Volume 6, Issue 2, February 2016 ISSN: 2277 128X

International Journal of Advanced Research in Computer Science and Software Engineering

Research Paper

Available online at: www.ijarcsse.com

Design of Broadband Microstrip Patch Antenna Using Stack and Notch Techniques

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Abstract-With the rapid evolution of mobile communications, broadband antennas for multisystem are in great need. The demand for small and mobile communication devices, especially the RFID, has grown rapidly. Devices having internal antenna is a trend and is required for such applications. But, antenna size is a major factor that limits device miniaturization. To decrease the size, antenna design is based on microstrip and can be embedded into the RFID tag. However, reducing antenna size generally degrades antenna performance. The advancement of the technology has given birth to a lot of mobile communication standards. The increasing demand for higher data rates continues in wireless technology enabling wireless data, voice, and video applications at multigigabit speeds has recently been attracting much interest in both academic and industry. Thus, the bandwidth of the antenna is very important for high data rate transmission. The narrow impedance bandwidth is the major weakness of a microstrip antenna. Simulation is done by using the software Advanced Design System (ADS) 2009. The antenna is designed at 2.45GHz and a bandwidth of 110MHz is obtained. By changing the parameters like air gap, width of the patch and length of the patch using the same technique have been also simulated and provided a bandwidth of 250MHz which resonate at 2.4GHz.

Keywords- Microstripe patch antenna, Notch, stacked, Wideband, miniaturized, isotropic

I. INTRODUCTION

The demand for compact and multifunctional wireless communication systems has spurred the development of miniaturized broadband antennas with high gain. It is complex to incorporate all the features such as uniformly high gain, broad bandwidth, efficiency, compact size along with desired radiation pattern into a single antenna design. The numerous advantages of microstrip antenna, such as its low weight, small volume, and ease of fabrication using printed-circuit technology, led to the design of several configurations for various applications. With increasing requirements for personal and mobile communications, the demand for smaller and low-profile antennas has brought the microstrip antenna to the forefront. A microstrip antenna in its simplest form consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side. However, other shapes, such as the square, circular, triangular, semicircular, sectoral, and annular ring shape can also be used. Radiation from the microstrip antenna can occur from the fringing fields between the periphery of the patch and the ground plane. Various methods of exciting the radiating patch exist, like coaxial feed, inset feed, microstrip feed, aperture coupled feed, electromagnetic coupled feed and coplanar waveguide feed.

The fundamental specifications used in the patch antennas are

a) *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.

b) *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.

c) *Antenna efficiency:* It is a ratio of total power radiated by an antenna to the input power of an antenna.

d) *Return loss / S11:* Return loss is the reflection of signal power from the insertion of a device in a transmission line. The antenna is one port device. Hence the scattering parameter S11 acts as return loss.

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

f) *Impedance bandwidth/return loss bandwidth:* This is the frequency range wherein the structure has a usable bandwidth. The impedance bandwidth depends on a large number of parameters related to the patch antenna element itself (e.g., quality factor) and the type of feed used. It indicates the return loss bandwidth at the desired S11/VSWR (S11 wanted/VSWR wanted). The bandwidth is typically limited to a few percent. This is the major disadvantage of basic patch antennas.

II. MICROSTRIP PATCH ANTENNA

A. Conventional Microstrip Antennas

Conventional microstrip antennas suffer from narrow bandwidth. Increasing frequency results in larger size. This is a challenge for this type of antenna. Increasing substrate thickness, using low dielectric substrate, using impedance matching and feeding techniques and using slot geometry in antennas are some methods for improvement of bandwidth and size [11]. The stacked-notch technique is used for this purpose. The antenna designs are designed to resonate at 2.4GHz and 2.45GHz. The MPMAA design for the 60GHz band is presented. They have use the moment method as the calculation method and assume that the ground plane is infinite. Package topology integrated in multilayer miniaturized antennas is also presented [13]. Such a functional package is suitable for the design of a system-on-chip device, or of system-on-package applications. A stacked patch antenna is designed and integrated in a package using a low temperature co-fired ceramic process. The very short shelf-life time of BCB under room temperature is another disadvantage. In order to create thick enough substrates, SU-8 [12] is an excellent choice. Combining the advantages of SU-8 along with these techniques yields an antenna substrate that is both electrically and mechanically an efficient solution. To obtain a directional radiation pattern, a conductor backing is used for a CPW-fed slot antenna in [3]. Microstrip patch antennas can, for many applications, be fed using a simple coaxial probe feed. This type of feed can be advantageous because of the ease of fabrication.

