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Review and Survey of Arbitrary Shape Dual Frequency and Dual Polarized Microstrip Patch Antenna

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Abstract - Microstrip Patch Antenna is mostly used in modern communication devices, and day-to-day communication is done through it. Study of literature of past few year shows that, the leading work on Microstrip Patch Antenna (MPA) is focused on designing for dual frequency and dual polarized operation on arbitrary shape of patch with commercially simulated software. This review paper demonstrates some commonly engaged techniques to fabricate Microstrip patch antenna with dual frequency and dual polarized operation since last few decades.

Index Terms - *Patch Antenna, Simulator Software, Frequency, Polarization, Gain.*

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I. INTRODUCTION

Microstrip Patch Antenna (MPA) is commonly used because of its low profile, low cost and ease of manufacturing. A patch antenna is made by etching metal on one side of dielectric substrate whereas on the opposite side there is continuous metal layer of the substrate which forms a ground plane. MPA are inherently a narrowband antenna so; various bandwidth enhancement techniques are engaged while keeping its size as compact as possible with that the wireless communication systems are often faced with many problems of multiple path fading. Recently, research work has focused on frequency reuse and polarization diversity. A number of techniques available for analyzing Microstrip patch antenna. The analytical techniques include transmission line model and cavity model. The most common numerical techniques are moment method and the finite element method. The later technique is time consuming while the former method and the analytical techniques have been applied to regular shapes only like rectangular, circular, and elliptical shapes. These techniques are dealt with comprehensively in a special issue. For an arbitrary shape, the finite element method can be used. This allows communication systems to be able to send and receive signal with more alternative polarization. Due to which many studies and researches are being done throughout the globe. To achieve dual frequency and dual polarization many techniques are used and some of them are explained further in this review paper.

II. BANDWIDTH ENHANCEMENT TECHNIQUES FOR DUAL FREQUENCY AND DUAL POLARIZATION MICROSTRIP PATCH ANTENNA

The major need for today's communication devices is to operate at dual frequency and dual polarization such as to support high speed internet, multimedia communication and similarly many more broadband services, this is achieved by using microstrip patch antennas, but inherently microstrip antennas are narrow band antennas so, various techniques are used to enhance the bandwidth of microstrip antenna. In this section dual frequency and dual polarization enhancement techniques are explained. Planar Array configuration, Multi-layered configuration and Stacked Arbitrary microstrip patch antenna are mainly used in dual frequency and dual polarized operation.

A. Modified Planar Array Shape Dual Frequency and Dual Polarized Microstrip Patch Antenna

In this technique bandwidth and polarization diversity enhancement is done by changing/modifying the Planar Array of radiating patch. Dual-band and Dual- polarized shared-aperture array antennas with single-layer substrate is given by Jin-Dong Zhang, et al. [1]. In this paper two prototype arrays with 4x4 elements is presented. Its configuration is shown in figure (1).

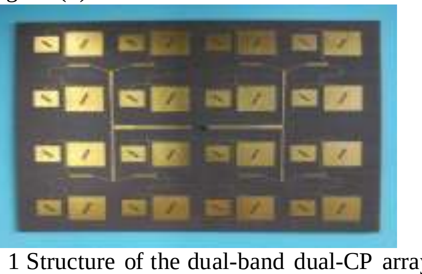

Fig. 1 Structure of the dual-band dual-CP array with conventional feed network: fabricated 4×4 element array.

This antenna is applicable for 12.1 GHz and 17.4 GHz frequency with Right Hand Circular Polarization (RHCP) and Left Hand Circular Polarization (LHCP). Substrate used in this antenna is Arlon DiClad 880 ($\varepsilon r = 2.2$) and 3-dB Axial Ratio (AR) bandwidth is around 1.5% for both bands. In the lower band centered at 12.1 GHz, the -10-dB return loss bandwidth is 8.3%, the 3-dB AR bandwidth is 14.2% (RHCP); in the higher band centered at 17.4 GHz, the corresponding data are

18.9% and 14.9% (LHCP), respectively. Gain of proposed antenna is almost constant in the frequency range where broadband operation is realized.

