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# Slot Antennas

## A Comprehensive Survey

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***Abstract—***Wireless Communication has found a rapid growth over the past decades starting from handheld devices to spacecraft applications. The efficient operation of all such wireless devices depends on the design and proper working of the transmitting and receiving antennas. Microstrip antennas are most commonly preferred for major wireless applications, because of their miniaturized structure, ease of fabrication, low power consumption, flexibility with printed circuit board, low profile, light weight, effective return loss and better radiation properties. This paper provides a comprehensive survey on microstrip antennas whose performance is improved to meet the increasing demand, by introducing slots of different shapes and sizes. These slots of various kinds helps in obtaining wider bandwidth over the C and Ultrawideband

***Keywords-*** *slot antenna, axial ratio bandwidth, UWB, WLAN/Wi-MAX, resonator .*

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## I. Introduction

A waveguide slot antenna is the one where the radiating slot antenna is cut on a waveguide. Typically, the waveguide is hollow but sometimes is filled with dielectric to reduce the guided wavelength. The waveguide slot antenna [8] has features of low loss and high power capability. It is mainly used for communication and radar systems in the order of microwave range and higher.The theories for the analysis and the designs on the waveguide slot antennas and their arrays have been developed well for a long time by using mathematical knowledge. Recently, electromagnetic wave simulators have also been developed well which are used to analyze and design the waveguide slot antennas and their arrays.

At first, Watson [8] investigated experimentally the concept of waveguide slot antennas. A slot cut on a waveguide wall interrupts the current flow and couples the power from the waveguide modal field into free space. Stevenson [8] formulated the theoretical analysis (of what) as a boundary value problem. It was found that an aperture electric field of a resonant slot had sinusoidal distribution in the first approximation. Expressions for the normalized conductance and resistance were derived for various resonant slots. Oliner [8] derived an equivalent impedance of a slot on a transmission line model by the vibrational method. The expression for the conductance was depended on both the offset and length of the slot, but the susceptance was not depended the offset. It also included the effects of the waveguide wall thickness to verify the theoretical results with the experimental ones.

The typical structure of a slot antenna is depicted in Fig 1. It is a narrow straight rectangular aperture on a flat metal plate. The length is about a half wavelength for the slot antenna to resonate. The width is much smaller than the length and the wavelength. The slot antenna is excited by an electric current crossing with it (equivalently a magnetic field along it). The excitation is controlled by the intensity [8] of the current. It is also controlled by the crossing angle of the current. When the current is perpendicular to the slot antenna (the magnetic field is parallel to the slot antenna), the excitation is the maximum and when the current is parallel to the slot antenna (the magnetic field is perpendicular to the slot antenna), the excitation is zero. Also, when the length is smaller than half a wavelength, the excitation becomes weaker.

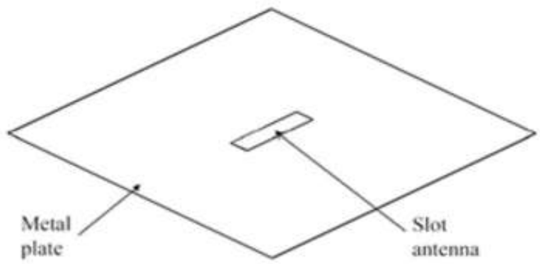


Figure 1. Slot Antenna

## II. Literature Survey

Dongo Kim et al [1] proposed a novel method to significantly reduce the physical dimensions of reflect array antennas. A directional radiator has been used as a common source of conventional reflectarray antennas where an inevitably longer distance (F) between the source antenna and the reflect array is required to obtain high illumination, phase and blockage efficiency. This approach is not applicable for commercial applications due to bulkier size. Therefore, the

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source antenna has been moved to the location nearer to the ground plane of a reflect array antennas. With this reduction in F, diameter (D) of the reflectarray can be greatly reduced which inturn increases the illumination and phase efficiency. Considering with spillover efficiency, the proposed omnidirectional antenna looks unfavourable as it radiates in all directions. To eliminate this problem, the source is taken very close to the reflectarray structure since closer the source to the reflectarray higher will be the spillover efficiency.

The proposed reflectarray antenna [1] consists of many rectangular metallic patches of different size etched on a commercial Taconic RF-35 dielectric substrate. The opposite side of the substrate is filled with copper material as given in fig 2. Assuming that the source antenna placed very close to the reflectarray, it is evident that source antenna shapes and types much affect blockage efficiency. For this reason, a common dipole antenna can be selected as a source, as it occupies smaller area to improve the blockage efficiency. The source dipole antenna comprises of a T-shaped radiating dipole element with hairpin shaped feeder that is printed on both sides of the substrate. The feeder is directly connected to a 50Ω coaxial cable. The electromagnetic waves which are fed into the feeder are coupled to the T-shaped radiator from which it radiates into the air.

