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COMPACT DUAL BAND ANTENNA FOR SPACE BORNE SAR

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ABSTRACT: A compact three-layer shared-aperture dual-band dual-polarised array operating in L/C-band is investigated for applications in remote sensing sensors. The array comprises square, aperture-coupled patches in the C-band and a square, perforated L-band patch, both on the same layer. The feed networks for both the bands are placed behind the ground plane on the same layer. The ground layer provides the aperture for feed coupling. The three-layer L/C-band sub-array gives promising results for low weight application such as space borne synthetic aperture radar (SAR).

1 INTRODUCTION

Microstrip antennas have undergone tremendous growth during recent times. Single layer, regular shaped geometry is no longer able to provide solutions to ever more complex, critical and demanding applications of the future such as synthetic aperture radar (SAR). Typical SAR antennas must have dual-polarisation capability, low cross-polarisation, 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. Future SAR systems can be expected to operate in more than 2 frequency bands. All known dual-band SARs currently have 2 separate antennas for each of the frequencies. This presents a limitation since the antennas have a large aperture, especially space borne SARs. The extra mass and volume required for 2 antennas will increase the cost 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-polarisation 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 polarisation at the two frequencies, as well as with a dual-polarisation. Typically the lower patch is fed by any convenient arrangement, while the upper patch is proximity coupled with the lower patch. In

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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 behaviour. 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 4.2, C/X band is 1.8 and L/X band is 7.7. 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. Instead of developing a radiating element capable of radiating at two frequencies simultaneously, separate radiating elements for each band is designed. Then, both of these elements are stacked on top of each other on the same aperture but separate layers. Thus, if each of the frequency bands is of a three layer sandwich configuration, essentially a six layer structure would result. However, typical design would merge one or more layers together, such that the total number of layers is minimized.

One of the first discussions on this method of implementing a shared-aperture dual-frequency dual-polarised antenna was reported in [2]. A combination of X- and C-band slots and patches was studied for a shared-aperture. The feed network was placed on two layers while for the radiating element one and two layers were used. It was 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 were printed on the ground plane and fed by feed network behind the ground plane. The resulting structure is a three layer sandwich.

At about the same time, a combination of stacked perforated L-band patch overlaid over an array of C-band patches to achieve shared-aperture L/C-band operation was reported in [4]. Here, a similar feeding principle was employed, 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, resulting in a four layer structure. This idea was further developed and applied to L- and X-band array in [5] [3]. Here the lower L-band perforated patch was removed and the top L-band patch is fed via proximity feed line. This feed line is in the same layer with the X-band patches. However, the number of layers is still four.

3 DESCRIPTION OF ANTENNA ELEMENT

Practical dual band antenna structure may require up to five layers; two for radiating element, two for feed network and a single ground layer. In addition, some of the layers may be combined. Generally, a feed layer and a radiating element layer is combined as in [3] [4] [5], resulting in four layers. More recently in [6], both the feed layers were combined, resulting in four layers. In this paper, we continue the work in [6] by combining the remaining two radiating layers to essentially develop a dual band antenna element with only three layers. In our proposed configuration, there can only be one layer each, for the radiating element, ground (with the apertures) and feed network (Figure 1). Thus, C-band square patches and L-band perforated square patch has to share the same layer.

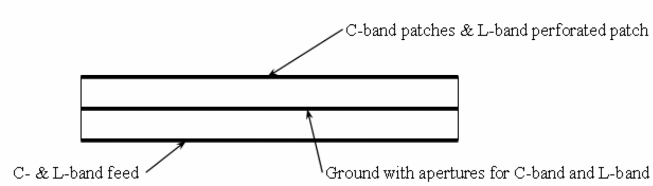

Figure 1: Cross-sectional view of the compact dual-band dual-polarised microstrip sub-array

For the C-band, a 4×4 array of identical square patches is designed. The patches are aperture coupled to the feed network via apertures in the ground plane. The apertures are offset from the centre to allow for dual-polarisation configuration. For the L-band radiator, a perforated square patch is placed along with 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 patch. Figure 2 shows the C-band patch and its feed network on the left and the L-band patch over the C-band, on the right.

