Tri-band Dual-polarized Multilayer SAR Microstrip Antenna

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Abstract— A novel tri-frequency (C, X and Ku) bands with dual-linear polarized each, multilayer microstrip antenna single element is proposed and presented. The triple band operation is obtained by using two antenna elements, one for a dual-band resonance at C and X bands with dual linear polarization and above is for the Ku band (also with dual linear polarized behavior). The feeding mechanism for the dual antenna element is an aperture coupling through cross shaped slot with different shaped feeding ports (to enhance isolation). The Ku band antenna element has an electromagnetically coupled microstrip T-junction feed for one polarization and a direct feeding for the orthogonal polarization. The multilayer microstrip element exhibits a selective frequency band of operation, good isolation among the different feeding ports, good directivity pattern and high gain for both polarizations at all frequency bands. The performance of the proposed antenna was simulated using a commercial software based on the Finite Element Method (FEM) algorithm. The proposed antenna is designed to meet the requirements of Synthetic Aperture Radar (SAR), where multiple frequency with dual linear polarization is needed.

1. INTRODUCTION

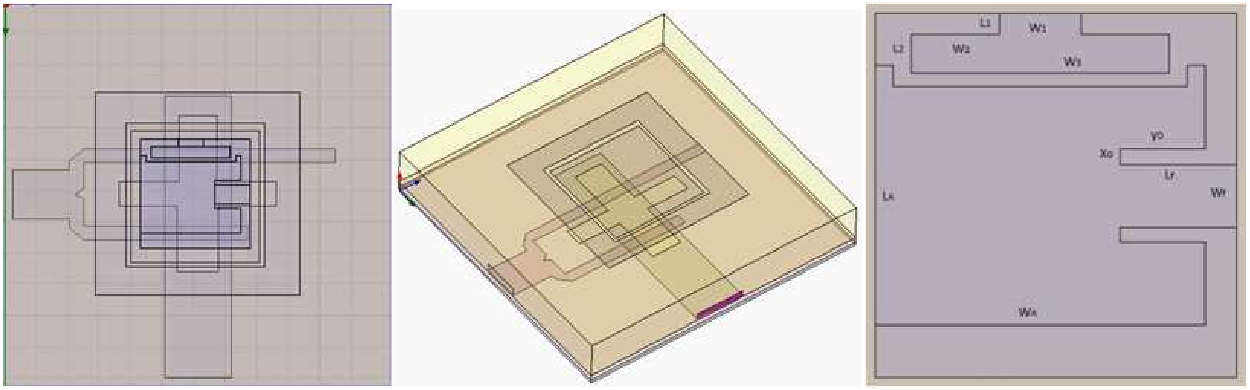
SAR operations mainly depend on synchronized measurements using different frequencies, preferably simultaneous dual polarized. Since the performance of a SAR system such as synthetic aperture length, PRF, slant range resolution and so on are directly dependent on the antenna design and since the reflection behavior of an object depends on the different incident frequency and polarization, hence, SAR antenna design should satisfy multi-band operation to provide more information such as object penetration depth, while the dual-polarization capability will provide additional information and hence enhance the probability of mapping and identification [1]. Many Dual-Band Dual-Polarization (DBDP) antenna designs have been presented to meet some requirements in this field, such as shared-aperture including perforated structure [2], interlaced structures [3] and overlapped layout [4]. A considerable number of feed methods, such as probe-feed [5], aperture-coupled [6], proximity-coupled [7] and L-shape feed [8] are proposed. Also, enhanced port isolation or cross-polarization performance were handled in [9]. Recent work extends the use of DBDP antennas to obtain TBDP where L/S and L/X DBDP subarrays and L-band sub-array are applied [10].

In this paper a novel TBDP shared aperture SAR antenna based on one C/X DBDP and single Ku band DP antenna is proposed and simulated.

2. ANTENNA DESIGN AND CONFIGURATION

During the design, it was noted that using dual offset feed line beside a single feed line to couple the aperture helped to reduce the mutual coupling. A section of the microstrip line was placed at the end of each feed line to facilitate the impedance matching between the microstrip feed and the aperture. The DBDP antenna layers are organized as follows, a dual offset feed line with unequal arms lengths alongside [11] is underneath a foam layer with $\varepsilon_r = 1.06$ and thickness 0.245 mm, above this layer is the orthogonal line feed. The ground plane having an equal arms cross shaped slot in center is over a two thin Rogers RT/Duroid 6006 with $\varepsilon_r = 6.15$ and thickness 0.245 mm. The antenna above is a slotted square patch to provide two center resonance frequencies 7 GHz and 11.5 GHz placed over a foam substrate of thickness 3.2 mm in order to fulfill the lightweight constraint of SAR systems. Another layer of foam of thickness 1.016 mm is placed above the dual-band antenna.