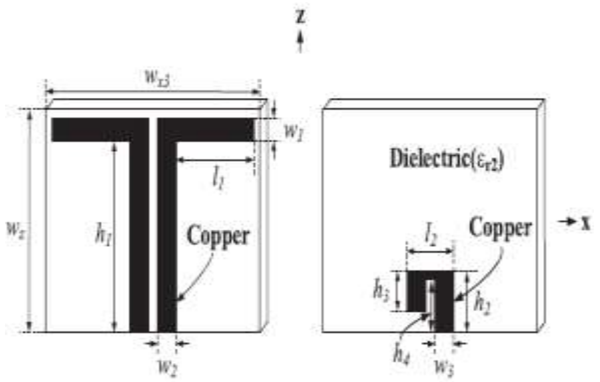


Figure 2. Geometry Of (a) a Radiating Dipole Antenna and (b) a Hair-Pin-Shaped Signal Feeder Printed on the Opposite Side of the Dipole

The dimensions of the above antenna is given as $wx2$ = 78 mm, $wz$ = 47.22 mm, $w1$ = 5 mm, $w2$ = 6 mm, $w3$ = 6 mm, $l1$ = 29.5 mm, $l2$ = 15 mm, $h1$ = 40.22 mm, $h2$ = 11 mm, $h3$ = 8 mm, $h4$ = 10 mm, $\varepsilon r2$ = 3.5, and tan $\delta$ = 0.0018. The thickness of the substrate is 1.52 mm.

Anil Kumar Gautam et al [2] developed a simple antenna design specifically for WLAN/WiMAX applications which can operate at multiple frequency bands. As per FCC the allocated spectrum for WLAN is centered at 2.4 GHz, 5.2 GHz and 5.8 GHz and for WiMAX it is centered at 2.5 GHz, 3.5 GHz and 5.5 GHz. Several different geometries of microstrip antennas have been incorporated to reduce the size and also to enhance the bandwidth for the desired application.

TABLE I: SLOT TYPES AND ITS APPLICATIONS

| S.No | Slot Type | Applications |
|---|---|---|
| 1 | Square slot, Pair of L-strips with monopole radiator | Excite three different resonances |
| 2 | Microstrip feedline with simple slots etched | Provides triband operation |
| 3 | Nonuniform meander line and fork-type ground | Triple-band WLAN applications |
| 4 | M-shaped patch | Triple band antenna |
| 5 | Inverted L-slot patch with defected ground plane | Triple band operation |
| 6 | Ear-type antenna | Desirable bands of WLAN /WiMAX |
| 7 | F-shaped slot with both open-ended and short-ended slots connected via metal | WLAN and WiMAX MIMO systems |

Among all the reported antennas exhibiting triple band operation, F-shaped microstrip slot antenna [2]finds its application in WLAN/WiMAX since it occupies smaller area with simpler geometry to realize the desired operating bands.

The proposed F-shaped slot antenna consists of two F-shaped slots [2] etched on the left and right sides of a rectangular patch as shown in fig 3. so as to achieve triband operation. By printing a circular shaped patch which is gap-coupled with the ground plane on the other side of the substrate impedance matching can thus be achieved. With the antenna size of 19 × 25 mm, two F-shaped slots are etched on the rectangular surface of the patch to obtain triple band operation.

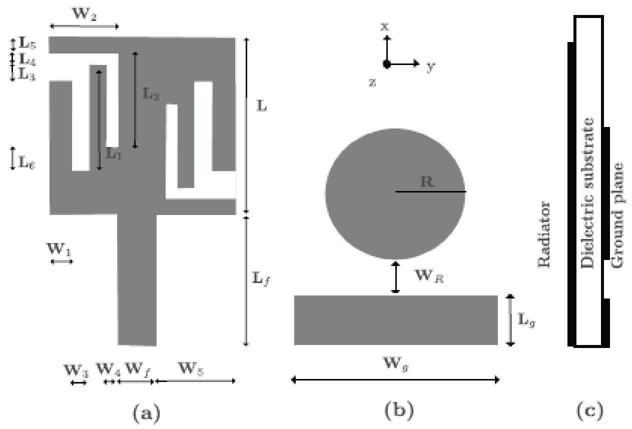


Figure 3. Schematic configuration of the proposed triple-band antenna. (a) Top view (b) Bottom view (c) Side view

The evolution of antenna design involves the following step-by-step process:

(1) With a conventional rectangular patch and ground plane, a single resonant mode is formed at 3GHz.

(2) Inclusion of two L-shaped slots leads to the formation of two modes resonating at 2.8 and 4.2 GHz respectively.

(3) Additional L-shaped slot on the radiating patch (final F shape) provides additional resonance.

(4) Impedance matching is achieved with the modification of ground plane by printing circular shaped patch.

