Design Analysis of Single Band Micro Strip Antenna for Enhancing the Impedance Bandwidth

This chapter deals with two antenna designs, one is narrow band circular micro strip patch antenna (as a reference antenna) and the other one is wide band, compact sized micro strip antenna by using DGS (defected ground structure) and DMS (defected micro strip structure). The later design is of compact size and is used for enhancing the impedance bandwidth of the former by using a simple mathematical formula which has been developed to enhance the impedance bandwidth of the micro strip patch antenna and by inserting DGS & DMS in the micro strip antenna.

5.1 Introduction

Micro strip antenna is basically an antenna for the new generation style because of various advantages like light weight, less expensive, low profile, low manufacture cost and integrated with MMIC design, i.e., monolithic microwave integrating circuit design [176]. But, the microwave patch antenna may suffer from different types of disadvantages like excitation of the surface wave, narrow impedance bandwidth and poor radiation characteristics etc. The micro strip antennas input impedance has a tendency to be sensitive to alter or change in frequency, therefore the deviancy of an input impedance of a micro strip antenna from a actual fixed value frequently determine the micro strip antenna’s operating range. The micro strip antenna’s input impedance may hinge on its dimension/ geometrical shape and type of feeding technique. Hence, the input impedance of micro strip antenna is a very significant design parameter/ factor, which reins the radiating electromagnetic power and bandwidth (impedance) of micro strip patch antenna.

In most of the applications of wireless transmission, a high data-rate is required, so the low bandwidth of micro strip antenna is not acceptable. So, to fulfill the large bandwidth demand for wireless communication, different type of methods have been described;
one of the most commonly used methods is increasing the dielectric substrate thickness which is used for supporting the patch of micro strip antenna. But, the restriction or limitations still exist on the capability to effectively or successfully feed the micro strip patch on a dense dielectric substrate and the electromagnetic radiation proficiency can vitiate with the increasing thickness of dielectric substrate [177]. The band restricting or limiting problems can be overcome by various methods or techniques. The band restricting difficulty can be attained by using the technique of parasitic tuning elements, exterior matching and parting the micro strip antenna and feed. Impedance bandwidth of the circular micro strip patch antenna (CMSA) can also be enhanced by using the technique of defected ground structure (DGS) and the method of defected micro strip structure (DMS). The technique of using defected ground structure (DGS) was initially projected by Park et al [179] supported on the thought of photonic band-gap (PBG) structure, and had observed its useful application in the design of planar micro wave circuits and low-pass filters [178],[179],[180],[181]. DGS & DMS is achieved by etching a particular pattern in the micro strip patch antenna’s ground plane (defected ground structure) or on the defected micro strip structure (DMS). Defected micro strip structure disrupts the shield current distribution in the micro strip antenna’s ground plane. This disruption can alter the characteristics of an electromagnetic transmission line like equivalent inductance and capacitance to attain the slow-wave outcome and band-stop characteristic [182].

In the formulation method, a simple easy formula has been developed by using defected ground structure & defected micro strip structure. A simple circular micro strip patch antenna (CMSA) operating at 1.5659GHz having 0.48% impedance bandwidth has been used as a reference antenna. It has been shown that with DGS & DMS impedance bandwidth of the micro strip patch antenna has been increased from 0.48% to 20% when some defect is generated on the surface of line or on the micro strip antenna’s ground plane. In these designs simple mathematical formula has been developed and verified to enhance the impedance bandwidth of the micro strip patch antenna.
CHAPTER 5  DESIGN ANALYSIS OF SINGLE BAND MICROSTRIP ANTENNA FOR ENHANCING THE IMPEDANCE BANDWIDTH

meanwhile a size reduction technique to get compact size has also been applied. A circular micro strip patch antenna (CMSA) operating at 1.5659GHz having a reference antenna with impedance bandwidth 0.48% has been used. The impedance bandwidth of the micro strip patch antenna has been increased by using defected ground structure (DGS) and defected micro strip structure (DMS) from 0.48% to 20%. Additionally, it has been also revealed that the compensation marginally modifies SWR & reduces the size of the antenna. Here we apply Slot like DMS/DGS structure which is used to enhance the inductance of structure and reduce the capacitance but the product of both capacitance and inductance is same with respect to the reference antenna hence using this technique we get 19.5% increased BW and 72% reduced size.

5.2  Design Methodology

The two micro strip antennas have been designed, the first one is narrow band circular micro strip patch antenna and the other one is wide band circular micro strip patch antenna with DGS and DMS. The later design is used to increase the impedance bandwidth and to reduce the size of the former by inserting DGS & DMS. The work flow is shown in Figure 5.1.

