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Design of an Antenna Array for Radar Application

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ABSTRACT

This paper presents, a rectangular shaped microstrip patch antenna was designed for radar application at an operating frequency of 9.6 GHz. Four radiating element of patches are used to design the antenna array. The dielectric constant 4.6 and having the substrate height 1.6mm. This antenna array design is combined with 4 radiating elements. These radiating elements are used in this design to increase gain and directivity. The substrate taken for the design is compared with the frequency range to get the appropriate result, so we have chosen the FR4 substrate with a Dielectric constant of 4.6, Height of 1.6mm, and Loss Tangent of 0.018. The FR4 substrate is chosen because of its efficiency in cost and performance. The gain and directivity of the antenna array have been increased for this design. The Advanced Design System software tool is used for designing and simulating the antenna array.

Keywords

Microstrip patch antenna, Radar application, microstrip patch antenna array, X band Radar frequency, Advanced design system software, Momentum, Radiation pattern.

Introduction

Currently, radar application developed in various technologies. This technology is used for long distances communication such as satellite communication. A electromagnetic waves is used in the system to detect, measure distances and build objects for communication. The radar frequency should use a waveguide of 8 to 12 GHz. The antenna designed is small antenna size and light-weight by considering efficiency of the antenna as the technology is developing its new trends day by day. An antenna system is important in a radar application, since the antenna has the efficient purpose on the communication system. The antenna is designed by selecting the proper substrate like FR4. The dielectric constant for the substrate is 4.6 with 1.6mm in height. The simulation process is done in Advance design system software tool for acquiring the radiation pattern and the simulated graph. Microstrip technology is important for the antenna which can have small size, lightweight and easy in fabrication with low cost. Considering all the features radar application is suitable for the design of microstrip patch antenna. Rectangular shape patch is taken in consideration as it has high directivity and polarization. Rectangular shaped antenna is highly omni-directional. The Microstrip patch antenna array designed for Radar consisting of 4 radiating elements patch antenna in-array implemented for better performance. Instead of using single antenna in the design, 4 array of antenna is design to increase the gain and directivity.

Literature Review

A unique way of literature survey has been carried out in this paper for reference purposes to obtain the best results.

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Ashikur Rahman et al[1]demonstrates the output of a wideband microstrip patch antenna for RFID applications in ISM. The substrate is made of Flame Retardant-4 (FR-4) material. At the ISM band, the output of the proposed antenna is analyzed and compared to that of various RFID reader antennas. CST Microwave Studio is used to plan and simulate it. VasujadeviMidasala et al[2] demonstratedthe 3x3 rectangular antenna array to work in the Ku Band. The antenna was constructed as a patch arrayand feeding currents optimised to meet the requirements of low side lobe and good cross polarisation.The return loss, 3D polar map, Directivity, VSWR, and Gain of the antenna are computed using the FEM-based HFSS 14.0. The results of the software simulations show that the proposed antenna array performs well in terms of return loss, VSWR, and gain.

Asif Ali Bhoot et al[3] demonstrates that the microstrip patch antenna (MPA) is the first option for wireless communication systems due to various advantages such as ease of configuration, low weight, and low cost. They compare and contrast the output of four different formed antennas. E, T, H, and F are the shapes that are considered. On various frequency bands, the effects of various antenna parameters such as return loss, VSWR, radiation pattern, gain, and directivity are analyzed.The antenna simulation tool High Frequency Structure Simulator (HFSS) is used.Anjaneyulu Gera et al[4]demonstrates therectangular patch array antenna for satellite applications. The antenna array is designed to operate in the 12 GHz frequency range. Since it is easier to fit the impedance with the inset feeding system, it is used for the patch. On an RT Duroid 5880 dielectric substrate, a single element patch antenna with optimal output is constructed, as well as a two-element and four-element linear array with the same dimensions.The four-element array resonates at four different frequencies between 10 and 13 GHz, with a modest gain for S11 > 10 dB, according to simulation performance.YudiYuliyusMaulana et al[5]demonstrated that the rectangular Patch Antenna Arrays are numerically and experimentally explored. This antenna is designed for radar applications and operates at a frequency of 9.4GHz. The 1x16 patch antenna array is used to build antenna arrays, and the patch antenna is implemented using microstrip lines.

The survey listed above show various antenna design concepts. Several approaches have been investigated based on the antenna's shape, design parameters, resonant frequency, dielectric constant, gain, directivity, and return loss. In comparison to those articles, the proposed model performs better and is more accurate.

Methodology

A.RADAR

Radar is a tracking device that uses radio waves to calculate an object's length, angle, or velocity. A radar system consists of a transmitter that generates electromagnetic waves in the radio or microwave frequency range, a transmitting antenna, a receiving antenna and a receiver and processor that determines the object's properties. The transmitter's radio waves bounce off the object and return to the receiver, providing data on the object's position and speed.

