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DESIGN AND ANALYSIS OF ARRAY OF SLOT ANTENNA FOR S-BAND APPLICATION

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Abstract:

The analysis and design of S-band patch feed array of slot antenna for Broadband application is proposed. The array of slot antenna is able to operate at 3.5 GHz and thus the antenna becomes a necessity for many applications in recent wireless communications such as Radar, Microwave and Space Communication. The array of slot antenna offers an increased Bandwidth as compared to single slot antenna. The array of slot antenna is designed using IE3D software. The return losses are observed by the radiation pattern. The analysis of antenna parameters such as VSWR, directivity, radiation pattern (3D), return loss, gain and relation between them are performed using IE3D software.

Key Words: VSWR, Gain, Return Loss, Directivity, Efficiency & Slot

1. Introduction:

Antennas are basic components of any electric system and are connecting links between the transmitter and free space or free space and the receiver. In the world of communication basic need is an antenna. Antennas are employed in different systems in different forms. The antennas are used to radiate electromagnetic energy in an omnidirectional or finally in some systems for point-to-point communication purpose in which increased gain and reduced wave interference are required. Microstrip antennas have extensive applications in wireless communication system following to their advantages such as low profile conformability, low cost and ease of fabrication. However, conventional Microstrip antenna suffers from very narrow bandwidth with respect to the center frequency. To overcome this, slot antenna have been considered as a good source in conforming to these trends. In order to reduce antenna size, recent research has involved many miniaturization techniques for slot antennas. For compact slot antenna design, increasing the length of the slot [9] or adjusting the shape of the slot [10] is needed. By employing different shapes of the slots [11-16], the antenna size can be reduced for a given operating frequency. The rest of the paper is divided as follows. Section II discusses the Literature Survey, Section III present the Parameter Study, Section IV explains the Performance Analysis, Section V describes Results and finally section VI gives the conclusion.

2. Review of Literature:

For the requirement of high gain and directional radiation, feed patch or Microstrip antenna is employed. For reducing the size of antenna many designs are implemented by maintaining good performance. Even slot antenna design have low profile with wide bandwidth and low cost PCB substrates but it is challenging in reducing its structure. Small dimensions are obtained by bending antenna into various shapes. The square slot is designed with step by step procedure for individual bands works properly [1].With the introduction of fractals shapes of radiating element in antenna engineering, the multiband resonance with single antenna, becomes attractive. In modern technology, multiband antennas play an important role [2]. The dual band antenna can be realized by low cost commercialized inkjet printed fabrication technique. To print the antenna, it is important to consider a low cost transparent and flexible substrate with low loss factor [3]. Some of the most common methods which can be employed to reduce the size of the antenna are inserting slots, shorting pins, corrugation structure and iris structures [7, 8]. The resonance frequencies can be controlled by adjusting the dimensions of the slots [16]. The Microstrip patch was one of the most preferred antenna structures for low cost and compact design for Wireless system. By loading properly arranged U slot on a rectangular Microstrip patch, broadband operations of a single feed rectangular patch was achieved. The design of multiband antennas with low volume is of practical interest for the ever growing wireless communication industry [20].

The radiating elements in this antenna were composed of rectangular and triangular slots. These slots were engraved in the rectangular and triangular patch, joined together in one structure, and by single probe feed. The rectangular and triangular slots make the antenna to operate at multiband with relatively high gain [21]. Two notched frequency bands were obtained by embedding two U-shaped slots in the Radiation patch and a rectangle slot in the ground plane. The two notched bands can be controlled by adjusting the length of the responding slots [17]. The slot was optimized with respect to width, length and position for a detailed study of notched-band characteristics. It was observed that the centre frequency and bandwidth of notched-band depend on the length and width of slot respectively [18]. Resonant frequency has been reduced drastically by cutting two different slots. The first one was the combinations of two triangular and another rectangular slot at the upper right corner and rest was bilateral triangle at the lower left corner from the conventional Microstrip patch antenna. Simulated antenna size has been reduced by 48.11% with an increased frequency ratio when compared to a Conventional Microstrip patch antenna [26]. Mutual coupling effect has to be taken care in designing for improving active return loss and radiation efficiency [19].Three identical narrow open end meandering slots were embedded in the antenna ground plane parallel to plus shaped radiating edge and study is made. This antenna is radiating at dual resonant frequencies [24].

3. Parameter Study:

The basic antenna parameters like length, width, height, dielectric constant must be properly chosen to design an antenna to meet an appreciable outcome. Several parameters have been investigated using IE3D software. The design specifications for array of slot antenna are:

- ✓ The dielectric material is FR – 4.
- ✓ Dielectric constant (ε_r) is 4.2.
- ✓ Height of substrate (h) is 1.6mm.

