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Patch Array Antenna to Achieve Efficiency Improvement and to Carry out Analysis of Antenna Parameters for Battle Field Surveillance Radar (Short Range)

(Design of an X-Band antenna to be used for Battle Field Surveillance Radar (Short Range) to achieve efficiency improvements in terms of antenna parameters)

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***Abstract*—The aim of this paper is to design a patch array antenna to achieve efficiency improvement and to carry out analysis of antenna parameters for Battle Field Surveillance Radar (Short Range). Simulation of design and comparative performance analysis to include theoretical and experimental analysis of antenna parameters using CST Studio Suite as simulation software. Processes involved in design of an X-Band antenna has been described, keeping in view all the parameters of antenna design and simulation outputs with aim of efficiency improvement with use of proposed antenna. Necessary comparisons have been done for ease of understanding of various antenna parameters. Proposed antenna has been successfully demonstrated along with the simulation results.**

Keywords—X-Band antenna; patch array; antenna parameters.

I. INTRODUCTION

There are lots of researches which are undergoing on single patch antennas but there is limited research material on performance of microstrip patches when used in arrays. With help of this paper a fair attempt has been made to understand the specifications and performances of microstrip patch array antenna of an existing military radar as well as the proposed antenna for the same radar. Also, the antennas have been designed using number of geometry but the performance analysis after parametric variations with different geometries has not been done especially for those operating with higher frequencies like for X-Band application. In this paper the antenna parameters have been obtained for a 24 x 24 array antenna having an octagonal patch with help of simulation software. After the design process, comparative analysis has been done for better understanding of parametric variations so as to obtain optimized results. In this paper, important parameters with respect to this study have been discussed in a very deliberate manner. In the end, these parameters will be explained to obtain the results out of the simulations done for design of proposed antenna. The design specifications of the Military radar are not readily available, being of confidential nature. However, the information which has been presented in this dissertation is of generic nature and which holds relevance to the research work. Results for array of all radiating elements of the proposed antenna have been simulated using CST Studio Suite 2019 as simulation software and the results have been compared accordingly for demonstrating the specifications, antenna parameters and the technology. With limited information available on the selected military radar, an attempt has been made with help of this paper to consolidate and refine all data available on Microstrip Patch Array antenna present in Battle Field Surveillance Radar (Short Range). Accordingly, a new design has been proposed and demonstrated which has better specifications in terms of its dimensions, antenna parameters and various other factors.

II. BATTLE FIELD SURVEILLANCE RADAR (SHORT RANGE)

A. Radar

Battle Field Surveillance Radar (Short Range) Indigenous is a fourth-generation, short range, ground surveillance and acquisition radar. This radar is developed by Defence Research & Development Organisation and manufactured by Bharat Electronics Limited, Bengaluru. The radar works reliably during both day and night operations, and even under inclement weather conditions and in exposed areas.

Fig 1: Battle Field Surveillance Radar (Short Range)

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B. ***Specifications***

The radar uses a Microstrip Patch Array Antenna with patches arranged in a 32 x 16 array configuration. The dimensions of patch array of antenna are 610 mm x 390 mm and the shape of radiating patch of BFSR (SR) is rectangular planar geometry. The Gain of antenna as claimed by the Original Equipment Manufacturer is 29.5 dB ± 0.5 dB (with radome). Antenna is having 3 dB beam width as 3.2 ± 0.3º (Azimuth) and 5.0 ± 0.5º (Elevation). It works in X-Band and is capable of 2-D tracking and TWS (Track While Scan).

III. PERFORMANCE ANALYSIS AND PARAMETRIC VARIATIONS

A. Transmission Line Model has been used to study and calculate the parameters of the antenna of BFSR (SR). The transmission-line model has an advantage of being easiest of all the methods for analysis. Based on the data already available and calculations done using the Transmission Line Model, at first, we will now simulate one radiating patch of BFSR antenna to obtain antenna parameters for the antenna on which the study is based and then will apply the array operation, i.e., will obtain results in terms of antenna parameters for 32 x 16 array of BFSR (SR). This will also prove the correctness of the model selected for design of the antenna which will later help to design the proposed antenna to improve efficiency.