B. Wideband microstrip patch antenna

A Wide-Band Single-Layer Patch Antenna is presented by Naftali Herscovici in [10]. The patch is suspended over the ground plane and supported by a nonconductive pin. A wideband electromagnetic-coupled single-layer microstrip patch antenna is studied experimentally by Mark et al in [9]. A notable structure in the feeding design is that an inverted L-shaped strip is connected to the end of the microstrip line and no matching network is required. The remarkable feature of the antenna is that a small step is introduced at the end of the feed line.

C. Broadband Microstrip Patch Antenna

Broadband microstrip patch antennas for MMICs is presented by Rowe et al [11]. The stacked antenna consists of a 50Ω microstrip feed line and a patch element fabricated on alumina substrate which emulates the high dielectric constant materials used in MMICs. High directivity fractal boundary microstrip fractal boundary microstrip patch antenna presented by Borja et al [2] shows that a patch antenna with a fractal boundary exhibits localized modes. A broad band U-slot rectangular patch antenna on a microwave substrate is presented by Tong et al [7]. It is found that the crucial step to design a broad-band -slot patch antenna printed on a microwave substrate. The foam material in the previous studies is replaced by a dielectric substrate of relative permittivity 2.33.A broadband two-layer shorted patch antenna with low cross-polarization is presented by Baligar [1]. The antenna has a bandwidth of 11% centered around 1.975GHz with a gain of 8.6dB, and exhibits better than -13dB cross-polarization levels in the H-plane.

D. Quarter wave patch antennas

Bandwidth enhancement technique for Quarter wave patch antennas are presented in [3] by Chiu et al. By increasing the thickness of the patch antenna will increase the impedance bandwidth. A quarter-wavelength diversity patch configuration for the 2.4GHz ISM band PC card application is presented by Laurent Desclos et al [8]. The structure is based on partly interdigitation of two quarter wavelength separated patches through a set of fingers for achieving the required space diversity. The quarter-wave patch and half-mode cavity antennas [4] are two typical designs of half-size resonator antennas that are suitable for wearable applications.

E. Circularly polarized patch Antenna

Novel design of a circularly polarized linear patch antenna array fed [5] by a coplanar waveguide (CPW) is presented. The array elements are placed in the direction transverse to the feeding CPW line and are excited by a couple of 100 slotlines, which are combined to form the 50 feeding CPW. A novel circularly polarized patch array [6] fed by a slotted waveguide is proposed. Optimized circular polarization is achieved with a split truncated patch flexibly. Improved bandwidth and efficiency are obtained by utilizing the feeding waveguide.

III. PROPOSED METHOD

Conventional microstrip antennas suffer from narrow bandwidth. Increasing frequency results in larger size. This is a challenge for this type of antenna. Make one better results in degrading the other. From other side, compact antenna is a need for portable mobile devices. These make researchers to improve the antenna’s methods have been suggested for upgrading size and bandwidth of antenna. Increasing substrate thickness, using low dielectric substrate, using impedance matching and feeding techniques and using slot geometry in antennas are some methods for improvement of bandwidth and size. Our objective is to improve the bandwidth of the microstrip antenna while retaining other desired parameters. The stack and notch technique is used for this purpose. All the antenna designs discussed below are designed to resonate at 2.4GHz or 2.45GHz.

A. Antenna Design

The proposed antenna comprises two patches: They are lower rectangular patch and upper rectangular patch. The lower rectangular patch as a ground element and the upper rectangular patch as a parasitic element which is stacked by separating with an air gap. The circle at the center of the top view shows the feed point of the microstrip patch antenna. The below figure 1 shows the top view and side view of the designed microstrip patch antenna.