The physical dimensions like length, width and height are calculated based on the following formulae [17].

$$L = \frac{c}{2 f_0 \sqrt{\varepsilon_r}} = 20.91\text{mm} \qquad (1)$$

$$w = \frac{c}{2 f_0 \sqrt{\frac{2}{(\varepsilon_r + 1)}}} = 16.06\text{mm} \qquad (2)$$

$$h \geq \frac{0.06\lambda}{\sqrt{\varepsilon_r}} \geq 1.6\text{mm} \qquad (3)$$

Generally, the relationship of width, height and effective dielectric constant of substrate are related as in equation (4)

$$\varepsilon_{eff} = \left[\frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{2}\right] * \left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}} \qquad (4)$$

The wavelength (λ), velocity of light (c) and frequency (f_o) are shown in equation (5),

$$\lambda = \frac{c}{f_o} = 0.0546\, m \qquad (5)$$

Many shapes of slots are available in antenna design like U shape [17, 20], H shape [6, 8], W shape [15], circular shape [16] etc. We use array of square shape slots. Since all the four sides are equal, so the radiation will be equally split into the elements in all directions. i.e., the gain of the antenna will be improved gradually. Among the various feed techniques like coaxial feed, coupled feed and patch feed, the patch feed is implemented in the proposed antenna as shown in Figure 1. The feed point is the excitation for an antenna. The antenna must be excited with the help of current source only. The reason and description for chosen the patch feed is discuss in Table 2. Patch antennas can be fed by variety of methods. These methods can be classified into two categories:

- ✓ Conducting
- ✓ Non- Conducting

In the conducting method, the RF power is fed directly into the radiating patch using a connecting element such as a Microstrip line. In the non-conducting scheme, Electromagnetic field coupling is done to transfer power between the Microstrip line and the radiating patch. The dimension of proposed antenna structure is given in Table 1 and the 2D view of the proposed antenna is shown in Fig.2.The four most popular feed techniques are classified below:

Conducting Schemes:

- ✓ Microstrip Line
- ✓ Coaxial Probe

Non-Conducting Schemes:

- ✓ Aperture Coupling
- ✓ Proximity Coupling

Table 1: Physical Parameter of Antenna

S.No	Description	Value (mm)
1	Patch dimension (L*W)	20.91 * 16.06
2	Feed length	13
3	Feed width	3
4	Thickness (h)	1.6
5	Frequency (f_o)	3.5GHz

Table 2: Antenna Feeding Techniques

Description	**Patch Feed**	**Coaxial Feed**	**Aperture Coupled Feed**	**Proximity Coupled Feed**
Feed Radiation	More	More	Less	Minimum
Reliability	Better	Poor	Good	Good
Fabrication	Easy	Soldering and drilling needed	Alignment Required	Alignment required
Impedance Matching	Easy	Easy	Easy	Easy
Bandwidth	2-5%	2-5%	2-5%	2-5%

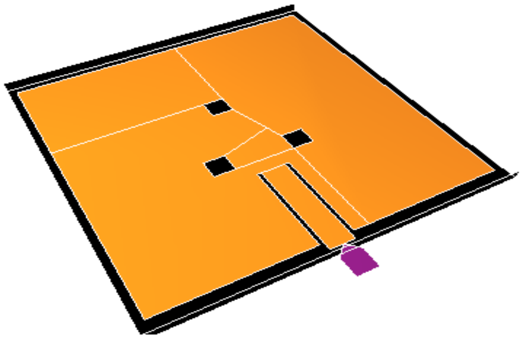

Figure 1: Array of square shape slot antenna (3D)

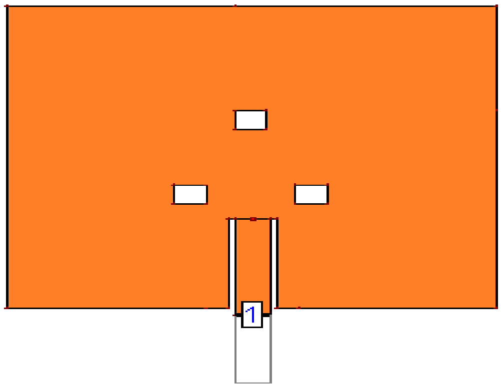

Figure 2: Array of square shape slot antenna (2D)