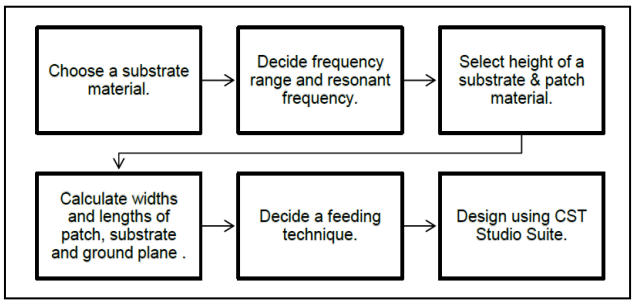

Fig 2: Antenna Design Process

B. Dimensions for Ground, Substrate and Patch utilised for design are shown in the figure below. The designed patch of BFSR (SR) antenna have been simulated using CST Studio Suite to observe simulation results such as Return Loss, Gain, Bandwidth, Directivity, VSWR etc.

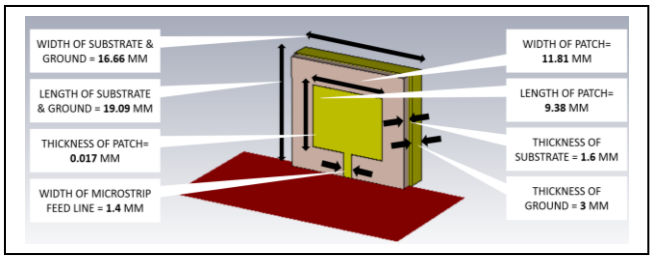

Fig 3: Single Patch of BFSR (SR) Antenna

C. The minimum return loss or S (1,1) value of -16.65 dBi is obtained and minimum value of VSWR obtained is 1.36. The array (32 x 16) operation of the BFSR (SR) results in gain to 31.82 dBi (realized gain of 29.90 dBi) at 10.2 GHz and directivity of 33.89 dBi. Radiation pattern obtained at 10.2 GHz in 3D and polar representation has been shown in figures below:-

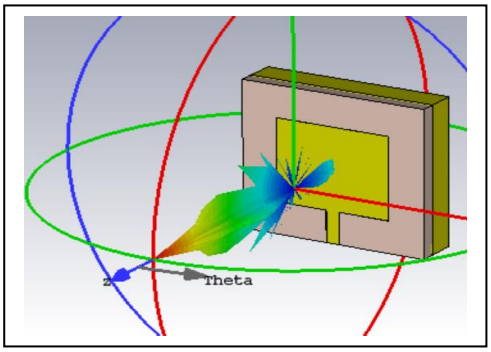

Fig 3: 3D Radiation pattern at 10.2 GHz

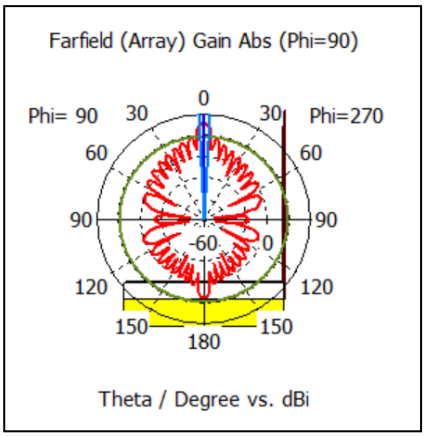

Fig 4: Polar pattern at 10.2 GHz

D. Designing an antenna is a trade-off engineering, which means, if we want one desirable characteristic, we have to compromise with another desirable characteristic. Keeping in mind the limitations and options available with the simulation application in hand and the scope of work, number of parametric variations have been performed in the subsequent paragraphs. However, for parametric variations, the results of single patch are considered and analysed. Comparative analysis has been done side by side using atleast four iteration for each idea so as to obtain the best techniques / dimensions for the design of proposed X- Band antenna having efficiency improvements. Four geometries of patches have been studied and results obtained after simulation for same material (RT Duroid 5880 for Substrate) and dimensions of substrate and ground. The maximum/best value of Return Loss and VSWR has been for Octagonal geometry.