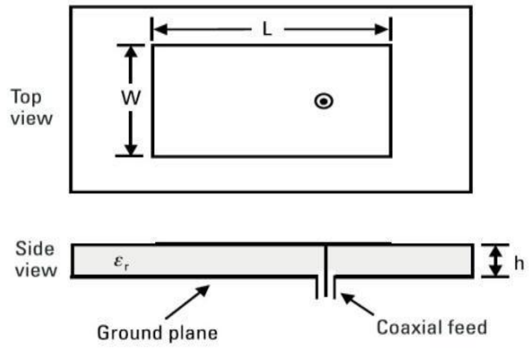

Figure 1 Top and side view of the microstrip patch antenna

1). Frequency of Operation

The length of the patch controls the resonant frequency. Even for more complicated microstrip antennas, the length of the longest patch on the microstrip controls the lowest frequency of operation. The resonant frequency of the antenna must be selected appropriately. The Mobile Communication Systems uses the frequency range from 1800-1900MHz. Hence the antenna designed must be able to operate in this frequency range. The resonant frequency selected for the design is 1.8GHz. The wireless communication systems uses the frequency range from 2300-2500MHz Hence the antenna designed must be able to operate in the frequency range. The resonant frequency selected for the design is 2.45GHz. (2)

Where,

f_r - resonant frequency

L - Length of the patch

W - width of the patch

ε_r - permittivity of the substrate,

Hence, if the permittivity is increased by a factor of 4, the length required decreased by a factor of 2. Using higher values for permittivity is frequently used in antenna miniaturization.

2). Bandwidth

The following equation roughly describes how the bandwidth scales with these parameters: (3)

Where *h* is the height of the substrate '*h'* controls the bandwidth as shown in the above equation. Increasing the height increases the bandwidth and thereby increases the efficiency of the antenna. But increasing the height induces surface waves that travel within the substrate which is an undesired radiation and may couple to other components.

3). Antenna Design Equations

The dimensions of the basic single-layer microstrip antenna are calculated using the equations (4) to (8).

Effective permittivity

εref=εr+12+εr-12*11+12*hw (4)

ΔLh=0.412ξreff+0.3Wh+0.264ξreff-0.258Wh+0.8 (5)

Patch width

W=C02fr2ξr+1 (6)

where c_o is the velocity of light

Effective Length

Leff=L+2ΔL (7)

Patch Length

L=c2frξreff-2ΔLE (8)

The dielectric substrate of low permittivity, 4.4 is selected for the microstrip antenna which is FR4. It has a loss tangent value 0.02. The type of copper cladding used for this substrate is the 35µm thick rolled copper. Antenna is coaxial probe method. The 50 Ohms-SMA connector is used as the feed. The simulation was carried out using the Momentum analysis simulation tool by Advanced Design System 2009(ADS).

4). Dielectric Constant of the Substrate (ξr)

The dielectric material selected for our design is FR-4 which has a dielectric constant of 4.4. A substrate with a high dielectric constant has been selected since it reduces the dimensions of the antenna.

5). Thickness of Dielectric Substrate (H)

For the microstrip patch antenna to be used in RFID, it is essential that the antenna is not bulky. Hence, the thickness of the dielectric substrate is selected as 1.6 mm. Hence, the essential parameters for the design are,

f_r = 2.45GHz

ε_r = 4.4

h = 1.6mm

6). Other Parameters

The other parameters are as follows,

L1 - length of the driven patch
W1 - width of the driven patch
L2 - Length of the parasitic patch
W2 - Width of the parasitic patch
X1 - Width of the notch in driven patch
Y1 - height of the notch in driven patch
X2 - Width of the notch in parasitic patch
Y2 - height of the notch in parasitic patch

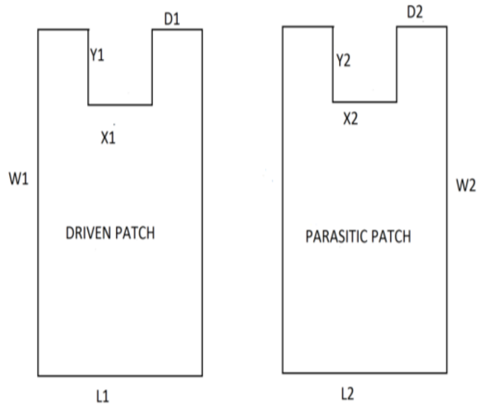

Figure 2 Patch dimensions of the microstrip patch antenna 1

Table 1 The patch dimensions and other parameters of antenna 1

Parameters	Value
L1	26.00mm
W1	37.26mm
L2	25.80mm
W2	37.06mm
D1	10.20mm
X1	5.00mm
Y1	4.86mm
D2	10.10mm
X2	5.30mm
Y2	4.96mm

In order to improve the bandwidth we designed a structure with two radiating elements, a driven patch and a parasitic patch. The driven patch is excited by using a coaxial feed. The coaxial feed used is 50omhs coaxial feed. The field thus generated by the driven patch is coupled with the parasitic patch to improve the overall bandwidth, directivity, gain and overall efficiency of the structure.