**Antenna Design 1: Design of Micro Strip Antenna without DGS and DMS**

Firstly the microstrip patch antenna has been designed without disbursing the methods of defected ground structure and defected microstrip structure. Simple circular patch has been observed with various design parameters with the use of simple inset feed technique. The bandwidth achieved with this method was not up to the mark and hence the antenna with DGS structure was enforced to design.

**Antenna Design 2: Design of Micro strip Antenna by inserting DGS and DMS**

Secondly the micro strip antenna has been designed with the aim to accomplish wide bandwidth. In this design the DGS technique has been used
for the design as it worked well for enhancing the micro strip antenna’s bandwidth. The almost same design parameters are taken in this design.

Design and Simulation of Circular Patch Antenna at 1.56 GHz without DGS/DMS

Design Simulation and Measurement of the proposed Circular Patch Antenna with DGS/DMS for Achieving Wider Band at same frequency i.e 1.56GHz

Figure 5.1  Work flow

The Design and study of micro strip patch antenna is done with or without using defected micro strip technology/ defected ground structure.

5.2.1 Proposed Formulation

Higher bandwidth with compact volume in planner microwave devices is today’s need. But if size is reduced its gain and efficiency decreases. According to universal law BW×GAIN is always constant. Hence if we increase the bandwidth we lose the other parameter. The size of antenna can be reduced if the defected micro strip technology and the defected ground structures are used in a proper manner.

DGS technology is used by deliberately inserting the slot in the micro strip patch antenna’s ground plane.

DMS technology is used by deliberately creating the defect in the micro strip line.
Both these technologies can be used for increasing the performance of antenna parameters and the value of parameters used in the transmission line can be changed to different values.

If we create DGS & DMS, the inductance and capacitance of the circuit will be changed. According to the size reduction technique \[182\] if the product of inductance and capacitance created due to DGS & DMS are more than the previous then size will be reduced. But bandwidth enhancement technique is concern with the ratio of inductance and capacitance. Hence both the size reduction and band width will be achieved only when the product of inductance and capacitance as well as ratio of inductance and capacitance should maximum or both should be on compromised level. If the transmission line model of device is parallel tank circuit i.e. LC= maximum and L/C = maximum. Then by using maxima and minima we can achieve our goal by calculating the inductance and capacitance as:

Without Defect

\[
C_0 = \frac{1}{2\pi Z_0 (f_U - f_L)}
\]

and

\[
L_0 = \left( \frac{1}{4\pi^2 f_0^2 C_0} \right) \quad \text{or} \quad L_0 = \frac{Z_0 (f_U - f_L)}{2\pi f_0^2}
\]

We know that the quality factor is

\(Q_0 = \frac{f_0}{BW_0}\)

Where

\(f_0 = \) resonating frequency
\(f_U \) & \(f_L = \) cutoff frequencies (upper & lower respectively) at 10dB return loss,
$BW_0$=the bandwidth at operating frequency of a parallel tank circuit (without defect)

$$BW_0 = \frac{f_0}{Q_0} = \frac{f_0}{Z_0} \sqrt{\frac{L_o}{C_o}}$$

Where

- $z_o$ = characteristic impedance.
- $L_o$ = inductance at $f_o$ frequency
- $C_o$ = capacitance at $f_o$ frequency
- $Q_o$ is total Quality factor at resonance frequency.

(With defect)

When the defect is created in ground or on surface of line then due to slow wave geometry the new bandwidth at shifted frequency is

$$BW_d = \frac{f_d}{Z_0} \sqrt{\frac{L_d}{C_d}}$$

Where

$$C_d = \frac{1}{2\pi Z_0 (f_{du} - f_{dl})}$$

&

$$L_d = \left(\frac{1}{4\pi^2 f_d^2 C_d}\right)$$

Where

- $f_d$ = is shifted resonating frequency,
- $f_{du}$ & $f_{dl}$ = cutoff frequency (upper & lower respectfully) at 10dB return loss (with defect).
- $BW_d$ =is the bandwidth at operating frequency of a parallel tank circuit (with defect)
Where

\( z_o = \) characteristic impedance.

