International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Multilayer Microstrip Antenna for broadband Applications

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Abstract: ***A novel broadband multilayer-layer coaxial coupled patch antenna is proposed. A simple patch geometry that is based on a rectangular patch which is place above the ground at a height (h_1 +h_2) fed by oaxialc coupled is introduced in this paper. A new resonant mode is excited using this novel patch structure. The results shows that the bandwidth is 450 to 750 GHz (S11<–10dB), larger than 40%. The gain is achieved to 4.65dB. The radiation patterns are similar and the gain can meet the demand for the communication applications over the operating frequency band. Simulation are done by using high Frequency Structure simulation (HFSS).***

Keywords: Coaxialc -coupled patch antenna; Multi-layer Broadband-band*; Suspended microstrip antenna.*

1. Introduction

In order to meet the miniaturization requirements of portable communication equipment, researchers have given much attention recently to compact microstrip antennas. Many related compact designs with broadband dual-frequency operation, dual polarized radiation, circularly polarized radiation, and enhanced antenna gain have been reported. Many significant advances in improving the inherent narrow operating bandwidth of microstrip antennas have been published in the open literature since 1997. By using presently available techniques, one can easily achieve an impedance bandwidth (1:2 voltage standing wave ratios) of larger than 25% for a probe-fed single patch microstrip antenna. Other feeding methods such as the use of an aperture coupled feed, a capacitive coupled feed, and impedance bandwidths greater than 40% with good radiation.

1.1 Objective

To design, simulate and fabricate broadband multilayer microstrip patch antenna operating at ISM band 2.4 GHz and study the effect on Impedance bandwidth after adding multilayer structure in microstrip antenna.

1.2 Scope

The scope of this project is to study the basic multilayer antenna properties from several published papers and books, design a conventional rectangular microstrip antenna operating at 2.4GHz frequency. Comparing the results of conventional rectangular microstrip antenna and multilayer microstrip antenna.

2. Working Principle

In telecommunication, there are several types of microstrip antennas (also known as printed antennas) the most common of which is the microstrip patch antenna or patch antenna. A patch antenna is a narrowband, wide-beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. Microstrip or patch antennas are used widely within the mobile phone market because they are low cost, have a low profile and are easily fabricated. Consider the microstrip antenna shown in Figure 1, fed by a microstrip transmission line. The patch, microstrip and ground plane are made of high conductivity metal. The patch is of length L, width W, and sitting on top of a substrate (some dielectric circuit board) of thickness h with permittivity (ξ_r). The thickness of the ground plane or of the microstrip is not critically important. Typically the height h is much smaller than the wavelength of operation.

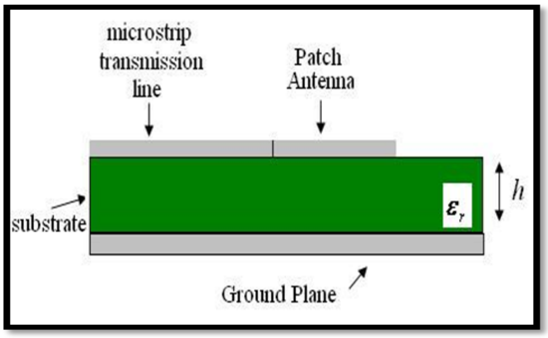

Figure 1: Microstrip antenna

From the below figure 1 it is observed that the total excited patch surface currents are increased, and the excited surface current distribution in the central portion of the radiating patch is also greatly enhanced for the proposed project design. As we change the shape of ground lane the surface current in that changes which in turn changes the return current on radiating patch. Due to this change in the surface current the change in radiation pattern, frequency of operation occurs. Hence by simply modifying ground plane we can miniaturize the antenna and there is no need to change the antenna if we want the antenna to be operated on other frequency. By modifying the ground planne the frequency of operation reduces means same antenna can work on lower frequency. That is anteena isize is reduce.

