Design and Analysis of Polygon Slot Dual band Antenna

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Abstract: This paper presents a novel design of polygon shaped microstrip slot antenna for dual band operation. The dual bands are achieved by placing ring slot in the conventional polygon microstrip antenna. The impedance bandwidth of each operating band is found to be 6.58% and 27.53%. These bands are enhanced to 22.68% and 36.03% respectively by truncating two corners of polygon patch, which also reduces the overall size of the patch by 27.48% when compared to conventional square microstrip antenna. The enhancement of impedance bandwidth does not affect the nature of broadside radiation characteristics. Design concept of antennas is given and simulation results are discussed.

Keywords: Dual Band, Polygon Slot, Impedance Bandwidth, Ring Slot

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Introduction: Microstrip antennas (MSAs) have attracted wide spread interest due to their small size, light weight, low cost and low profile. They are simple to manufacture, suitable to planar and non-planar surfaces, mechanically robust, easily integrated with circuits and possible to get multi frequency operation. However, they possess the intrinsic limitation as the narrow impedance bandwidth [1]. Many techniques are available in the literature for the enhancement of impedance bandwidth of MSAs [2]. Many techniques have been used to reduce the size of antenna, such as using dielectric substrates with high permittivity [3], applying resistive or reactive loading [4], increasing the electrical length of antenna by optimizing its shape [5], Utilization of strategically positioned notches on the patch antenna [6]. Various shapes of slots and slits have been embedded on patch antennas to reduce their size. Slot antennas are used typically at frequencies between 300 MHz and 24 GHz. These antennas are popular because they can be cut out of whatever surface they are to be mounted on, and have radiation patterns that are roughly omni directional. The currents travel around the slot perimeter increasing the electrical length. As such, a slotted small size antenna is made to perform equivalent to its larger counterpart.

GSM band allocations

There is a total of fourteen different recognised GSM frequency bands. These are defined in 3GPP TS 45.005.

BAND	UPLINK (MHZ)	DOWNLINK (MHZ)	COMMENTS
380	380.2 - 389.8	390.2 - 399.8	
410	410.2 - 419.8	420.2 - 429.8	
450	450.4 - 457.6	460.4 - 467.6	
480	478.8 - 486.0	488.8 - 496.0	
710	698.0 - 716.0	728.0 - 746.0	
750	747.0 - 762.0	777.0 - 792.0	
810	806.0 - 821.0	851.0 - 866.0	
850	824.0 - 849.0	869.0 - 894.0	
900	890.0 - 915.0	935.0 - 960.0	P-GSM, i.e. Primary or standard GSM allocation
900	880.0 - 915.0	925.0 - 960.0	E-GSM, i.e. Extended GSM allocation
900	876.0 - 915	921.0 - 960.0	R-GSM, i.e. Railway GSM allocation
900	870.4 - 876.0	915.4 - 921.0	T-GSM
1800	1710.0 - 1785.0	1805.0 - 1880.0	
1900	1850.0 - 1910.0	1930.0 - 1990.0	

Figure1: GSM Band Allocation Table

Further the dual band antennas are more attractive in many cases where each band can be used independently for transmit/receive applications, particularly in SAR [7]. The dual band operation of antenna is achieved by many methods [8]. In the present study a simple concept has been used to achieve the dual-band operation by placing slotted polygon patch in the conventional square microstrip antenna. The polygon microstrip patch has been designed by using equations available for the design of square patch [9] and it has been excited through coaxial feed, which is designed by using the equations available for the design of microstrip coaxial feed for the rectangular patch [10]. It is shown that enhancement of impedance bandwidth at each operating band may be achieved by truncating the two corners of polygon microstrip patch. This also reduces the overall size of the antenna to a greater extent compared to conventional square microstrip patch.

Antenna Geometry:

The patch antenna consists of a substrate located in between ground plane and patch. The material used for ground plane and patch is copper.Design Parameters of the antenna is taken from the conventional square patch antenna and is converted in to polygon shape. The length and width of substrate=2a, thickness of substrate=1mm and substrate is Jeans fabric whose dielectric constant ε_r=1.7 and loss tangent δ = 0.025. Ground dimensions same as substrate dimensions and Antenna size = 240mm x 240mm x 1mm. a =120mm, u = 25mm, v = 50mm, d = 45mm. feed location = (75 mm, 120 mm), r =18mm, s =16mm, w = 4mm. Circular slot width is 5mm and patch is polygonal which is cut at both ends.