\( L_{d} = \) inductance at \( f_d \) frequency

\( C_{d} = \) capacitance at \( f_d \) frequency

After minimization of the size the resonant frequency of the patch is shifted to its previous resonant frequency due to alteration in parameters like capacitance and inductance then the bandwidth is

\[
BW_{dm} = \frac{f_0}{Q_{dm}} = \frac{f_0}{Z_0} \sqrt{\frac{L_{dm}}{C_{dm}}}
\]

By using tuning technique to achieve the criteria LC should be constant and \( L/C \) should maximum then higher bandwidth is achieved. After simulation we can calculate \( L_{dm} \) and \( C_{dm} \)

\[
C_{dm} = \frac{1}{2\pi Z_0 (f_{dmu} - f_{dml})}
\]

\[
& L_{dm} = \left( \frac{1}{4\pi^2 f_{dm}^2 C_{dm}} \right)
\]

Percentage increment in bandwidth in compact with regard to bandwidth of conventional design is

\[
\frac{BW_{dm} - BW_0}{BW_0} \times 100 = 100 \left( \sqrt{\frac{L_{dm} \times C_{dm}}{C_0 \times L_0}} - 1 \right)
\]

Here it can be seen that, if the quality factor is decreased, bandwidth is increased but circuit performance degrades. So the value of \( L/C \) ratio should be achieved carefully to achieve successful bandwidth without degrade the performance.
The L and C can be created and transformed by using slot and gap like structure on ground or on surface. The DGS slot on the ground is basically for introducing some kind of defect which can alter the micro strip antenna factors like impedance, resonant frequency, performance and electrical length of the structure.

The flow chart after introducing the DGS and DMS structures in the micro strip antenna’s ground plane and micro strip feed line is shown in Figure 5.2 below. The alteration in the parameters like impedance, inductance, capacitance, resonant frequency, performance and electrical length has been mentioned in the flow chart after introducing DGS in the design.

**Figure 5.2** Flow chart for the consequence of DGS/ DMS
5.3 Antenna Design and Geometry

5.3.1 Design of Circular Micro Strip Patch Antenna without DGS/DMS (as a reference antenna)

Design Specifications
The reference micro strip antenna with circular shaped patch has been designed with the inset feed technique.

With the proper selection of antenna dimensions and substrate thickness the input impedance of 50 ohm is achieved.

Figure 5.3 show the simulated model of simple circular patch antenna which has been used as a reference antenna. The parameters, dimensions, their descriptions can be tabulated for design specification of circular micro strip patch antenna without DGS and DMS (reference antenna) are mentioned in Table 5.1. In this simulated model – a circular patch with black color is shown at the top of the antenna’s system. This feed of the patch with electromagnetic energy is done through inset feed (micro strip line) technique which is also exists at the top of the system. The metallic ground with red color is also shown at the bottom side of the system. The dielectric material is present in between circular patch and the ground plane.

![Model of simple circular patch (simulated model)](image)

Figure 5.3   Model of simple circular patch (simulated model)
Design Parameters

The various parameters and dimensions of the reference circular patch antenna are mentioned in the Table 5.1 below. These design parameters like resonant frequency, material of the substrate, dielectric constant of the substrate material and dimensions of thickness of the substrate material, thickness of conductor material, patch radius, ground plane length, ground plane width, feed line length, feed line width and the gap side are essential in the design of reference antenna. There values are mentioned in Table 5.1 for microstrip antenna without using the technique of DGS and DMS.

Table 5.1 Design parameters of circular patch antenna without DGS/DMS

<table>
<thead>
<tr>
<th>Parameters/Dimensions</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resonant Frequency $f_0$</td>
<td></td>
<td>1.569 GHz</td>
</tr>
<tr>
<td>Substrate Material sub. mat.</td>
<td></td>
<td>RT Duroid 5880</td>
</tr>
<tr>
<td>Dielectric Constant of Substrate Material $\varepsilon_r$</td>
<td></td>
<td>2.2</td>
</tr>
<tr>
<td>Substrate Material Thickness $h$</td>
<td></td>
<td>0.7874mm</td>
</tr>
<tr>
<td>Thickness of Conductor $t$</td>
<td></td>
<td>0.035mm</td>
</tr>
<tr>
<td>Radius of patch $r_p$</td>
<td></td>
<td>38.2265mm</td>
</tr>
<tr>
<td>Length of ground plane $l_g$</td>
<td></td>
<td>80mm</td>
</tr>
<tr>
<td>Width of ground plane $w_g$</td>
<td></td>
<td>80mm</td>
</tr>
<tr>
<td>Length of feed line $l_f$</td>
<td></td>
<td>63.068mm</td>
</tr>
<tr>
<td>Width of feed line $w_f$</td>
<td></td>
<td>2.413mm</td>
</tr>
<tr>
<td>Gap size $g_p$</td>
<td></td>
<td>0.3mm</td>
</tr>
<tr>
<td>Feeding Technique-</td>
<td>Inset Feed</td>
<td></td>
</tr>
</tbody>
</table>
5.3.2 Design of Circular Micro Strip Patch Antenna With DGS and DMS (proposed antenna)

Design Specifications
The proposed micro strip antenna with DGS and DMS has also been designed with the inset feed technique. With the proper selection of antenna dimensions for ground plane (DGS dimension) and for the patch and substrate thickness the input impedance of 50 ohm is achieved.