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Table 1: Antenna Parameters for Different Patch Geometry

Iteration	Type Of Geometry	Return Loss (dB)	VSWR	Gain (dB) @ 10 GHz	Directivity (dBi) @ 10 GHz	Radiation Efficiency (%)
(i)	Rectangular	**-32.436**	**1.04**	5.611	8.092	69.34
(ii)	Circular	-13.732	1.507	5.508	7.981	69.01
(iii)	Triangular	-19.433	1.239	4.684	7.399	63.30
(iv)	Octagonal	-19.623	1.162	**5.745**	**8.118**	**70.77**

E. The feed in microstrip patch antenna is used for excitation via direct or indirect radiation contact. Feeding techniques commonly used with microstrip patch array antennas can be classified into contacting and non-contacting techniques which are discussed in subsequent paras. Selection of feeding technique plays an important role in dictating the antenna parameters of the designed antenna. In the contacting method of feeding, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line or a Co-axial pin/probe [02, 03, 17 & 21]. In non-contacting feeding method, the patch of the antenna is indirectly fed with the RF Power and the RF Power is transported to the patch through an electro-magnetic coupling.

1) Most common antenna feeding techniques employed for antenna design [17] are Microstrip Line Feed, Coaxial Feed, Aperture Coupled Feed and Proximity Coupled Feed.

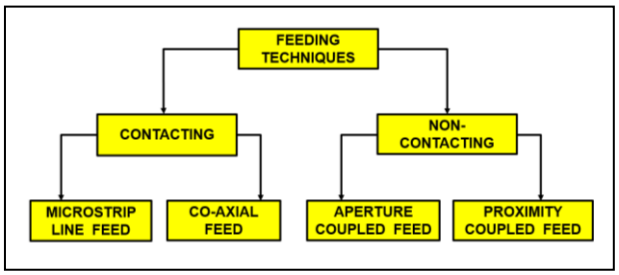

Fig 5: Commonly used Feeding Techniques

2) Based on the iterations done during the research work, it has been analysed that better gain is achieved in the antenna having Microstrip Line as a feed and also this feeding method is best suited for this research because of ease of fabrication and cost effectiveness.

Table 2: Comparison of Different Feeding Techniques

FEEDING VS CHARACTERISTICS	Microstrip Line Feed	Co-axial Feed	Aperture Coupled Feed	Proximity Feed
Fabrication Process	Easy	Require drilling and soldering	Requires proper alignment	Complex manufacturing and alignment required
Reliability	Better	Poor due to soldering	Good	Good
Bandwidth	2-5 %	2-5 %	2-5 %	10-15 %
Spurious Radiations	More	More	Less	Minimum
Cost	Cheapest	Cheap	Costly	Costly

IV. DESIGN OF PROPOSED X-BAND ANTENNA

A. It is important that the resonant frequency of the antenna is selected appropriately. For this research the frequency of antenna has been kept same as the exesting antenna. The resonant frequency which has been selected for the proposed design is 10.2 GHz.

- The dielectric material *or the substrate* selected for the proposed design is Rogers RT Duroid 5880 (lossy) [07] which has dielectric constant of 2.2. The height of the dielectric substrate has been selected as 1.6 mm as this was found ideal during the parametric variations in previous chapter.
- Rectangular and circular patches have been widely used in Microstrip Patch array antennas. In this paper, we have used octagonal shape of the radiating patch which includes a mix of both circular and rectangular or square design, thus utilizing advantages of both geometries.

