Analysis of MSA, Paraboloid and Lens Antennas Using SHF for Wireless Communication Devices

[1]A SAIDA, Assistant Professor, [2] MD ASIF, Assistant Professor.
[1]Department of ECE, [2]Department of ECE
[1]K G Reddy College of Engineering and Technology Hyderabad, Telangana, [2]K G Reddy College of Engineering and Technology Hyderabad, Telangana,

Abstract: As per Microstrip antenna (MSA) provide low profile and low volume, so it is use in a now a day's communication devices. In this paper study of past few years shows that most of labour on MSA is targeted on planning compact sized microstrip antenna. A novel super high frequency band antenna based on IC's fabrication process monopole antenna can be used in wireless communication devices. In this speedy dynamical world in wireless communication dual or multiband antenna playing a key role for wireless service needs application. In this paper, we study microstrip patch antenna design with form of substrate, paraboloid and lens antennas, feed techniques and slots for SHF based system applications.

Index Terms— Microstrip patch antenna, Super High Frequency band, IC's fabrication, operating frequency, feeding techniques, Paraboloid and lens antennas.

I: INTRODUCTION

An antenna both transmitting and receiving the information so it is the essential part of the microwave communication. It is a device that is made to efficiently radiate and receive the radiated electromagnetic waves. Antenna is a transducer which converts the voltage and current on a transmission line into an electromagnetic field in a space, consisting of an electric and magnetic field travelling right angles at each other.Generally, to detect the cancerous tissue, the microwave imaging system is made by a circular cylindrical array antenna microwave imaging system need little antennas with omni-directional radiation patterns and enormous information measure.

Thus, in microwave imaging systems, over the full operative band one of key issues is that the style of a compact antenna whereas providing wideband characteristic. It is a well-known incontrovertible fact that placoid monopole antennasphysical options, like easy structure, little size and low-price present very appealing Consequently, variety of planner monopoles with totally different geometrics are through an automatic style strategies and experiment characterized have been developed to attain the optimum placoid form. With the event of band wireless communication systems, ultra-wide band (UWB) systems have been increasing quickly. The Federal communications Commission allotted the wave band 3.1~10.6 GHz for the UWB services. These UWB systems have been used for radiolocation applications, localization, information communications etc. The antennas of UWB systems area unit embedded into these transmission devices, the house networking system is wide utilized in transmission devices like HDTV's, DVD's, cameras and private computers through the UWB service channels.

The most commonly employed microstrip patch antenna is a rectangular patch. The rectangular patch antenna is approximately a one wavelength long section of rectangular microstrip transmission line. The antenna is loaded with a dielectric as its substrate, the length of the antenna decreases as the relative dielectric constant of the substrate increases. When the air is the antenna substrate the length of the rectangular microstrip antenna is approximately one half of a free space wavelength. The proper miniaturized antenna will improve the transmission and reception.

Microstrip resonators will be classified into 2 sorts counting on the length and width of antennas. Resonators with a slim conductor known as microstrip dipole and resonators with a large conductor are referred to as microstrip patch. Resonance happens once the dipole or patch dimensions are of a half-guided wavelength. Longitudinal current distribution here for their pattern and gain are similar, however the alternative properties (e.g. input electrical phenomenon and polarization) will vary.

When the signal frequency is within the section of a resonance, a microstrip resonator radiate comparatively broad beam, broadside to the plane of the substrate. A serious a part of the sign participates in radiation and so the resonator acts as an antenna. Since patch dimensions should be of the order of a radio-controlled wavelength, its directivity is extremely
low as an example, a half-wavelength dipole generally features a gain of regarding 5-6 Db and beam width between 70 and 90 degrees.

The design of a microstrip antenna begins by deciding used for the antenna so the size of the patch. due to the fringing fields on the radiating edges of the antenna there's a line extension related to the patch. The basic structure of the microstrip patch antenna design is shown in fig.1.