Another design for modified array patch is Novel Wideband Dual-frequency patch antenna array for Dual- Polarization Operation shown in figure (2) is given by P. Li and K. M. Luk [2]. In this paper an array achieves two broad operating bands, which cover 0.82-0.96 GHz and 1.71-2.17 GHz, with return loss less than -14 dB. Across both pass bands, a high isolation of more than 30 dB is measured between two polarizations. The geometry of the proposed dual-frequency and dual-polarization antenna array is shown in fig.2. Totally 6 elements are employed in the structure with two larger patch for the lower band and four pairs of smaller ones for the upper band. Detailed dimensions are listed as follows: M=75.2; N=24.4; W1=12.6; W2=6.2; W3=5.05; l1=3.8; l2=1.5; l3=2.9; l4=3.1; T=0.2; t1=0.2; t2=0.1; h1=2.75; h2=1.05; h3=1.1; H1=3.8; H2=1.4; H3=1.4; L=3.5(cm).

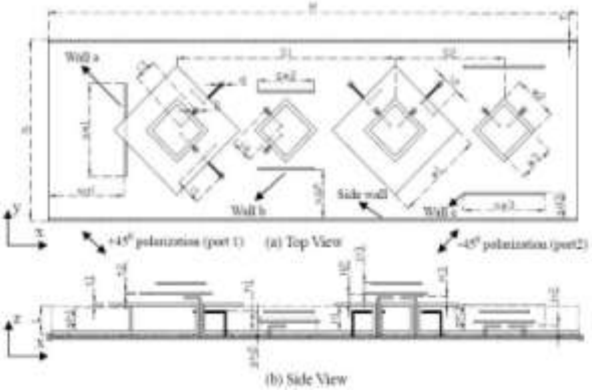

Fig.2. Geometry of wideband dual-frequency patch antenna array for dual-polarization operation

A novel dual-frequency dual polarization stacked parch microstrip array feed for remote sensing reflector antenna is given by Keertu S. Kona, el at. [3] This paper presents the design and implementation of a dual-frequency (1.13GHz and 3.75GHz) dual-linear polarization stacked patch array feed with a novel probe-feeding architecture for future space borne synthetic aperture radar (SAR). Shown in fig.3. Results demonstrate a good correlation between the measurements and simulation form finite-difference time domain (FDTD) and reflector analysis codes thus validating the design for use in SAR for soil-moisture application.

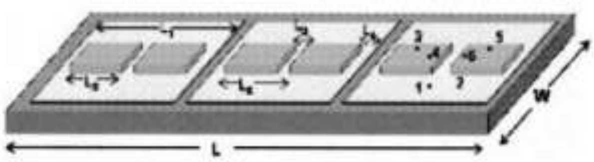

Fig.3. Conceptual feed array for the reflector with array dimensions: L=39.3cm, W= 13.3cm, L_1=11.5cm, L_2=2.95cm, L_3=3.2cm, L_4=0.9cm and L_5=6.15cm. Port1: V-port lower patch, Port 2: H-port lower patch, Port3: V- port upper patch, Port 4: H-port upper patch, Port 5: H- port upper patch

A design for a dual-band dual-polarized microstrip array antenna for base stations is given by K. Moradi, et al. [4] in this paper the antenna is based upon an aperture stacked patch layout and incorporates a simple and novel dual-layered feeding technique to achieve dual linear polarized radiation. Peak antenna gains about 11dBi and 11.6 dBi have been obtained for lower and upper bands. The polarization isolation is greater than 30 dB in both bands. The antenna consists of 4 layers, 3 layers of FR4 dielectric material (Ɛr=4.4) and 1 air layer (Ɛr=1) shown in fig.4. Result is simulated by HFSS for a frequency of 900 MHz and 1800 MHz.

Fig.4. The configuration of 1 X 4 antenna array.