Wu et al [3] proposed a novel Substrate Integrated Waveguide (SIW) higher order mode cavity fed slot array antennas. This method feeds all the array elements simultaneously where the resonant mode is excited only by a slot aperture which helps in simplifying the feeder network. Also, the array has been designed as an asymmetric structure inorder to enhance the bandwidth. Another way for the enhancement of bandwidth is with the introduction of new resonant modes. With the proposed 2×2 array design it is possible to implement 4×4 array structures based on the phenomenon of subarrays. This slot array structure can be implemented and finds application in millimeter-wave and THz frequency bands.

Tang et al [4] developed a UWB antenna to achieve improved broadside-realized gains. For this improvement, an arc-shaped slot is etched into the radiating patch of a compact UWB monopole antenna which is of elliptical shape. Impedance matching can also be maintained without any significant changes made to the design parameters. In comparison with the previous design, 61.7% reduction in size is achieved with further enhancement in the realized gain of 6dB near 10GHz frequency range. To improve its high frequency characteristics, a multimode resonator filter is combined with this slot modified UWB antenna. After integrating with the filter design, a 2.12 dB further increase of the broadside realized gain can be obtained near 10 GHz. Moreover, the performance of the radiation pattern in the upper frequency range is improved especially obtaining omnidirectional pattern in the H-plane.

This antenna was constructed using printed circuit board technology [4] and the substrate is a planar Rogers 4350B with the relative dielectric constant $\varepsilon_r$ =3.48 and the loss tangent = 0.0038. The geometrical configuration of the antenna is given as 37mm×25mm×1.524 mm and the thickness of the copper film is 0.017mm. The top side of the board has an elliptical shaped radiating patch which is shown in fig 4. while at the bottom side a rectangular slot is etched into the ground plane at its upper edge for the purpose of impedance matching. The introduction of this rectangular slot effectively tunes mutual coupling effect between the radiating patch and the ground plane.

Figure 4. Fabricated prototype of printed planar UWB antenna with an arc-shaped slot

The filter consists of a single-wing resonator [4] and a pair of interdigital-coupled lines as given in fig 5. Because of strong coupling effects and consequent overlapping of higher order modes, this filter design exhibits UWB bandpass performance. It is to be noted that the integrated arc-slot antenna with this filter produces high quality cut-off performance both at the upper and lower edges of UWB band range.

Fig 5. Fabricated prototype of UWB antenna with both arc-shaped slot and multimode resonator filter

Saini et al [5] presented a square slot antenna of dual circular polarization for broadband applications. The fabricated square slot antenna is depicted in fig 6.This antenna is used to obtain highly good isolation performance by the use of coplanar waveguides. It comprises of two asymmetrically placed T-shaped feed lines in orthogonal direction and inverted L-shaped grounded strip to enhance axial ratio bandwidth. One of the T-shaped feed line is excited and the other one acts as a stub as the electric field produced will be used to excite two orthogonal electric fields having quadrature phase shift between them. AR bandwidth can be further improved by the placement of other straight strips which are connected to L-shaped grounded strips.

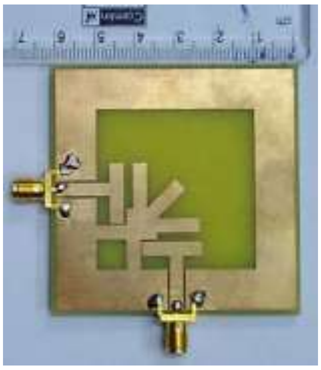

Fig 6. Fabricated square slot antenna

The Axial Ratio (AR) bandwidth [5] is 1.7 GHz for isolation greater than 15 dB and 1.47 GHz for isolation more than 20 dB with the variation of antenna gain from 1.5 to 4 dB. This proposed design is used suitably for Bluetooth/WLAN and Wi-MAX applications.

Zong et al [6] presented a wide bandwidth slot antenna at low frequencies for mobile applications. The slot antenna is composed with the hybrid combination of a close ended circle with two rectangles. A 50Ω microstrip line feed is connected to a circular patch by an open ended strip. The fabrication of this antenna type is done by two methods: (1) Corrosion of double-layered copper covered FR4 board by acid, (2) Cutting copper foil. The latter has the merits of low cost and easy fabrication which can work well below 6 GHz frequency. The antenna has wider frequency bandwidth at lower frequencies covering LT700, GMS850, and GSM900

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while covering LTE2300, LTE2500, and WLAN 2.4GHz at higher band of frequencies.

Majid et al [7] developed a square ring slot antenna for frequency reconfiguration. The designed antenna is composed of two small rectangular ring slot and a square ring slot fed by a microstrip line. To provide frequency configurability, two switches are placed between the rectangular and square ring slots. It has the ability to reconfigure for the three frequency bands at 1.9 GHz, 2.1 GHz and 2.3 GHz. It can be used for GSM, 3G and Wi-MAX wireless systems.

