A Dual Frequency Dual-Polarized Planar-Array Antenna Stacked Using Foam Layer with Different Dielectric Constants

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Abstract- *A new dual-frequency dual-polarized array antenna for airborne applications is presented in this paper. Two planar arrays with thin substrates (RIT Duroid 5880 substrate, with$\mathcal{E}$ = 2.2 and a thickness of 0.13 mm) are integrated to provide simultaneous operation at S band (3 GHz) and X band (10 GHz). Each 3 GHz antenna element is a large rectangular ring resonator antenna and has a 9.5 dBi gain that is about 3 dB higher than the gain of an ordinary ring antenna. The 10 GHz antenna elements are circular patches. They are combined to form the array with a gain of 18.3 dBi, using a series-fed structure to save the space of the feeding line network. The ultra-thin array can be easily placed on an aircraft's fuselage, due to its lightweight and conformal structure. It will be useful for wireless communication, radar, remote sensing, and surveillance applications.*

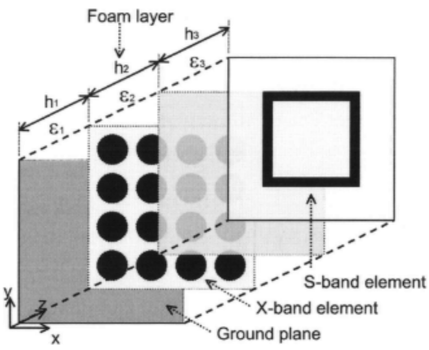
Keywords- Antenna arrays; microstrip arrays; microwave antenna arrays; aircraft antennas; planar arrays; polarization.

I. INTRODUCTION

Dual-polarized operation provides more information for radar systems, can increase the isolation between the transmitting and receiving signals of transceivers and transponders, and can double the capacity of communication systems by means of frequency reuse. Furthermore, dual-polarized antennas can provide polarization diversity, which prevents the system's performance degradation due to multipath fading in complex propagation environments. To create dual polarization, the antenna element has to be fed at two orthogonal points or edges, such that two degenerate resonant modes can be excited for the orthogonal polarizations, i.e., vertical and horizontal polarizations. Design techniques of dual polarized antennas can be classified into three main categories. The first is to make an orthogonal arrangement of the radiation elements for two polarizations. The second is to properly choose stacked structures of the radiating elements. The third is to use special feeding techniques. In general, symmetric structures tend to give better dual-polarization performance. The dual-polarized antenna elements can be assembled to construct a high-gain array. Although many dual-polarized antennas have been proposed, not all of them are good candidates for array design, due to their complex structures and feeding-line network. To minimize the coupling between the feed-line networks, a proximity/aperture-coupling structure can be applied to prevent radiation due to the microstrip line and radiator from degrading the polarization performance. The multilayer structurecan be used to enhance the isolation, in which isolations ofbetter than 20-30 dB can be obtained with more-complicated structures. However, most dual-polarized antenna designs will result ina bulky array that is not suitable for use in aircraft, airships, orunmanned aerial vehicles (DAVs).In many airborne applications, an array antenna should havegood isolation, high efficiency, and ease of integration with theaerial vehicle. A simple feeding-line network with lower loss andhigh isolation is generally desired. Microstrip series-fed arrays have been shown to have a structure that enhances the antenna'sefficiency. A planar structure with a thin and flexible substrate isa good choice, because it will not disturb the appearance of the aircraft and can be easily integrated with electronic devices for signalprocessing. In this paper, a dual-frequency dual-polarized array antenna ispresented for airborne antenna applications. A multilayer structureis adopted for dual -band operation. The antenna arrays for the twofrequencies are separated on different layers. To reduce the array'svolume and weight, a series-fed network is used. An ultra-thin substrate is chosen in order to make the array conformal, and the arraycan be easily placed on an aircraft's fuselage, or inside the aircraft. The parameters affecting the array 's characteristics are discussed,and the measured return losses, radiation gains, and array patternsare presented.