B. Arbitrary Shape Configuration of Dual Frequency and Dual Polarization Microstrip Patch Antenna.

In such a configuration microstrip antenna of different shape other than regular shape Circular patch with eight curved slots and a disk-loaded coaxial probe. Omnidirectional Dual-Band Dual Circularly Polarized Microstrip Antenna using TM01 and TM02 modes is given by Dan Yu, et al. [5]. In this paper the measured axial ratios (ARs) TM01 and TM02 modes in the azimuth plane are 1.71 and 2.82 dB, respectively the measured left-hand Circular Polarization (LHCP) and right-hand Circular Polarization (RHCP) gains in the azimuthal plane are 0.1 dBic at the 1.65 GHz lower centre frequency and 1.1 dBic at the 2.76 GHz upper centre frequency respectively. Using dielectric constant (Ɛr=9.8) shown in fig.5.

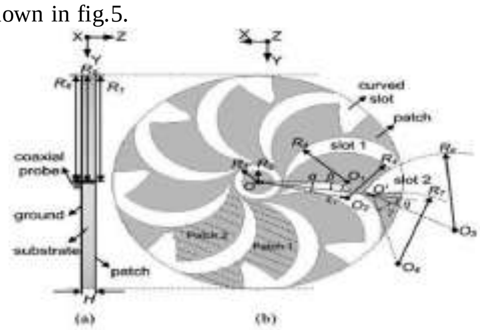

Fig.5. Configuration of the proposed antenna. (a) Side View (b) Top View

The Parameter R_1=3cm, R_2=0.33cm, R_3=0.5cm, R_4= 1.48cm, R_5= 3cm, R_6=2.3cm, R_7=2.1cm, R_8=3cm, L_1=1.77cm, L_2=2.4cm, H=0.3cm, $\alpha=14^0$, $\beta=9^0$, $\gamma=45^0$, $\eta=0^0$, $\varepsilon r=9.8$.

Another design of dual band dual polarized modified circular microstrip antenna is given by Amit A. Deshmukh, et al. [6]. The proposed configurations were analyzed on low cost glass epoxy substrate which realizes gain of 4 and 6 dBi, at dual frequencies. The rectangular slot is cut such that its increasing dimensions (Ls) is orthogonal to the surface currents at second order patch mode and it is parallel to the surface currents at first order mode as shown in fig.6. Ls=4.0cm, Ws=0.2cm, and y=1.0cm, r=4mm, Ɛr=4.3 the result analyzed by IE3D simulation gives the 764 MHz and
985 MHz frequency at TM11 and TM21 mode.

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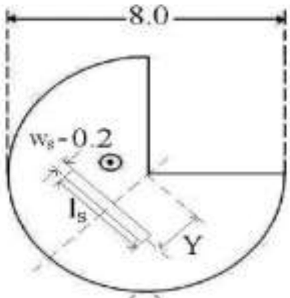

Fig.6. dual band slot cut 270^0 sectoral MSA.

A design of a single-feed dual band dual-polarized printed microstrip antenna using a Boolean particle swarm optimization is given by Farzaneh Afshinmanesh, et al. [7]. The Boolean particle swarm optimization algorithm in conjunction with the method of moment (MoM) is employed to optimize the geometry. The measured results show excellent performance with more than 15dB of return loss and 10dB of cross polarization in both frequency bands of operation, i.e., 12 and 14 GHz. A gain of 4.8 dBi has been measured for both frequency bands and linear polarization.

Fig.7. Final antenna layout fabricated on RT/Duroid 5880

C. Multi-Layered Configurations of Dual Frequency and Dual Polarization Microstrip Patch Antenna.

In multi-layered configuration patch are placed over different dielectric substrates and they are stacked on each other. Based on the coupling mechanism, these configurations are of two types electromagnetically-coupled or aperture- coupled. Electromagnetic coupled microstrip antenna one or more patches are located on different dielectric layers. Patch dimensions and dielectric constant of substrate may be different where as resonant frequency is closer to each other to obtain dual frequency and dual polarization operation. In aperture coupling, the field is coupled from the microstrip feed line placed on the other side of ground plane to the radiating patch through an electrically small aperture/slot in the ground plane. Two different dielectric substrates could be chosen one for the patch and other for feed line.

