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Back Fire Microstrip pacth Antenna for wireless communication

Puran Gour[1] and Ravishankar Mishra[2]

[1]Nri Institute of Information Science and Technology, Bhopal, India.

[2]Sagar Institute of Science and Research Technology, Bhopal.

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ABSTRACT

A method to improve the bandwidth for L and C band of backfire antenna is proposed. The performance of backfire antenna is investigated by performing numerical calculation by using various mathematical formulas to determine necessary dimension of the antenna and simulation by using IE3D software. Here we design proposed geometry for 3GHz. For proposed geometry we got 37.5% bandwidth for VSWR < 1.5 return loss -45 dB and directivity is 8 dBi .

Introduction

Antenna is one of the important elements in the RF system for receiving of transmitting the radio wave signals from and into the air as the medium. Without proper design of the antenna, the signal generated by the RF system will not be transmitted and no signal can be detected at the receiver. Many type of antenna have been designed to cater with variable application and suitable for their needs. The backfire antenna was original described in 1960 by H.W.Ehernspeck and much simplified version called the short backfire antenna has been subjected of extensive experimental studies[1],[2]. A short backfire antenna is a type of a directional antenna characterized by high gain, relatively small size and narrow band [3],[4]. The feed location in the backfire antenna construction upon the antenna characteristics is also examined. Several attempts have been made to enhance the bandwidth performance of the common dipole –fed backfire by employing various other feeding mechanisms with moderate success. The micro strip patch excited SBA is superior over these other designs in its reduced size and mass while maintaining comparable performance[3],[4]. The backfire antenna can be obtained by placing of a big reflector at the open end of a back fire antenna perpendicularly to its axis. The geometry of the backfire antenna is shown in fig 1. It consists of a source F, Surface wave structure S and two parallel disk reflectors: small reflectors R1 and big reflector R2. Which reflects the surface wave SW2 toward the small reflector R1, where it is radiated from the antenna aperture VV' into the space. Thus, the radiation of the antenna is directed in inverse direction in comparison with the radiation of the ordinary end-fire antenna used as a backfire antenna prototype. Because of this reason it is called Backfire Antenna.[1][2]

Feeding Techniques

There are four feeding techniques that can be used when design the short backfire antenna. These are coaxial probe / probe coupling, micro strip feed, proximity (Electromagnetically) coupled micro strip antenna, aperture couple micro strip antenna feed. In this report, the coaxial probe and inset feed are used because it simple fabrication and easy impedance matching[3].

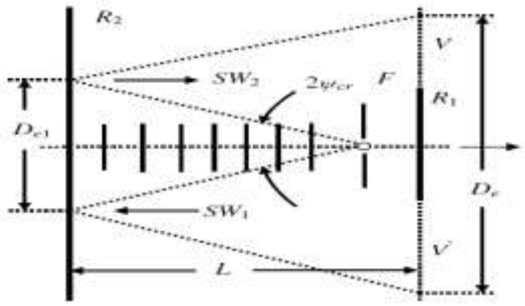

Fig: 1 Basic geometry of back fire antenna

Coaxial Feed

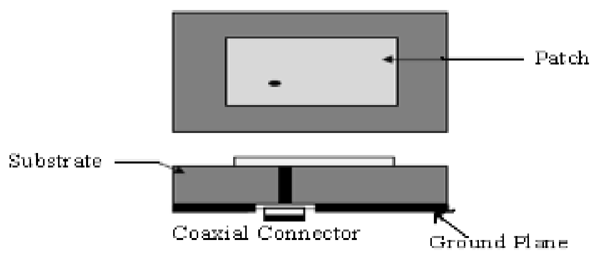

Fig: 2.1 Coaxial probe feed

Coaxial probe is a coupling of power through a probe. A typical short backfire antenna is using N type coaxial connector. The coaxial connector is attached to the back side of the printed circuit board and the coaxial center conductor after passing through substrate is soldered to the patch metallization. The location of feed point is determined for the given mode so that the best impedance match is achieved. It has narrow bandwidth and difficult to manufacture, especially for thick substrates.