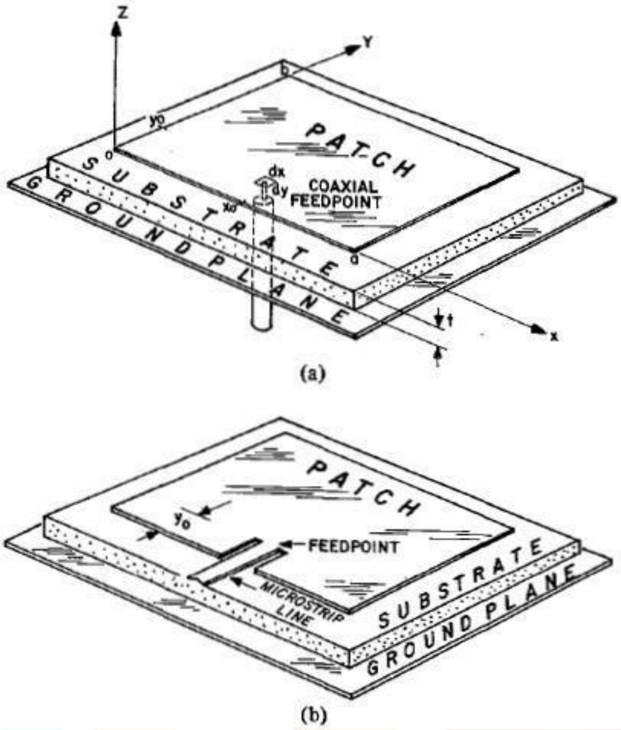


Fig. 1 The structure of microstrip antenna.

II: LITERATURE REVIEW

The construct of microstrip antenna with conducting patch on a ground plane separated by insulator substrate was undeveloped till the revolution in electronic circuit shrinking and large-scale integration in 1970. After that several mortals have drawn the radiation from very cheap plane by a insulator substrate for numerous configurations. Various mathematical analysis models were developed for this antenna and its applications were extended to several numerous fields. The little strip antennas unit today antenna designer's selection. Throughout this section, the microstrip antenna literature survey is mentioned. "Nasser Ojaroudi" has proposed a compact with multi-resonance characteristics UWB/Omni-Directional Microstrip Monopole Antenna with multi-resonance characteristic has been projected for microwave imaging systems leads to compact antenna with smart omni-directional radiation characteristics for projected in operating frequencies.
The fictious antenna satisfies the VSWR<2 demand from 2.95 to 14.27 GHz so as to reinforce information measure frequency, two pairs of formed slits and parasitic structures in the ground plane area unit used and therefore abundant wider electrical phenomenon with an ordinary square radiating patch and small size of 12×18mm. As the designed antenna meeting the requirements of GSM application, it could be highly useful for mobile application. In this paper, design and Analysis of Microstrip Patch. An antenna for GSM application is presented by. Antenna parameters such as Return Loss, VSWR of the designed antennas are -29.21dB, 1.0717 respectively. "Ramna" has proposed Design of Rectangular Microstrip Patch Antenna Using Particle Swarm Optimization. In this Particle swarm optimization is a popular optimization algorithm used for the design of microstrip patch antenna. He was presented design using soft computing technique, particle swarm optimization (PSO) of probe fed rectangular microstrip patch antenna for WCDMA. For the design of microstrip patch antenna a substrate with dielectric constant of 4.4 and height 1.588 mm has been used. To optimize the parameters like patch length, width and feed position at center frequency of 1.95 GHz using Sonnet13.52, PSO has been used. Microstrip patch antenna resonated at exact 1.95GHz.PSO saves time as compared to the design of patch antenna without optimization algorithm and also PSO restricts the variation from centre frequency. "Jyoti Ranjan Panda" has researched that A Compact Printed Monopole Antenna(PMA) for Dual-band RFID and WLAN Applications. From 9-shaped folded antenna, dual-band operation is achieved which is printed on a non-conductor backed dielectric. Impedance bandwidth 33.13% at 2.43 GHz and 36.43% at 2.43GHz is measured of the PMA. The proposed antenna exhibits broadband impedance matching, consistent omni directional radiation patterns and appropriate gain characteristics (>2.5 dB i) in the RFID and WLAN frequency regions [11]. "Mohammad Ojaroudi" has presented a novel, compact printed monopole antenna (PMA) for UWB applications. The fabricated antenna satisfies the 10-dB return loss requirement from 3.12 to 12.73 GHz. The feed-gap distance, the sizes of T-shaped notch, and the sizes of two rectangular slots in the antenna's patch is used to obtain the wide bandwidth have been optimized by parametric analysis. This antenna exhibits good radiation behaviour within the UWB frequency range.
"Y. Chen", has proposed Design and Analysis of Wideband Planar Monopole Antennas Using the Multilevel Fast Multipole Algorithm. In this to analyze the impedance bandwidth and radiation performance of the monopoles a full-wave method of moment based on the electric field integral equation (EFIE) is applied. Meanwhile, to reduce the memory requirements and computational time, the multilevel fast multipole algorithm (MLFMA) is employed. Two wideband planar monopoles attached to finite sized ground planes are designed, analysed, and fabricated. Both of the simulated and measured results shows that the two monopoles are capable to cover the AMPS, GSM900, and DCS band. In the whole operating frequency, both of the monopoles can provide a nearly omni-directional radiation pattern in the azimuth plane.

