# COMPACT DUAL-BAND DUAL-POLARIZED MICROSTRIP PATCH ANTENNA FOR SYNTHETIC APERTURE RADAR

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***Abstract:*** *There is an increasing demand for newer microwave and millimeter-wave systems to meet the emerging telecommunication challenges with respect to size, performance and cost. Microstrip antennas offer the advantages of thin profile, light weight, low cost, ease of fabrication and compatibility with integrated circuitry. This paper presents a coaxilly-fed single-layer compact microstrip patch antenna for achieving dual-polarized radiation suitable for applications in the IEEE Radar Band C and X. Simultaneous use of both frequencies should dramatically improve data collection and knowledge of the targets in an airborne synthetic aperture radar system. The designed antenna consists of three rectangular patches which are overlapped along their diagonals. The design and simulation of the antenna were performed using 3D full wave electromagnetic simulator IE3D. The antenna with a bandwidth of VSWR<2 reaches 154MHz ($f_0$=6.83GHz) and 209MHz ($f_0$=9.73GHz) was designed and simulated successfully.*

***Keywords:*** *Microstrip antenna, Dual-band, SAR*

## 1 INTRODUCTION

Remote Sensing is the general science of gathering data and information about features, objects and classes on the Earth's land surface, oceans and atmosphere from sensors located beyond the immediate vicinity of such source. One such sensor that has captured the interest of the scientific community is the Synthetic Aperture Radar (SAR) [1]. It is capable of producing high-resolution imagery in microwave bands by using a special processing technique that synthesises a very long antenna aperture, thus the name synthetic aperture. Microwave frequencies are preferred as it can penetrate clouds; certain wavelength can even penetrate forest canopy. SAR sensors are active sensors, thus day and night operation is possible. SAR is usually carried on board satellites or aircrafts, as it requires relative motion between the sensor and the surface being imaged.

The radar group at the Goodyear research facility in Litchfield, Arizona is credited with building the first airborne SAR, back in 1953. It operated at 930MHz using a Yagi antenna with a very wide beamwidth ($100^0$). Subsequently many more airborne SAR systems was developed, notable among them are the AIRSAR by Jet Propulsion Laboratory (JPL), E-SAR by German Aerospace Research Establishment (DLR), C/XSAR [2] by Canadian Centre for Remote Sensing (CCRS) and EMISAR by Danish Centre for Remote Sensing (DCRS). These airborne SAR systems employed many types of antennas, ranging from Yagi, slotted-waveguide to microstrip. However, modern civilian SAR system generally operates in L-, C- and X-band, where microstrip antenna dominates [3].

Recently, dual-band and dual-polarized antennas have been studied using different techniques for satellite and wireless communication applications [4-7]. In particular, since microstrip antennas have attractive features such as low profile, light weight, and easy fabrication [8], the antennas are widely used to satisfy demands for polarization diversity and dual-frequency. The work described in this paper focuses on the design of a C-band and X-band dual-polarized synthetic aperture radar (SAR) antenna sharing the same physical aperture.

## 2 DESIGN AND OPERATING PRINCIPLE

The basic configuration of the proposed patch antenna for exciting dual-band dual-polarization is illustrated in Fig. 1. Three rectangular patches are overlapped along their diagonals. The dimensions of the patches are $(W \times L)\text{mm}^2$. $S_1$ and $S_2$ indicate the overlapping dimensions of the patches. The radiating patch is fed by a coaxial probe type feed in this design. As shown from Fig. 1, the inner conductor of the coaxial connector extends through the dielectric and is connected to the radiating patch, while the outer conductor is connected to the ground plane. The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance. This feed method is easy to fabricate and has low spurious radiation.

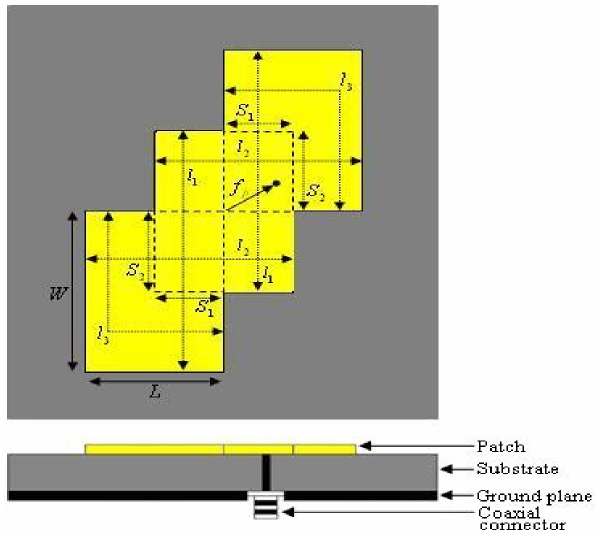

Fig. 1 Probe feed microstrip patch antenna top view (upper) and side view (lower)

