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Design and Simulation of Microstrip Patch Single Element, 1*2 Array Design and 1*4 Array Design for SART Applications

[1]K Radhakrishna
PG Student, RF and Microwave Engineering Program,
Department of Telecommunication Engineering
RV College of Engineering, Bengaluru

[2]Dr. K Sreelakshmi
Professor and HoD
Department of Telecommunication Engineering
RV College of Engineering, Bengaluru

Abstract:- The Search and Rescue Transponders are used to search for the lost ship and aircraft. The transponder antenna resonates at the frequency of 9 GHz. The design is considered using FR4 (Flame Retardant) substrate of dielectric constant 4.4 and loss tangent 0.0019. A micro strip line fed rectangular patch antenna is designed in such a way that it resonates at 9 GHz. The return loss and gain for the designs are, Single Element Design: Return Loss is -24.291 dB, Gain Total is 5.9083 dB, 1*2 Array Design: Return Loss is -19.3635 dB, Gain Total is 8.5915 dB, 1*4 Array Design: Return Loss is -34.4773 dB, Gain Total is 9.4879 dB. Other antenna parameters such as VSWR, Radiation Efficiency, Gain 2D, Specific Absorption Rate are observed. The antenna structure is simple, flat and straightforward. The design can be embedded easily in Search and Rescue Transponder Transmitter because it is geometrically small. The simulation and analysis were done using High Frequency Structure Simulator (HFSS).

Keywords:- *Search and Rescue Transponder, Aeronautical Radio Navigation Systems.*

I. INTRODUCTION

Aeronautical radio navigation service (ARNS) according to the International Telecommunication Union's Radio Regulations is defined as 'A radio navigation service intended for the benefit and for the safe operation of aircraft'. The service is called as safety-of-life service which must be protected for interferences and is one of the essential parts of navigation. The search and rescue transponders (SART) are a waterproof transponder and self-contained which is intended to use at sea for emergency purposes. The radar-SART is used to locate a lost ship/aircraft, survival craft or distressed vessel by creating a series of dots on a rescuing ship's radar screen display.

The Search and Rescue Transponder (SART) will respond to only 9 GHz. The primary use of the SART is to allow rescue vessels or aircraft equipped with X-band radar which is usually used as common marine navigational radar, to home in on the precise and exact position of the SART by enhancing the radar return so that it is clearly visible on the radar of any vessel including search and rescue vessels.

The different bands for various applications under Ultra-wide band is designed using heptagon and nonagon ring like structure [1]. The dynamic conditions that should be met by a SART antenna and international requirements for a SART antenna is reported [2]. The investigation on Ka-Band for Search and Rescue Applications is to analyze the potential use of commercial off-the-shelf satellite capacity for real-time teleoperation scenarios over a geostationary relay network [3]. The performance analysis of uniquely designed wideband hexagonal patch antenna having partial ground plane technique is implemented [4]. A reconfigurable antenna design which is implemented using a self-structuring wearable antenna for the local user terminal of a Search and Rescue system (Cospas-Sarsat at 406MHz) is considered in [5]. The microstrip patch antenna which is circularly polarized is designed for wide bandwidth used for X-band applications [6].

II. ANTENNA STRUCTURE DESIGN

The antenna design was carried out in such a way that the resonating frequency should be at 9 GHz. Two different slots are considered. One slot cut exactly at half of the entire patch and other a hexagonal shape of radius 2mm slot cut in the first half of the patch.

An antenna array design is considered to obtain better antenna properties such as Higher Gain Total, Better Radiation Efficiency etc., The wavelength of the antenna is $\lambda_0 =$ 33.3 mm and the antenna spacing should be between $\lambda_0 / 2$ to λ_0.

The necessary parametric optimization is considered to obtain practically reliable values after simulation. All elements in the array network are spaced effectively to avoid mutual coupling effect which results in decrease in the efficiency of the antenna.