"Nakchung Choi" has proposed a notch-frequency band for a UWB antenna which can be embedded into laptop computers with an I-shaped parasitic element. This novel band-notched UWB antenna has the capability to provide easy tuning of the notch-frequency function and bandwidth with good stop band rejection.

III: Study of Antenna Designing Parameters There are three essential parameters for design of a rectangular microstrip Patch Antenna. Firstly, the resonant frequency (f0) of the antenna must be selected appropriately. The frequency range for ultra-wide band applications is 3.1 to 10.6 GHz and the design antenna must be able to operate within this frequency range. The second important parameter of antenna is substrate thickness. The height of dielectric substrate (h) of the microstrip patch antenna with coaxial feed is to be used in S-band range frequencies. Hence, the height of dielectric substrate employed in this design of antenna is h= 1.6mm, the third important parameter of good antenna design is dielectric substrate (Ɛr). A thick dielectric substrate having low dielectric constant is desirable. This provides better efficiency, larger bandwidth and better radiation. The low value of dielectric constant increases the fringing field at the patch periphery and thus increases the radiated power lower quality factor Q. FR-4 Epoxy which has a dielectric constant of 4.4 and loss tangent equal to 0.02 can be used for new antenna design. The look of patch is going to be fed by a microstrip transmission line. Patch is act as a conductor. This structure of the antenna having length of patch L, width W, height of dielectric substrate h and Loss tangent. The dielectric constant of the substrate material is an important design parameter. These are placed on infinite ground plane. The length is formed around L g/2, that the patch starts to radiate, that typically incorporates 50 Ohm impedance. The antenna is typically fed at the diverging edge on the dimension W because it offers sensible polarization, but the disadvantages area unit the spurious radiation and want for electric impedance matching this is often as a result of 150 to 300typical edge resistance of a microstrip antenna ranges. The antenna parameters antenna can be calculated by the transmission line method [Balanis, 2005] and as exemplified below:

Width of the Patch:

$$W = \frac{c}{2f\sqrt{\frac{(\varepsilon r+1)}{2}}}$$

The width of the antenna can be determined by (James et al, 1989): where, c = speed of light in free-space.

Resonant Frequency:

$$f_0 = \frac{c}{2Le\sqrt{\varepsilon r}}$$

and length Le (Effective Length) is chosen as Le = L+2ΔL the actual length *L* of the patch is given as (Pozar et al, 1995): Formula for the extended length due to fringing effect is given as,

$$\frac{\Delta L}{h} = 0.412\left(\frac{(\varepsilon reff+0.3)(\frac{w}{h}+0.264)}{(\varepsilon reff-0.258)(\frac{w}{h}+0.8)}\right)$$

$$\varepsilon_{eff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left(1+\frac{12h}{w}\right)^{\frac{-1}{2}}$$

Where, h = Height of dielectric substrate W = Width of the patch

Ground Dimension For practical considerations, it is essential to have a finite ground plane if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Hence, the ground plane dimensions would be given as (Huang, 1983)

L g = 6h+L W g= 6h+W By using these formulas we can calculate L*W the dimension of the main patch and L g*W g the dimension of the ground plane of the main patch.