An easy feed method to get dual polarized patch is to directly connect two orthogonal microstrip ports to the horizontal and vertical side of the microstrip patch. But a main drawback of this type is the DC contact between ports through the patch, also, the resonant frequency can be changed easily according to the depth of the inset which has the role of impedance matching. In order to avoid the above mentioned problems, we propose an electromagnetically coupled microstrip T-junction adjusted in a gap truncated from the patch alongside [12], hence, no lumped capacitors for blocking DC contact will be needed. The single Ku band DP antenna is a rectangular patch over a finite conductor with a direct inset line feed placed in the orthogonal side. This antenna is designed over Rogers RT/Duroid 5880 $\varepsilon_r = 2.2$ and thickness 0.508 mm and having a center frequency of 16.24 GHz. Figure 1 shows the configuration of the TBDP antenna, DBDP antenna and detailed structure of the Ku patch.



(a) (b) (c)

Figure 1: (a) Configuration of TBDP antenna top view, (b) DBDP antenna only, (c) detailed Ku patch showing the T-junction.

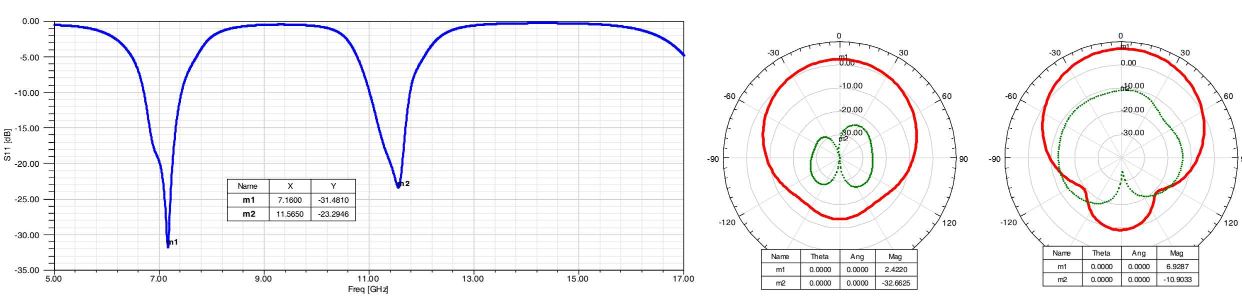
The geometrical dimensions of the proposed antenna is listed as follows, the C-band is a square patch of 13 mm edge length, the insider X-band is 8.4 mm by 8.5 mm rectangular patch, feed line of width equal to 4.2 mm and length 18.075 mm, the dual offset feed is two 100 Ω lines connected by a simple power divider to a 50 Ω line, the widths are 0.9 mm and 3.2 mm respectively and the Ku band DP patch antenna has $w_A = 6.4$ mm, $L_A = 5$ mm, T-junction $w_1 = 1.6$ mm, $L_1 = 0.4$ mm, $w_2 = 1.7$ mm, $L_2 = 0.75$ mm, $w_3 = 5$ mm, inset feed line $w_f = 1.2$ mm, $L_f = 2.25$ mm, $x_0 = 0.3$ mm and $y_0 = 1.65$ mm.

3. SIMULATIONS AND RESULTS

SAR missions may require single, dual or triple resonance operating frequency equipped with single or simultaneous linear polarization. The simulation of the proposed TBDP antenna is done to satisfy these requirements. The study includes each reflection coefficient and gain of a single feed in ON state (excited) while all other ports are OFF, then studying the reflection coefficient and isolation results when all ports are ON.

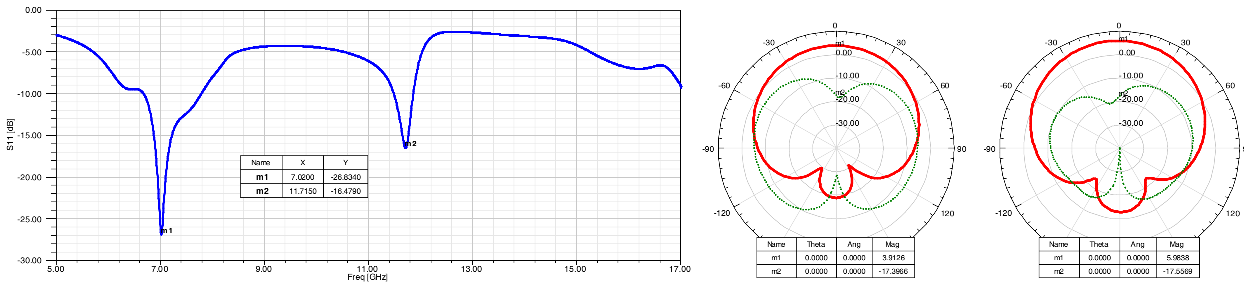
Figure 2 through Figure 5 show the return loss and E-plane co-polarized (solid) and cross-polarized (dashed) gain patterns at different ON states of the antenna, the C/X line feed and the Ku T-junction are named as the vertical polarization feeds, while C/X dual offset and Ku patch inset feed are the horizontal polarization feeds. The results are summarized in Table 1.