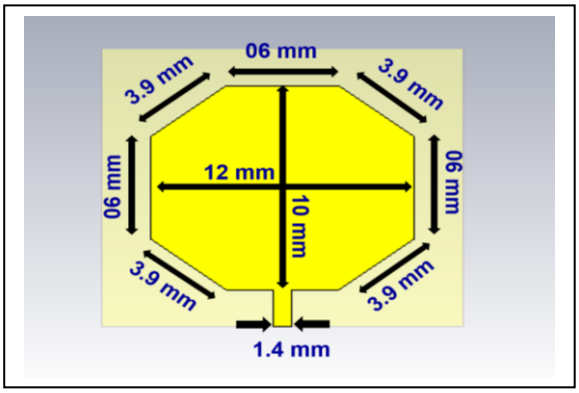

Fig 6: Dimensions of Octagonal Patch / Radiating Element

- The dimensions (length and width) of the ground and substrate has to be equal. It should be noted that the completed plane should be able to accommodate the patches which has been proposed in the antenna design. In this proposed design width, W has been kept 480 mm and length, L has been kept 400 mm. It should be noted that dimensions of proposed antenna design are 21 % shorter in width and 2.5 % longer in length, i.e., overall reduction of 19.29 % of surface area / size is being achieved in the proposed antenna design which is a great achievement for any antenna design.
- The radiating patches must be adequately spaced both horizontally and vertically otherwise they may lead to interferences and result in reduction of overall gain of the array. It was observed that Horizontal Spacing of 7.18 mm between two patches and Vertical Spacing of 6.36 mm results in best overall efficiency as far as basic antenna parameters are concerned.
- The proposed design of antenna has been designed with the aim that it should be fully compatible for operation in place of existing antenna of BFSR (SR).

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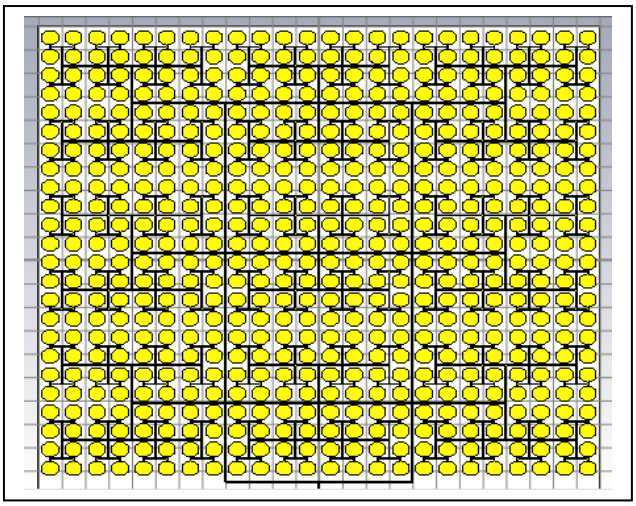

Fig 7: Patch array (24 x 24) Design of Proposed Patch Antenna

- A Boolean addition function has been applied in the software to merge the network of microstrip feed lines with the patch material. The width of the feed line has been kept as 1.4 mm; however, the thickness of the line remains same as that of the patch, i.e., 0.020 mm.
- Once the basic architecture is ready, the design can now be simulated to obtain the results. Project is now simulated in Time domain by normalizing the impedance at 50 Ohm.

B. After the simulation is completed, number of results are obtained/derived in terms of antenna parameters in 2-D and 3-D options for comparative analysis with respect to the existing antenna system of BFSR (SR).

- Best value of S (1,1) obtained is -12.904 dB at 10.2 GHz in the desired X-band (8 GHz-12 GHz).

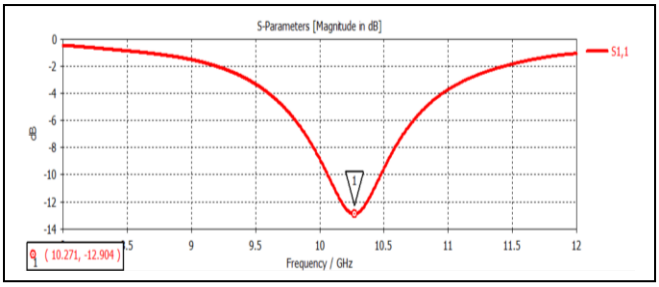

Fig 8: S-Parameters of Proposed Microstrip Patch Array Antenna

- The value of Gain obtained is 31.08 dBi (with losses) which has improvement by 3.95% (approximately 04 %) considering losses.
- The VSWR obtained is optimal (approximately = 1.5) at 10.2 GHz. The value at 10.2 GHz is the desired/desired value with good matching and minimum losses.