Microstrip Line Feed

The microstrip line is also a conduction strip, usually much smaller width compared to the patch. The microstrip line is easy

Tele:

E-mail addresses: purangour@rediffmail.com

to fabricate, simple to match by controlling position and rather simple to model.

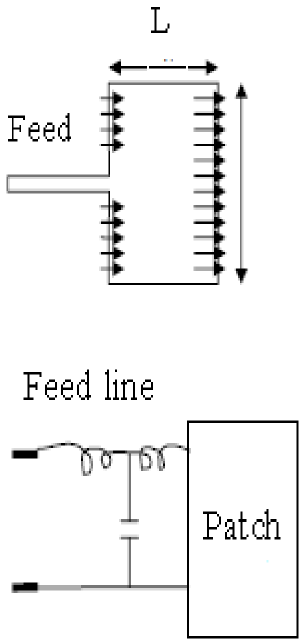

Fig: 2.2 Microstrip feed at the radiating edge and there equivalent circuits

However as the substrate thickness increased surface waves and spurious feed radiation increases. Which for practical designs limit the bandwidth (typically 2-5%). The coupling between the microstrip line and the patch could be in the form of edge coupling or gap between them[3].

Proximity Coupling

It is two layered like Aperture coupling and has the largest bandwidth (as high as 13%), is somewhat easy to model and has low spurious radiation. However its fabrication is somewhat more difficult and has spurious radiation from the feed. The length of the feeding stub and the width-to-line-ratio of the patch can be used to control the match. Both the microstrip feed line and the probes feed possess inherent asymmetric, which generate higher order modes which produce cross-polarized radiation [3].

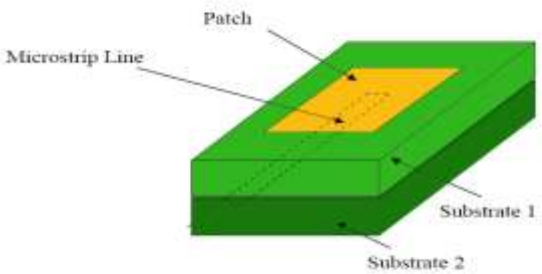

Fig: 2.3 Proximity coupling

Aperture Coupling

This is the most difficult of all four to fabricate and it also has narrow bandwidth. However, it is somewhat easier to model and has moderate spurious radiation. It consist of two substrate separated by the ground plane. On the bottom side of the lower substrate there is a microstrip feed line whose energy is coupled to the patch through a slot on the ground plane separating the two substrates. This arrangement allows independent optimization of the deed mechanisms and radiating element. Typically a high dielectric material is used for bottom substrate, and thick low dielectric constant material for the top substrate. The ground plane between the substrate also isolates the feed from the radiating element and minimizes interference of spurious radiation for pattern formation and polarization purity. In this thesis we are used coaxial feeding due to its easy impedance matching and easy fabrication[3].

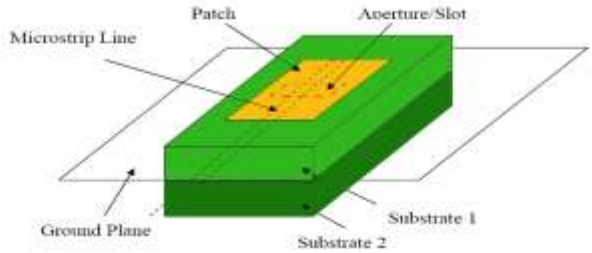

Fig: 2.4 Aperture coupling

Comparative Analysis of Different Feeding Methods

Hence from above discussion it is very much clear that there is a variety of feeding technique for microstrip patch antenna, here is a brief comparison among various feed methodology are given to have a trade off for design requirement.

Table 2.1: Comparison of different feeding methods

Characteristics	Line Feed	Coaxial Feed	Aperture Coupled	Proximity Coupled
Configuration	Coplanar	Non planar	Planar	Planar
Spurious Feed Radiation	More	More	More	More
Polarization Purity	Good	Good	Excellent	Poor
Ease of Fabrication	Easy	Soldering and drilling needed	Poor	Poor
Reliability	Better	Poor due to soldering	Good	Good
Impedance Matching	Easy	Easy	Easy	Easy
Bandwidth	2-5%	2-5%	2-5%	13%

From the four most popular techniques to feed the proposed antenna the coaxial feed is chosen. This technique allows independent optimization of the feed and radiating parts of the parts of the antenna due to the metal ground plane placed between them.