From the patterns above, it can be noted that the pattern radiated by the C/X dual-band antenna using line feed exhibits co-polarization gain level for C-band equal to 2.422 dB that is about 34 dB up in direction of maximum compared to the cross-polarization level, while the dual offset feed shows C-band co-polarization level 21.3 dB up compared to cross-polarization level. While the



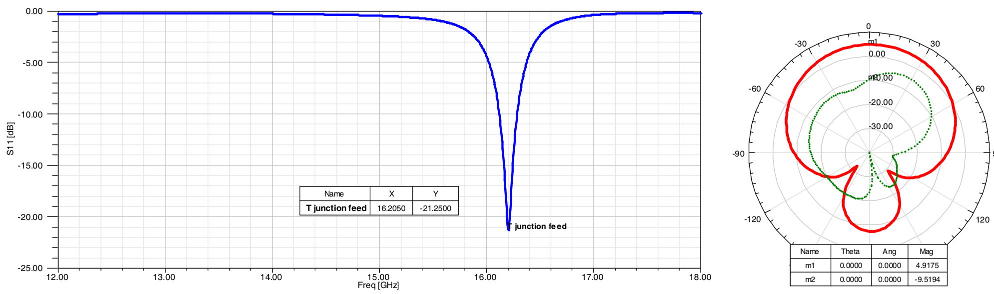
(a) (b) (c)

Figure 2: C/X Feed line. (a) Return loss [dB], (b) C-band Gain [dB], (c) X-band Gain [dB].



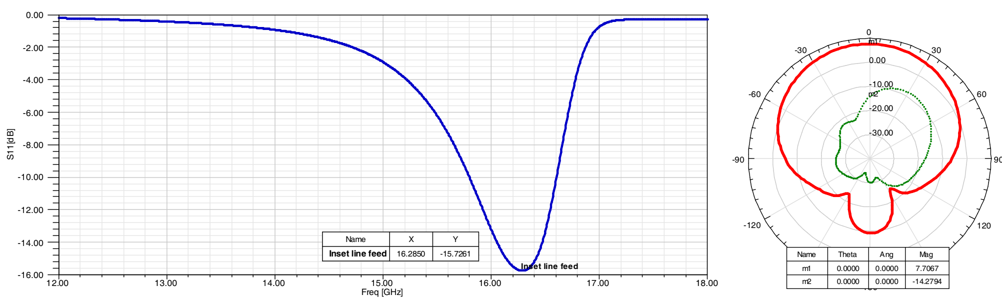
(a) (b) (c)

Figure 3: C/X dual offset feed. (a) Return loss [dB], (b) C-band Gain [dB], (c) X-band Gain [dB].



(a) (b)

Figure 4: Ku electromagnetically coupled T-junction feed. (a) Return loss [dB]. (b) Gain [dB].



(a) (b)

Figure 5: Inset feed line. (a) Return loss [dB]. (b) Gain [dB].

Table 1: Return loss and gain of the proposed TBDP antenna one feed in ON state at a time.

	DBDP antenna				Ku band antenna	
Feeding port	Line Feed		Dual offset		T-junction	Inset Feed
Frequency [GHz]	7.16	11.565	7.02	11.715	16.205	16.285
Return loss [dB]	−31.481	−16.574	−26.834	−16.479	−21.25	−15.7261
Gain [dB]	2.422	6.9287	3.9126	5.9838	4.9175	7.7067

line feed exhibits a cross polarization −17.83 dB down the direction of maximum, whereas the dual offset feed cross-polarization drops to −23.54 dB compared to the co-polarized level. The antenna gains at Ku band are 4.9175 dB T-junction ON while other ports are OFF, and the co-polarized gain of the inset feed is 22 dB up the cross-polarized gain.

The case when all antenna ports are excited (ON state) is shown in Figure 6 below. The return loss shows the stability of resonance frequency of all ports regarding the state of other ports either ON or OFF. Hence, validate the structure and reveal that the isolation between different feeding ports for the same frequency band is less than −15 dB and less than −30 dB among different feeding ports for different frequency bands.

