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A Review on Microstrip Stacked Patch Antennas and Defective Ground Structures

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ABSTRACT- Microstrip patch antennas have numerous advantages but have biggest drawback of narrow bandwidth. Various techniques such as Aperture coupling and stacked patch configurations have been studied to enhance the bandwidth of a microstrip antenna. Various results are reported in the literature have been studied and discussed in the paper presented. The areas for continued research efforts are identified. Parametric analysis which includes variations in the design such as incorporation of additional patches and defects in ground are also discussed.

1. INTRODUCTION

Microwave components such as filters, couplers, antennas etc., in the microstrip technology, are used for high performance aircraft, spacecraft, satellite and missiles where size, weight, cost, performance, ease of installation, and aerodynamic profile are constraints. Presently there are many other government and commercial applications, such as mobile radio and wireless communications, microwave communication and millimetre wave communication [1]. For this an antenna is required which must have a wideband, good radiation performances and sometimes can be reconfigured also. This requirement can be fulfilled by an aperture coupled microstrip patch antenna. The small size and ease of manufacturing of the microstrip patch antenna make it suitable for many applications. Figure 1 shows an aperture coupled microstrip patch antenna. The microstrip technology consists of a microstrip transmission line made of conducting material on one side of a dielectric substrate which has a ground plane on the other side. These two substrates are coupled electromagnetically through an electrical small aperture in the ground plane between them. This efficient design maximizes the energy coupled to the patch from the feed line with the minimum reflections and radiations on the feed side. The availability of various types of substrate material can be chosen to improve antenna performance. Due to different shapes of slot and patch the aperture coupled microstrip antenna provides flexibility in design parameters and therefore gives more freedom in antenna design. However, the major drawback is that a multilayered substrate structure with the coupling slot on the ground plane can result in coupled surface-wave modes which can leads to distortion radiation patterns and reduced radiation efficiency [2]. In this paper techniques to increase the performance of antenna have been analysed.

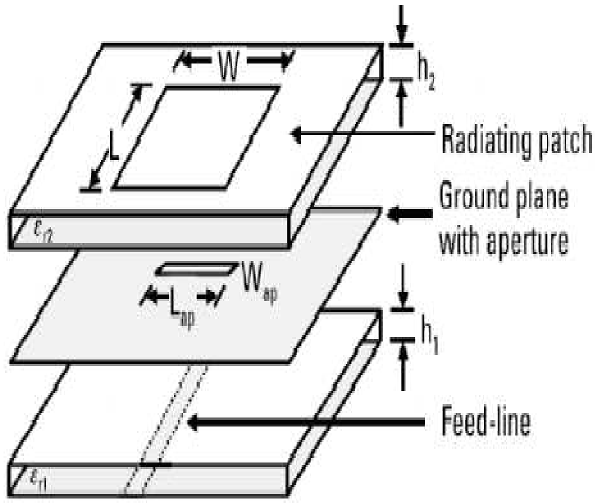

Fig. 1 Aperture feeding technique

2. MICROSTRIP STACKED PATCH ANTENNA USING APERTURE COUPLED FEEDING

Using aperture coupling the layer alignment problem can be solved but this leads to surface wave excitation. This problem can be solved by taking the patch large enough in size which leads to TM surface wave not excited anymore. But again such methods have narrowband. Using a method called stacking of microstrip antennas, such problems can be solved by mounting the patch on high dielectric constant material and other patch on low dielectric constant material [3]. A figure below shows the stack geometry.