Figure 5.3 and Figure 5.4 present the simulated model of the proposed micro strip antenna with DGS and DMS technique. The descriptions of parameters, dimensions can be charted for design specification of the proposed micro strip antenna with circular patch with the use of DGS and DMS technique (proposed antenna) are mentioned in Table 5.2. In this simulated model as shown in Figure 5.4 and Figure 5.5 – a cylindrical defected ground structure with some radius having rectangular slots which are 4 in number with some width and height and defected micro strip having outer angular ring with some thickness and inner cylinder attachment to the feed line is shown in the figure.
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The values of R1 (annular outer patch radius), R2, R1-R2 and R3 (outer patch radius) are:
R1=20mm (annular outer patch radius)
R2=14mm
R1-R2=6mm
Radius of the inner patch R3=10mm

Figure 5.4  Design of proposed circular micro strip patch antenna (Front View)

The values of radius R1,R2 and R1-R2 are:
R1=13.894mm
R2 =2mm
R1-R2=11.894mm

Figure 5.5  Design of proposed circular micro strip patch antenna (Back View)
Design Parameters

The various parameters and dimensions of the proposed micro strip antenna are mentioned in the table 5.2 below. These parameters are described with some values for the proposed micro strip antenna with circular patch using the defected ground structure and defected micro strip technique. With the use of DGS and DMS technique, the size of the antenna can be minimized and bandwidth of antenna can be increased. After creating the defect in ground plane and micro strip, some parameters differ from the parameters/dimensions mentioned in the reference antenna. The table is basically required for revealing the values of parameters which are suitable for the design.

Table 5.2 Parameters of the proposed circular patch antenna with DGS/DMS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resonant Frequency</td>
<td>f_r</td>
<td>1.569 GHz</td>
</tr>
<tr>
<td>Substrate Material</td>
<td>sub mat.</td>
<td>RT Duroid 5880</td>
</tr>
<tr>
<td>Dielectric Constant of Substrate Material</td>
<td>( \varepsilon_r )</td>
<td>2.2</td>
</tr>
<tr>
<td>Substrate Thickness</td>
<td>H</td>
<td>0.7874 mm</td>
</tr>
<tr>
<td>Thickness of Conductor</td>
<td>T</td>
<td>0.035 mm</td>
</tr>
<tr>
<td>Length of ground plane</td>
<td>l_g</td>
<td>80 mm</td>
</tr>
<tr>
<td>Width of ground plane</td>
<td>w_g</td>
<td>80 mm</td>
</tr>
</tbody>
</table>
The values of resonant frequency, dielectric constant, substrate thickness, conductor thickness, ground plane length and ground plane width is given in the above mentioned table.

Table 5.3 Parameters of the proposed circular patch antenna on ground plane – DGS dimension

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius of outer ground cylinder</td>
<td>R1</td>
<td>13.894 mm</td>
</tr>
<tr>
<td>Radius of inner ground cylinder</td>
<td>R2</td>
<td>2 mm</td>
</tr>
<tr>
<td>Thickness of Annular ring (Outer DGS etched dimension)</td>
<td>R1-R2</td>
<td>11.894</td>
</tr>
<tr>
<td>Length of rectangular slot (4-slots)</td>
<td>l_s</td>
<td>7.597 mm</td>
</tr>
<tr>
<td>Width of rectangular slot (4-slots)</td>
<td>w_s</td>
<td>2 mm</td>
</tr>
</tbody>
</table>

The values of radius of outer ground cylinder, radius of inner ground cylinder, thickness of annular ring (outer DGS etched dimension), Length of rectangular slot and width of rectangular slot is given in the above table. When the defected ground structure with outer cylinder with radius equal to 13.894 mm and inner ground cylinder with radius equal to 2 mm with thickness of angular ring equal to 11.894 are etched on the ground plane with the four slots having length and width equal to 7.597 mm and 2 mm respectively, then the proposed antenna produces the improved parametric value. Basically the defected ground structure on the ground plane is very effective for obtaining the enhanced bandwidth.
### Table 5.4 Parameters of the proposed circular patch antenna on patch – DMS dimension

