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Design Development of Antenna for TV Transmission for Connecting Outdoor Broadcasts Van to the Studio for Rural Areas

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***Abstract*—Imagine the world without Antenna there will be no effective wireless communication between two entities. It is the wireless communication, which effectively brings the whole world together. So Antenna is a very useful & essential device for effective communication. The patch Antenna is a low profile, simple in construction, low weight, and smaller in size Antenna. So it can be used in high performance Aircraft, Spacecraft missile applications, WLAN and many more. Rectangular patch is the most popularly used and easy to design. We have used probe feed method for feeding. We have designed Microstrip rectangular patch Antenna of the center frequency 750 MHz, we have employed dielectrics as FR4 PCB. Patch fed via a semi rigid coaxial cable of 50 ohms Impedance. One side fully copper plated PCB acts as ground plane for the patch.**

***Index Terms* —Bandwidth, Feeding, Gain, Microstrip, Patch.**

I. Introduction

Antenna is a very important component of communication systems. By definition, an Antenna is a device used to transform an RF signal, traveling on conductor, into an electromagnetic wave in free space [3]. The transmitter signal energy is sent into space by a transmitting antenna; the RF signal is picked up from space by a receiving Antenna. The voltage is induced into the receiving Antenna (a conductor), as the electromagnetic field arrives at it. The RF voltage induced are then passed into the receiver and converted back into the transmitting RF information. The Antenna must be able to radiate efficiently so the power supplied by the transmitter is not wasted. An efficient transmitter must have exact dimensions [4]. The dimensions are determined by the frequencies and gets critical at higher frequencies. Microstrip antennas can be made to emulate many of the different styles of antennas explained above. Microstrip antennas offer several tradeoffs that need to be considered. Because they are manufactured with PCB traces on actual PCB (Printed Circuit Boards) boards, they can be very small and lightweight. This comes at the cost of not being able to handle as much output power as other antennas, and they are made for very specific frequency ranges [5].

In many cases, limiting the frequencies that can be received is actually beneficial to the performance of a radio. Due to this characteristic, Microstrip antennas are not well suited for wideband communications systems [6].

TABLE 1. Comparison of Different Antennas

Antenna	Radiation Patterns	Power Gain	Directivity	Polarization
Dipole	Broadside	Low	Low	Linear
Yagi Antenna	Endfire	Medium/High	Medium/ High	Linear
Slotted Antenna	Broadside	Low/Medium	Low/Medium	Linear
Microstrip Antenna	Endfire	Medium	Medium	Linear

Microstrip antenna is also referred as a patch antenna See in Fig 1. It consists of a very thin (t << λ0 where λ0 is the free – space wavelength) metallic strip (patch) placed a small fraction of a wavelength (h << λ0, usually $0.003\lambda_0 \le h \le 0.05\lambda_0$) above a ground plane. The Microstrip patch is designed so its pattern maximum is normal to the patch (broadside radiator). This is accomplished by properly choosing the mode (field configuration) of excitation beneath the patch. In designing Microstrip antennas, a number of substrate can be used. The dielectric constant of the substrate usually ranges of $2.2 \le \varepsilon_r \le 12$. Thick substrates whose dielectric constant is in the lower range is the most desirable for antenna performance because they provide better efficiency, larger bandwidth, loosely bound fields for radiation into space, but at the expense of larger element size [1].

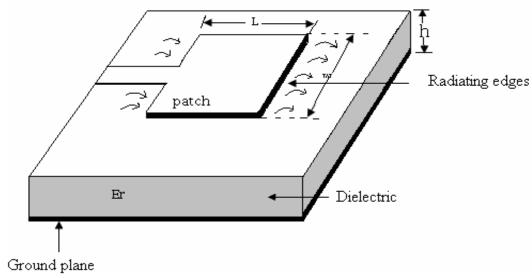

Fig.1 Microstrip antenna

A. *Different Shapes Of Patches*

The radiating elements and the feed lines are usually photo etched on the dielectric substrate. Patch shapes are versatile in term of resonant frequency, polarization, pattern and impedance. The radiating patch may be square, rectangular, thin strip (dipole), circular, elliptical, triangular or any other configuration. These and other are illustrated in Fig 2.