The design specifications for the Single Element, 1*2 Array Design and 1*4 Array design are given in Table 1.

Design Parameters	Single Element Design	1*2 Array Design	1*4 Array Design
Length of the Patch	9 mm	15 mm	23.9 mm
Width of the Patch	12 mm	39 mm	102 mm
Di-electric Constant	4.4	4.4	4.4
Height of the Substrate	1.6 mm	1.6 mm	2 mm
Resonating Frequency	9 GHz	9 GHz	9 GHz
Slot Width	0.5 mm	0.5 mm	0.5 mm
Hexagon Slot Radius	2 mm	2 mm	2 mm
Antenna Spacing	N.A	21 mm	23.5 mm
Characteristic Impedance	100 Ω	50 Ω	50 Ω

Table 1:- Specifications for various designs

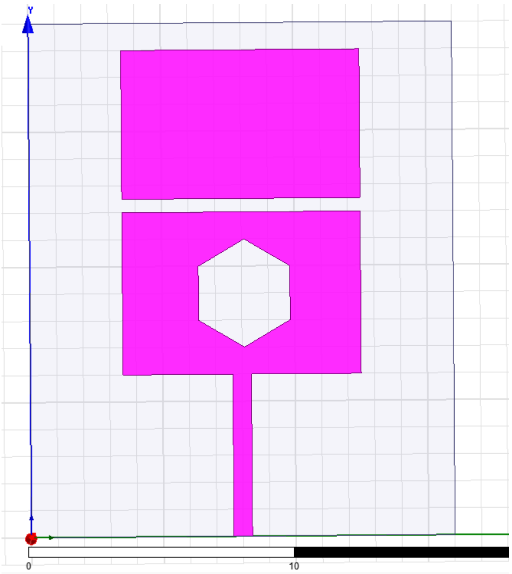

Fig 1:- Single Element Design

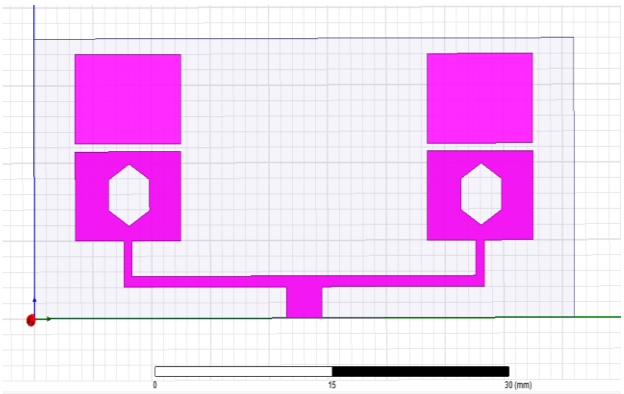

Fig 2:- Two Elements(1*2 Array) Design

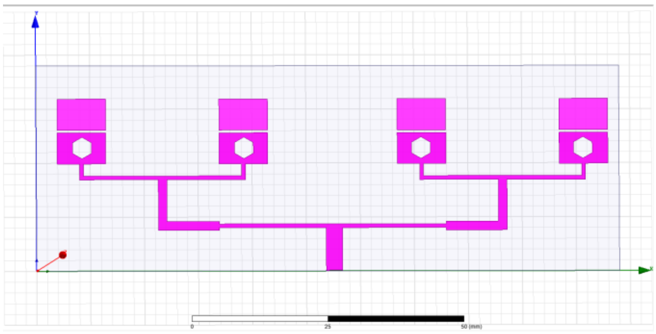

Fig 3:- Four Elements(1*4 Array) Design

III. RESULTS AND DISCUSSION

The performance of the designed antenna is studied using the High Frequency Simulator Software (HFSS) tool. The return loss and gain total for all three designs(Single Element, 1*2 Array Design and 1*4 Array Design) is tabulated in Table II. The radiation efficiency is one of the important parameters for SART applications and for all three designs the radiation efficiency is found to be more than 97%.