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B. RADAR COMPONENTS

Since it transmits electromagnetic power and analyses the energy returned to the target, the radar's working theory is very simple. If the returned signals are received at the same location as their source, an obstruction is in the way of transmission. The working theory of radar is as follows.

The essential parts of this system include the following.

- **A Transmitter:** A power amplifier, such as a Klystron, a Traveling Wave Tube, or a power Oscillator, such as a Magnetron, may be used. A waveform generator generates the signal, which is then amplified in the power amplifier.
- **Waveguides:** The RADAR signals are transmitted via waveguides, which are transmission lines.
- **Antenna:** A parabolic reflector, planar arrays, or electronically steered phased arrays may all be used as antennas.
- **Duplexer:** The antenna may be used as a transmitter or a receiver with the aid of a duplexer. It may be a gaseous system that causes a short circuit at the receiver's input when the transmitter is turned on.
- **Receiver:** It may be a superheterodyne receiver or some other receiver with a processor to process and detect the signal.
- **Threshold Decision:** To detect the presence of any item, the receiver's performance is compared to a threshold. The existence of noise is considered if the output falls below some threshold.

C. ANTENNA DESIGN

The antenna is designed for radar application; it is determined by the intended application and is constrained by the object to be defined, its size, and position. If the application needs a longer range, the antenna's directivity would be more important. There are other factors to consider when selecting an antenna, such as manufacturing costs, antenna dimensions, gain, and efficiency.To increase gain and directivity, we constructed an antenna array with four radiating sources in this paper.

Single patch antenna design

The substrate used in the design of RFID systems makes the antenna more effective and useful in the field. To minimise energy losses, a FR4 substrate with a dielectric permittivity of 4.6, a height of 1.6mm, and a tangential loss of 0.018 was used. The antenna's resonance frequency is 9.6GHz.The configuration of a microstrip patch antenna in ADS program is shown in Fig. 2.

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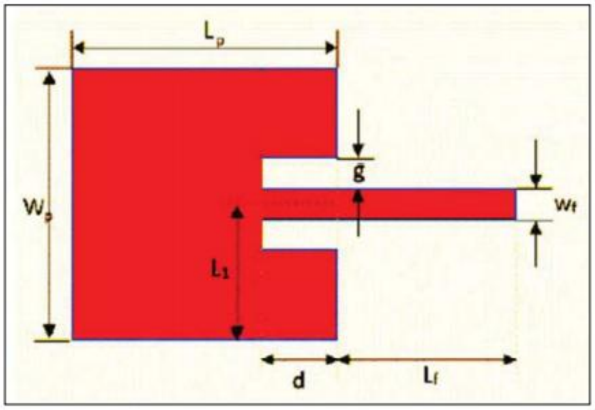

Figure 1.Microstrip patch antenna

Calculations of antenna parameters

1. Formal for the Width (W) of the patch,

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

2. Formula for the Effective Dielectric Constant of the patch,

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

3. Formula for Effective length of the patch,

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}}$$

4. Formula for the length ΔL

$$\Delta L = 0.412h\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

5. Formula for actual length of the patch

$$L = L_{eff} - 2\Delta L$$

PARAMETER	DIMENSION
Width of the patch Wpa	28.5

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Width bottom stub Wsb	0.8
Width feeding Wp	5.0
Length of the patch Lpa	9.6
Length bottom stub Lsb	2.5
Length feeding Lp	7.0

Table:1 Parameters of antenna design

Parameters used for design,

- εr = Dielectric constant
- H = Height of the substrate

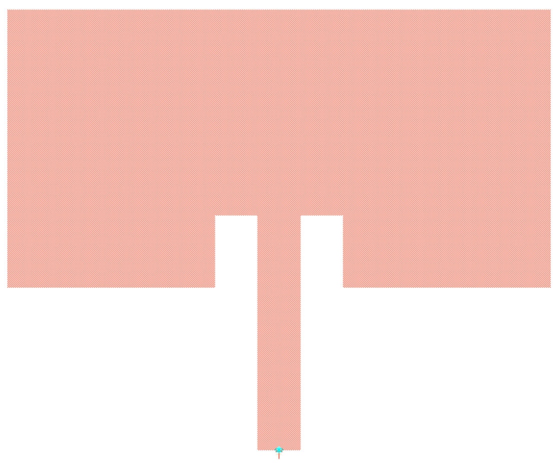

Figure 2. Microstrip patch antenna in ADS

Patch antenna array design

Microstrip patch antenna arrays are made up of several patches that act together as a single antenna to transmit or receive radio waves over longer distances than a single antenna. The aim of antenna array design is to increase gain and directivity. So, using the patch antenna with the dimensions mentioned in table 1, we created an antenna array with four radiating components.

The input signal from a SMA connector is processed in the proposed antenna array and divided into four output patches by the feeding network. A λ /4 transformer of 70Ω is demonstrated to match between the impedance line of 100Ω and the feeding line of 50Ω. The coupling between the patches has been used to prevent patch separation, which can eventually

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affect the gain output of the patch antenna array. The aim of designing a patch antenna array is to achieve the best possible parameters, such as return loss, gain, and directivity. Figure 3 depicts the antenna array's optimised architecture under ADS.