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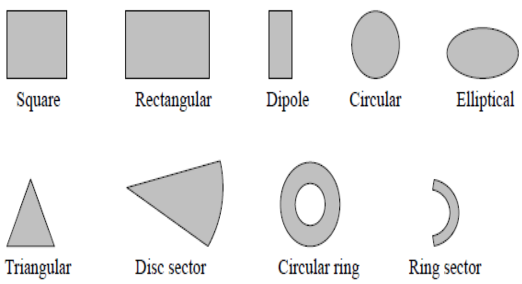

Fig.2 Common shapes of Microstrip patch elements

Square, rectangular, dipole (strip), and circular are the most common because of ease of analysis and fabrication, and their attractive radiation characteristics, especially low cross polarization radiation [7].

B. Operation of Microstrip Antenna

In Microstrip antenna, the electromagnetic (EM) wave fringe off the top patch into the substrate, reflecting off the ground plane and radiates out into the air. Radiation occurs mostly due to fringing field between the patch and ground. Fig 3. Shows the operation of Microstrip antenna.

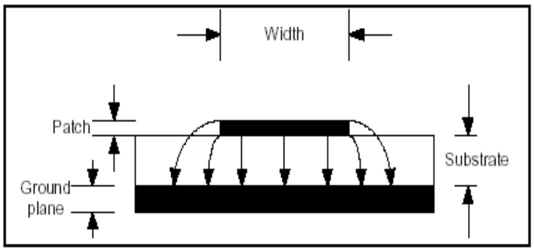

Fig.3 Operations of a Microstrip Patch

The radiation efficiency of the patch antenna depends largely on the permittivity ($\boldsymbol{\varepsilon_r}$) of the dielectric. Ideally, a thick dielectric, low $\boldsymbol{\varepsilon_r}$, and low insertion loss is preferred for broadband purposes and increased efficiency.

III. Feeding Methods

Feeding methods influences the input impedance and the polarization characteristic. Feeding methods can be classified into two categories, contacting and non – contacting schemes [1]. In contacting scheme, the RF power is fed directly to the radiating patch using a connecting element such as a Microstrip line. In non contacting scheme, EM field is done to transfer power between the Microstrip line and the radiating patch. There are four most popular structures that are used to feed Microstrip antenna. They are Microstrip line, coaxial probe, aperture coupling and proximity coupling. Microstrip line and coaxial cable are contacting scheme while aperture coupling and proximity coupling are the non – contacting scheme.

A. Microstrip Line Feed

A conducting strip is connected directly to the edge of the Microstrip patch as shown in Fig 4. The conducting strip is smaller in width as compared to the patch. The advantage of this feeding method is that the feed can be etched on the same substrate to provide a planar structure.

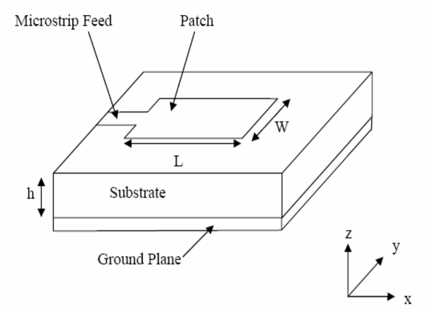

Figure 4-Microstrip Line Feed

So this is easy feeding scheme, since it provides ease of fabrication and simplicity in modeling as well as impedance matching. However as the thickness of the dielectric substrate being used, increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the Antenna. The feed Radiation also leads to undesired cross polarized radiation.

B. Coaxial Feed

As can be seen from the Fig .5, the inner conductor of the coaxial Connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane.

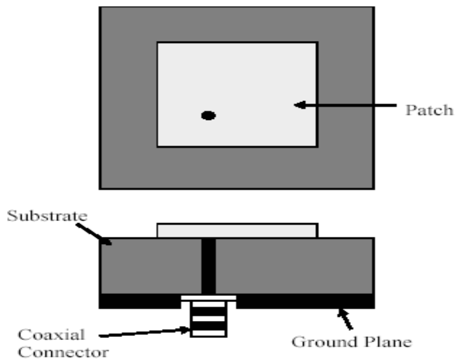

Fig 5 Coaxial probe feed

The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance. This feed method is easy to fabricate and has low spurious radiation. It provides narrow bandwidth and is difficult to model since a hole has to be drilled in the substrate and the connector protrudes outside the ground plane, thus not making it completely planar for thick substrate ($h>0.02\lambda$).Also, for thicker substrate, the increased probe length makes the input impedance more inductive, leading to matching problems. It is seen above that for a thick dielectric substrate, which provides broad bandwidth [2].