Designing of Backfire Antenna

For designing of any backfire antenna we can use mainly two Parts:

➢ Mathematical Analysis:

- For designing of SBFA first we have to choose the substrate of the antenna.
- For numerical analysis various formulas are used.
- And last for input purpose different feeding methods are used; in this I used coaxial feed line technique.

➢ Antenna Design by using IE3D software:

- For simulation part different software's are used, I used IE3D software
- Different steps are followed for designing of SBFA antenna.

Mathematical Analysis

Mathematical analysis is necessary for knowing the exact dimension of the patch to be designed. By performing mathematical analysis we calculate width and length of the patch, ground plane & reflectors. For mathematical purpose main important point is how we can choose substrate. The bandwidth of the short backfire antenna is directly proportional to the substrate thickness (h). The bandwidth of the short backfire antenna is inversely proportional to the square root of substrate dielectric constant (εr).Substrate thickness is another important design parameter. Thickness of the substrate increases the fringing field at the patch periphery like low dielectric constant and thus increases the radiated power. It also gives lower quality factor and so higher bandwidth. The low value of dielectric constant increases the fringing field at the patch periphery and thus increases the radiated power. A small value of loss tangent is always preferable in order to reduce dielectric loss and surface wave losses and its increase the efficiency of the antenna.[3]

There are three essential parameters that should be known while performing mathematical analysis:

➢ Frequency of operation (f0): The resonant frequency of the antenna must be selected appropriately.

➢ Dielectric constant of the substrate (ε_r):The dielectric material selected for my design for micro-strip patch & ground plane is FR-4 which has a dielectric constant of 4.3. Also an effective dielectric const ant (ε_{eff}) must be obtained in order to account for the fringing and the wave propagation in the line.

➢ Height of dielectric substrate (h): The height of the dielectric substrate is selected as 1.5 mm.

Formulae's Used for Mathematical Calculations:

$$w = \frac{c}{2f\sqrt{\frac{(\varepsilon_r + 1)}{2}}} \quad (3.1)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \quad (3.2)$$

$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \quad (3.3)$$

$$L = \frac{c}{2f\sqrt{\varepsilon_{eff}}} - 2\Delta L \quad (3.4)$$

$$L_0 = L + 6h \quad (3.5)$$

$$W_0 = W + 6h \quad (3.6)$$

where:

f = Operating frequency

εr = Permittivity of the dielectric

εeff = Effective permittivity of the dielectric

W = Patch's width

L = Patch's length

h = Thickness of the dielectric

L_0 = Length of ground plate

W_0 = Width of ground plate

Effects of substrate:

While performing mathematical analysis effect of substrate is also considered. Some of the important points that needed to be considered are [5] – [7]:

➢ The bandwidth of microstrip patch antenna is directly proportional to the substrate thickness (h) and inversely proportional to the square root of substrate dielectric constant (ε).

➢ Thick substrate increases the fringing field at the patch periphery and thus increases the radiated power.

➢ A small value of loss tangent is always preferable in order to reduce dielectric loss and surface wave loss and it increases the efficiency of antenna.

➢ Low dielectric constant is used which has very low water absorption capability.