The designed antenna [7] consists of FR4 board as the substrate with a thickness of 1.6 mm, tangential loss tangent of 0.019 and permittivity of 4.5. The dimension of the antenna designed is 45 mm × 45 mm. The length and width of microstrip feedline is given as: $l$=22 mm and $w$=3 mm and the feed is placed at the centre of $x$ axis. The length and width of the square ring slot is $b$ = 21 mm and the square ring slot is placed at the center of $x$-axis with a height of $e$ = 15 mm. To preserve the radiation pattern and polarization of the antenna, symmetrical antenna geometry is required. The two rectangular ring slot is placed at the side of the square ring slot. The length and width of the rectangular ring slot are
$c$ = 5.4 mm and $d$ = 2.4 mm.

Indhumathi et al [9] proposed a wearable textile antenna for indoor application, were the antenna is compatible in size and can be easily integrated with fabrics. The antenna is mounted on a cordura fabric substrate with taffeta fabric acting as a conducting material. The antenna is fed with a microstrip feeding element. The circular patch antenna is designed using formula given as.

$$a = \frac{87.94}{f_r\sqrt{\varepsilon_r}} \qquad (1.1)$$

Where $a$ is the radius of the circular patch, is the resonant frequency, is the dielectric constant of the substrate. The microstrip feed line is calculated using the formula

$$W = \frac{7.48 * h}{Z_0 \frac{\sqrt{\varepsilon_r + 1.41}}{87}} - 1.25 * t \qquad (1.2)$$

Where $h$ is the height of the substrate, is the characteristic impedance, $t$ trace thickness.The performance of the designed structure is improved by etching a slot at the edge of the patch, followed by a diamond slot in the centre. The above two steps increases the current flow in the conducting element, thus resulting in good return loss, followed by increase in bandwidth with better impedance matching.

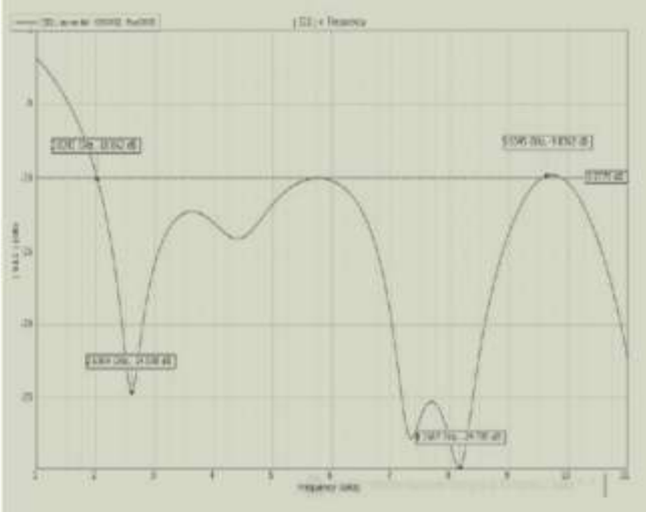

Figure 7. Return loss

The fig 7 shows the graph of return loss (dB) vs frequency (GHz) of the proposed antenna. The radiating element excites at two frequencies: 8.1 GHz and 2.6 GHz, with a return loss of -29 dB and 24 dB respectively. The bandwidth of the antenna is found to be 7.6 GHz enclosing a wide range of frequencies from 2 GHz to 9.6 GHz.

Anand Kumar et al [10] proposed a paper on multiband, metamaterial loaded microstrip patch antenna. Closed C- shaped EBG structure is etched on the metamaterial substrate which inhibit the propagation of electromagnetic waves over a certain range of frequencies. This structure helps in shifting the bandgap of the microstrip antenna from 6.5GHz to 5.5GHz. The EGB structure when used as a substrate for the patch antenna results in multiband operation due to its coupling between metamaterial and antenna patch. The similar type structure is etched on patch antenna to further reduce the operating frequency. The design consists of a metallic patch mounted on a FR4 substrate of height 1.26 mm with a ground plane of dimension 4.4*4.8 mm.

TABLE II. ANTENNA GAIN AT ITS RESONANT FREQUENCY

| **Operating frequency (GHz)** | 2.5 | 4.7 | 5.3 | 6.2 |
|---|---|---|---|---|
| **Gain (dB)** | 5.48 | 6.09 | 5.77 | 8.4 |

The C-shape slot is radiated using a coaxial feed of diameter 0.24mm. Resonating frequency of patch antenna on metamaterial substrate and loaded with metamaterial is given in Table 1 and the return loss for the corresponding frequencies is shown in Fig 8.

