great strain on the design of such antennas.

Current civilian SAR systems mainly operate in the L-, C- and X-bands. Early SAR systems were typically a single band system, but recently many multi-band systems are in operation. All known dual-band SARs currently have 2 separate antennas for each of the frequencies. This presents a somewhat awkward situation since the antennas have a large aperture, especially space borne SARs. The extra mass and volume required for 2 antennas will increase the cost

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of the mission. To overcome this, future SAR systems are expected to operate with dual-band antennas.

2. REVIEW OF DUAL BAND SAR ANTENNA

Microstrip antennas operating at two frequencies have been the topic of research studies for some time. One of the simplest ways to operate at dual-frequency is to use the first resonance of the two orthogonal dimensions of the rectangular patch. These are the TM_{100} and TM_{010} modes of the patch. The frequency ratio obtained from this method is approximately equal to the ratio between the two sides of the patch. Early studies have focused on utilising this property and are known collectively as *orthogonal-mode dual-frequency patch antennas* [1]. The obvious limitation of this approach is that the two different frequencies excite two orthogonal polarisations. Dual-polarization for each band is not possible.

Other dual-frequency patch antennas found in the literature can be subdivided into *multi-patch dual-frequency antennas* and *reactively-loaded dual-frequency patch antennas* [1]. The former uses more than one radiating elements, each of them radiating at different frequencies to achieve dual-band operation. This category includes multi-layer stacked patches of all shapes. These antennas operate with the same polarization at the two frequencies, as well as with a dual-polarization. Typically the lower patch is fed by any convenient arrangement, while the upper patch is proximity coupled with the lower patch. In order to avoid disappearance of the upper resonance, the size of the two patches should be close, so that only a frequency ratio close unity may be obtained.

The reactively-loaded patch antenna uses stub, notch, pin and slot loads to achieve multi-frequency operation. This is the most popular technique for obtaining dual-frequency behavior. However, these methods excite second resonance close to the first. The ratio of the frequencies is generally below 2. In the case of SAR systems the ratio of L/C band is 4.24, C/X band is 1.82 and L/X band is 7.72. Thus, except for C/X band, other combinations may not be achieved with the above techniques. Dual-band SAR antennas with wide frequency ratios requires a different approach altogether. Instead of developing a radiating element capable of radiating at two frequencies simultaneously, separate radiating elements for each band is developed. Then, both of these elements are stacked on top of each other on the same aperture. Thus, essentially a dual-frequency and dual-polarization array is constructed by simply "combining" the individual antenna into a single dual-band antenna.

One of the first discussions on methods of implementing a shared-aperture dual-frequency dual-polarised antenna was reported in [2]. Their motivation is to find a viable concept for application in spaceborne SAR. In their discussions, a combination of X- and C-band slots and patches were studied for a shared-aperture. Pokuls et al. concluded that C-band patch/X-band slot concept had the greatest merit. In their design, the C-band patches were fed by a feed network coplanar with the patches. The X-band slots was printed on the ground plane and fed by feed network behind the ground plane.

At about the same time, Shafai et al. [4] used a combination of stacked perforated L-band patch overlaid over an array of C-band patches to achieve shared-aperture L/C-band operation. Shafai et al. employed similar feeding principles, with the C-band patches aperture-coupled to the feed network behind the ground plane. The L-band feed network is coplanar with the lower L-band perforated patch. Targonski and Pozar [5] further developed this idea and applied it to L- and X-band array. They removed the lower L-band perforated patch and fed the top L-band patch via proximity feed line. This feed line is in the same layer with the X-band patches. Pozar and Targonski [3] later developed a prototype sub-array, which exhibited good radiation properties suitable for spaceborne SAR applications. Similar method of element layout is demonstrated in [6] and [7] where S- and X-band elements are stacked in multi layered configurations.

3. DESCRIPTION OF ANTENNA ELEMENT

For a compact antenna configuration, there can be only one layer each, for the radiating element, ground (with the apertures) and feed network. C-band square patches and L-band perforated square patch has to share the same layer. In a multilayer configuration, neither of the patches is significantly affected by the presence of the other patch [6]. The L-band and C-band patch radiates fairly well in the presence of the other patch. However, this is not the case if the L- and C-band patches are on the same layer. The C- and L-band patches' properties are affected by each others' presence. Thus this effect, on the C-band patches due to the L-band patch, and vice versa has to be examined and compensated for. In this design, the four C-band patches inside the perforations of the L-band patch shows a slight deviation away from the centre frequency. Modification in the patch dimension was done to compensate for this effect.