Design Parameters	Single Element Design	1*2 Array Design	1*4 Array Design
Return Loss(S11)	-24.291 dB @ 9GHz	-19.3635 dB @ 9GHz	-34.4773 dB @ 9GHz
Gain Total	5.9083 dB	8.5915 dB	9.4879 dB
VSWR	1.13 @ 9GHz	1.24 @ 9GHz	1.0385 @ 9GHz
Terminal Impedance	100 Ω	50 Ω	50 Ω
Radiation Efficiency	98.52% or 0.9852 @ 9GHz	97.88% or 0.9788 @9GHz	98.32% or 0.9832 @9GHz

Table 2:- Antenna Results v/s Design

The single element design has yielded the return loss of -24.291 dB at 9 GHz. The Gain Total of the single element design is found to be 5.9083 dB. The port impedance is normalized to 100 Ω. The Return Loss and Gain Total for Single Element Design can be found in Fig.4 and Fig.5 respectively.

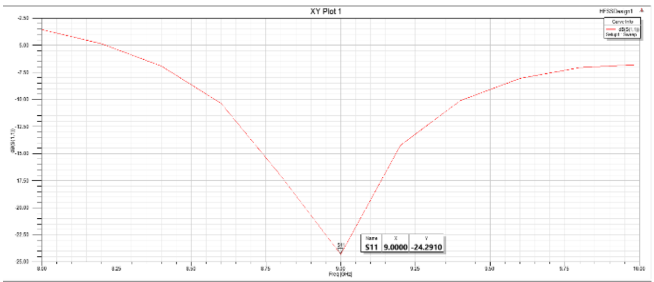

Fig 4:- Return Loss for Single Element

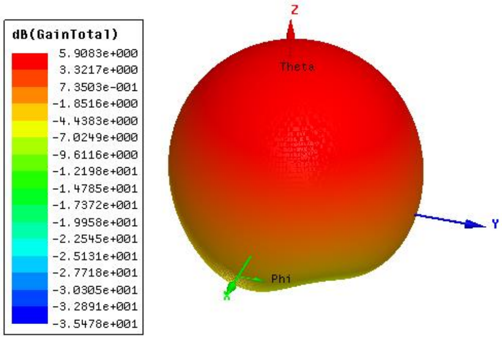

Fig 5:- Gain Total for Single Element

Radiation efficiency is one of the important parameter to describe how efficiently an antenna transmits and receives RF signals, which is defined as the ratio of the total power radiated by an antenna to the total input power received.The radiation efficiency for single element design is found to be 0.9852 or 98.52% at 9 GHz. The plot for radiation efficiency versus frequency can be seen in Fig.6.

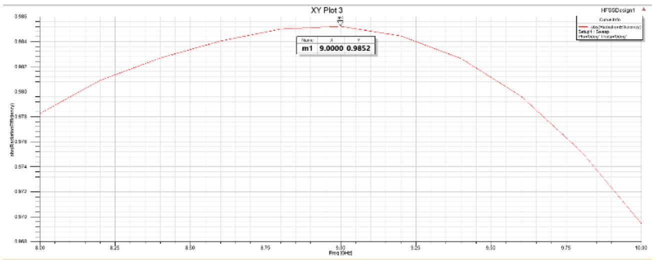

Fig 6:- Radiation Efficiency v/s Frequency for Single Element Design

The Gain 2D plot denotes the gain for every frequency calculated in the designated range. This design's Gain v/s Frequency plot for Single Element Design as seen in Fig.7 is calculated from 8 GHz to 10 GHz. Necessary optimization techniques can be considered to obtain highest gain at the resonant frequency. The Gain at 9 GHz is 5.8658 dB.