Design of Single feed dual band dual polarized microstrip antenna with defected ground structure for aeronautical and radio navigation applications is given by P. R. Prajapati, et al. [8]. To realize dual band and dual polarization the proposed antenna radiates right hand circular polarization at the lower band (1.59-1.67 GHz), which covers aeronautical and radio navigation and satellite application spectrum, and linear polarization at the upper band (2.45-2.52 GHz) which cover fixed mobile radio location and radio determination application spectrum allocated in India. Geometry shown in fig.8. The 3dB axial ratio band width of 20 MHz at the lower band and a gain of 5.1 dB at the lower resonant frequency and a gain of 6.7 dB at the upper frequency band are achieved.

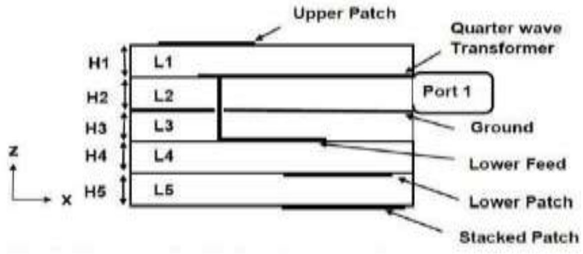

Fig.8. Cross-sectional view of proposed antenna.
Parameters: Ɛr and tanδ of layers L_1,L_2.L_3,L_4= 2.5 and 0.0017 respectively, Ɛr and tanδ of layer L_5=4.4 and 0.0019 resp. H_1, H_2, H_3, H_4, H_5 = 0.15 cm.

Other design of a new dual-frequency and dual- polarization microstrip element is given by Reuven shvit, et al. [9]. The feeding mechanism of the element is aperture coupling for one polarization and direct feeding for the orthogonal polarization. A parametric study was conducted using IE3D commercial software based on method of moments (MoM). The multilayer substrate dimensions are
5x5 cm. port 1 is 0.26 cm and its width is 0.8 cm while at port 2 the length of 0.3 cm and the width is 0.236 cm. gives the frequency of 11.2 and 14.25 GHz. Geometry is given in fig.9.

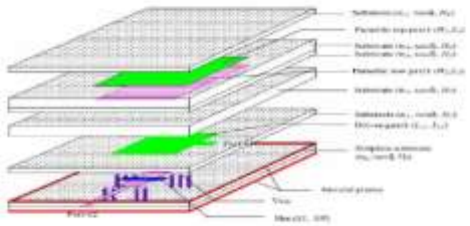

Fig. 9. Geometry of the dual-frequency, dual-polarization microstrip antenna

A design of high-gain dual-band dual-polarized Electromagnetic band gap resonator antenna with an all- dielectric superstructure is given by Basit Ali Zeb at el. [10]. A fabricated prototype of the dual-band DP-ERA is shown in fig.10. the superstructure is constructed using 3.175mm-thick Rogers Tmm10 material (Ɛr=9.2, δ= 0.0022) and its dimensions are 11 x 11 cm^2. A prototype of this dual- polarized electromagnetic band gap resonator antenna with a frequency ratio of 1.245 has been fabricated and measured, peak gains of 17 and 16.6 dBi at 10.6 and 13.15 GHz respectively and cross-polarization levels of less than -18dB, have been achieved.

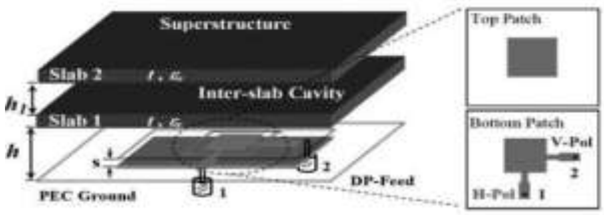

Fig.10. Configuration of the dual-band dual-polarized ERA and its stacked-patch feed

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III. TABLE FOR THE COMPARATIVE STRUCTURE ANALYSES OF DUAL FREQUENCY AND DUAL POLARIZTION.