4. Performance Analysis:

The radiation pattern and radiation resistance of an antenna is the same when it transmits and when it receives, if no non-reciprocal devices are used. Non – reciprocal device states that, the devices which are having the properties that the forward characteristics are not equal to the reverse characteristics (i.e. $S_{12} \neq S_{21}$). So, same antenna can be used for Transmission and Reception of Electromagnetic Waves. Antenna is a passive device, it does not amplify the signals, and it only directs the signal energy in a particular direction in reference with isotropic antenna. Antenna Beam width is the angular width measured at the half power points of the main lobe. Large gain of antenna means narrow beam width. Polarization of EM fields describes the time variations of the time harmonic field vectors at a given points. In other words, it describes the direction of the field vectors change in time. Polarization is a time harmonic field characterizes. The equation (6) gives the beam width with respect to polarization of waves.

$$B = \theta_E * \theta_H \quad (6)$$

The Effective Antenna aperture is the ratio of the available power at the terminal of the antenna to the power flux density of a plane wave incident upon the antenna which polarization matched of the antenna. Area over which the antenna extracts energy from the travelling EM waves. The wavelength (λ), Directivity (D) and Effective Aperture (A_e) are related in equation (7),

$$A_e = \frac{D\lambda^2}{4\pi} \quad (7)$$

The proposed array of slot antenna has met an appropriate result and resonates over the frequency of 3.5GHz (S-Band).

5. Simulation and Results:

The software used to model and simulate the proposed array of square shape slot antenna is IE3D. IE3D is an Integrated Electromagnetic 3 Dimensional Simulator based on the method of moments. It analyzes

3D and multilayer structures of various shapes. There are various issues while we design an antenna such as size, gain improvement, directivity enhancement, increased bandwidth, suppressed side lobes or back lobes. Antenna is not able to radiate all energy in single perfect direction. Some of the energy can be radiated in other direction, often there are small peaks in the radiated energy in different directions. This peak is referred as side lobes**.** Due to the presence of slots in simulated antenna resonant frequency operation is obtained with large value frequency ratio. It is found that the antenna resonates at 3.5GHz. The simulated gain of an antenna is 8.57 dBi ≈ 13.37 dB at 3.5 GHz resonant frequency, which indicated appreciable gain. Similarly, directivity of an antenna is 10.8 dBi ≈ 15.64 dB at 3.5 GHz (S–band) resonant frequency. The results can be tabulated in table 3 as follows:

Table 3: Simulated Results

S.No	Performance Parameters	Observed Value @ 3.5GHz
1	Return loss	-10.25dB
2	VSWR	1.98
3	Gain	13.37dB
4	Directivity	15.64dB
5	Band Width	15.38MHz

5.1 VSWR: The VSWR determines the matching properties of an antenna. It indicates that how much efficiently antenna is transmitting / receiving electromagnetic wave over particular band of frequencies. It describes the amount of power reflected by an antenna. In practical, the VSWR should be between 1 and 2 for less reflection losses. Based on the VSWR value only we found that how, the device is efficiently operated. The VSWR value at 3.5 GHz is 1.98 shown in Fig 3.

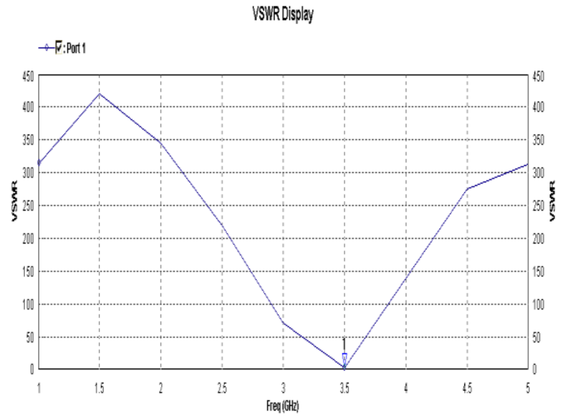

Figure 3: Simulated VSWR Value

5.2 Return Loss: The return loss is a measurement from which we can judge how much amount of power is reflected by the antenna. The numerical value of the S_{11} space parameter from the Fig.4 is -10.25dB.

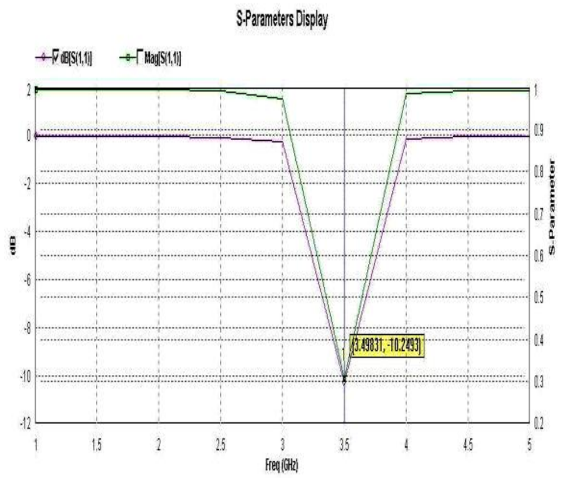

Figure 4: Simulated S – Parameter Value

5.3 Radiation Pattern: Radiation pattern is a graphical representation of the radiation properties of the antenna as a function of space coordinates. It is an indication of radiated field strength around antenna. It is different for different antennas and is affected by the location of antenna with respect to ground. The 3D view of Radiation pattern is shown in the Figure 5.