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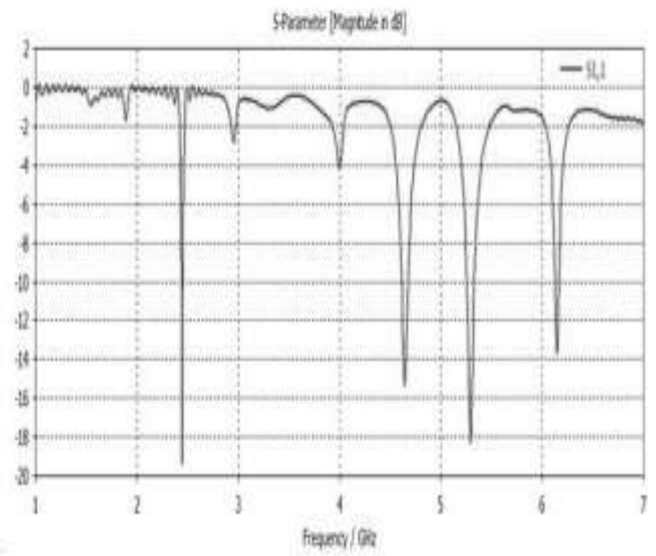



Figure 8. S-parameter of patch antenna when loaded with metamaterial substrate with metamaterial structures.

From Fig 8. it is observed that the antenna operates at four frequency bands i.e 2.45 GHz, 4.7 GHz, 5.3 GHz, 6.1 GHz and these frequencies reflects the ability of antenna to work in ISM band, 3G, WiFi and WiMax where the mobile communication takes place.

Deepa Dubey et al [11] proposed a circular fractal antenna for multiband wireless application. The fractal shape is based on Sierpinski gasket approach and due to its self-similar property the antenna is suitable for multiband operation. Fractal structure helps in obtaining improved bandwidth, radiation efficiency and reduced sized. The antenna resonant frequency is centered at 2.6 GHz, 4.8 GHz, 5.6 GHz, 6.3 GHz, 7 GHz, 8 GHz, 8.6 GHz and 9.2 GHz over the UWB range with 3 stages of iteration.

The basic structure consists of a normal circular patch antenna of radius 24 mm fed with a microstrip line. The substrate is 1.6 mm thick consisting of FR4 epoxy material. The antenna is made to resonate with its centrefrequency 2.4 GHz. Following are the design equations used [12] for calculating the radius of the patch.

$$a = \frac{F}{\{1 + \frac{2h}{\pi \varepsilon_r F}[ln(\frac{\pi F}{2h}) + 1.7726]\}^{1/2}}$$

$$F = \frac{8.791 \times 10^9}{f_r\sqrt{\varepsilon_r}} \qquad (1.3)$$

Where a is the radius, is the dielectric constant, is the resonant frequency and h is the height of the substrate. The diameter of the circles during the first iteration is given as D1=20 mm. In the second iteration two more circles of D2=12 mm are substrate from the base antenna, followed by D3=4 mm for the final iteration. The comparison graph for return losses of each iteration is shown in Fig 9.

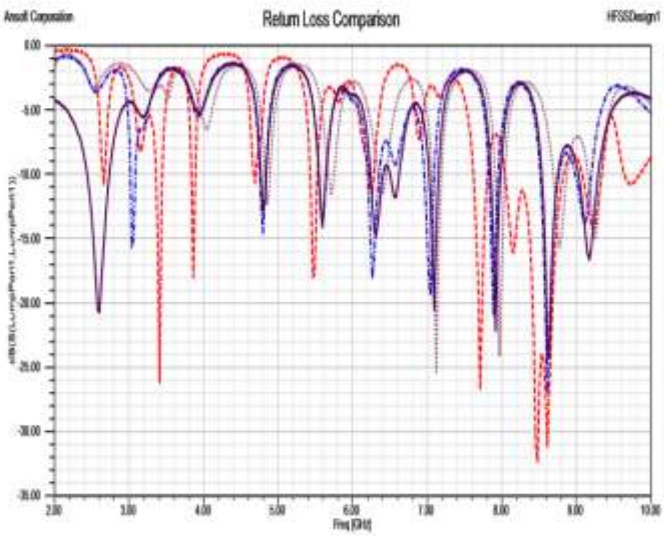



Figure 9. Comparison of $S_{11}$ of progressive fractal antenna

Simulated results from the comparison graph shows that, the antenna works perfectly for multiband wireless applications by satisfying the scattering parameter ($S_{11}$).