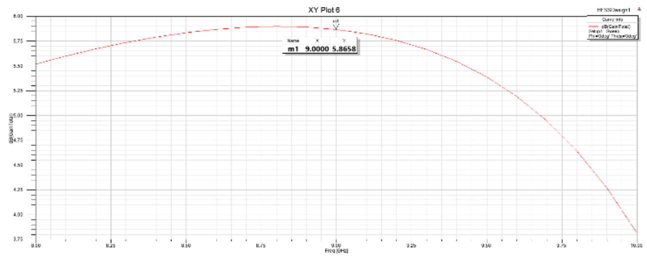

Fig 7:- 2D plot of Gain v/s Frequency for Single Element Design

The return loss for two elements(1*2 Array) design is found to be -19.3635 dB at 9 GHz. The Gain Total of the two elements design is increased to 8.5915 dB. The port impedance is normalized to 50 Ω. The Return Loss and Gain Total for Two Element Design(1*2 Array Design) is seen in Fig.8 and Fig.9 respectively.

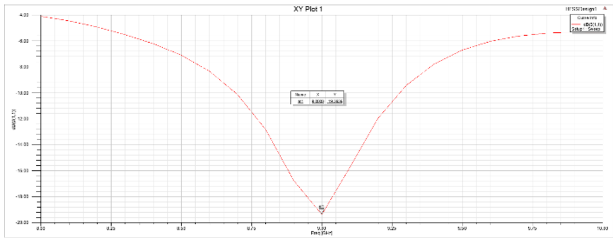

Fig 8:- Return Loss of 1*2 Array Design

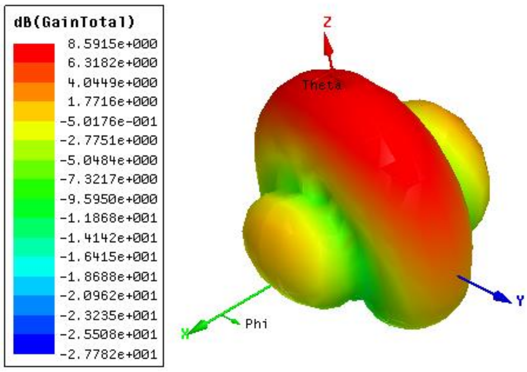

Fig 9:- Gain Total of 1*2 Array Design

The radiation efficiency for SART application should be higher and for array designs due to mutual coupling the efficiency decreases. The radiation efficiency for 1*2 Array Design is found to be 0.9788 or 97.88% @ 9 GHz. The plot for radiation efficiency versus frequency can be seen in Fig.10.

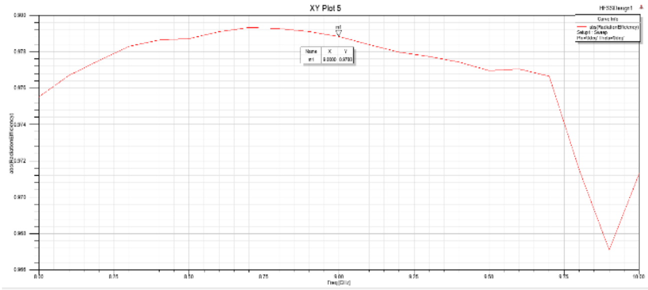

Fig 10:- Radiation Efficiency v/s Frequency for 1*2 Array Design

The 2D plot of Gain v/s Frequency for the 1*2 Array Design can be seen at Fig.11 and the Gain at 9 GHz is 8.3539 dB.