II. ARRAY DESIGN

The multilayer array structure comprises of dual-bands such as S band and X band. The S-band antenna elements sit on the top layer, and the X-band antennas are on the bottom layer. A foam layer *(h2)* serves as the spacer and is sandwiched between the two substrate layers. One of the important design considerations for this multilayer dual-band array is that the S-band antenna element should be nearly transparent to the X-band antenna elements. Otherwise, the S-band element may degrade the Performance of the X-band antenna. Two RT/Duroid 5880 substrates ($\varepsilon 1 = \varepsilon 3 = 2.2$) and a foam layer ($\varepsilon 2 = 1.06$) form the multilayer structure. The thicknesses of the substrates *(h1*and *h2)* are both only 0.13 mm. These ultra-thin and flexible substrates make it possible for the array to be easily attached onto the aircraft's fuselage, or installed inside=1.6 mm,

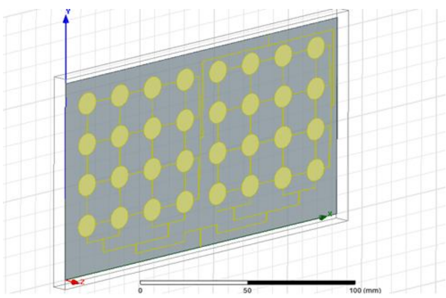


III. X BAND ANTENNA

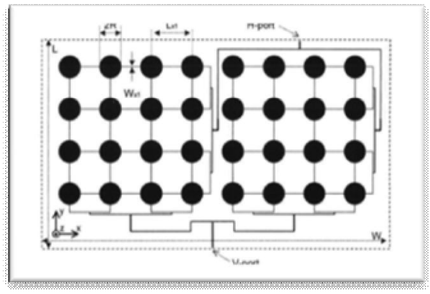
The X-band array uses the circular patch as its unit antenna element. The patch radius, *R,* for the dominant TM11 mode at the resonant frequency (frin GHz) can be calculated from

$$R = \frac{F}{\left\{1 + \frac{2h}{\pi \varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{0.5}},$$

Where εr and h (in cm) are the relative dielectric constant and thickness of the substrate, respectively. At the operating frequency, fr =10 GHz, an initial value of R of 5.82 mm.



ANSYS DESIGN



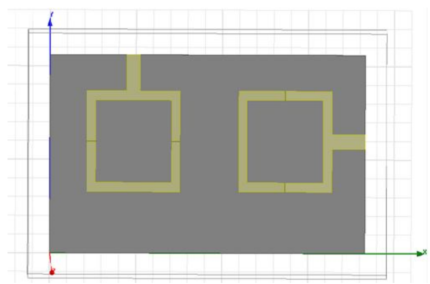
LAYOUT

The layout of the 4 x 8 dual-polarized X-band antenna, where *L* = 106, *W* =183, *R* =5.82, *Lx1*=22, and *Wx1* =0.17 (all dimensions Are in mm)

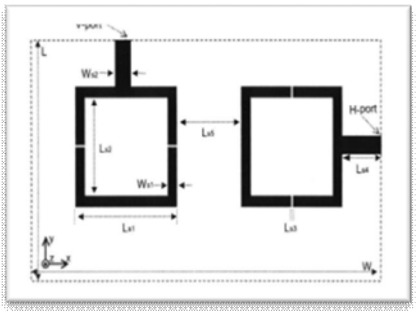
The circular patches are fed with micro strip lines at the circumferential edge. For a single circular patch, two micro strip feeding lines are used to feed the circular patch to generate two orthogonally radiating TM11 modes for dual polarized operation. The V port and the H port are the input ports for the two orthogonal polarizations (vertical and horizontal). The array is composed of two 4 x 4 sub arrays. The corporate-fed power-divider lines split the input power at each port to the sub arrays. Within each sub array, the circular patches are configured into four 4 x 1 series-fed resonant type arrays, which make the total array compact and have less micro strip line losses than would a purely corporate-fed type of array. An open circuit is placed after the last patch of each 4 x 1 array. The spacing between adjacent circular-patch centers is about one guided wavelength *(Ag* =21.5mm at 10 GHz). This is equivalent to a 3600-phase shift between patches, such that the main beam points to the broadside.