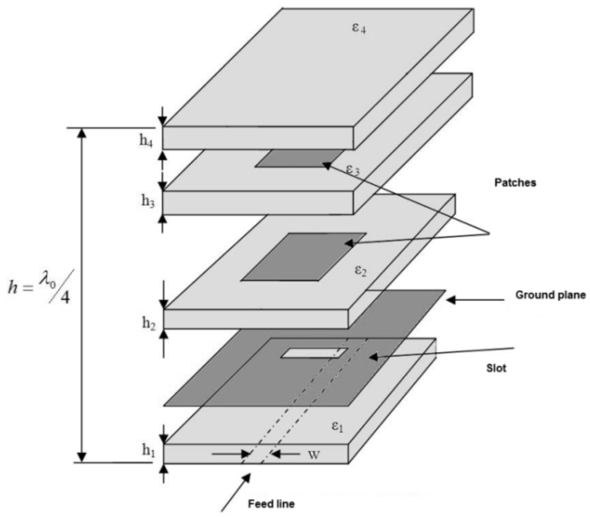

Fig.2 Microstrip stacked patch antenna

3. MATHEMATICAL MODEL

Since some of the waves travel in the substrate and some in air, an effective dielectric constant ϵ_{reff} is introduced to account for fringing and the wave propagation in the line. To introduce the effective dielectric constant, let us assume that the centre conductor of the microstrip line with its original dimensions and height above the ground plane[1].

$$\frac{W}{h} > 1$$

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2} \quad (1)$$

For microstrip stacked patch antennas the value of epsilon is taken as the net value given below

$$\epsilon_r' = \frac{2\,\epsilon_{reff} - 1 + A}{1+A} \quad (2)$$

Where

$$A = \left[1+\frac{12h_{12}}{W}\right]^{-1/2}$$

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

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

The resonant frequency of microstrip stacked patch antenna is as given below

$$(frc)_{010} = \frac{1}{2L_{eff}\sqrt{\epsilon_{reff}}\sqrt{\mu_0\,\epsilon_0}} \quad (4)$$

The values of length and width of the patch is given by

$$W = \frac{1}{2f_r\sqrt{\mu_0\epsilon_0}}\sqrt{\frac{2}{\epsilon_r+1}} = \frac{\upsilon_0}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}} \quad (5)$$

$$L = \frac{1}{2f_r\sqrt{\epsilon_{reff}}\sqrt{\mu_0\,\epsilon_0}} - 2\Delta L \quad (6)$$

Where
h= substrate thickness
L = Length of patch
W= Width of patch
L_{eff} = Effective length
C= speed of light
ϵ_r= relative permittivity
ϵ_{reff}= effective permittivity

4. LATER DEVELOPMENT OF APERTURE COUPLED MICROSTRIP ANTENNA AND STACKED PATCH ANTENNA

- In 2006, M. K. A. Rahim, A. Asrokin, M. H. Jamaluddin, M. R. Ahmad, T. Masril and M.Z.A. Abdul Aziz proposed that the multilayered substrate structure with the coupling slot on the ground plane can result in coupled surface-wave modes which can give distorted radiation patterns and reduced radiation efficiency[2]
- In 2011, M. T. Ali, S.Muhamud , N.R. Abd Rahman, and Norsuzila Ya'acob stated that the performance of the microstrip antenna depends heavily on the dimension of the slot. As the width of slot increase, the return loss and VSWR increase but the gain decreases[4]
- Himanshu Singh, Y.K. Awasthi and A.K. Verma in 2008 stated that the parasitic elements, stacked patches and thick substrates of low permittivity helps to improve the bandwidth of antenna[5]. But the broad banding design in microstrip antenna increases the size.
- Mouloud Challal, Arab Azrar and Mokrane Dehmas in 2011 stated that the variations in antenna thickness gives improved performance of return loss [6] , but we can use dielectric substrates with different permittivity. Aperture coupled antenna has low permittivity for upper substrate and high permittivity for lower substrate, there will be asymmetric radiations in dielectric constant.
- N. Ghassemi, J. Rashed-Mohassel, M. H. Neshati, S. Tavakoli and M. Ghassemi in 2008 stated that in microstrip stacked patch antenna the air gap has different effect. By varying the air gap between the single patch and aperture coupled patch antenna dual band can be achieved[7]

5. RESULTS OF ANALYSIS : IMPROVEMENT IN THE OUTPUT USING AN APERTURE COUPLED DESIGN

1) **Substrate thickness** has greater impact on bandwidth and coupling level of antenna. A thick substrate has wider bandwidth, but less coupling for a given aperture size.

2) **Slot length** determines the coupling level, as well as the back radiation level.

Therefore, the slot should not be larger than is needed for impedance matching.

3) **Tuning stub** is used to tune the excess reactance of the slot coupled antenna. The shortening of the stub will move the impedance locus in the capacitive direction on the Smith chart.