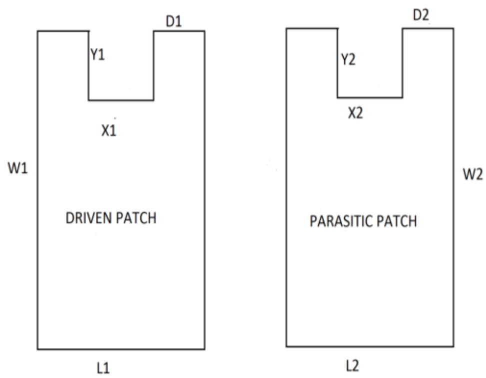

Figure 3 Patch dimensions of the microstrip patch antenna 2

The air gap results in lowering the effective. The feeding method for this permittivity and also contributes to increase in the height of antenna which is essential to increase the bandwidth. After obtaining desired results we worked to improve the bandwidth further using the same substrate and same stacked notch method. We came up with another one different structure to achieve more bandwidth. The details of the first structure are shown in Table 1 with reference to

Figure 2. The geometrical dimensions of the lower patch are 26.00mm X 37.06mm and of the upper patch are 25.80mm X 37.26mm. A rectangular notch is introduced in both the patches of different dimensions.

Table 2 The patch dimensions and other parameters of antenna 2

Parameters	Value
L1	26.06mm
W1	36.00mm
L2	30.50mm
W2	36.00mm
D1	9.99mm
X1	5.93mm
Y1	6.06mm
D2	10.08mm
X2	6.06mm
Y2	6.02mm

The slot results in meandering of surface currents thus, their paths are lengthened, while patch dimensions are fixed, and fundamental resonant frequency is decreased. Equally, with fixed operating frequency, a large amount of size reduction can be obtained. The Figure 3 shows the patch dimensions of the microstrip patch antenna 2. The table 2 shows the various parameters used to the design the second microstrip patch antenna of 250MHz bandwidth. The air gap is kept as 10mm and the FR-4 substrate thickness used for both the patches is 1.6mm.The structure described provides a gain of 6.735dB and a directivity of 8.155dB at resonating frequency 2.4GHz. The bandwidth of 250MHz ranges from 2.32GHz to 2.57GHz with providing an efficiency of 76.384% at resonating frequency.

IV. RESULT AND DISCUSSION

According to the design steps explained in the previous chapter, broadband microstrip patch antennas of 110MHz and 250MHz are designed and simulated. The results obtained from the simulations are demonstrated and discussed here. A microstrip patch antenna is a narrowband, wide-beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate, such as a printed circuit board, with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane.

The design of the microstrip patch antenna 1 in Advanced design system (ADS) 2009 is shown in Figure 4. A rectangular notch is introduced in both the patches of different dimensions. There is a feed point which is kept in between the two patches namely driven patch and parasitic patch. The geometrical dimension of the microstrip patch antenna 1 are,