*C. **Aperture** Coupled Feed*

In this type of feeding techniques, the ground plane separates the radiating patch and the Microstrip feed line. Coupling between the patch and the feed line is made through a slot or an aperture in the ground plane. The amount of coupling from the feed line to the patch is determined by the shape, size and location of the aperture see in Fig 6.

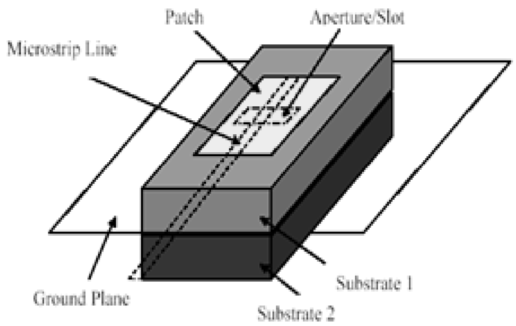

Fig. 6 Aperture coupled Feed

Since the ground plane separates the patch and the feed line, spurious radiation is minimized. Generally, a high dielectric material is used for the bottom substrate and a thick, low dielectric constant material is used for the top substrate to optimize radiation from the patch.The major disadvantage of this feed technique is difficult to fabricate due to multiple layers, which also increases the antenna thickness. This feeding scheme also provides narrow bandwidth [10].

D. *Proximity Coupled Feed*

This type of technique is also called as the electromagnetic coupling scheme. As shown in Fig 7, two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth (as high as 13%), due to overall increase in the thickness of the Microstrip patch antenna. This scheme also provides choices between two different dielectric media, one for the patch and one for the feed line to optimize the individual performances. Matching can be achieved by controlling the length of the feed line and the width-to-line ratio of the patch. The major disadvantage of this feed scheme is that it is difficult to fabricate because of the two dielectric layers, which need proper alignment. Also, there is an increase in the overall thickness of the antenna. In Table 2 we can see the Comparison of the different feed techniques

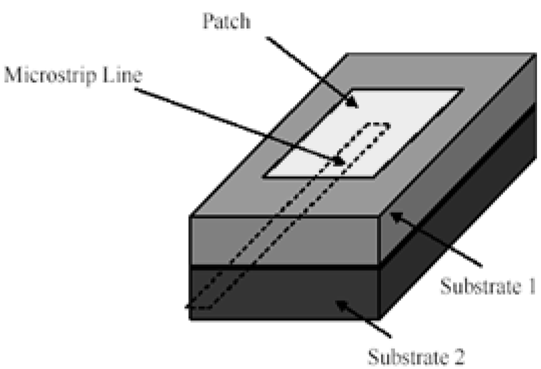

Fig.7Proximity – coupled Feed

TABLE 2. COMPARISON THE DIFFERENT FEED TECHNIQUES

Characteristic	Microstrip line Feed	Coaxial Feed	Aperture coupled Feed	Proximity coupled Feed
Spurious feed radiation	More	More	Less	Minimum
Reliability	Better	Poor due to soldering	Good	Good
Ease of fabrication	Easy	Soldering and drilling needed	Alignment required	Alignment required
Impedance matching	Easy	Easy	Easy	easy
Bandwidth (achieved with impedance matching)	2 – 5%	2 – 5%	2 – 5%	13%

Before the validation process of design, it is important to identify the fundamental aspects, specification and parameter of the proposed antenna configuration. This is important to make sure that the simulation and fabrication process is carried out correctly.

IV. DESIGN METHODOLOGY

During the progress of the project, the design methodology used will be as shown in below Fig 8. The project starts with the study and literature review related to get the fundamental knowledge about Microstrip antenna. Then the configuration to be used for the antenna as well as the related basic parameters and specification is set as desired. The validation starts with the simulation process by using the PCAAD software in order to confirm that the set parameters can produce a result as desired. Finally, actual fabrication and field measurement is carried out and comparison with the simulation result is done.