Wan Noor et al [13] presented a paper that investigates antenna performance under bending condition when it is placed over a denim substrate. The antenna is designed from a basic rectangular patch of dimensions 58 mm × 48 mm with a partial ground plane of length 23 mm is made to resonate at 2.4 GHz wearable application. The ground and patch is made by copper tape and the radiating element is fed by a microstrip feed line. The height of the substrate is given as h=0.7 mm and the dimensions of the patch is calculated by using equations in [14]. The partial ground plane acts as a better impedance matching element which controls the bandwidth of the rectangular patch. For further optimization, a triangular slot is cut at the top of the radiating element that helps in distributing the current path which results in better resonance at higher frequencies[15 16]. The return loss of the antenna is improved with the slot which is shown in Fig 10

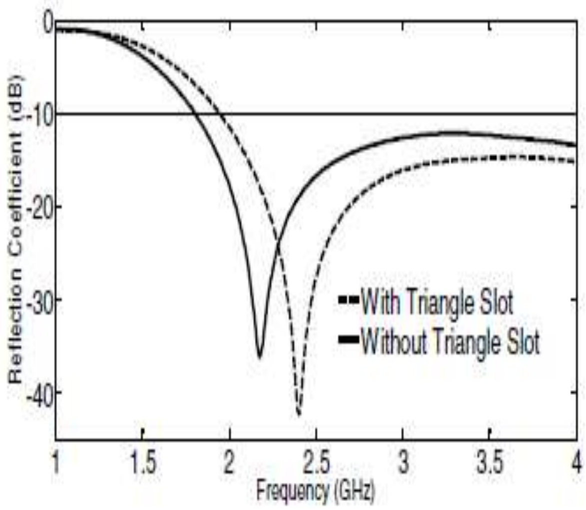



Figure 10. Return loss with and without slot

From Fig 10. it is noted that the introduction of triangle slot helps in shifting the frequency from 2.15 GHz to 2.4GHz, which is the operating frequency for wearable applications with a good return loss of -45dB.

Jing-Ya Deng et al [17] proposed a compact ultra-wideband MIMO antenna that covers 2.4GHz for WLAN/WiFi and 3.1 to 10.6 GHz UWB. The antenna is designed by bending the monopoles and including two inverted L-shape strips to function in an ultra-wide bandwidth. For better system performance, the isolation between the elements must be high which is a greater challenge in the wireless industry. Acceptable isolation can be obtained by placing the elements at $\lambda/2$ distance. In [18], the isolation is increased by etching a slot in the centre of the ground plane.

The design process includes four antennas which is placed on a FR4 substrate of height 0.8 mm and 30 mm * 40 mm dimension. The reflection coefficients of the antenna is shown in Fig 6. Antenna I consists of two bended monopole antenna. Since it covers only WLAN band as shown in Fig 11, antenna II is built. It involves two inverted L-shaped strips which covers the entire UWB. To improve the impedance matching in 10-10.6 GHz, two L-shaped strips are used, which corresponds to antenna III. It is seen that antenna III obtains a new resonance at 10.4 GHz as observed in Fig 6, thus involving operation over the entire UWB. Further optimization is obtained by etching two narrow slots under the L stubs in the ground.

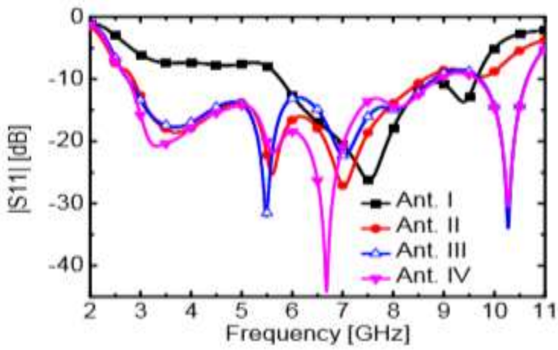



Figure 11. Simulation of $S_{11}$of all the four antennas

To improvise the isolation between two ports, a slot is etched at the center of the ground; the structure of the antenna is changed from antenna IV to antenna V.

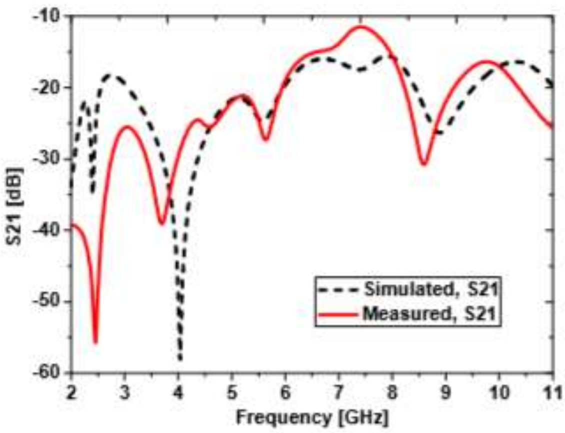
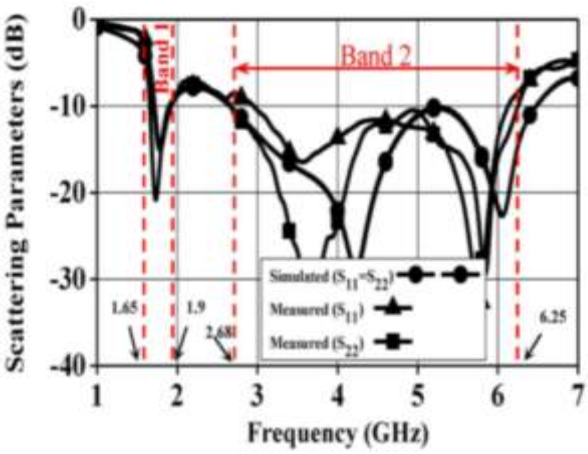