The feed layer is placed behind the ground plane to reduce unwanted radiation from the transmission lines. The radiating structures are then aperture coupled to the feed line in the ground plane. A shared-aperture, L/C dual-band antenna element with dual-polarization is constructed as an example of the concept. The side view showing the position of each layer is in Figure 1. For the C-band, a 4×4 array of square patches is designed. Figures 2(a) and (b) show the C-band patches and their feed network.

For the L-band radiator, a perforated square patch is placed above the C-band patches. The perforated patch is placed in the middle of the C-band array, overlapping four of the higher-frequency patches. The perforations are introduced onto the L-band patch to allow for the C-band patches to be placed in the array. The L-band patch is probe-fed to the feed lines, unlike the C-band patch which was aperture coupled. This is due to space and feed layout constraints. Figure 3 shows the L-band patches and its feed network. The L-band feed network and C-band feed network is combined to produce the feed network for the sub-array.

A unit of sub-array, as described above has sixteen C-band patches and one L-band perforated patch. This sub-array will be considered as

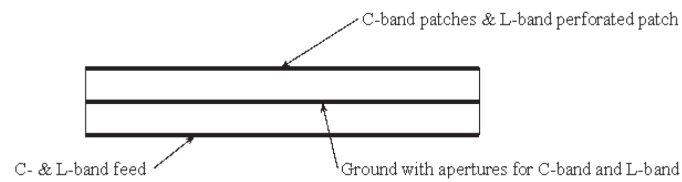

Figure 1. Cross-sectional view of the dual-band dual-polarised microstrip sub-array.

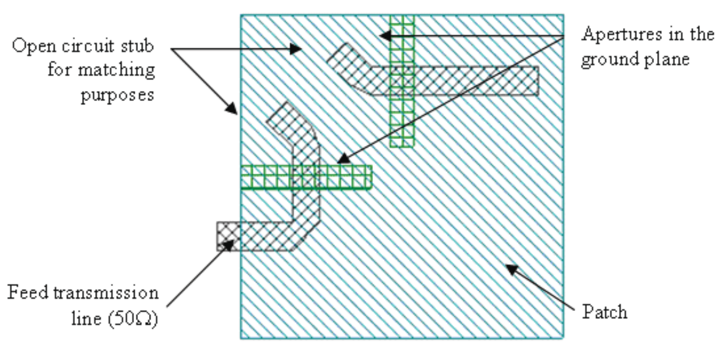

Figure 2a. A single C-band patch with its feed transmission line and apertures.

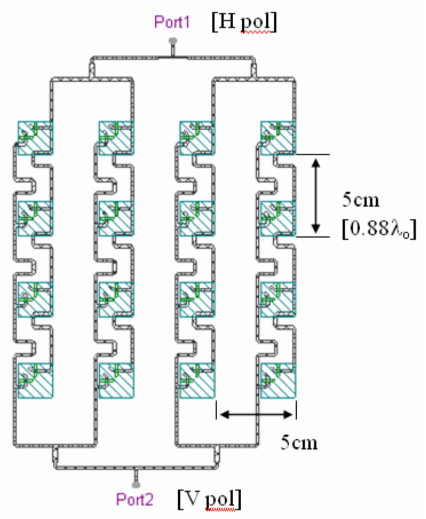

Figure 2b. The complete C-band array with its feed network.

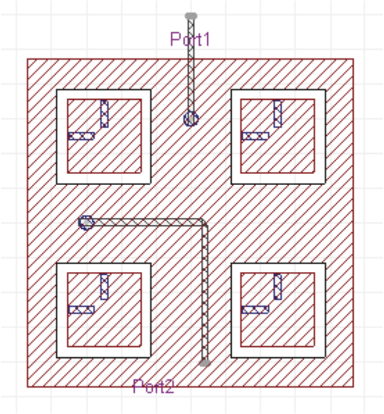

Figure 3. L-band perforated patch overlaid on top of C-band patches.

one dual-band radiating unit and the feed network for both the bands are combined at the input to this unit [6].

4. RESULTS

The L/C band sub-array configuration was tested using full-wave simulation (Ansoft Designer and HFSS). Port 1 excites horizontal polarization while port 2 excites the other. The scattering-parameters