IV. S BAND ANTENNA

Here, a square-ring micro strip antenna is used as the unit element of the S-band array. Unlike an ordinary micro strip-ring antenna that has a meancircumference equal to a guided wavelength, the antenna proposedhas a mean circumference of about *2Ag (Ag* =82.44mm at 3 GHz).



ANSYS DESIGN

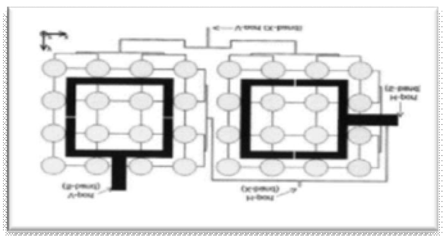


The layout of the S-band antenna, where L = 106, W=183,Ls1 =53.89,Ls2 =44.6, Ls3 =0.94,Ls4 =19.31, Ls5=34.17, Ws1=4.9, and Ws2 =7.8 (all dimensions are in mm).

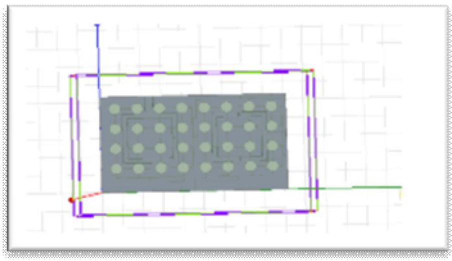
Although the size of the proposed unit element is largerthan an ordinary ring antenna, its gain is about twice as high, because of its larger radiation-aperture area. For an edge fedmicro strip ring, if a second feed line is added to the orthogonaledge, the coupling between the two feeding ports will be high. TheV-port and H-port feeds are therefore placed at two individual elements, so that the coupling between the two ports can be significantlyreduced.

V. COMBINED STRUCTURE

In the Dual Polarized planar array antenna structure, the S-band antenna elements are printed on the top substrate and are separated from the X-band elements by the foam layer. To reduce the blocking of the radiation from the X-band elements at the bottom layer, the shape of the S band elements has to be carefully selected. A ring configuration was a good candidate, since it uses less metallization than an Equivalent patch element. In the stacked X-band and S-band array antenna structure, the four sides of the square ring element are laid out in such a way that they only cover part of the feeding lines on the bottom layer, but none of the radiating elements.



LAYOUT



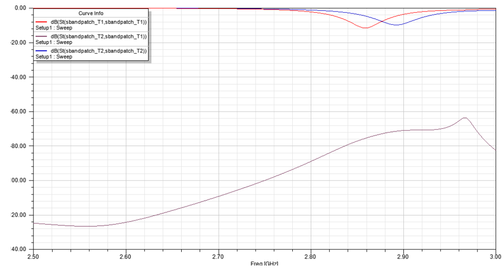
ANSYS DESIGN

VI. RESULTS

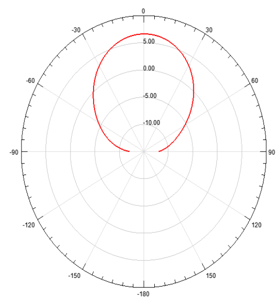
S BAND OBSERVATION

FOR FOAM LAYER, Ɛ =1.06

For V port feed, we obtain return loss of -10.4 dB at a resonant frequency of 2.86GHZ and obtained gain is 3. 6dB.For H port feed,We obtain return loss of -11.6 dB at a resonant frequency of 2.93GHZ and obtained gain is 5.6dB.