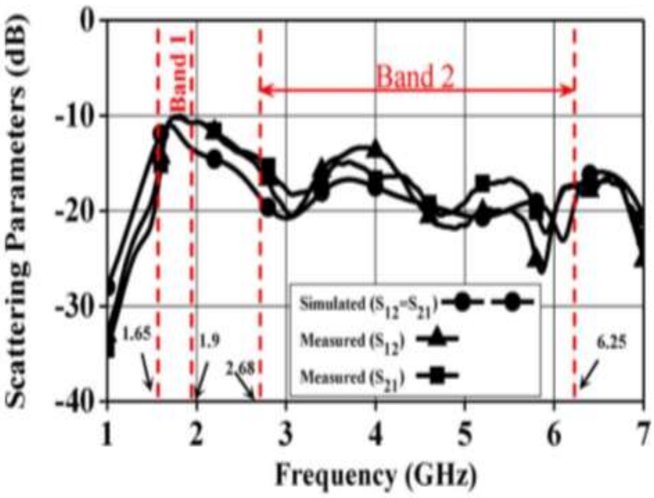

Figure 12. $S_{12}$ between two MIMO antennas

The $S_{12}$-parameters of antennas is given in Fig. 12, it can be seen that the isolation between two ports are improved because of the etched center slot. Another benefit due to this center slot is that the around 2.4GHz gets better than -10dB, the lower limit of the operation band shifts from 2.75GHz to 2.4GHz. This makes the antenna available for both UWB and WLAN MIMO applications. As a sacrifice of this 2.4 GHz WLAN coverage, the reflection coefficient on 3-5.5GHz becomes worse. But it is still smaller than -10dB, which is acceptable for commercial applications.

Yogesh Kumar et al [19] A hybrid fractal shape planar monopole antenna covering multiple wireless communication bands is presented for mul- tiple-input-multiple-output (MIMO) implementation for handheld mobile devices. The proposed structure is the combination of Minkowski island curve and Koch curve fractals. It is placed with edge to edge separation of at 1.75 GHz. The T-shape strip is inserted and rectangular slot is etched at top side of ground plane, respectively to improve the impedance matching and isolation between the antennas.




(a)




(b)

Figure 13. Simulated and measured scattering parameters of the proposed antenna. (a) Reflection coefficient magnitude ($S_{11}$ and $S_{22}$) and (b) isolation ($S_{12}$ and $S_{21}$ ).

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Measured and simulated values of the reflection coefficient magnitude and isolation are plotted in Fig. 13(a) and (b), respectively. It can be seen, measured impedance bandwidth is 14% from 1.65 GHz to 1.9 GHz for the band 1 and 80% from 2.68 GHz to 6.25 GHz for the band 2. The bandwidths achieved meet the requirements of LTE/ WiFi/ WiMAX/ WLAN communication applications. The isolation between the two antennas is below -10 dB and -15 dB for the lower and higher frequency bands, respectively.

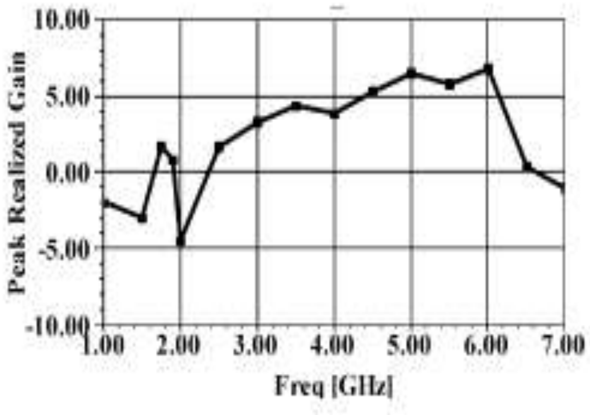


Figure 14. Peak Realized Gain

It is found that due to the symmetry of the antenna structure and their fabrication tolerances; the gain values of the two radiators are likely to be the same. Therefore, the gain of the antenna1 alone is presented, while the antenna 2structure is terminated in a 50Ω matched load. The measured peak gain is varying in the range between 0 and -2.5dBi with a maximum gain of around 2dBi for the band1. Similarly, for the band2, the measured peak gain is found to vary between 2.5dBi and 4.85 dBi with a maximum gain of 7 dBi.

The various types of slot antennas discussed above is compared based on their methodologies used and showcased in the form of a table.