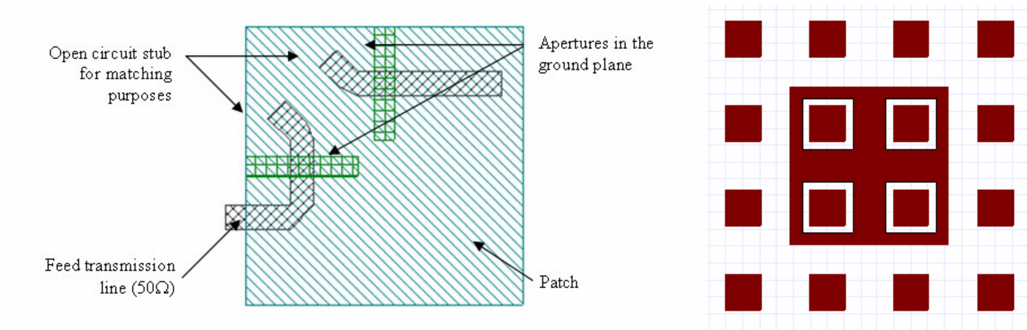

Figure 2: A single C-band patch and the L-band perforated patch

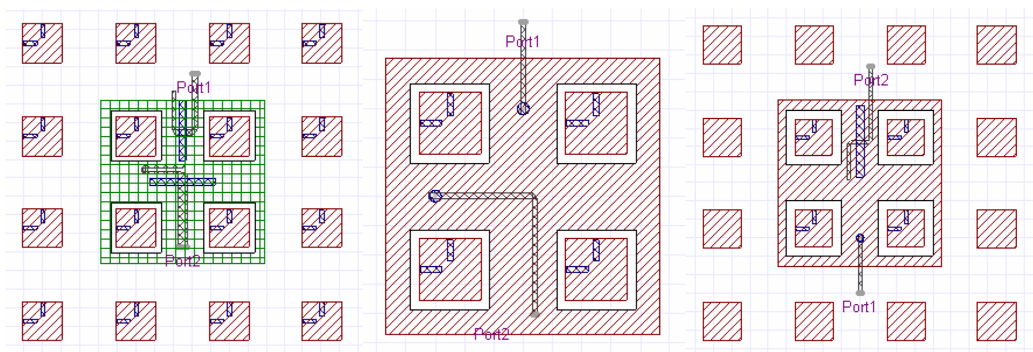

Figure 3: Feed configuration for the L-band perforated patch

The feed for the L-band patch is rather complicated due to the limited area available on the feed layer. The L-band patch could either be aperture coupled or probe fed to the feed layer. Figure 3 shows the possible feed configuration for the patch. The left-most figure shows aperture coupling with one of the aperture shifted to the middle due to space constraint. The centre figure shows probe fed patch. Both the feeding method produces almost the same performance. However, the aperture coupled patch requires a large area for the matching stub, while the probe feed arrangement’s horizontal polarization feed requires offset from centre. Thus, as a compromise a combination of aperture coupled and probe fed is employed here as shown in the right-most of Figure 3.

In a multilayer configuration, neither of the patches is significantly affected by the presence of the other patch [3]. 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 a single 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.

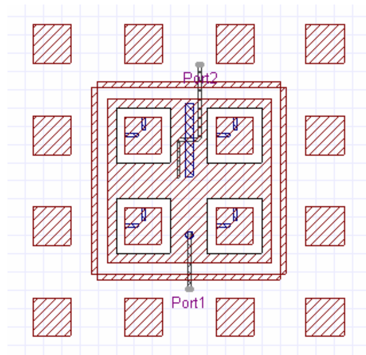

Figure 4: Strip loaded L-band patch for wider bandwidth

4 RESULTS

The L/C band sub-array configuration was tested using a software simulator. Both the bands achieved a 4% bandwidth. For the C-band this is sufficient for SAR requirement. However, for L-band there is need for further improvement in bandwidth. One possible solution is to attach strip load to the patch as in Figure 4. In this case slightly larger bandwidth was achieved, however still not sufficient for SAR applications. Further improvement is required. The radiation properties for both the bands are fairly good.

5 CONCLUSION

In this paper, a compact three-layer dual-band antenna on a single aperture is studied. The concept has been demonstrated on the L- and C-band sub-array. The performance of the array is mixed. The L-band perforated patch does exhibit good radiation performance but with rather low bandwidth. The co-polarisation radiation for both of the band is satisfactory.

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