Another aspect to be considered is the bandwidth, for a SAR system to transmit or receive a HV/VH look, the proposed antenna provides 570 MHz intersecting BW in C-band between the horizontal and vertical polarizations, 380 MHz in X-band and 165 MHz in Ku band.

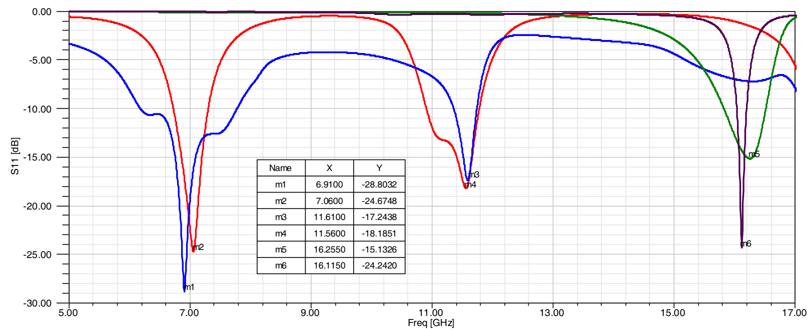


Figure 6: Return loss in [dB] for all TBDP antenna ports are excited.

4. CONCLUSION

A novel TBDP shared aperture microstrip antenna for the synthetic aperture radar (SAR) application is designed and simulated. The design based on sharing a single Ku band dual polarized patch on finite ground over a DBDP antenna. The dual polarizations are done by feeding the two antennas from two orthogonal directions by four different feeding lines. The proposed TBDP simulations included two steps, first step is studying the performance of each feed line for every antenna in ON state while all other ports are not excited. The second step is to introduce more than feeding port in ON state. The simulations results showed good return loss, gain, considerable high isolation and low cross polarization.

REFERENCES

1. Zhong, S.-S., *DBDP SAR Microstrip Array Technology*, edited by N. Nasimuddin, California, 2011.
2. Pozar, D. M. and S. D. Targonski, "A shared-aperture dual-band dual-polarized microstrip array," *IEEE Trans. Antennas Propagat.*, Vol. 49, No. 2, 150–157, Feb. 2001.
3. Pokuls, R., J. Uher, and D. M. Pozar, "Microstrip antennas for SAR applications," *IEEE Trans. Antennas Propagat.*, Vol. 46, No. 9, 1289–1296, 1998.
4. Li, P., K. M. Luk, and K. L. Lau, "A Dual-feed dual-band L-probe patch antenna," *IEEE Trans. Antennas Propagat.*, Vol. 53, No. 7, 2321–2323, Jul. 2005.
5. Waterhouse, R. B., "Design of probe-fed stacked patches," *IEEE Trans. Antennas Propagat.*, Vol. 47, No. 12, 1780–1784, Dec. 1999.
6. Gao, S. C., L. W. Li, M. S. Leong, and T. S. Yeo, "Dual-polarized slot-coupled planar antenna with wide bandwidth," *IEEE Trans. Antennas Propagat.*, Vol. 51, No. 3, 441–448, Mar. 2003.
7. Gao, S. and A. Sambell, "Dual-polarized broad-band microstrip antennas fed by proximity coupling," *IEEE Trans. Antennas Propagat.*, Vol. 53, No. 1, 526–530, Jan. 2005.
8. Wong H., K.-L. Lau, and K. M. Luk, "Design of dual-polarized L-probe patch antenna arrays with high isolation," *IEEE Trans. Antennas Propagat.*, Vol. 52, No. 1, 45–52, Jan. 2004.
9. Sun, Z., S. S. Zhong, X. R. Tang, and J. J. Liu, "C-band dual-polarized stacked patch antenna with low cross-polarization and high isolation," *Proceedings of EuCAP*, 2994–2997, Berlin, Germany, Mar. 2009.
10. Zhong, S. S., Z. Sun, L. B. Kong, C. Gao, W. Wang, and M. P. Jin, "Design of TBDP shared-aperture SAR array," *IEEE Microwave Conference Proceedings (APMC) Asia-Pacific*, 159–162, 2011.
11. Smith, C. B., "Wideband dual-linear polarized microstrip patch antenna," Doctoral Dissertation," Texas A&M University, 2008.
12. Choi, D. H. and S. O. Park, "Dual-band and dual-polarization patch antenna with high isolation characteristic," *IEEE Microwave Conference Proceedings (APMC) Asia-Pacific*, 2014–2016, 2006.