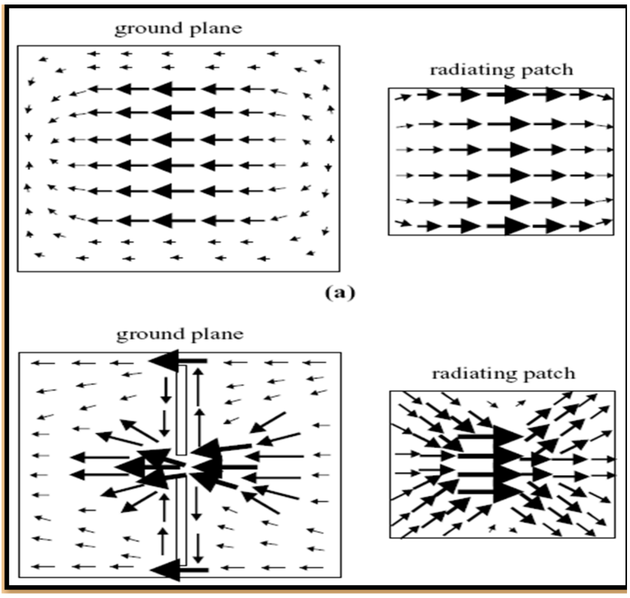

Figure 2: Flow of Surface current

3. Multilayer Microstrip Antenna in Brief

When an antenna has more than one patch over the dielectric substrate it is called as a Multipatch Microstrip antenna. Multipatch Microstrip antenna provides basic information on patch antenna design and operation, directed to engineers who are mainly designers of RF/microwave circuits. In high performance aircraft, spacecraft, satellite and missile applications, where size, weight, cost, performance, ease of installation and aerodynamic profiles are important, low profile antennas may be required. To meet these requirements, Multipatch Microstrip antennas are used. Multipatch antennas are narrowband, wide beam antennas fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate with a continuous multi metal layer bonded to the opposite side of the substrate which forms a ground plane.

Figure 3: A schematic diagram of patch antenna

Figure 4: A schematic diagram of multilayer patch antenna

4. Literature Survey

Ref [1] This paper present Microstrip patch antennas have several well known advantages, such as low profile, low cost, light weight, ease of fabrication and conformity [1, 3]. However, the microstrip antenna inherently has a low gain and a narrow bandwidth. To overcome its inherent limitation of narrow impedance bandwidth and low gain, many techniques have been suggested e.g., for probe fed stacked antenna, microstrip patch antennas on electrically thick substrate, slotted patch antenna and stacked shorted patches have been proposed and investigated [2].

Ref[2] This paper present for a three layer electromagnetically (EM)coupled structure, an air layer is often used between a substrate and a superstrate [4,5]. The patch is etched on top surface of a grounded substrate, and acoupled patchis on top [4] or bottom [5] surface of these upersubstrate.

Ref [3] This paper present A broad-band U-slotted rectangular patch antenna printed on a microwave substrate is investigated. The dielectric constant of the substrate is 2.2. The antenna is fed through via-hole connecting between patch antenna and feeding line at a lower microwave substrate with dielectric constant equals 3. The characteristics of the U-slotted patch antenna are analyzed by the Method of Moment (MoM). The results show maximum impedance bandwidth of more than 20% of centered frequency around 17.25 GHz, with good pattern characteristics.

Ref [4] In this paper they make different slots in ground plane and observe their result. They make H, U and T shape in ground plane and found that it is suitable for 3G mobile communication

Ref [5]This paper presents a novel design of a printed circular monopole antenna for ultra-wideband applications. It consists of a circular patch with an arc slot notched, which intends to obtain frequency notched for WLAN. To broaden the bandwidth and shorten the width of the substrate, a truncated ground plane is introduced. Aa novel printed circular monopole antenna (PCMA) with an arc slot notched on the patch a for UWB applications is developed.

Ref [6] This paper presents a small novel UWB antenna with and without slotted ground plane. Two notches, T slot and slotted ground plane are implemented to obtain the UWB characteristics. The proposed antenna has a small size and provides an ultra wide bandwidth from 3.2 to 10.5 GHz with VSWR level less than 2. The impedance bandwidth of the antenna is improved by adding two notches at the bottom of patch, T slot, and slotted ground plane.

Ref [7] This paper presents an optimization design for the rectangular printed antenna with a slot ground plane for ultra wideband (UWB) application. The introduction of rectangular slot in the ground plane and size of the ground plane can be used to improve the bandwidth. The simulated return loss of antennas exhibit ultra wideband impedance bandwidth for 2 GHz to 11 GHz with respect to -10 dB. The slot on the ground plane improves the return loss for all the frequency range.