Table 3.1 Data sheet of different substrate

Properties	LTCC	FR4 Epoxy	RT Duroid
Dielectric constant	7.4	4.36	2.2
Loss Tangent	0.023	0.019	0.0004
Breakdown voltage	20-28 kv	55 kv	>60 kv

Antenna Design by using IE3D software

The proposed antenna designs such as the return loss, directivity and the radiation pattern can be obtained by using the EM Simulator IE3D (version 9.0) software. The results for the antenna simulation does not accurately give similar result as measured. Based on the simulations and measurements that haves been done, the operating frequency of the antenna fabricated are shifting to the lower frequency. By using equation (3.1)-(3.6). we find the length and width of rectangular microstrip patch of short backfire antennas, which is calculated as:

Table 3.2 Values from mathematical calculation for Proposed Antenna

S.no	Parameters	Values for Proposed Antenna
1	Resonant frequency(f_0)	3 GHz
2	Dielectric constant (ε_r)	4.3
3	Height of substrate (Hs)	1.5mm
4	Loss tangent of FR4	0.019
5	Width of rectangular patch(W)	30.7148mm
6	Length of rectangular patch(L)	23.7388mm
7	Width of ground plane(W_0)	39.7148mm
8	Length of ground plane(L_0)	32.7388mm
9	Diameter of sub-reflector(d)	50mm
10	Height of sub-reflector(Hr)	25mm
11	Feed location: X_f(along length) Y_f(along width)	 $X_f = 6.975$ $Y_f = -10.4$

Validation from previous paper

Simulation and Results

The antenna was simulated by IE3D software, which uses the Method of Moments approach in its modeling equations with the final patch obtained shown in figure 3 below.

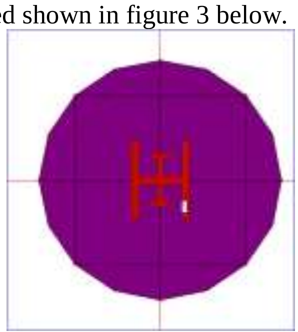

Fig 3.1: Geometry of short backfire antenna

The geometry consists of two reflector one is rectangular and second is circular in between that patch is connected.

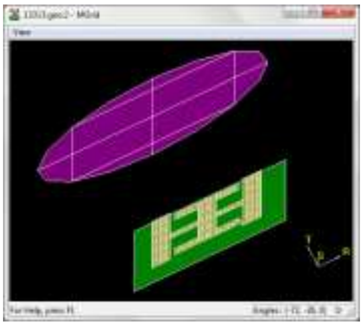

Fig 3.2 3D view Geometry of backfire antenna

The 3D view of the proposed antenna is as shown above fig 3.2

Fig.5.1 S11 parameter curve for geometry 1

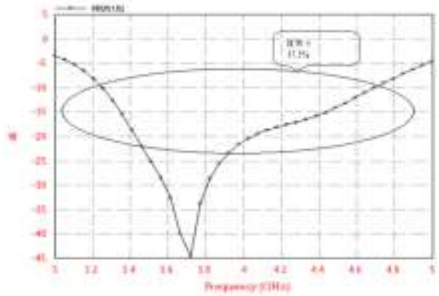

Fig 3.3 S11 parameter curve for geometry (Return Loss)

The return loss of the antenna obtained is -45 dB at the center frequency of 3.73 GHz as shown in figure3.3. Thus, the bandwidth obtained from the return loss result is 37.5% .

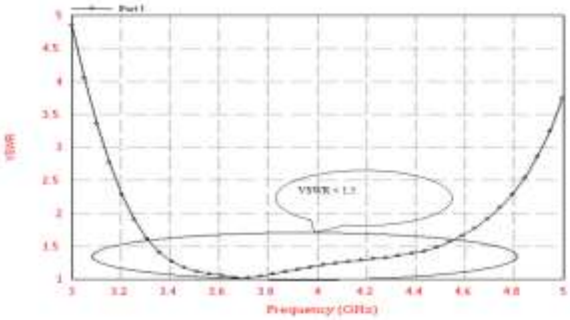

Fig.3.4 VSWR curve for geometry

Moreover, VSWR is a measure of how well matched antenna is to the cable impedance. A proposed antenna would have a VSWR of less than 1.5 for 3.23-4.73GHz. This indicates less power is reflected back from source. VSWR obtained from the simulation is less than 2 which is approximately equals to 1.1:1 as shown in figure . This considers a good value as the level of mismatched is not very high because high VSWR implies that the port is not properly matched