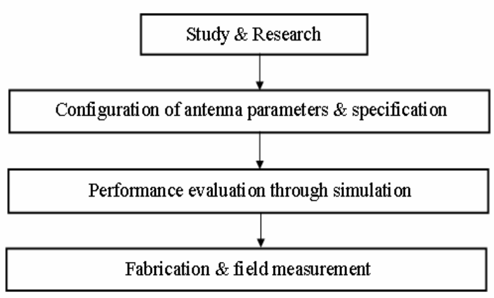

Fig 8. Methodology flowchart

The Microstrip antenna is tuned to operate at 750 MHz the material to be used is FR4 with dielectric constant of 4.34 and thickness of 1.6 mm. In choosing the material the constraints in term of material cost and time is considered [8]. Feeding technique using a coaxial probe feeding is used. Using this technique, the inner conductor of the coax is attached to the radiating patch while the outer conductor is connected to the ground plane. This feeding method is chosen mainly due to its easy fabrication process. Other advantages of coaxial feeding are its robust nature, can be place d at any desired location for input impedance matching, good isolation between the feeding network and the radiating element that contributes to a good front to back ratios and minimum misalignment difficulties due to direct contact between the probe and the patch.

A. Calculation of Different Parameters

Operating Frequency: 750MHz

Dimensions: 94.5mm × 122.3mm × 1.6mm
Reading Distance: 0.5m
Impedance: 50Ω
Polarization: LINEAR

The width of the Microstrip patch antenna is given by[7] ,

$$w = \frac{c}{2\,fr}\sqrt{\frac{2}{\mathcal{E}_r+1}} \qquad (1)$$

Where, c= 3× 10^8 m/sec, Fr= 750 MHz, $\boldsymbol{\varepsilon_r}$= 4.34So,
w= 0.1223m or w = 12.23.

Effective dielectric constant ($\mathcal{E}_{reff}$): following equation gives the effective

Dielectric constants as [7],

$$\mathcal{E}_{reff}=\frac{\mathcal{E}_r+1}{2}+\frac{\mathcal{E}_r-1}{2}\left[1+12\frac{h}{w}\right]^{-\frac{1}{2}} \qquad (2)$$

Substitute the value of $\boldsymbol{\varepsilon_r}$,h, w. we get $\boldsymbol{\varepsilon_{reff}}$ = 4.22 ,Element

extension length due to fringing effects: the equation given

By [7] ,

$$\Delta L = \frac{h(0.412)(\mathcal{E}_{reff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\mathcal{E}_{reff}-0.258)\left(\frac{w}{h}+0.8\right)} \qquad (3)$$

$\Delta L = 7.4681 \times 10^{-4}$m or $\Delta L = 0.7468$ mm

Final length[7] : Equation below gives the Final length as,

$$L = \frac{c}{2\,fr\sqrt{\mathcal{E}_r}} - 2\Delta L \qquad (4)$$

L= 0.09450× 10^2cm or L= 9.450 cm

Ground plane dimensions (Lg and Wg):

The transmission line model is applicable to infinite ground planes only. However, for practical consideration, it is essential to have a finite ground plane. It is known that similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Here we assume the length and width of the ground plane is equal to the wavelength of the Antenna. So equation for Lg and Wg is same[7] ,

$$Lg = Wg = \frac{c}{fr} \qquad (5)$$

Where, c= 3× 10^8m/sec
Fr= 750 MHz, So ,Lg = Wg= 40cm

Determination of feed point location (Xf , Yf):

A coaxial probe type feed is to be used in this design. The center of the patch is taken as the origin and the feed point location is given by the co-ordinates (Xf , Yf) from the origin. The feed point must be located at that point on the patch, where, the input impedance is 50 ohms for the resonant frequency. Usually it is found practically that feed point is found at one third of the length and width of the patch. And to get exact location of the feed point a trial and error method is used, i.e., to compare the return loss (R.L.) and select the feed point where the R.L is most negative. Approximately X_f= 3.15cm, Y_f= 4.07cm

B. Steps for Antenna Designing

- Develop schematic diagram
- Convert to board layout
- Optimize board layout
- Use laser printer to print layout to Peel-n-Press paper
- Clean copper clad PCB material with steel wool
- Iron Press-n-Press to copper clad PCB material
- Quench PCB material under cold water, remove peel-n-pres
- Etch in ferric chloride, illustrated in Fig. 9

Fig. 9 Etching process using the ferrite chloride

- Clean etched PCB
- Use steel wool and water to remove peel-n-press coating
- Drill hole where we have to feed
- Install probe connecter through hole
- Solder inner conductor to patch and outer conductor to ground plane, illustrated in Fig. 10
- Final design of Antenna(PCB), illustrated in Fig. 11

(a)Patch

(b) Ground plane

Fig.10 Final design of antenna

V. Results & Discussion

A. Simulated Results

All simulated results are possible with the help of PCAAD5.0 software; these are visualized in following manner Fig. 11 Polar pattern plot, Fig. 12 Rectangular polar plot, Fig. 13 3D pattern plot, Fig.14 VSWR plot [9].