Feed Location Design:

To radiate the antenna a feed is used to excite by direct or indirect contact. The feed of microstrip antenna can have many configurations like microstrip line, coaxial, aperture coupling and proximity coupling. But for fabricate easily microstrip line and the coaxial feeds are relatively used. Coaxial probe feed is used because it is easy to use and the input impedance of the coaxial cable in general is 50-ohm. There are several points on the patch which have 50-ohm impedance. We have to find out those points and match them with the input impedance. Feed point is chosen so that where at the point of radiating patch maximum area of patch is covered. By changing feeding points antenna is radiate at different radiating frequency. We will use coaxial probe feeding technique.

The Parabolic Reflector: The high level of gain that can be achieved by using a parabolic reflector is one of the main reasons they are used. Parabolic reflector antenna gain can be as high as 30 to 40 dB - figures that would not be easily achievable using other forms of antenna. Antennas would be mechanically large and unwieldy.

The parabolic reflector antenna is ideal for high gain applications. At microwave frequencies where these antennas are normally used, they are able to produce very high levels of gain, and they offer a very convenient and robust structure that is able to withstand the rigours of external use, while still being able to perform well. Many other types of antenna design are not practicable at these frequencies.

Parabolic reflector antenna gain

The parabolic antenna gain can easily be calculated from a knowledge of the diameter of the reflecting surface, the wavelength of the signal, and a knowledge or estimate of the efficiency of the antenna. The parabolic reflector antenna gain is calculated as the gain over an isotropic source, i.e. relative to a source that radiates equally in all directions. This is a theoretical source that is used as the benchmark against which most antennas are compared. The gain is quoted in this manner is denoted as dBi. The standard formula for the parabolic reflector antenna gain is:

$$\text{Gain } G = 10 \log_{10} k \left(\frac{\pi D}{\lambda}\right)^2$$

Where:

G is the gain over an isotropic source in dB
k is the efficiency factor which is generally around 50% to 60%, i.e. 0.5 to 0.6
D is the diameter of the parabolic reflector in metres
λ is the wavelength of the signal in metres.

Parabolic antenna beamwidth calculation

As the gain of the parabolic antenna, or any antenna, increases, so the beamwidth falls. Normally the beamwidth is defined as the points where the power falls to half of the maximum, i.e. the -3dB points on a radiation pattern polar diagram. It is possible to **estimate** the beamwidth reasonably accurately from the following formula.

$$\text{Beamwidth } \psi = \frac{70\ \lambda}{D}$$

Where:

G is the gain over an isotropic source in dB
D is the diameter of the parabolic reflector
λ is the wavelength of the signal.

All dimensions must be in the same units for the calculation to be correct, e.g. both diameter and wavelength in metres, or both in feet, etc.

Arrays of feeds – In order to produce an arbitrary shaped beam, instead of one feed horn, an array of feed horns clustered around the focal point can be used. Array-fed antennas are often used on communication satellites, particularly direct broadcast satellites, to create a downlink radiation pattern to cover a particular continent or coverage area. They are often used with secondary reflector antennas such as the Cassegrain.

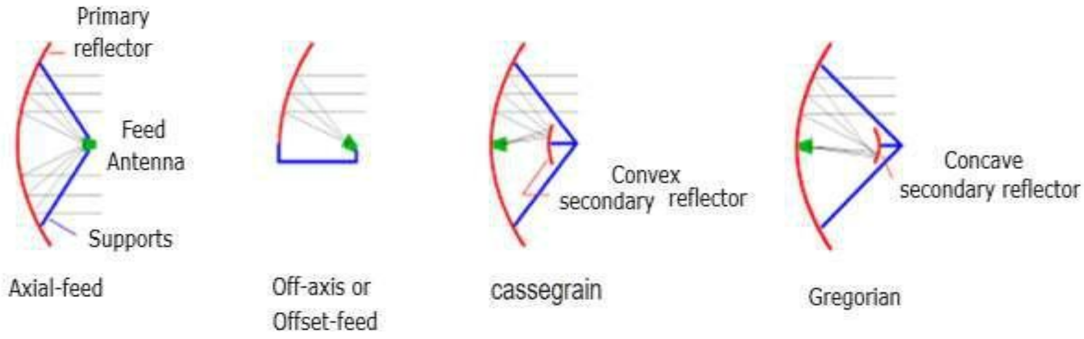
Parabolic antennas are also classified by the type of feed, that is, how the radio waves are supplied to the antenna.

