

# A Wideband, Low Profile P- and Ku-band Dual Polarized Shared Aperture Antenna

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## 1. Introduction

Dual-band antennas are often used for Remote Sensing [1] to provide for frequency diversity. By sharing the same antenna aperture in the two selected bands can reduce the size and weight of the antenna. Microstrip antenna seems to be most suitable for the shared-aperture array. Therefore, a number of Dual-Band Dual-Polarized (DBDP) shared-aperture antenna arrays have been proposed and studied. The typical configuration of DBDP array includes perforated patches and patches [2,3], interlaced slot/dipole with patch [4-6]. These antennas mentioned above include the frequency combination between L-, S-, C- and X- bands, so the largest frequency ratio is the L/X-band shared aperture array. However, there are certain advantages in operating dual-band applications at lower low-frequencies, such as P-band and higher high frequencies, such as Ku-band [7]. The frequency ratio between P- and Ku-band is so large that the techniques mentioned above may not be suitable. One reason is that elements for higher frequency bands and for lower frequency bands are usually interlaced and this restricts the frequency band ratio. This is because narrow grid spacing required at the higher frequency band antenna elements to achieve grating-lobe free operation is too small for obtaining a lower frequency band antenna element to achieve reasonable bandwidth. This paper focuses on a design that is suitable for wide frequency ratio between the high and low frequencies band.

This paper focuses on a design to integrate P-band and Ku-band antenna in a shared compact planar aperture. As seen in Figure 1, the antenna consists one antenna element for P-band and a  $8 \times 8$  planar array for Ku-band. To share the same radiation aperture, the Ku-band antenna array is placed on the P-band patch. This means that the P-band patch serves as both the radiation patch in P-band and the reflector plane in Ku-band. To obtain a wide bandwidth, stacked patch antenna is selected for Ku-band and L-probe feeding is selected for P-band. The antenna is analysed with HFSS software and the simulated results are presented. Based on  $VSWR < 2$  criteria, bandwidths of 26.4 % (325-424 MHz) and 13.3 % (14.0-16.0 GHz) are obtained for P- and Ku-bands respectively. As the feeding network in the Ku-band contributed some unwanted radiation, sidelobes of below -10 dB is obtained over the frequency band from 14.1 to 15.7 GHz. The simulated gain varies from 5.4 to 7.4 dB in the P-band (325-424 MHz) and 23.0 to 24.4 dB in the Ku-band (14.1-15.7 GHz) respectively. Good isolation and cross polarization performances of this antenna are observed in both bands.