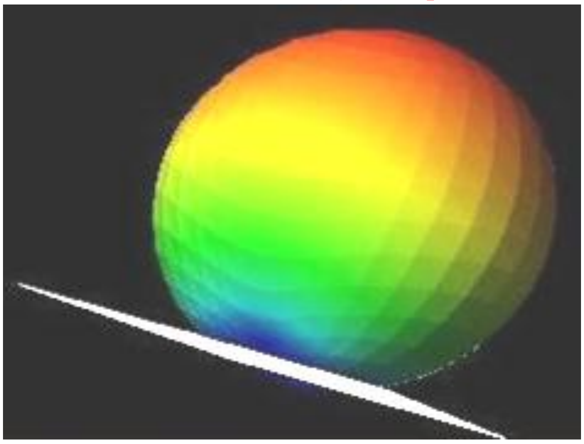

Figure 5: Radiation Pattern

5.4 Gain: The gain is also called as directive gain when the antenna radiates power in a particular direction relative to the average power radiated by the Antenna. An antenna has large aperture has more gain. The gain of an antenna is 8.57 dBi is equal to 13.37 dB which is shown in Fig.6.

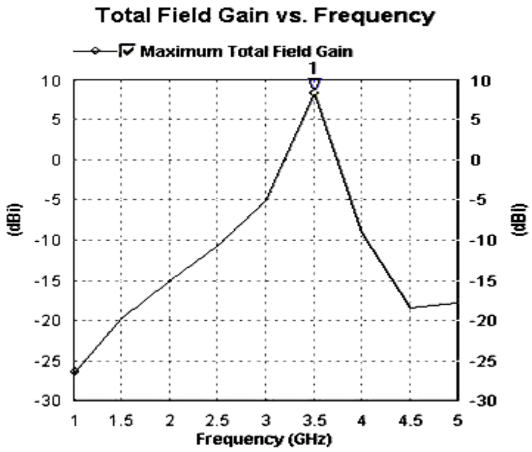

Figure 6: Simulated Gain Value

5.5 Directivity: Directivity of an antenna is the ratio of the radiation intensity in a particular direction and the radiation intensity averaged over all directions. The Directivity of proposed antenna is 10.8 dBi is equal to 15.64 dB which is shown in Fig.7.

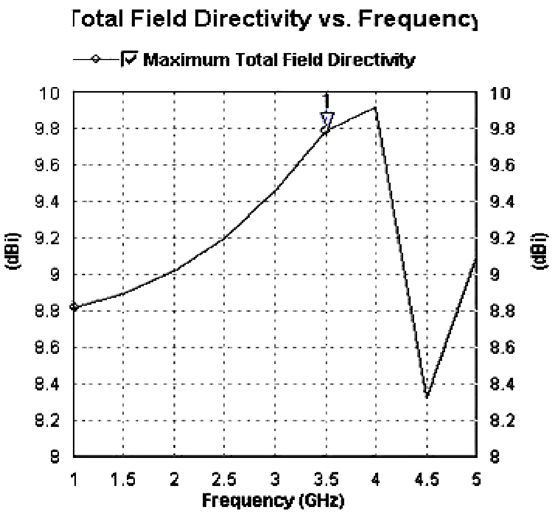

Figure 7: Simulated Directivity Value

5.6 Bandwidth: The Bandwidth (BW) is calculated manually using the equation (8) given below, at 3.5 GHz (S – Band) the total BW of the array of slot antenna is 15.38 MHz, and it is increased BW as compared to single slot antenna [16].

$$Bw = 3.77 * \left[\left(\frac{\varepsilon_r - 1}{\varepsilon_r^{2}} \right) * \left(\frac{w}{L} \right) * \left(\frac{h}{\lambda_0} \right) \right] \quad (8)$$

BW = 15.38 MHz

6. Conclusion:

Slot antennas have become a rapidly growing area of research. Their potential applications are limitless of their light weight, compact size and easy manufacturing. A variety of approaches have been taken, including modification of the shape and size of the slot, experimentation with substrate parameters. It is therefore concluded that array of slot antenna is perfectly designed with a increased BW as compared to single slot antenna [16]. The antenna which is mentioned in this paper it being used in RADAR, Terminal Air Traffic Control and WLAN applications.

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