Axial or **front feed** – This is the most common type of feed, with the feed antenna located in front of the dish at the focus, on the beam axis, pointed back toward the dish. A disadvantage of this type is that the feed and its supports block some of the beam, which limits the aperture efficiency to only 55–60%.

Off-axis or **offset feed** – The reflector is an asymmetrical segment of a paraboloid, so the focus, and the feed antenna, are located to one side of the dish. The purpose of this design is to move the feed structure out of the beam path, so it does not block the beam. It is widely used in home satellite television dishes, which are small enough that the feed structure would otherwise block a significant percentage of the signal. Offset feed can also be used in multiple reflector designs such as the Cassegrain and Gregorian, below.

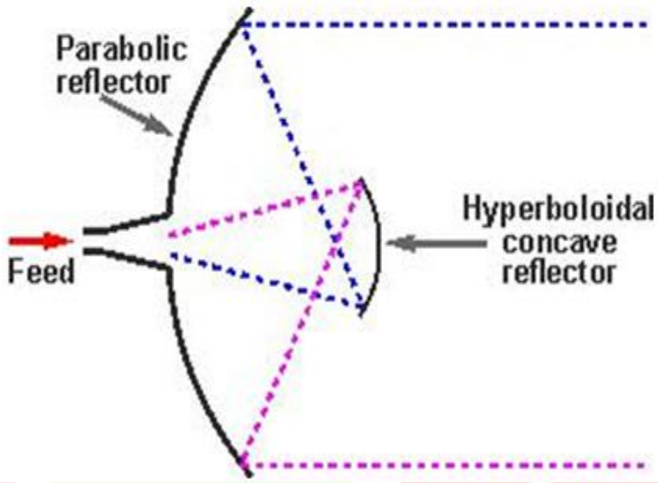
Cassegrain – In a Cassegrain antenna, the feed is located on or behind the dish, and radiates forward, illuminating a convex hyperboloidal secondary reflector at the focus of the dish. The radio waves from the feed reflect back off the secondary reflector to the dish, which forms the outgoing beam. An advantage of this configuration is that the feed, with its waveguides and "front end" electronics does not have to be suspended in front of the dish, so it is used for antennas with complicated or bulky feeds. Aperture efficiency is on the order of 65–70%.

Gregorian – Similar to the Cassegrain design except that the secondary reflector is concave, (ellipsoidal) in shape. Aperture efficiency over 70% can be achieved



Cassegrain Feed:

Cassegrain is another type of feed given to the reflector antenna. In this type, the feed is located at the vertex of the paraboloid, unlike in the parabolic reflector. A convex shaped reflector, which acts as a hyperboloid is placed opposite to the feed of the antenna. It is also known as secondary hyperboloid reflector or sub-reflector. It is placed such that it's one of the foci coincides with the focus of the paraboloid. Thus, the wave gets reflected twice.



Working of a Cassegrain Antenna

When the antenna acts as a transmitting antenna, the energy from the feed radiates through a horn antenna onto the hyperboloid concave reflector, which again reflects back on to the parabolic reflector. The signal gets reflected into the space from there. Hence, wastage of power is controlled and the directivity gets improved.

Advantages

- Reduction of minor lobes
- Wastage of power is reduced
- Equivalent focal length is achieved
- Feed can be placed in any location, according to our convenience
- Adjustment of beam (arrowing or widening) is done by adjusting the reflecting surfaces

Disadvantage

- Some of the power that gets reflected from the parabolic reflector is obstructed. This becomes a problem with small dimension paraboloid.