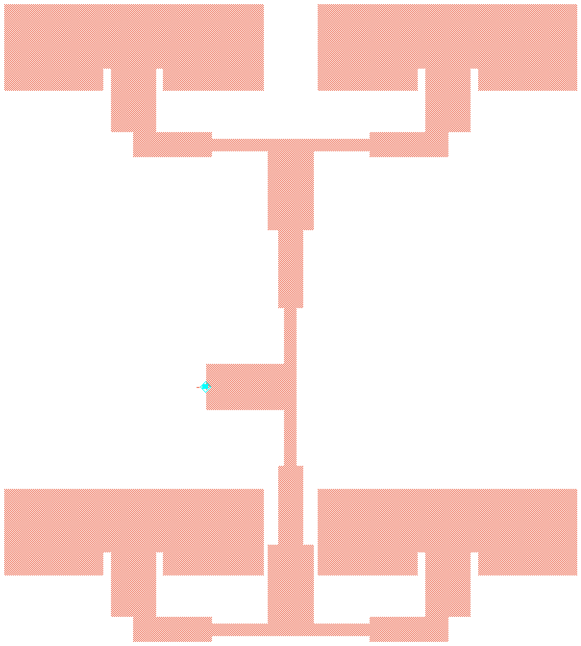

Figure 4. Optimised design of antenna array in ADS

Results

The simulation results for the microstrip patch antenna (2.4GHz) and microstrip antenna array are presented in this section. Advanced Design System (ADS) software was used to design and simulate the antenna. Benefit, directivity, and reflection losses are the parameters that are recognized.The return loss of the antenna arrays is shown in dB in the diagram above. Any operation should have a return loss of less than -10 dB. At 9.6GHz, the 2x2 antenna array has a lower return loss value of S_{11} = -4.487dB, shown in figure 5.The results show that the antenna array arrangement effectively increases the patch's gain and directivity, making the design ideal for use in the X band.However, the most important aspect of the project is the development of an antenna array for an RFID reader to increase gain and directivity for long-range applications such as vehicle identification.

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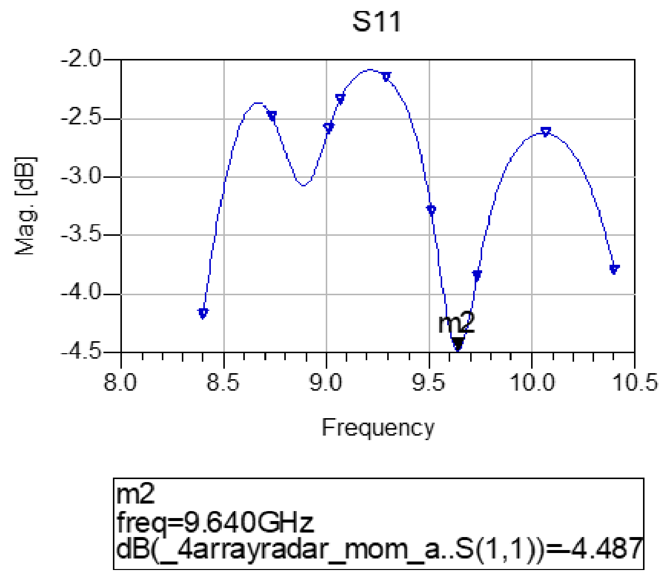

Figure 5. Simulated reflection coefficient (in dB) of antenna array (9.6 GHz)

The radiation pattern of the microstrip patch antenna array is determined in Figure 6. Using far-field, the result was 9.640 GHz. Since the combination of multiple radiating elements added where it is possible to increase the gain and hence the directivity, this radiation pattern is more effective and directive.

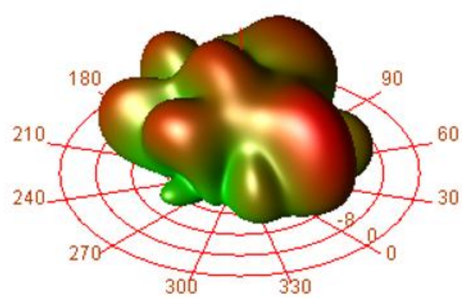

Figure 6 Radiation pattern of antenna array

Conclusion

Using ADS simulation software, antenna array for 9.6GHz is proposed in this paper. The proposed design is a basic framework that can be created at a low cost.The antenna array's gain was calibrated to be 18.453 dB in each case. The use of a four-patched antenna array improves the radiation efficiency substantially, according to simulation results.When a single patch is used, the antenna's directivity and gain are average, however as the number of patches combined in the antenna array grows, the directivity and gain increase with time, and reflective losses are reduced.

As a result, the antenna's output is directly influenced by the number of radiating elements in the array as well as the feeding process. The results show that a microstrip antenna array for 9.6 GHz is a viable option for radar applications.

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