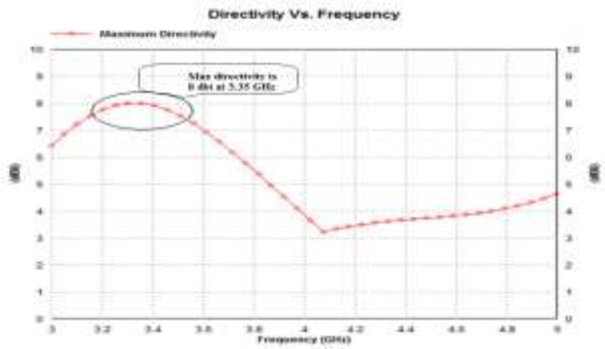

Fig.3.5 Directivity vs frequency curve for geometry

The directivity of proposed antenna is 8dBi at 3.35Ghz

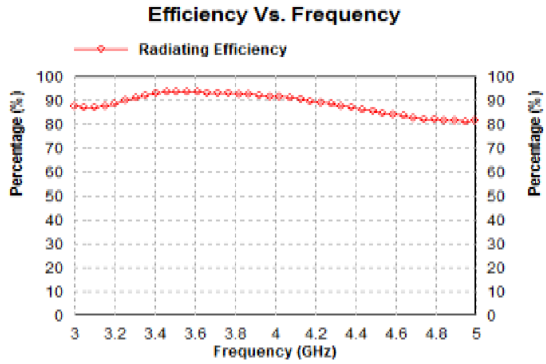

Fig. 3.6 Radiating efficiency curve for geometry

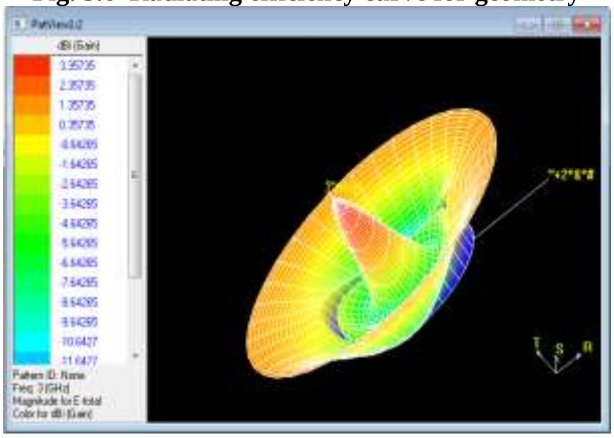

Fig. 3.7 3D Radiation Pattern

Also, the radiation pattern of the antenna is obtained as figure shows3.7. The E-plane and H-plane pattern at 3.35 GHz center frequency. It can be observed from this radiation that the design antenna has stable radiation pattern throughout the whole operating band.

Conclusion

In this paper, we presented the design of a back fire rectangular patch antenna covering the 3GHz−5GHz frequency spectrum. It has been shown that this design of the back fire rectangular patch antenna produces a bandwidth of approximately 37.5% with a stable radiation pattern within the frequency range. The design antenna exhibits a good impedance matching of approximately 50 Ohms at the center frequency. This antenna can be easily fabricated on substrate material due to its small size and thickness. The simple feeding technique used for the design of this antenna make this antenna a good choice in many communication systems.

S.no	Parameters	For Geometry
1	S11 Parameter	-45 dB at 3.72 GHz
2	Bandwidth	37.5% between (3.23-4.73)GHz
3	VSWR	<1.5 between (3.32-4.52)GHz
4	Directivity	8 dBi at 3.35 GHz

Authors and Affiliations

Puran Gour received his MTech from M.A.N.I.T. Bhopal and He is presently a PhD scholar at AISECT. Bhopal.His current research interests are in Microwave and Antenna design. His published works refer to design of wideband and high gain design with electromagnetic Simulators.

Dr.Ravi Shankar Mishra received his MTech from M.A.N.I.T. Bhopal and his PG diploma in VLSI design from C-DAC Bangalore. He ispresently a PhD scholar at M.A.N.I.T. Bhopal. His current Head of Department in Electronic and Communication department Sagar Institute of science and Technology Bhopal his research interests are in broadband optical communication system and design of integrated optical components. His published works refer to design of wideband amplifier and integrated optical components design with VHDL-AMS.

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