- The lower patch are 26.00mm X 37.06mm
- The upper patch are 25.80mm X 37.26mm

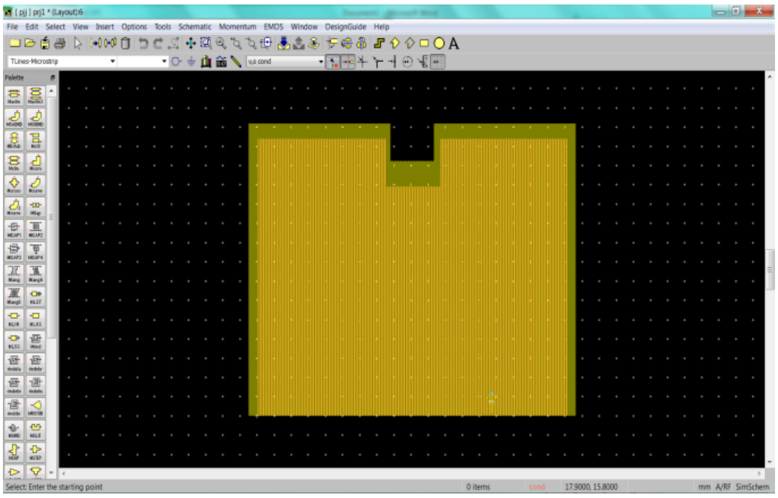

Figure 4 Microstrip patch Antenna 1

The antenna structure is simulated using the software Advanced Design System (ADS) 2009. The total size of the antenna is 26mm x 37.26mm. It has two patches. The upper patch and lower patch are stacked together with a large air gap which is used to reduce the effect of the dielectric loss of the antenna material. The length and width of the lower patch is 26 mm and 37.06 mm respectively. The length and width of the upper patch is 25.8 mm and 37.26mm respectively. The antenna is designed at 2.45GHz and a bandwidth of 110MHz is obtained. The design of the microstrip patch antenna 2 in Advanced design system (ADS) 2009 is shown in Figure 5.

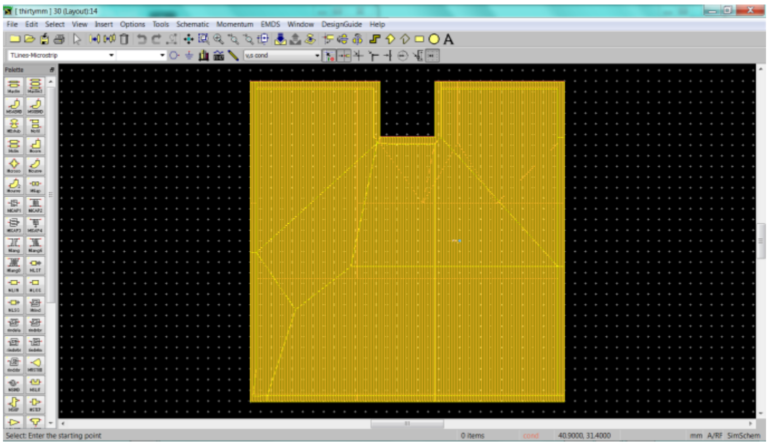

Figure 5 Microstrip patch Antenna 2

1. Return Loss

Return loss (dB) is defined as that the difference in dB between power sent towards antenna under test (AUT) and power reflected. The requirement for reflection coefficient for wireless devices is to be less than or equal to 10dB. The simulated return loss for the designed antenna 1 and antenna 2 is shown in Figure 6 and 7. At the operating frequency the return loss is less than 10dB. A frequency range of 0.1-3GHz is selected and 100 frequency points are selected over this range to obtain accurate results. The center frequency is selected as the one at which the return loss is minimum.

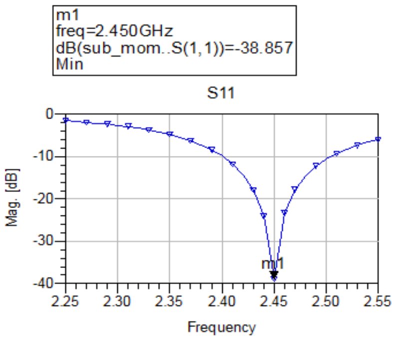

Figure 6 Return loss for the microstrip patch antenna1

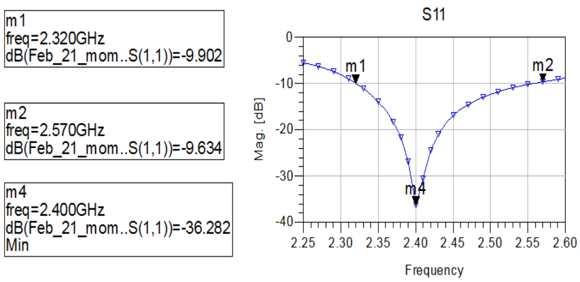

Figure 7 Return loss for the microstrip patch antenna2

2. Radiation Pattern

Since a microstrip patch antenna radiates normal to its patch surface, the elevation pattern for φ = 0 and φ = 90 degrees would be important. Figure 8 below shows the gain, radiated power and effective area of the simulated antenna at the operating frequency 2.45GHz. The maximum gain is obtained in the broadside direction and this is measured to be 5.79dB and 6.735dB.