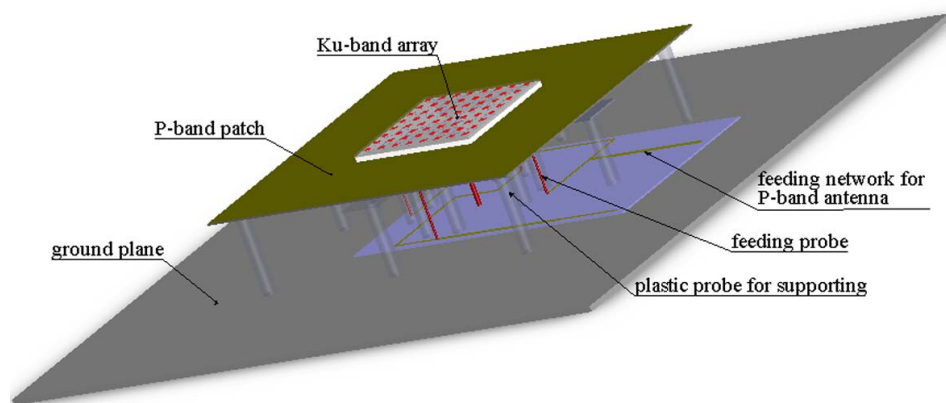


Figure 1: Configuration of the P/Ku-band antenna

## 2. Design of Antennas

### 2.1 P-band Antenna Design

Firstly, the P-band antenna is presented. As shown in Figure 2, the antenna consists only of a single radiating patch. This element is fed by four (i.e. 2 pairs) of L-shape probes. Each pair of the L-shape probes feed the patch in a differential manner for both vertical and horizontal polarization. A feed network combines the respective differential pairs of L-shape probes to two ports to obtain vertical and horizontal polarizations. Both the patch and feeding network are etched on a 1.6mm-thick FR4 substrate. The L-shape probe is fabricated with a copper cylinder and a metal strip etched on a piece of FR4 substrate. The key dimensions of the antenna are as follows:  $ppb=5\text{mm}$ ,  $ppl=63\text{mm}$ ,  $pphb=300\text{mm}$ ,  $pph=65.6\text{mm}$  and  $pah=73.2\text{mm}$ . The overall height is 73.2 mm or  $0.08\lambda_0$  at 325 MHz.

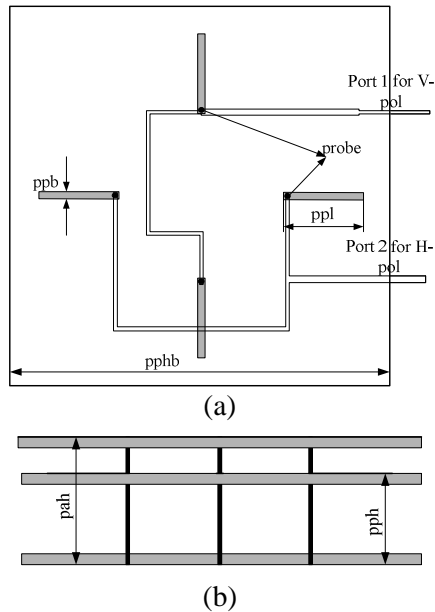


Figure 2. Geometry of the P-band antenna. (a) Top view, (b) Side view

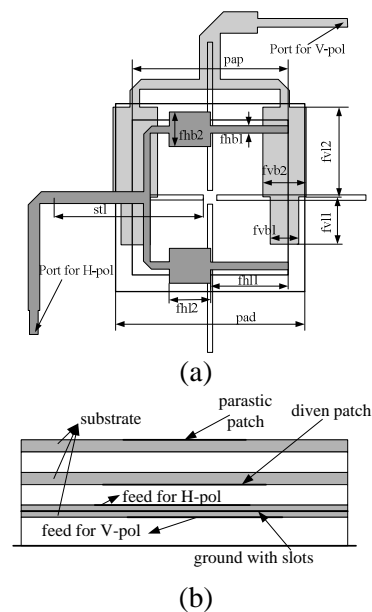


Figure 3. Geometry of the Ku-band antenna. (a) Top view, (b) Side view

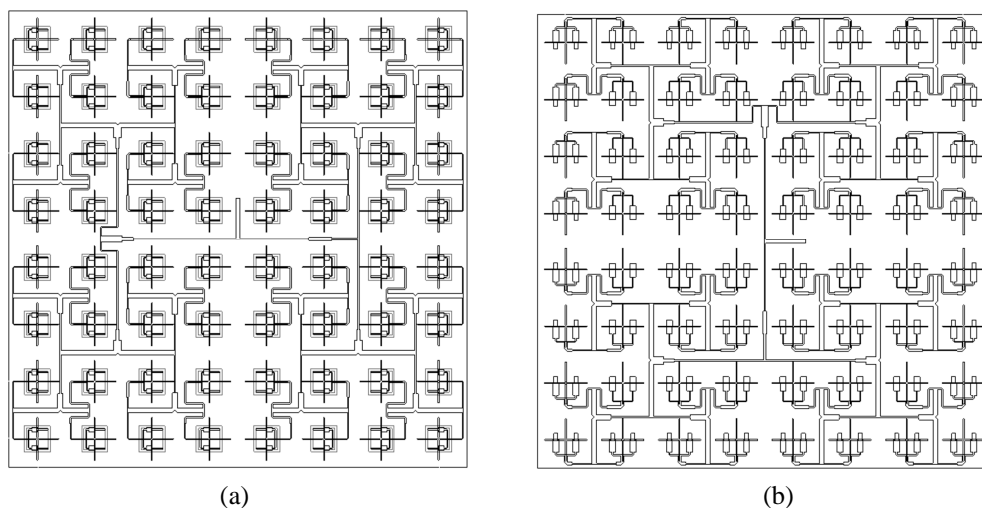


Figure 4. Geometry of the 8x8 Ku-band array (a) top view (b) bottom view

### 2.1 Ku-band Antenna Design

The aperture coupled stacked patch antenna is adopted for the Ku-band. The geometry of the element is shown in Figure 3. The antenna consists seven layers, which includes four substrate layers and three foam layers. Crossed slots are used for the two orthogonal polarizations and the feed lines for the two orthogonal polarizations are separated by the ground plane. To obtain good results, the dimensions of feeding lines for the horizontal and vertical polarization designed