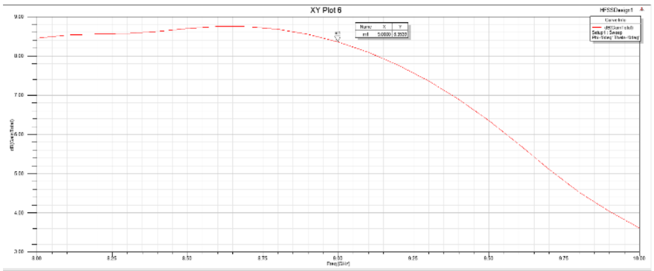

Fig 11:- Gain v/s Frequency plot for 1*2 Array Design

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The four elements(1*4 Array) design is observed with return loss of -34.4773 dB at 9 GHz. The Gain Total of the two elements design is increased further to 9.4879 dB. The Return Loss and Gain Total for Four Elements Design(1*4 Array Design) is seen in Fig.12 and Fig.13 respectively.

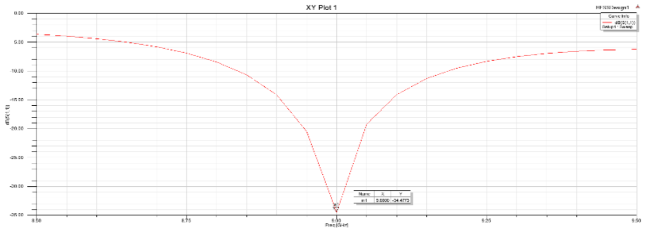

Fig 12:- Return Loss of 1*4 Array Design

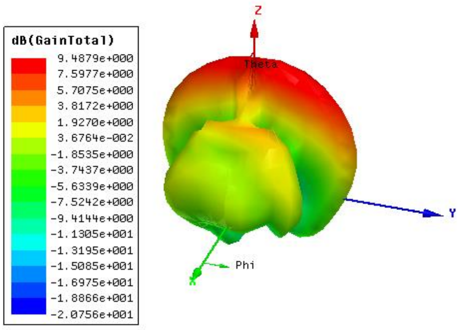

Fig 13:- Gain Total of 1*4 Array Design

The design should be taken care in such a way that the radiation efficiency should not be decreased drastically. The radiation efficiency is found to be 0.9832 or 98.32% at 9 GHz. The plot for radiation efficiency versus frequency can be seen in Fig.14.

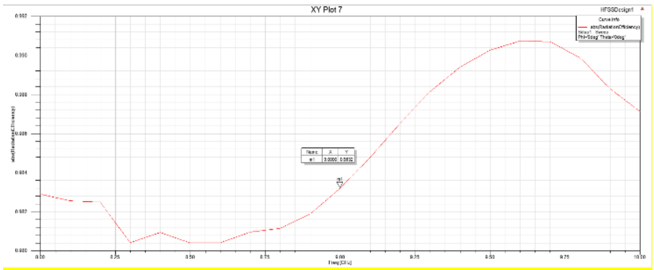

Fig 14:- Radiation Efficiency v/s Frequency for 1*4 Array Design

The Gain for the Array Design increases if there are increase in number of patch elements. Gain of 9.2751 dB is obtained at 9 GHz for Gain v/s Frequency plot for the 1*4 Array Design found at Fig.15.

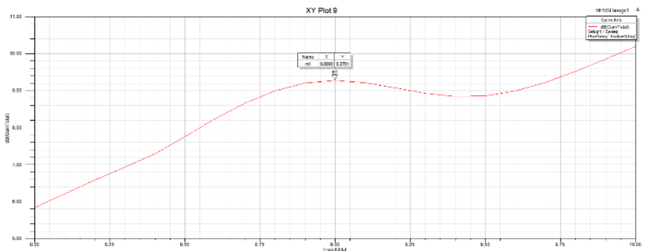

Fig 15:- Gain v/s Frequency plot for 1*4 Array Design

IV. CONCLUSIONS

The Search and Rescue Transponders is one of the important applications used to detect the lost aircrafts or naval machines. The antenna used which can be used in SART is designed here using economically feasible Microstrip Patch Antenna considering FR4 Substrate.

The results obtained by the design also depicts that the SART can use any of the above designed antennas for different applications thereby reducing the cost and allowing the common public too to use SART for detection of untracked unmanned aerial vehicles.

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