4) On increasing the length of patch antenna the resonant frequency moves towards the lower band and on decreasing the patch length the resonant frequency moves towards upper band. Maximum coupling will be obtained when patch is at the centre.

5) Narrow bandwidth is the major drawback of microstrip antennas. It can be improved by using stack patches. Back radiations can also be removed using stack patches. In stacked patches parasitic element is placed above the lower patch. The size of the lower patch is kept constant throughout generally. The dimensions of the upper patch, foam spacer and slot can be optimised to obtain wide bandwidth characteristics. But the best bandwidth is obtained when the dimensions of top patch is equal to that of bottom patch [8]. Therefore, it must be taken into consideration that patches must have same dimensions in order to maximise coupling and the resonance of each patch must be far apart in frequency[9]

6) In stacked patches mostly coupling aperture is used. But sometimes resonant aperture can also be used which nearly doubles the bandwidth. In this, aperture is directly used as a resonator instead of using it for coupling the patches[10]

7) When the spacing between the patches in stacked antenna is less, the mutual coupling between two patches exist and they disturb the resonance of each patch and results in dual band and when the spacing between two patches is accurate then the broadband antenna can be obtained with large bandwidth.

8) On varying the length of top patch the lower frequency band will get affected and on varying the length of bottom patch the upper frequency band will get affected.

6. DEFECTED GROUND STRUCTURES

The Defected ground structure is considered as an equivalent circuit consisting of capacitance and inductance. The value of the inductance and capacitance depends on the area and size of the defect which has been cut in the ground. The resonant frequency which is desired can be achieved by varying the dimensions of the defect. The formula for inductance and capacitance are as shown below:

$$L=\frac{1}{4\pi^2 f_0^2 C} \quad (7)$$

$$C=\frac{f_c}{2Z_0}\cdot\frac{1}{2\pi(f_0^2-f_c^2)} \quad (8)$$

The defect increases the inductive part and produces the high effective dielectric constant, that is, slow wave property Therefore, the defected ground structure line has longer electrical length than the standard microstrip line, for the same physical length. The designed antenna, with the transmission line model for a particular frequency is larger and is not compatible for many applications. So antenna size reduction becomes necessary in many cases.

Different techniques have already been used for the antenna size reduction such as using the substrate with high dielectric constant, edge shorted patched with shorting plates or shorting walls, use of the shorting pin at the suitable position etc. Defected ground structure is also used for cross polarisation reduction [11], mutual coupling reduction [12], and harmonic reduction [13].

7. DUAL BAND/ MULTIBAND BEHAVIOUR OF APERTURE COUPLED ANTENNA USING DGS

- A novel structure called Defected Ground Structure which has widely used in several applications such as reducing the size of patch antennas without degrading the performance of antenna as better as efficiency, better bandwidth etc. DGS has other application of suppression of harmonics without introducing a bit attenuation in the fundamental frequency[5]

- By varying the dimensions of E-shaped slot and length of Ls (matching stub), the antenna can be designed for high gain, dual band or quad band characteristic[14]

- For multiband applications, a series of curved microstrip antenna with DGS, which are more smaller, with wider radiation beam are suitable for WLAN applications in different environments. The DGS in the ground plane of the microstrip antenna are used to achieve useful multiband, small size and gain enhancement[15]

8. APPLICATIONS OF MICROSTRIP ANTENNAS

- Microstrip antennas are used in Global Positioning System at the frequency of 1575 MHz and 1227 MHz.
- It is also used in GSM, Paging, Cellular phones, WLAN and Wide Area Computer Networks.
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9. CONCLUSION

In this paper firstly aperture coupled antenna has been discussed and then microstrip stacked patch antenna with aperture coupling technique which actually increases the bandwidth of the antenna. The parameters are discussed with which the design, bandwidth, gain etc. are improved. The DGS also has effect on aperture coupled microstrip antenna which decreases the size of antenna and gives dual band and multiband antennas. It consists of L-C circuit which has a resonant frequency characteristic. It is also used in many microwave applications. These applications in the microstrip antennas with the defected ground structures give good performance in microwave circuits.

10. FUTURE SCOPE

- Microstrip stacked patch antennas can be further used for bandwidth enhancement.
- Various dual band, multiband etc. can be achieved using defected ground structures and size can also be reduced.

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