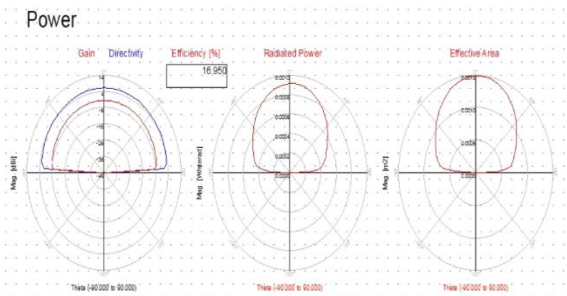

Figure 8 Radiation pattern for microstrip patch antenna 1

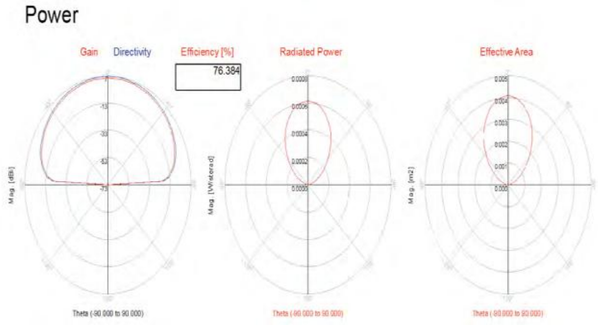

Figure 9 Radiation pattern for microstrip patch antenna 2

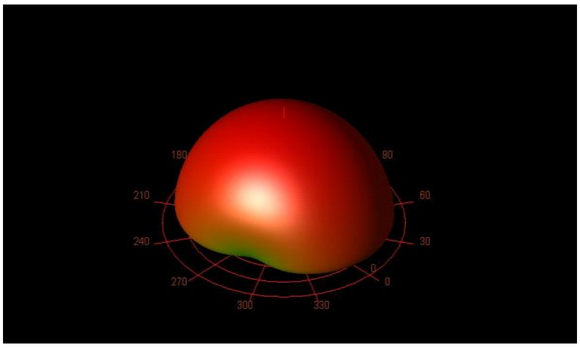

Figure 10 3D-view of radiation pattern for antenna 1

Figure 11 3D-view of radiation pattern for antenna 2

The second microstrip patch antenna is designed to obtain 250MHz bandwidth. The air gap is kept as 10mm and the FR-4 substrate thickness used for both the patches is 1.6mm.The structure described provides a gain of 6.735dB and a directivity of 8.155dB at resonating frequency 2.4GHz. Thebandwidth of 250MHz ranges from 2.32GHz to 2.57GHz with providing an efficiency of 76.384% at resonating frequency.

Table 4.1 Comparison result of microstrip patch antenna 1 and antenna 2

Parameter	Simulated Results for antenna 1	Simulated Results for antenna 2
Resonating Frequency	2.45GHz	2.4GHz
Bandwidth	110MHz	250MHz
Gain	5.79GHz	6.735GHz
Frequency range	2.4-2.51GHz	2.32-2.57GHz
Directivity	7.82dB	8.155dB
Efficiency	62.63%	76.384%

Comparison result of microstrip patch antenna 1 and antenna 2 is shown in the table 4.1 which shows the effective improvement in the bandwidth of the antenna.

V. CONCLUSION

In the proposed work the design and performance of microstrip patch antenna of two different structures have been proposed which provide broadband characteristics. The significant improvement in the bandwidth is the main achievement of this proposed work. The stacked-notch technique is used to achieve this wideband. This technique also provides improved efficiency, along with gain and directivity as compared to a simple microstrip patch antenna. The designed antenna presents much improved impedance bandwidth and directivity and larger gain. These improved parameters are achieved without much increase in the thickness of the structure. The stacking along with air gap reduces the effective permittivity while adding to the height of antenna, improves the bandwidth. The notch resulting in increased current path also adds to improvement in bandwidth.

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