TABLE I
Comparative Study of Dual Frequency and Dual Polarized Microstrip Patch Antenna

Types	Ref.	Dimensions		Dielectric Substrate	Simulated Software	Feeding Method	Operational Frequency	Polarization	Gain
		Length	Width						
Planar Array Shape	1	L1= 0.35 cm L2=0.27 cm	W1 = 0.05 cm W2 = 0.05 cm	Arlon Di Clad 880 ($\varepsilon_r = 2.2$)	HFSS (Finite Element software)	Co-axial Probe Feed	F1 = 12.14 GHZ F2 =17.4 GHz	RHCP & LHCP	Not Mention
	2	L1= 3.8 cm L2= 1.5 cm	W1 = 12.6 cm W2= 5.05 cm	Not Mention	Not Mention	Co-axial Probe Feed	F1 = 0.9 GHz F2 =2.0 GHz	Orthogonal polarization	10.5 dBi &14 dBi
	3	L1= 11.3 cm L2= 2.95 cm	W1 = 11.3 cm W2= 2.95 cm	RT Duroid ($\varepsilon_r = 2.2$)	FDTD	Not Mention	F1 = 1.13 GHz F2 = 3.57 GHz	Orthogonal polarization	Not Mention
	4	L1= 2.0 cm L2= 1.5 cm	W1 = 11 cm W2= 4.5 cm	FR 4 ($\varepsilon_r = 4.4$)	HFSS	Co-axial Probe Feed	F1 = 900MHz F2 = 1800MHz	Orthogonal polarization	11 dBi 11.6 dBi
Arbitrary shape configuration	5	R1 = 3 cm R2 = 0.32 cm		FR 4 ($\varepsilon_r = 2.55$)	Not Mention	Co-axial Probe Feed	F1 = 1.65 GHz F2 = 2.76 GHz	RHCP & LHCP	Not Mention
	6	Is = 4.0 cm	Ws = 0.2 cm	Glass Epoxy ($\varepsilon_r = 4.3$)	IE3D	Co-axial Probe Feed	F1 = 754 MHz F2 = 954MHz	Orthogonal polarization	4 dB 6 dB
	7	L = 0.625 cm		RT/ Duroid 5880 ($\varepsilon_r = 2.2$)	IE3D	Co-axial Probe	F1 = 12 GHz F2 = 14 GHz	Orthogonal polarization	4.8dBi
Multi layered configuration	8	L1=L2=l3=L4 =0.25 cm	L5= 0.44 cm	FR 4 ($\varepsilon_r = 2.55$)	Not Mention	Proximity coupled feed	F1 = 1.59 GHz F2 =2.45 GHz	RHCP & Linear Polarization	5.1 dB 6.7 dB
	9	L1= 0.563 cm L2= 0.671 cm	W1 = 0.563cm W2= 0.808 cm	($\varepsilon_r = 1.067$)	IE3D	Aperture coupled feed	F1 = 11.2 GHz F2 = 14.25 GHz	Orthogonal polarization	7.5 dB 8 dB
	10	11 x 11 cm^2		RT/Duroid 5880 ($\varepsilon_r = 2.2$)	CST	Co-axial Probe Feed	F1 = 10.6 GHz F2 =13.15 GHz	Orthogonal polarization	17 dB 16.6 dB

CONCLUSION

Narrow bandwidth of microstrip patch antenna is its major limitation; to improve/enhance bandwidth, many bandwidth enhancement techniques are used. This paper shows the review and survey of various such techniques used for dual frequency and dual polarization of microstrip patch antenna. Out of all techniques specified above in this paper the arbitrary shape configuration and Multilayered Technique yield maximum bandwidth.

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