Ref [8] this paper presents a metamaterials-based antenna is presented that consists of periodic electromagnetic band gap (EBG) cells on the top plane and triangular slots on the bottom ground plane. A novel microstrip patch antenna with ground embedded triangular slots has efficiency improvement. By increasing the size of triangular slots, the antenna efficiency of 14.7% is improved while the radiation patterns are almost unchanged at the zeroth-order resonant mode. Therefore, this proposed scheme may be very helpful in enhancing the antenna efficiency for metamaterials-based antenna with various periodic structures.

Ref [9] In this paper, a compact circular microstrip patch antenna with slotted ground structures is proposed for switchable circular polarization diversity. The alternative CP can be controlled from switching the current paths on the slot. The electrical switching has been simply achieved by changing a PIN diode state. An unequal cross-shaped slot on a ground plane is utilized as a perturbation. By switching pin diodes mounted on the slot, the CP sense of each antenna can be simply switched from left-handed (LH) CP to right-handed (RH) CP vice versa. Since the perturbation can be made on the ground plane and no bias circuit is required on the patch side, there is less distortion on the radiation pattern

Ref [10] In this paper, a quasi-fractal slotted ground plane is applied to a monopole antenna for dual-frequency applications. A trapezoid patch radiator and a quasi-fractal ground plane are analyzed separately. Then, they are combined to design an antenna for dual-band application. Its operating bands are determined by the sizes of the radiator and ground plane.

5. Antenna Parameters

Different parameter such as VSWR, Return Loss, Antenna Gain, Directivity, Antenna Efficiency and Bandwidth isanalyzed.

5.1 Gain

The gain of an antenna is defined as the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically. Formula for gain is , G=4π.U(θ,Φ) /Pin, where, U(θ,Φ) is a intensity in a given direction, Pin is input power.

5.2 Radiation pattern

The radiation pattern is defined as a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates.

5.3 Antenna efficiency

It is a ratio of total power radiated by an antenna to the input power of an antenna.

5.4 VSWR

Voltage standing wave ratio is defined as VSWR=Vmax/Vmin.It should lie between 1 and 2.

5.5 Return loss

Return loss is the reflection of signal power from the insertion of a device in a transmission line.Hence the RL is a similar to the VSWR to indicate how well the matching between the transmitter and antenna has taken place. The RL is given as by as:

$$RL= -20 \log10(\Gamma) \text{ dB}$$

For perfect matching between the transmitter and the antenna, Γ = 0 and RL = ∞ which means no power would be reflected back, whereas a Γ = 1 has a RL = 0 dB, which implies that all incident power is reflected. For practical applications, a VSWR of 2 is acceptable, since this corresponds to a RL of -9.54 dB.

6. Antenna Design

The three essential parameters for the design of a rectangular Microstrip Patch Antenna are:

1. Frequency of operation (*f o)*: The resonant frequency of the antenna must be selected appropriately. The resonant frequency selected for design is 2.4 GHz.
2. Dielectric constant of the substrate (ε_r): The dielectric material selected for design is glass epoxy which has a dielectric constant of 4.4.
3. Height of dielectric substrate (h*)*: For the microstrip patch antenna to be used in cellular phones, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1.6 mm.

The initial calculation starts from finding the width of the patch which is given as:

Step 1: Calculation of the width of Patch (W)
The width of the Microstrip patch antenna is given as

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}} \tag{1}$$

Step 2: Calculation of effective dielectric const

Fringing makes the microstrip line look wider electrically compared to its physical dimensions. Since some of the waves travel in the substrate and some in air, an effective dielectric constant is introduced, given as:

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{-1/2} \tag{2}$$

Where,
εreff = Effective dielectric constant
εr = Dielectric constant of substrate
H = Height of dielectric substrate
W = Width of the patch

Step 3: Calculation of Length of Patch(L)

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \tag{3}$$

The effective length due to fringing is given as:

$$L_{eff} = \frac{c}{2f0\sqrt{\varepsilon_{reff}}} \tag{4}$$

Due to fringing the dimension of the patch as increased by *ΔL* on both the sides.
Hence the length the of the patch is:

$$L= Leff-2\Delta L \tag{5}$$

Step 5: Calculation of Substrate dimension
For this design this substrate dimension would be

Ls=L+2*6h (6)
Ws=W+2*6h (7)

Step 6: Calculation of feed point
For this feed would be given L/4 distance.