separately. For a similar reason, the dimensions of the elements on the edge and in the centre are chosen differently. Some key dimensions of the Ku-band element are as follows:  $pap=5.24\text{mm}$ ,  $pad=6.35\text{mm}$ ,  $fhl=2.68\text{mm}$ ,  $fhl1=0.26\text{mm}$ ,  $fhl2=1.38\text{mm}$ ,  $fhl3=1.18\text{mm}$ ,  $fv1=1.6\text{mm}$ ,  $fvb1=0.97\text{mm}$ ,  $fv2=3.04\text{mm}$  and  $fvb2=1.44\text{mm}$ .

After the development of the element design, an  $8\times 8$  array was constructed. Figure 4 shows the geometry of the slots and feedlines for the  $8\times 8$  Ku-band array. The element spacing is 14 mm ( $0.7\lambda$  at 15.0 GHz). Corporate feed networks are used for both the polarizations to avoid pattern degradation of a series-fed architecture in the operating band. The impedance is matched at junctions in the corporate feed network with a two-step quarter-wave transformer. To reduce the coupling between the two bands, semi-rigid cables are used to feed Ku-band array. As the E-field in P-band is lowest at centre of the P-band patch, the cables for the Ku-band array should be placed as near the centre as possible. As seen in Figure 4, the feeding points are placed 10 mm from the centre of the P-band patch.

### 3. Simulated Results

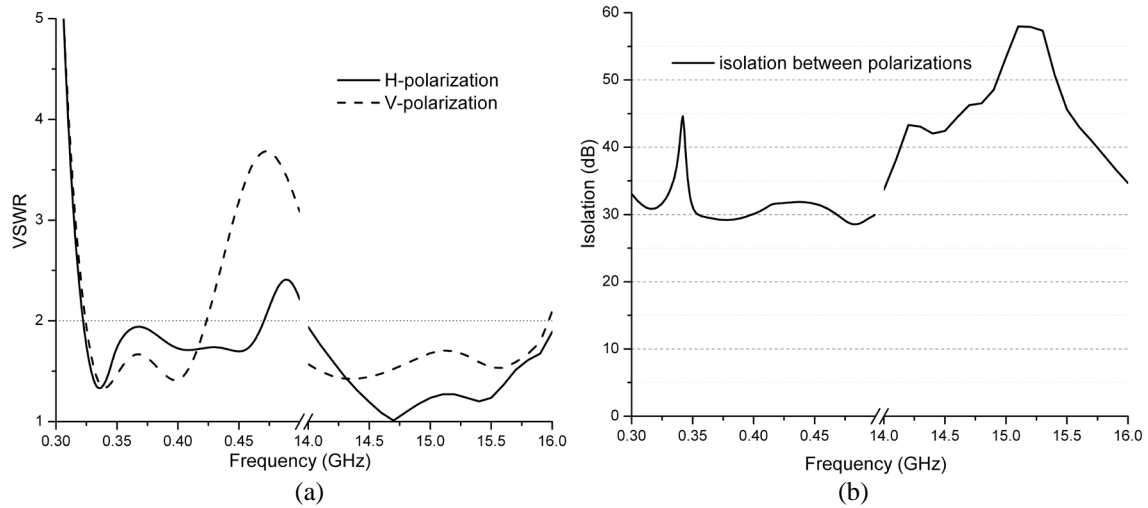


Figure 5. The simulated VSWR and isolation results (a) VSWR (b) Isolation

In this section, the performance of the array presented. Numerical results are obtained via HFSS 12.1. The simulated VSWR and isolation between the two ports for orthogonal polarizations are shown in Figure 5. It is seen that the antenna can cover the frequency bands of 325-424 MHz and 14.0-16.0 GHz with  $VSWR < 2.0$ . The isolation is below -28dB and -33dB in the P- and Ku-band respectively.