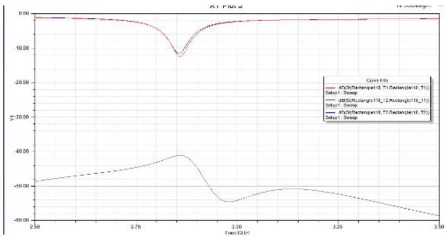
RETURN LOSS GRAPH



RADIATION PATTERN

FORFOAM LAYER, Ɛ =1.12

For V port feed, we obtain return loss of -11.8 dB at a resonant frequency of 2.8GHZ and obtained gain is 1. 04dB.For H port feed,we obtain return loss of -12.2 dB at a resonant frequency of 2.82GHz and obtained gain is 0.8dB



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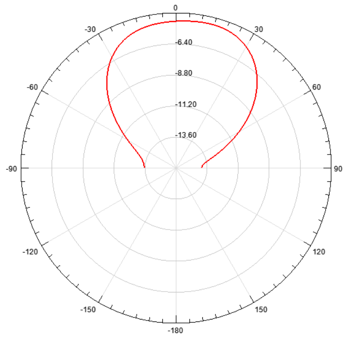
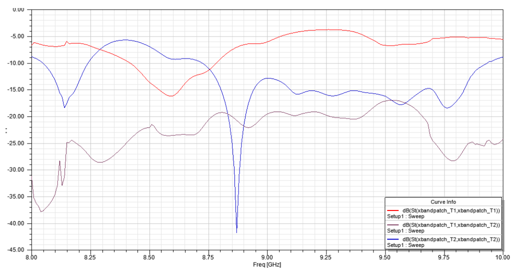


RADIATION PATTERN

X BAND OBSERVATION

FORFOAM LAYER, Ɛ =1.06

For V port feed,We obtain return loss of -37.5dB at a resonant frequency of 9.42GHZ and obained gain is 6.13dB.For H port feed, We obtain return loss of -17Db at a resonant frequency of 9.3GHZ and obtained gain is 6.67dB.



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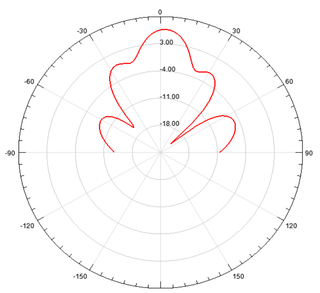
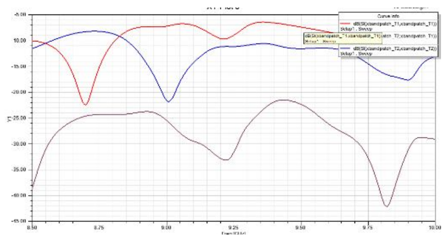


RADIATION PATTERN

FORFOAM LAYER, Ɛ =1.12

For V port feed, we obtain return loss of -22.5 dB at a resonant frequency of 8.7GHZ and obtained gain is 1. 2dB.For H port feed,We obtain return loss of -22.5 dB at a resonant frequency of 9GHZ and obtained gain is 4.2dB.



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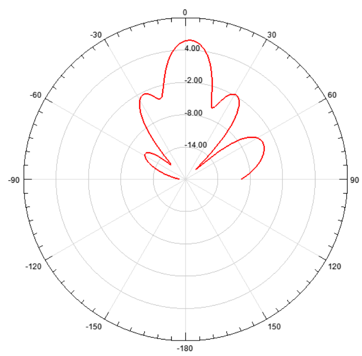

RADIATION PATTERN

VII. TABULATION

DIELECTRIC CONSTANT	FREQUENCY	POLARIZTION	RETURN LOSS	GAIN	RESONANT FREQUENCY
1.06	S BAND	V PORT FEED	-10.4dB	3.6dB	2.86GHz
		H PORT FEED	-11.6dB	5.6dB	2.93GHz
	X BAND	V PORT FEED	-37.5dB	6.13dB	9.42GHz
		H PORT FEED	-17dB	6.67dB	9.3GHz
1.12	S BAND	V PORT FEED	-11.8dB	1.04dB	2.8GHz
		H PORT FEED	-12.2dB	0.8dB	2.82GHz
	X BAND	V PORT FEED	-22.5dB	1.2dB	8.7GHz
		H PORT FEED	-22.5dB	4.2dB	9GHz

VIII. CONCLUSION

An ultra-thin array was adopted for the purpose of use with aircraft.The conformal array can be installed on the airframe or inside the aircraft, due to its small size and light weight.The newly developed dual-frequency dual-polarization array antenna should be useful for future wireless communications, remote sensing, surveillance, radar systems.

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