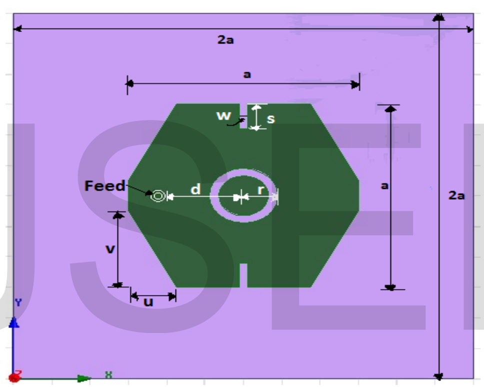

Figure 2: Antenna Geometry

Results and Discussion:

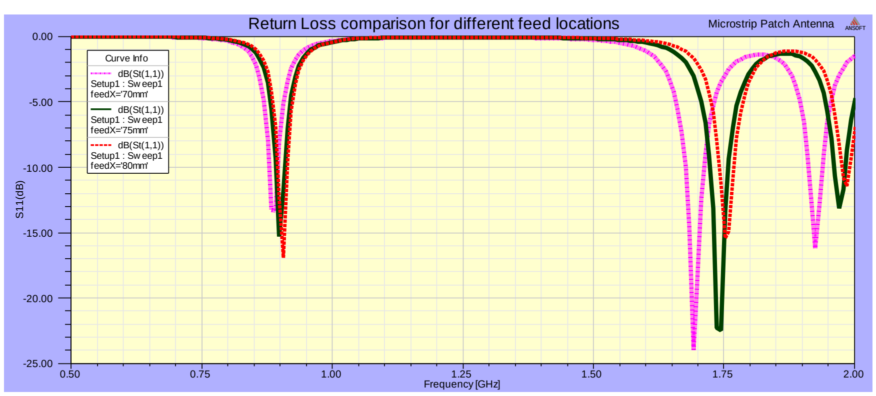

Figure 3: Return loss with change in Feed location

Two measures of stating the impedance matching are commonly used, both of which are based on the reflection coefficient, which is a measure of how much energy is reflected back into the source from the antenna's terminals. The first measure shows the reflection coefficient on a logarithmic scale as |S11|. Common definitions require that |S11| be below the -10 dB line to declare an acceptable impedance match. Fig 3 shows the reflection coefficient of the antenna with change in feed position. The bandwidth increases as the substrate thickness increases (the bandwidth is directly proportional to *h* if conductor, dielectric, and surface-wave losses are ignored). However, increasing the substrate thickness lowers the *Q* of the cavity, which increases spurious radiation from the feed, as well as from higher-order modes in the patch cavity. Also, the patch typically becomes difficult to match as the substrate thickness increases beyond a certain point (typically about 0.05 λ0).