TABLE III: COMPARATIVE ANALYSIS OF THE DIFFERENT TECHNIQUES

| S.No. | Proposed Antenna | Technique Applied | Remarks |
|---|---|---|---|
| 1 | A miniaturized Reflectarray Antenna for Scanned Beam Applications | A simple omnidirectional dipole antenna is used as a feeding source. | To miniaturize the antenna size, distance between the source antenna and reflectarray antenna is reduced. |
| 2 | Design of Compact F-shaped slot Triple Band Antenna for WLAN/Wi-MAX Applications | TwoF-shaped slots are etched on either sides of the radiator to provide triple-band operation | The proposed design can be used to simultaneouslyoperate over WLAN (2.4/5.2/5.8GHz) andWiMAX (2.5/3.5/5.5 GHz) frequency bands |
| 3 | A Substrate Integrated Slot Antenna Array using Simplified Feeding network based on higher order Cavity modes | SIW higher mode cavity fed four element slot array is proposed. The higher order mode cavity is used as not only a feeding network but also a resonatingelement for the slots. | Toenhance the bandwidth, an asymmetric structure is designed. In this way, new resonances are introduced and the bandwidth is thus broadened. |
| 4 | Planar UWB antennas with Improved Realized gain Performance | An arc-shaped slot is etched into the radiating patch of a standardcompact elliptically shaped UWB monopole antenna | The integration of a compact single-wing filter, whose optimized design was tested experimentally, into this arc slot modified antenna further enhanced its radiation properties. |
| 5 | A Broadband Dual Circularly polarized Square slot antenna | Consists of a square slot, two asymmetric T-shaped feed lines in orthogonal directionprotrude from signal lines, and an inverted-L grounded strip with three straight strips at the corner of the slot adjacent to both the feed lines | Axial ratio(AR) bandwidth is significantly enhanced because of inverted-L groundedstrip with attached three straight strips. |
| 6 | Design and Fabrication of a Wideband Slot Antenna for Handset Applications | Consists of hybrid combination of close-ended circle and two rectangles | wider frequency bandwidth at lower frequencies covering LT700, GMS850, and GSM900 while covering LTE2300, LTE2500, and WLAN 2.4GHz at higher frequencies |

| | | | |
|---|---|---|---|
| 7 | Frequency Reconfigurable Square Ring Slot Antenna | Consists of two small rectangular ring slot and a square ring slot fedby a microstrip transmission line | Two switches are placed between rectangular and square slots to provide frequency reconfigurability at 1.9 GHz, 2.1 GHz and 2.3 GHz |
| 8 | Wearable Textile Antenna for Indoor Applications | Rectangular and diamond shaped slots are introduced on the patch to regulate the flow of current, thus resulting in better return loss. | Slight variation in thickness or height of the substrate changes the operating frequency range of the antenna. |
| 9 | Microstrip Patch Antenna Loaded with Metamaterial for Multiband Applications. | Closed C- shaped EBG structure is etched on the metamaterial substrate which inhibit the propogation of electromagnetic waves over a certain range of frequencies | Metamaterial substrate makes the antenna to operate at four resonating frequencies like ISM, 3G, WiiFi, WiMAX. |
| 10 | Circular Sierpinski Fractal Antenna for Multiband Wireless Applications | Fractal geometry upto three iterations are introduced which improves the bandwidth for multiband wireless application. | Obtained the required operating frequency for mobile handset since it works is ISM band. |
| 11 | Rectangular Patch with Partial Ground Wearable Antenna for 2.4 GHz Applications | Triangular shaped slot is cut from the top side of the rectangular patch to regulate the current flow , thus resulting in good return loss at 2.4GHz operating frequency. | Comparison between measured and simulated results shows that denim fabric is suitable for wearable application. |
| 12 | An Ultra-wideband MIMO Antenna with a High Isolation | Two L-shaped monopoles, two L-shaped slots and two L-shaped strips are used to design the MIMO antenna. Mutual coupling between them is reduced by cutting out a rectangular slot from the ground plane. | Rectangular slot helps the antenna to resonate at 2.4GHz for WLAN and from 3.1-10.6GHz for UWB frequency range. |
| 13 | Hybrid Fractal Shape Planar Monopole Antenna Covering Multiband Wireless Commu-nications With MIMO Implementation for Handheld Mobile Devices | Fractal geometry along with I shaped slot is used to operate the MIMO antenna over the Ultra Wide Band with reduced mutual coupling between them. | The antenna performance is suitable for handheld devices covering several wireless communication bands (i.e., LTE/WiFi/WiMAX/WLAN). |

## III. CONCLUTION

With various types of slots of different shapes and sizes, the microstrip antenna performance can be improved. In this paper, a comprehensive survey is made to discuss the impact of different slots on microstrip patch antennas. The proposed design slot antennas find their application in C band and Ultrawide Band range that can be used for Satellite Communication,WLAN, WiMAX, WiFi etc. A comparative analysis of existing techniques is carried out to find which satisfies the desired application along with the enhancement in antenna performance such as return loss, gain and bandwidth.

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