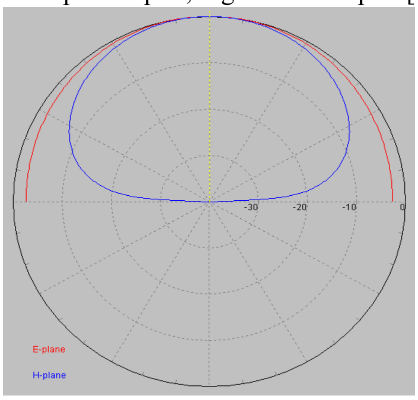

Fig. 11 Polar pattern plot

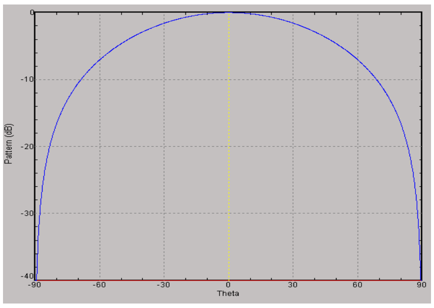

Fig. 12 Rectangular polar plot

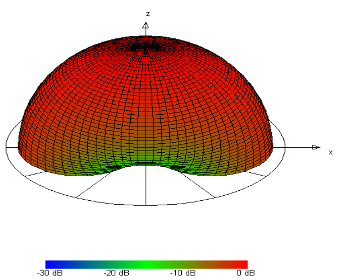

Fig. 13 .3D pattern plot

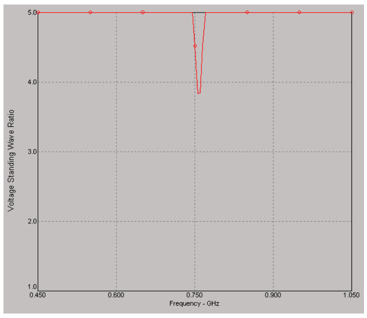

Fig.14 VSWR plot

B. Measured Results

In following Fig 15 we have mentioned a Measured Radiation pattern

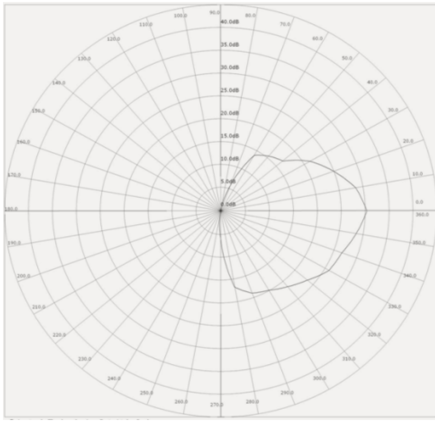

Fig.15 Measured Radiation pattern

C. Measured Parameters

- Beam width: 31; -3dB @ 343°, 14°
- Front to back ratio: 30.40
- Directive gain: Maximum gain: 30.4dB @ Azimuth angle: 0°
- Side lobe angle: 260°
- Front/side lobe: 30.40

With, the Tx dipole

- Max. Receiving current is: 15µA
- Distance between both antenna is: 15cm
- Input current: 50µA
- Gain of half wave dipole is 2.15dBi=1.64

So, Directive Gain of Rectangular Patch Antenna= 4.06= 6.0dBi

Fig.16 Setup for Testing an Antenna

IV. Conclusion

Simulation and actual hardware measurement was carried

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out in order to study the use of the probe coupled configuration that combined with the Microstrip antenna design. The purpose was to enhance the bandwidth performance up to the wideband level. The theoretical analysis is presented in the paper, including resonating frequency and substrate parameters influence on the antenna performance. The substrate thickness and loss is taken as the most significant design parameters. Both the Simulation analysis and the measurement results on a fabricated antenna show that employing moderate thick microwave substrate with small loss tangent helps to enhance the impedance bandwidth and the gain of the Microstrip antenna.

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