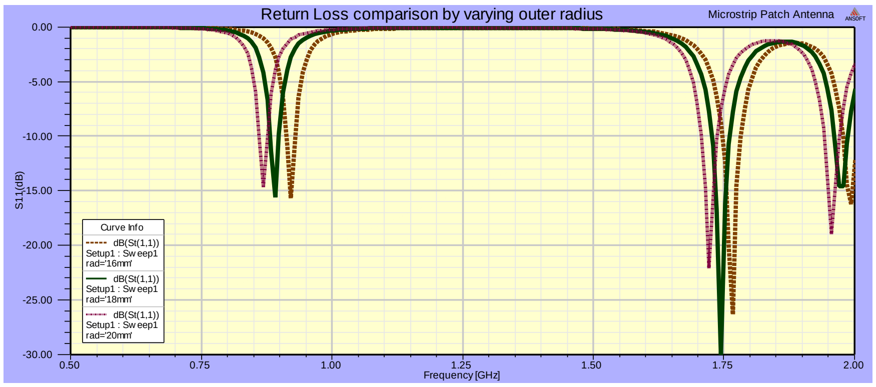

Figure 4: Reflection coefficient with change in radius

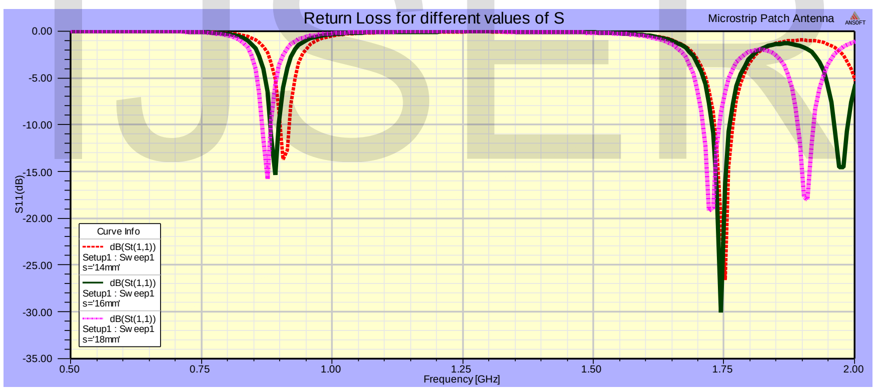

Figure 5: Reflection coefficient with change in S

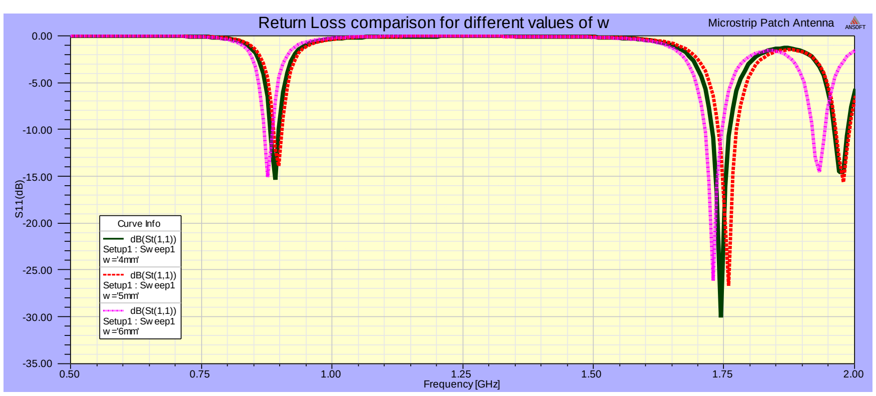

Figure 6: Reflection coefficient with change in W

After doing parametric analysis with change in different parameters of the antenna, finally the optimized model reflection coefficient is shown in Fig 7. The resonating frequencies are 899.5 MHz and 1758.8 MHz where the corresponding return loss are -14.63dB and -45.35dB. These are used for GSM applications.

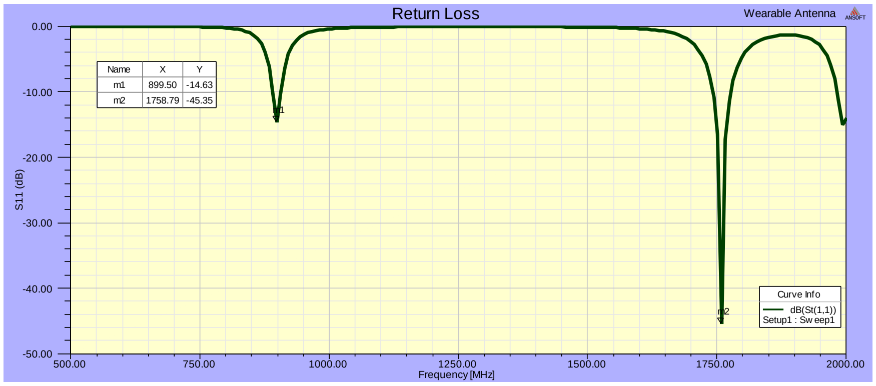

Figure 7: Proposed antenna return loss

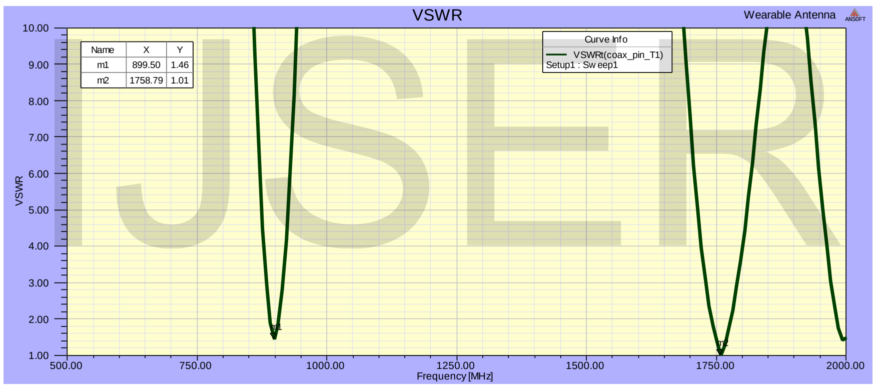

Figure 8: VSWR of the antenna

The second measure is similar, but on a linear scale and is referred to as VSWR (Voltage Standing Wave Ratio). In this terminology an antenna is deemed to be well matched to the line where VSWR is less than 2:1. Fig 8 showing the VSWR Vs Frequency curve for the proposed antenna. The VSWR's at resonant frequencies 899.5 MHz and 1758.8 MHz are 1.46 and 1.01 respectively.