Applications

- The cassegrain feed parabolic reflector is mainly used in satellite communications.
- Also used in wireless telecommunication systems.

Lens Antennas:

The frequency range of usage of lens antenna starts at **1000 MHz** but its use is greater at **3000 MHz and above.** To have a better understanding of the lens antenna, the working principle of a lens has to be known. A normal glass lens works on the principle of refraction.

Types of Lens Antennas

The following types of Lens Antennas are available-

- Di-electric lens or H-plane metal plate lens or Delay lens (Travelling waves are delayed by lens media)
- E-plane metal plate lens
- Non-metallic di-electric type lens
- Metallic or artificial dielectric type of lens

Advantages

The following are the advantages of Lens antenna-

- In lens antennas, feed and feed support, do not obstruct the aperture.
- It has greater design tolerance.

- Larger amount of wave, than a parabolic reflector, can be handled.
- Beam can be moved angularly with respect to the axis.

Disadvantages

- The following are the disadvantages of Lens antenna-
- Lenses are heavy and bulky, especially at lower frequencies
- Complexity in design
- Costlier compared to reflectors, for the same specifications

Applications

The following are the applications of Lens antenna

- Used as wide band antenna

Especially used for Microwave frequency applications

Dielectric Lens

Dielectric lens is also known as "H-plane Metal Plate Lens".

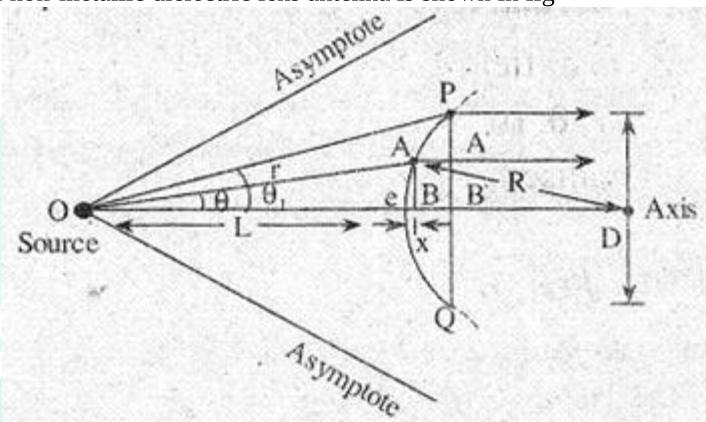
Here the travelling wave fronts are delayed or retorted by the lens medium. Again, dielectric lens antennas are classified into two types,

(a) Non-metallic dielectric lens antennas

(b) Metallic dielectric lens antennas.

Non-Metallic Dielectric Lens Antennas

Consider, the general arrangement of non-metallic dielectric lens antenna is shown in fig



Here source is located at point **O,** the rays are incident on the plane surface **PQ** of the lens. The rays emerging from source have equal distance and constant phase. According to the geometry,