The center of the patch is taken as the origin and the feed point location is given by the co-ordinates ($X_f$,$Y_f$) from the origin. The feed point must be located at that point on the patch, where the input impedance is 50 ohms for the resonant frequency. Hence, a trial and error method was used to locate the feed point. For different locations of the feed point, the return loss (R.L) was compared and that feed point was selected where the R.L was most negative. The structure has three different resonant lengths as follows:

$$l_1 = W + (W - S_2) + 2\Delta l_1 \quad (1)$$

$$l_2 = L + (L - S_1) + 2\Delta l_2 \quad (2)$$

$$l_3 = W + L - (L - S_1) + 2\Delta l_3 \quad (3)$$

The increments to the lengths, $\Delta l_1$, $\Delta l_2$ and $\Delta l_3$ are due to the fringing fields and can be computed from

$$\Delta l = 0.412h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \quad (4)$$

As an example, an antenna with the following dimensions was designed: three rectangular patches of dimension $(13 \times 9)\text{mm}^2$ with overlapping dimensions $S_1 = 4.5$ mm and $S_2 = 6.5$ mm; a dielectric substrate of relative permittivity $\varepsilon_r = 2.2$ and thickness $h = 1.58$ mm and the feed location $f_p = 4.43$ mm was used.

In the extreme edges, it illustrates the curved paths along the mean dimension $l_3$ and thus confirms the corresponding resonant frequencies given by equation 3. The dual-polarized behavior is explained as follows: At resonance frequencies $f_1$ and $f_2$, the antenna has two radiating strips perpendicular to each other, which radiate in vertical and horizontal polarizations (Fig. 1). At resonance frequency $f_3$, the radiating strip has a bend and its radiation is due to two perpendicular edges, which provides dual polarization [9].

## 3 RESULTS AND DISCUSSION

The results tabulated in Table 1 were obtained after varying the feed location along the diagonal length of the patch from the origin (center of patch) to its right most edge. The coaxial probe feed used was designed to have a radius of 0.5mm. A frequency range of 6–12 GHz was selected and 241 frequency points were selected over this range to obtain accurate results. Table 1 shows the calculated results for different feed locations.

Table 1 Effect of feed point on center frequency, return loss and bandwidth

| No. | Feed Location ($X_f, Y_f$) | C-Band | | | X-Band | | |
|---|---|---|---|---|---|---|---|
| | | Center Frequency (GHz) | Return Loss (dB) | Bandwidth (MHz) | Center Frequency (GHz) | Return Loss (dB) | Bandwidth (MHz) |
| 1 | (2.0,2.0) | 6.92 | -9.31 | - | 9.69 | -15.32 | 141 |
| 2 | (2.5,2.5) | 6.90 | -11.96 | 143 | 9.70 | -23.21 | 183 |
| 3 | (3.0,3.0) | 6.85 | -18.49 | 162 | 9.73 | -30.01 | 203 |
| **4** | **(3.25,3.25)** | **6.83** | **-24.13** | **154** | **9.73** | **-23.86** | **209** |
| 5 | (3.5,3.5) | 6.83 | -23.53 | 136 | 9.74 | -21.90 | 213 |
| 6 | (3.75,3.75) | 6.80 | -14.55 | 104 | 9.75 | -21.22 | 217 |
| 7 | (4.0,4.0) | 6.79 | -10.30 | 39 | 9.75 | -20.92 | 220 |