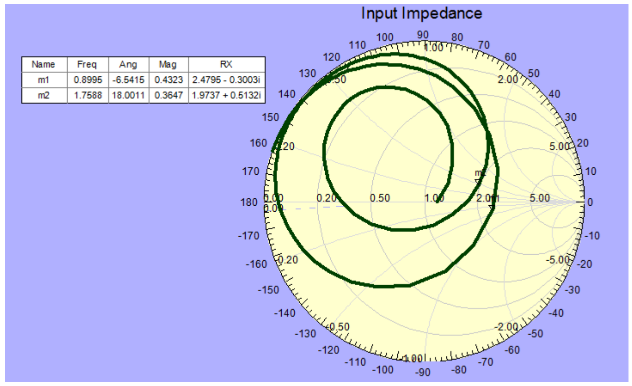

Figure 9: Input impedance smith chart

The bandwidth of an antenna refers to “the range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard”. The most common usage of bandwidth is in the sense of impedance bandwidth, which refers to those frequencies over which an antenna may operate. Fig 9 shows the input impedance smith chart and from which bandwidth of 0.91% is attained.

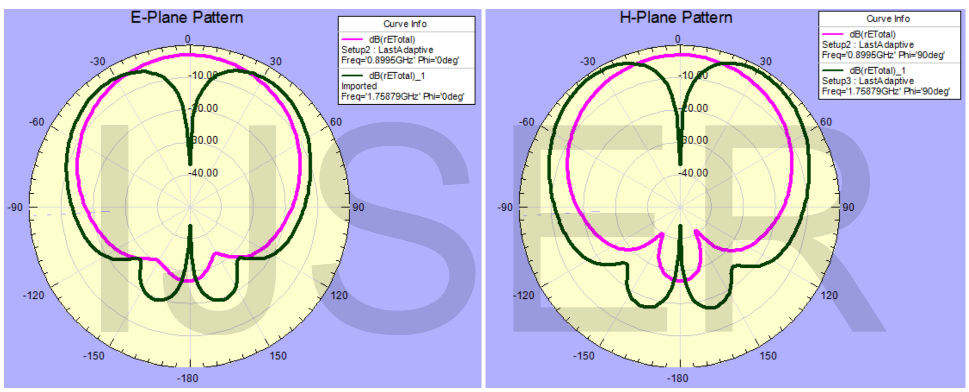

Figure 10: E-plane and H-plane radiation patterns

The radiation pattern of the antenna can be defined as the spatial distribution of a quantity that characterizes the electromagnetic field generated by an antenna. Fig 10 shows the radiation pattern of the antenna in phi and theta directions. The polar plots represent the radiation pattern in elevation and azimuthal angles. The radiation pattern represents the energy radiated from the antenna in each direction, often pictorially. E-Plane pattern (phi=0) and H-plane pattern (phi=90deg) at f=899.5MHz and f=1758.79MHz.

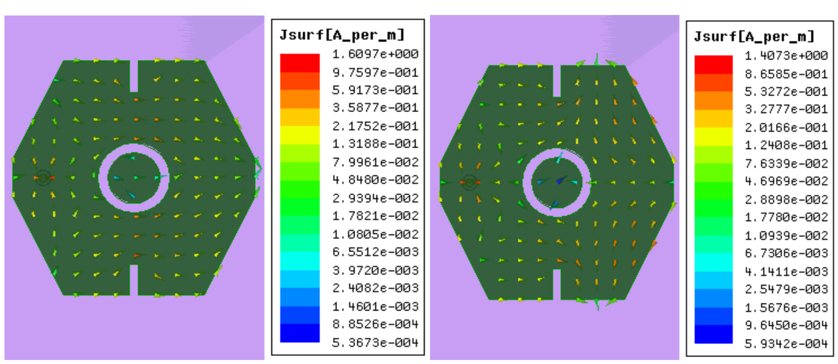

Figure 11: Surface currents at 899.5MHz and 1758.79 MHz respectively

The current distribution along the substrate and the patch is given in the Fig 11. The triangular zones at patch are having higher concentration over the zones on the substrate, which indicates the amount of current distribution and concentration on the surface of the antenna.

Conclusion: Here a polygon patch with circular slot is implemented to lengthen, the surface current path and thus the resonance frequency is decreased to desired band of operations. When compared with an antenna of the same resonance frequency of GSM band, a reduction of about 27.4% is achieved in antenna size. Though excellent size reduction is achieved, the bandwidth and the gain are very less. The 10-dB return loss bandwidth can be enhanced by using pair of transmission lines feed instead of coaxial feeding. Gain is enhanced to a great extent by making two annular slots. This work is thus a motivation towards applications where the overall volume of the structure is an important factor in modem wireless communication systems such as in GSM technology

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