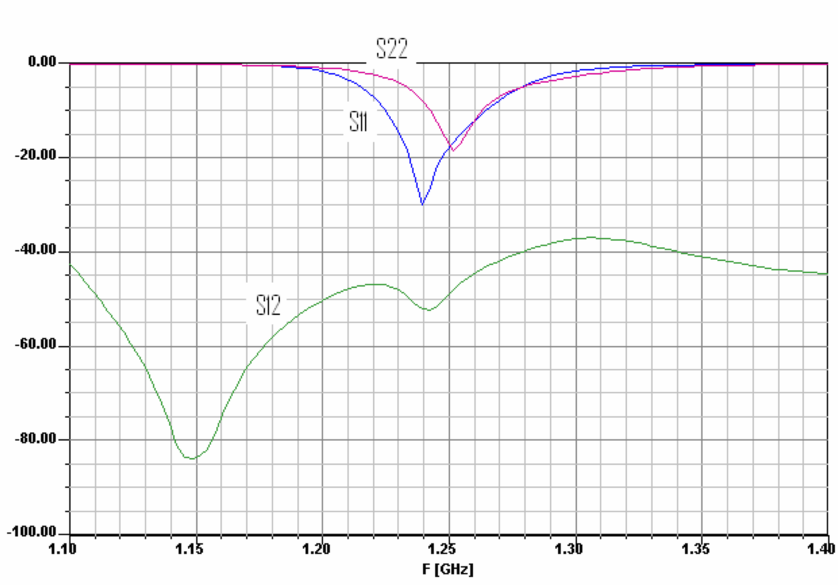

Figure 4. Return loss at L-band frequencies.

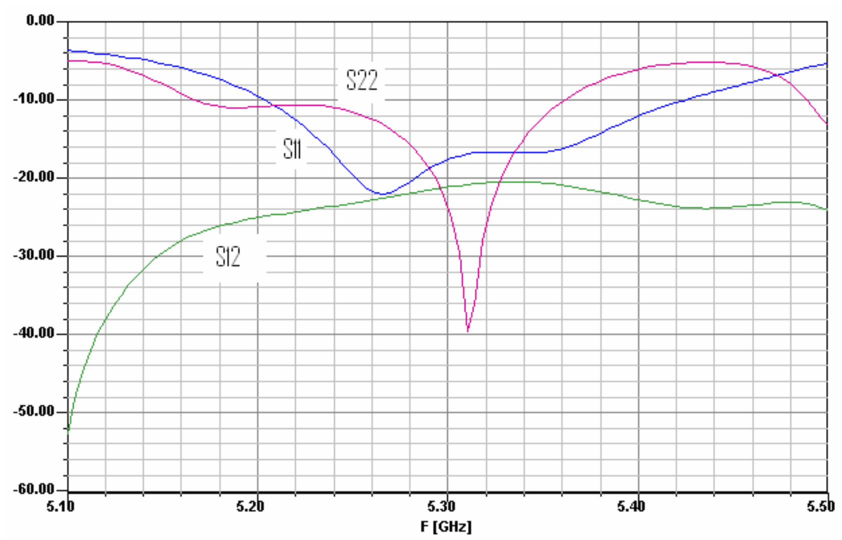

Figure 5. Return loss at C-band frequencies.

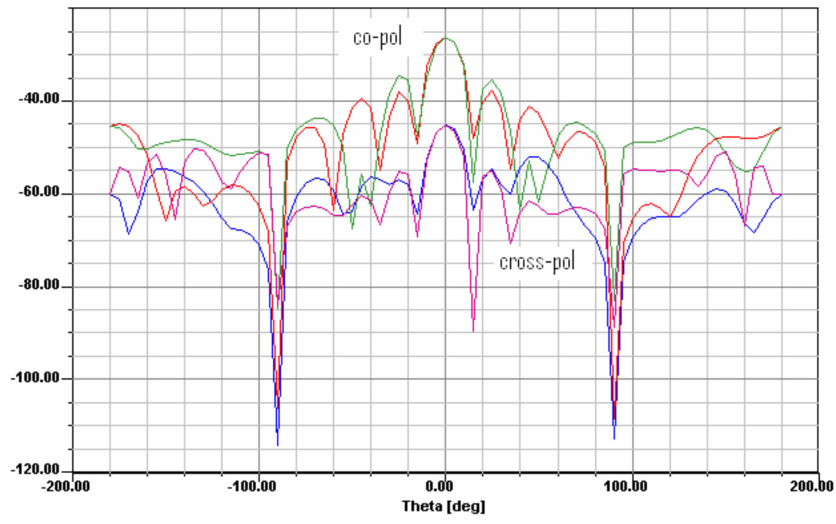

Figure 6. Radiation pattern for C-band with only port 1 excited.