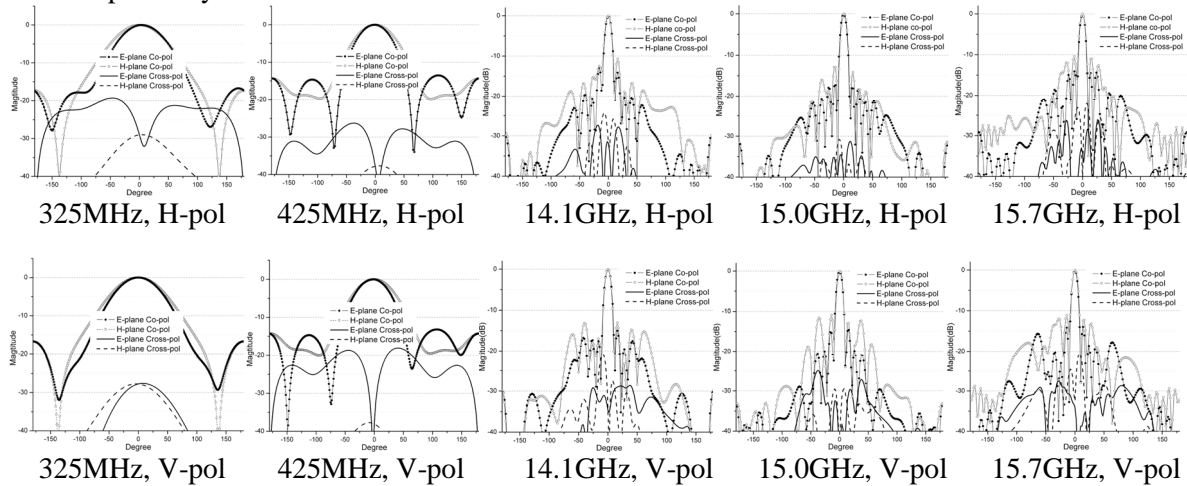


Figure 6. Normalized simulated patterns of the antenna

The simulated normalized patterns of the array are given in Figure 6, which include the E-plane and H-plane patterns at 325 MHz, 424 MHz for P-band and 14.1 GHz, 15.0 GHz and 15.7 GHz for Ku-band. Figure 7 gives the realized gain over the two frequency bands. It is seen that good radiation patterns are obtained both in P- and Ku-bands.

## 4. Conclusion

This paper presents a shared-aperture DBDP antenna with wideband. The L-probe and aperture coupled feeding styles are selected for P- and Ku-band design. The slots in Ku-band design for two orthogonal polarizations are separated by the ground to improve the cross-polarization and isolation. Corporate feeding networks are selected for Ku-band array to ensure good patterns over a wideband. The simulated results show that the bandwidths of  $VSWR < 2$  for the P- and Ku-band are 26.4 and 13.3%, respectively. The isolation between the cross-pol ports is below -28dB and -33dB for P- and Ku-band respectively. In the worst case, the cross-polarization in the P- and Ku-band are -18.1 and -20.4dB respectively. The details of the antenna are presented in the paper.

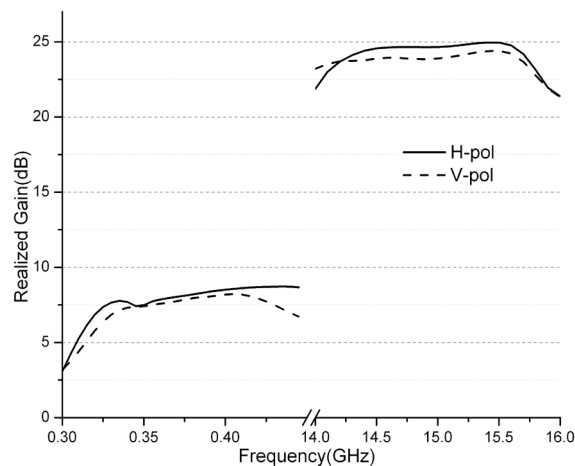


Figure 6. Simulated realized gain of the antenna

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