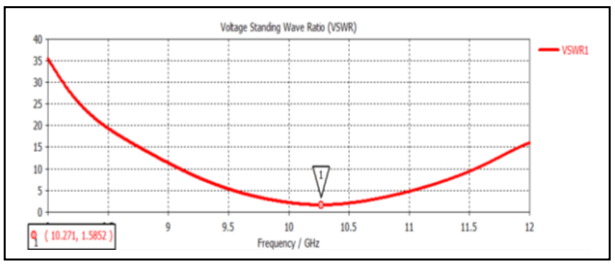

Fig 9: VSWR of Proposed Microstrip Patch Array Antenna

- The radiation pattern obtained at 10.2 GHz is presented below. It can be seen that the gain of obtained at this frequency for the proposed patch array antenna is 32.24 dBi.

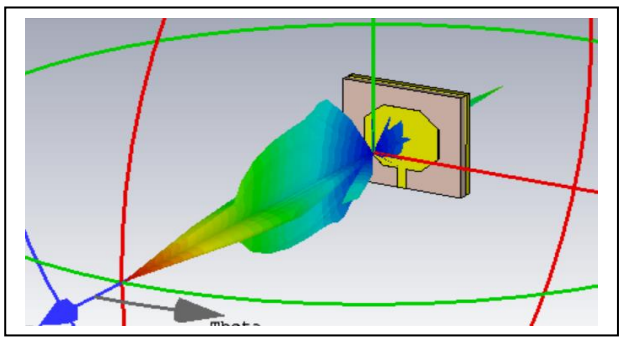

Fig 10: 3D Radiation Pattern of Proposed Antenna at 10.2 GHz

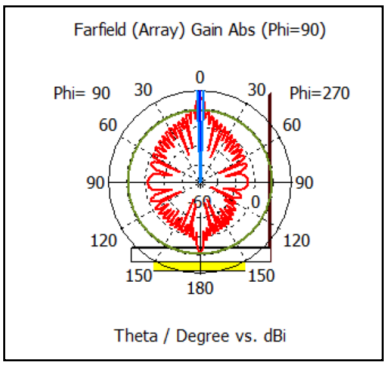

Fig 11: Polar Plot of Radiation Pattern of Proposed Antenna at 10.2 GHz

- The radiation efficiency achieved in proposed design is 90.29 % (with losses) as compared to 88.22% (with losses) in case of BFSR (SR) antenna which implies improvement of 2.35%, considering realized gain.
- The objective of this dissertation was to analyze the design parameters of Microstrip Patch Antenna of Battle Field Surveillance Radar (Short Range) Indigenous and then to exploit the new design within the X-Band and provide theoretical foundation for the development of antenna with enhanced efficiency alongwith optimization of other antenna parameters. There is a vast scope for development of other geometries to miniaturize the antennas of radar and at the same time achieve better gain, high return loss and higher range.

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V. CONCLUSION

As per the scope of this paper, X-band Microstrip Patch Array Antenna with efficiency improvements and enhanced bandwidth has been demonstrated to act as a replacement in BFSR (SR) radar. Since the antenna layout is simple and straightforward, the fabrication process will be easier as compared to complicated fabrication process in case of fractal geometries of patches or the radiating elements of antenna. The simulated results have been found reasonably well within the desired range. The radiation efficiency of the proposed antenna is above 90% (with losses) which is a satisfactory value. These attractive radiation patterns, efficiency as well as enhanced bandwidth and higher gain make the proposed antenna design compatible for its usage in BFSR (SR) Indigenous and in other X-band applications as well. Therefore, it is concluded that by exploiting the octagonal patch design in the military radars, their performance can be further be improved along with enhancement of capabilities that too with reduction of overall size.

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