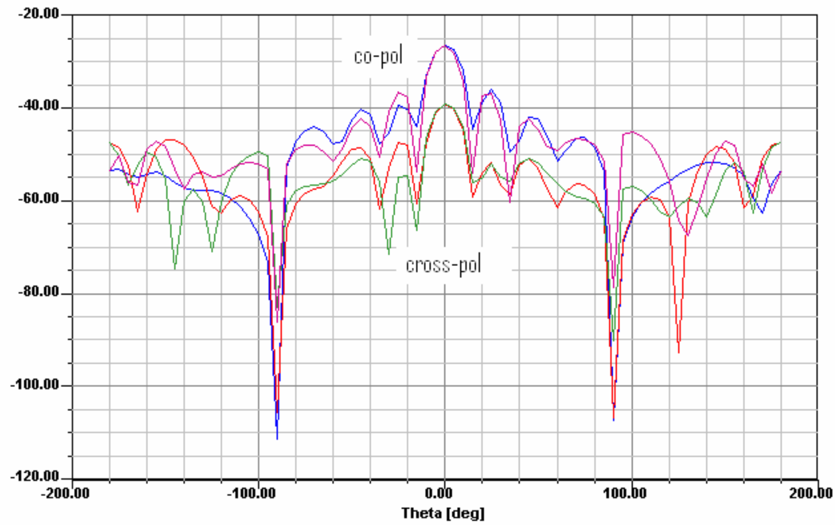

Figure 7. Radiation pattern for C-band with only port 2 excited.

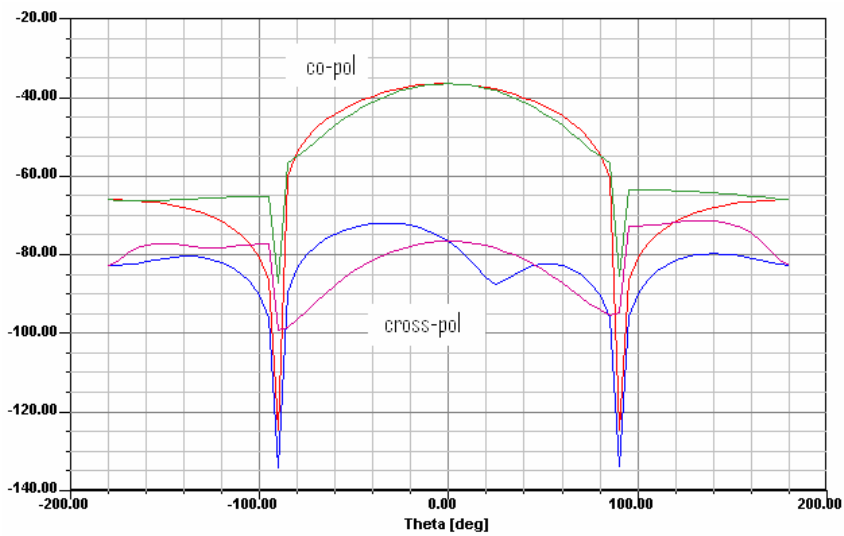

Figure 8. Radiation pattern for L-band with only port 1 excited.

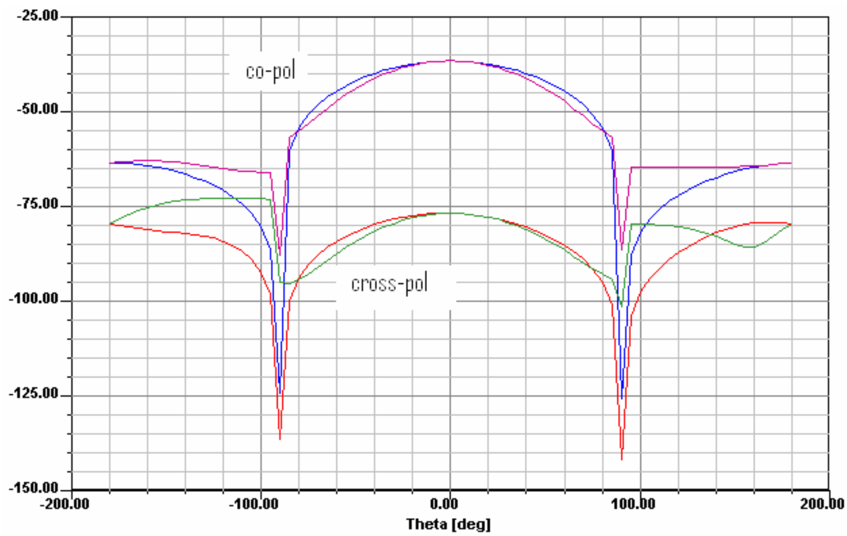

Figure 9. Radiation pattern for L-band with only port 2 excited.

for the two-port network are shown in Figure 4 and Figure 5. The isolation between the ports at L-band approaches 50 dB. However, at C-band the isolation is approximately 21 dB only. Figure 6 to Figure 9 shows the co- and cross-polarization performance for the sub-array.

5. CONCLUSION

In this paper, the concept of a highly compact dual-band antenna is studied. The concept has been successfully demonstrated on the L- and C-band sub-array. The performance of the array is good. The L-band perforated patch exhibit good radiation performance but with rather low bandwidth. The C-band array has moderate bandwidth. The co-polarization radiation for both of the band is satisfactory.

ACKNOWLEDGMENT

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