Table 6.1: Calculated values for propose antenna

Sr.No.	*Parameter*	*Calculated value*
1	W	58mm
2	ϵ_{reff}	3.99
3	L_{eff}	45mm
4	ΔL	0.75mm
5	L	45mm
6	L/4	11mm

7. Software Requirements

Ansoft HFSS
It is Debian based linux operating system, HFSS is the industry standard simulation tool for 3D full wave elcctromaganectic field simulation.HFSS provides E and H fileld,current,S-parameter and near and far radiation fileds results.Intrensic to the success of HFSS as an engineering design tool is its automated solution process where users are only required to specify geometry, material properties and the desired output.With the help of HFSS we can automatically generate an appropriate, efficient and accurate mesh for solving the problem.

8. Results Analysis

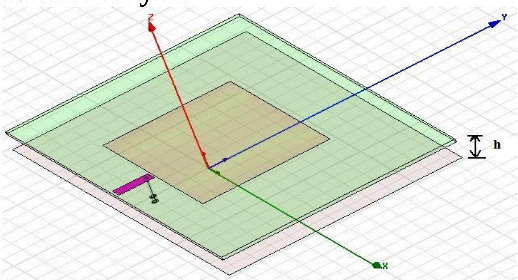

Figure5: Multilayer Microstrip antenna for 2.4GHZ

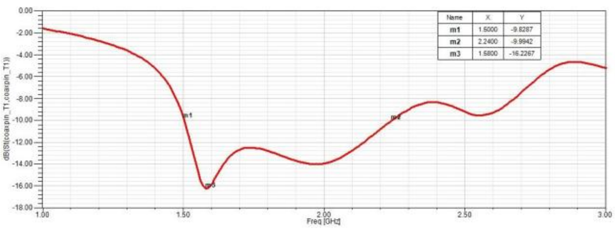

Figure 6: Return loss of proposed microstrip antenna

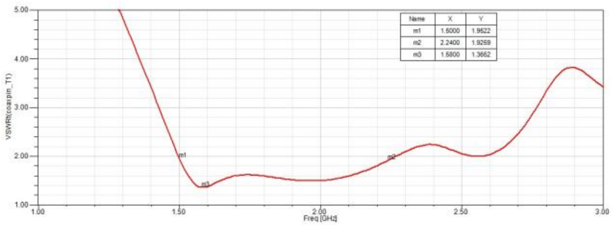

Figure 7: VSWR of proposed microstrip antenna

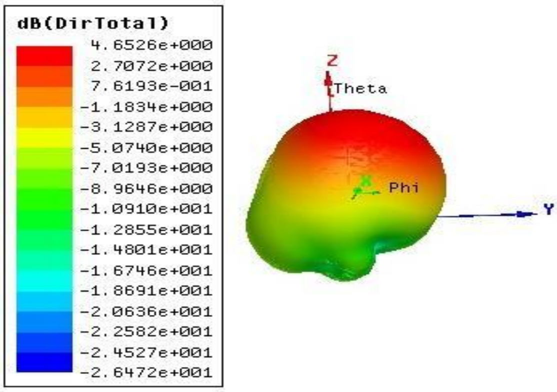

Figure 8: Gain of proposed microstrip antenna

The value of VSWR as shown in figure 7 at 2.3GHz frequency for multilayer patch antenna is 1.92 and banwidht is 740MHz which very good for broadband applications.This depicts that there is good impedance matching between inset-fed microstrip transmission line and the rectangular radiating element at the frequency 2.3GHz. Return loss is a measure of impedance bandwidth for which the antenna is sufficiently matched to its input transmission line such that 10% or less of the incident signal is lost due to reflections. Impedance bandwidth measurements include the characterization of the Voltage Standing Wave Ratio (VSWR) and return loss throughout the band of interest. From the return loss performance antenna operating bandwidth extends 450 to 740 MHz and return loss are -12.9db to -16.22db as shown in figure 6. The gain of the stated antenna was experimentally obtained using Ansoft HFSS shown in figure 8. Maximum measured gain of receiving antenna obtained is 4.65 db as shown in figure 8.

9. Conclusion

A high gain Multilayer coaxial feed microstrip patch antenna with gap-coupled mechanism has been investigated. The proposed antenna has shown to possess two times increasing gain as compared with that of the conventional microstrip patch antenna. The resulting size of this antenna makes it applicable for use in mobile handset application. The return loss, input impedance matching is perfectly showing the applicability of this antenna in the GPS applications.

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