OA + AA' = OC + CE = OC + CB + B B^1 since, From figure, AA' = BB^1

OA + AA' = OC + CB + BB^1 OA = O C + CB

Here, *c* = Velocity of wave in air

v = Velocity of wave in lens medium

Multiplying "*c*" on both side

$C(R/C) = C.(L/C) + C(X/V)$

$r = L + X.C/V$

$r = L + x(\mu)$ since $\mu = c/v$

$r = L + \mu(r\cos\theta - L)$ since $x = \mu(r\cos\theta - L)$

$r = L + \mu r\cos\theta - \mu L$

Therefore $r = L(1-\mu)/\mu\cos\theta - 1$

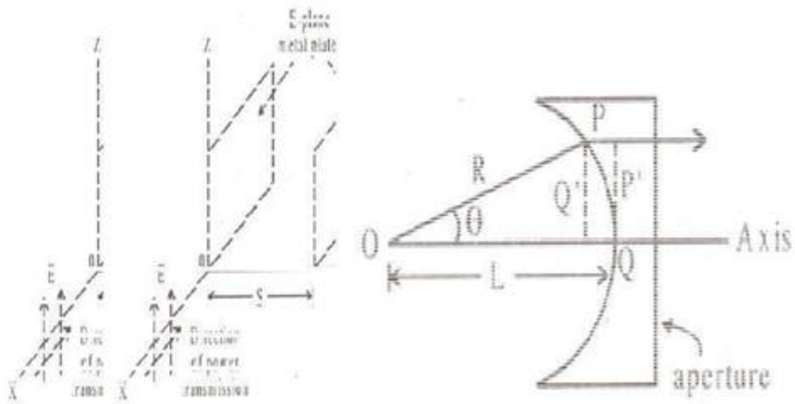
b) **Metallic Dielectric Lens Antennas**

The metallic dielectric lenses are made with discrete metal particles of microscopic size.

The particles should be so small compared to the design wave length that the maximum particle dimension (parallel to the E-field) is less than λ and the spacing to avoid diffraction effects.

E-Plane Metal Plate Lens

The velocity in between E-Plane Metal Plate is more than the Free space velocity v_0



According to optic theory of electric path length.

$$r=L(\mu-1)/(1-\mu\cos\theta)$$

IV: Results and Analysis

Result and analysis of previous literature papers is given in literature review table given in below Literature Review Table:

Ref No.	Approach	Conclusion
1	Modified ground plane with pairs of L-shaped slits an parasitic structures	Bandwidth of more than 130% (2.95-14.27 GHz) radia efficiency is greater than 86%
2	VSWR and Radiation Pattern	Return loss of - 29.2133 dB at 1.8 GHz
3	Inverted U-shaped slots and two L-shaped parasitic elements	Bandwidth of more than 130% (2.9-14.3 GHz) & good on directional radiation pattern
4	I-shaped slot on the feed-line and a pair of S-shaped slots in the ground plane	Wider impedance bandwidth & radiation efficiency is greater t 82%
5	Ground plane with inverted T-shaped notch	Bandwidth of more than 120% (3.12– 12.73 GHz)
6	Half-wavelength parasitic element printed on the rear side of the substrate.	Impedance bandwidth of antenna is 3.1-11.4 GHz (114%)
7	Two monopoles of the same size and a small strip bar	Band notch mechanism of the antenna was examined with curr distribution
8	Embedding a notch in the ground plane	Frequency band of 2.95 to 11.7 GHz with the stop band of 4.9 5.86 GHz.
9	Parabolic reflector antenna gain can be as high as 30 t 40 dB	Beamwidth can be70λ/D
10	Metal plate lens antenna used in high-temperature measurement is designed	Good performance of standing-wave ratio (SWR), gain and focus action at 10GHz is obtained.

V: Conclusion: This is a review paper shows that study of the Microstrip Patch Antenna, parabolic reflector and lens antennas using UWB and SHF frequency ranges for Wireless communication devices applications. After study of literature survey, it is concluded that multi resonance characteristics of MSA such as Return loss, VSWR, Radiation pattern, impedance bandwidth can be improved by changing the parameters such as operating frequency, ground plane structure dimensions, feeding techniques. Can be made usable new structure defined MSA within UWB ranges for many wireless devices communication applications. A spot-focusing metal plate lens antenna used in high-temperature measurement is designed, it consists of a conical horn, several metal plates and a water-cooling metallic sheath. Good performance of standing-wave ratio (SWR), gain and focusing action at 10GHz is obtained