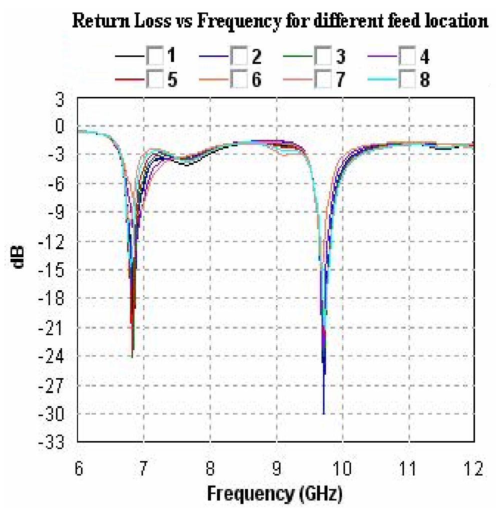


Fig. 2. Return loss for feed located at different locations

Fig. 2 shows the return loss plots for some of the feed point locations. The center frequency is selected as the one at which the return loss is minimum. As described in Section II, the bandwidth can be calculated from the return loss (RL) plot. The bandwidth of the antenna can be said to be those range of frequencies over which the RL is greater than -9.5 dB (-9.5 dB corresponds to a VSWR of 2 which is an acceptable Fig.). From Table 1, the optimum feed point is found to be at ( $X_f, Y_f$ ) = (3.25,3.25) where the RL of -24.13 dB and -23.86 dB are obtained for C-band and X-band respectively. The bandwidth of the antenna for this feed point location is calculated to be 154 MHz ($f_0$=6.83GHz) and 209 MHz ($f_0$=9.73). It is observed from Table 1 that, as the feed point location is moved away from the center of the patch, the center frequency starts to dicrease in the low frequency whereas slightly increase in the high frequency. It is also seen that though the maximum return loss is obtained at ( $X_f, Y_f$ ) = (3.0,3.0), the maximum bandwidth is obtained at ($X_f, Y_f$ ) = (4.0,4.0).

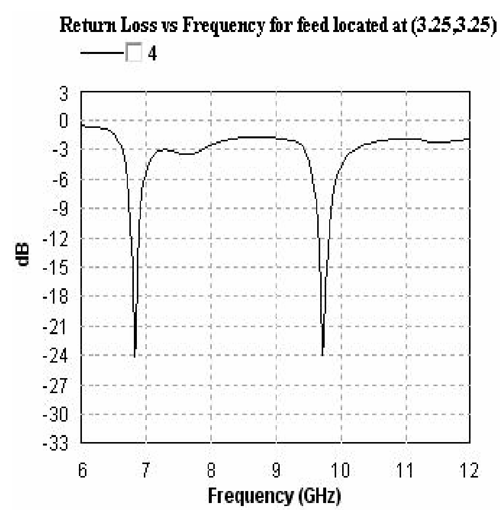


Fig. 3. Return loss for feed located at (3.25, 3.25)

Since a microstrip patch antenna radiates normal to its patch surface, the elevation pattern for φ = 0 and φ = 90 degrees would be important. Fig. 4 shows the radiation pattern of the antenna at C-band and X-band for φ = 0 and φ = 90 degrees.

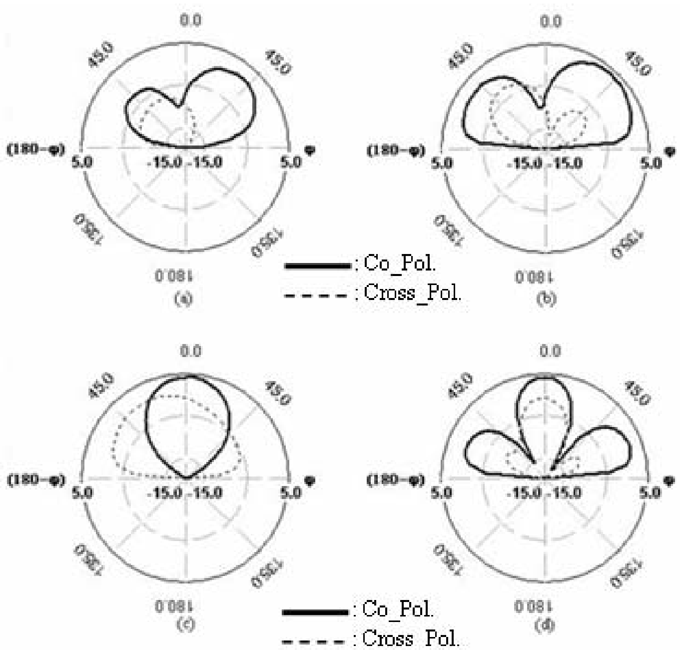


Fig. 4. Radiation pattern for 6.83GHz band (a) $\varphi = 0^o$ (b) $\varphi = 90^o$ and for 9.73GHz band (c) $\varphi = 0^o$ (d) $\varphi = 90^o$

## 4 CONCLUSION

A dual-band dual-polarized coaxially-fed single-layer microstrip patch antenna with a compact structure has been demonstrated and numerically studied. The proposed antenna with a bandwidth of 154MHz ($f_0$=6.83GHz) and 209MHz ($f_0$=9.73GHz) was designed and simulated successfully. From the results obtained, it can be seen that this novel antenna is capable of satisfying some of the requirements of an airborne SAR, for example, the radiation pattern and bandwidth requirements. In additions, For high data collections and accurate knowledge of targets missions which could need several frequency bands, this concept allows to share between C and X bands SAR system. Beside this, the concept can be simply adapted to design other antenna operating at different frequency band.

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