References*:*

[1]: Nasser Ojaroudi*, Mohammad Ojaroudi, and Yaser Ebazadeh "UWB/Omni-Directional Microstrip Monopole Antenna for Microwave Imaging Applications ". Progress in Electromagnetics Research C, Vol. 47, 139- 146, 2014.
[2]: A.Kasinathan, Dr.V.Jayaraj,M.Pachiyaannan," E-Shape Microstrip Patch Antenna Design for Wireless Applications" IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 1 Issue 3, May 2014.
[3]: T. Suganthi1, Dr.S. Robinson2, G. Kanimolhi3, T. Nagamoorthy4" Design and Analysis of Rectangular Microstrip Patch Antenna for GSM Application" IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 1 Issue 2, April 2014.
[4]: Darshana R. Suryawanshi, Prof. Bharati A. Singh,A Compact Rectangular Monopole Antenna with Enhanced Bandwidth, IOSR Journal of Electronics and Communication Engineering (IOSR-JECE), Volume 9, Issue 2, Ver. VII (Mar - Apr. 2014), PP 54-57.
[5]: Reza Jafarlou, Changiz Ghobadi, Javad Nourinia "Design, Simulation, and Fabrication of an Ultra-Wideband Monopole Antenna for Use in Circular Cylindrical Microwave Imaging Systems "Australian Journal of Basic and Applied Sciences, 7(2): 674-680, 2013 ISSN 1991-8178.
[6]: Ramna1, Amandeep Singh Sappal," Design of Rectangular Microstrip Patch Antenna Using Particle Swarm Optimization" International Journal of Advanced Research in Computer and Communication Engineerin Vol. 2, Issue 7, July 2013.
[7]: W. Mazhar, M. A. Tarar, F. A. Tahir, Shan Ullah, and F. A. Bhatti "Compact Microstrip Patch Antenna for Ultra-Wideband Applications" PIERS Proceedings, Stockholm, Sweden, Aug. 12{15, 2013. [8]: N. Ojaroudi, M. Ojaroudi, F. Geran, and Sh. Amiri "Omni-Directional/Multi-Resonance Monopole Antenna for Microwave Imaging Systems". 20th Telecommunications forum TELFOR 978-1-4673-2984- 2012 IEEE.
[9]: Jawad K. Ali, Mahmood T. Yassen, Mohammed R. Hussan, and Mohammed F. Hasan" A New Compact Ultra-Wideband Printed Monopole Antenna with Reduced Ground Plane and Band Notch Characterization" Progress in Electromagnetics Research Symposium Proceedings, KL, MALAYSIA, March 27–30, 2012 1531.
[10]: S. M. Naveen, R. M. Vani, P. V. Hunagund, "Compact Wideband Rectangular Monopole Antenna for Wireless Applications1" *Wireless Engineering and Technology*, 2012, 3, 240-243.
[11]: Jyoti Ranjan PANDA, Aditya Sri Ram SALADI, Rakhesh Singh KSHETRIMAYUM," A Compact Printed Monopole Antenna for Dual-band RFID and WLAN Applications" RADIOENGINEERING, VOL. 20, NO. 2, JUNE 2011.
[12]: Mohammad Ojaroudi, Changiz Ghobadi, and Javad Nourinia "Small Square Monopole Antenna with Inverted T-Shaped Notch in the Ground Plane for UWB Application" IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 8, 2009.
[13]: Y. Chen, S. Yang, S. He, and Z. Nie, Design and Analysis of Wideband Planar Monopole Antennas Using the Multilevel Fast Multipole Algorithm, Progress in Electromagnetics Research B, Vol. 15, 95-112, 2009.
[14]: Nakchung Choi, Changwon Jung, Joonho Byun, Frances J. Harackiewicz, *Senior Member*, *IEEE*, Myun-Joo Park,Yong-Seek Chung, Taekyun Kim, and Byungje Lee, *Member*, *IEEE* "Compact UWB Antenna With I-Shaped Band-Notch Parasitic Element for Laptop Applications" IEEE ANTENNAS And WIRELESS PROPAGATION LETTERS, VOL. 8, 2009.

[15]: K. Chung, S. Hong and J. Choi," Ultrawide-band printed monopole antenna with band-notch filter" IET Microw. Antennas Propag., Vol. 1, No. 2 April 2007.
[16]: Wooyoung Choi*, Jihak Jung, Kyungho Chung, Jaehoon Choi**" Compact Wideband Printed Monopole Antenna with Frequency Band-stop Characteristic" 0-7803-8883-6/05/$20.00 ©2005 IEEE.
[17]: BOOK: CONSTANTINE A. BALANIS," Antenna Theory Third Edition, Analysis and Design".