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius of annular outer patch cylinder</td>
<td>R1</td>
<td>20mm</td>
</tr>
<tr>
<td>Radius of annular inner patch cylinder</td>
<td>R2</td>
<td>14mm</td>
</tr>
<tr>
<td>Thickness of Annular ring</td>
<td>R1-R2</td>
<td>6mm</td>
</tr>
<tr>
<td>Radius of the inner patch</td>
<td>R3</td>
<td>10mm</td>
</tr>
<tr>
<td>Length of feed line</td>
<td>l_f</td>
<td>30.18mm</td>
</tr>
<tr>
<td>Width of feed line</td>
<td>w_f</td>
<td>2.413mm</td>
</tr>
<tr>
<td>Gap Size</td>
<td>g_p</td>
<td>0.3mm</td>
</tr>
<tr>
<td>Feeding Technique</td>
<td>Inset gap Feed</td>
<td></td>
</tr>
</tbody>
</table>

The dimensions of ground plane and patch of the micro strip antenna after applying DGS/DMS have been changed according to the desired structure.

### 5.4 Experiment and Result Analysis

#### 5.4.1 Simulated Results and Discussion of Reference Antenna (Circular Micro Strip Patch Antenna DGS/DMS)

The inset feed Circular Micro Strip Patch Antenna (CMSA) has been designed as a reference antenna. 50Ω input impedance of the micro strip patch antenna is obtained through proper choice of substrate thickness and the antenna dimension.

RT Duroid 5880, which has relative permittivity of 2.2 & a thickness of 0.7874 mm, has been used as a substrate material.

The patch dimension of radius a=38.2265 mm has been selected along with feed line dimension of length L=63.068mm, width W=2.413mm & a gap of 0.3mm as shown in Figure 5.1.
For the above mentioned physical dimensions, the designed antenna (reference) operates at
Operating Frequency \( f_0 \) 1.569 GHz with
return loss of 19.87 dB at the resonant frequency.
the VSWR at \( f_0 \) is 1.226 and
the bandwidth at -10 dB is 7.49 MHz.
The results have been calculated from the Figure 5.2.

**Return loss versus Frequency graph**
When the simulation results of the reference antenna or antenna without defected ground structure and defected micro strip structure are observed and measured, the following graphs between parameter return loss and other parameters frequency is obtained. The graph shown that the antenna operates at 1.569 GHz with return loss of 19.87 dB having bandwidth of 7.49 MHz (at -10dB return loss). The VSWR from this graph is approximately equals to 1.23.

![Return loss versus frequency graph](image)

**Figure 5.6** Return loss verses frequency
From the above figure it can be observe that
Operating Frequency \((f_0) = 1.569 \text{ GHz}\)
Return loss at \((f_0) = 19.87 \text{ dB}\)
Voltage standing wave Ratio (VSWR) at \((f_0) = 1.226\)
Bandwidth at -10 dB = 7.49 MHz

**Calculation of Inductance & Capacitance**

In case of reference antenna
\(L_o = 0.0243\text{nH}, \ C_o = 424.413\text{pf}\)

### 5.4.2 Measured and Simulated Results of Proposed Antenna (Circular Micro Strip Patch Antenna with DGS/DMS)

A new circular micro strip antenna that consist of DGS having cylinder of radius 2mm & four rectangular slot which has a length \(L=7.597\text{ mm}\) & width \(W=2\text{ mm}\) along with a annular ring of thickness 11.894 mm. It also consists of a DMS having annular ring of thickness 4 mm & an inner cylinder of radius 10 mm at the center. The designed antenna operates at Lower resonant frequency. The fabricated antenna is shown in Figures 5.7 and 5.8 below. In the fabrication model, the different parts of the antenna in from view and in the back view are displayed.

The top part of the top view of the antenna in figure reveals the patch micro strip line and effect of DMS.

The bottom of the back view of the fabricated circular micro strip antenna indicates the defected ground structure with four rectangular slots. Each part of the proposed antenna given in the figure has some dimensional values. The upper part of the micro strip antenna system contains patch and the feed line with the connection point for feeding electro-magnetic energy. The bottom part in the figure indicates the ground plane with defected ground structure and the back side of the connection point for feeding the electromagnetic energy. The DGS and DMS with various shapes and size have been shown in the below mentioned diagrams. With the help of DGS and DMS, various parameters of the micro strip antenna can be improved.
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Figure 5.7  Fabricated circular micro strip patch antenna (Front View)

Figure 5.8  Fabricated circular micro strip patch antenna (Back View)
Size reduction due to DGS and DMS
Design of DGS & DMS embedded circular patch antenna shown in figure 5.8. Now the circular patch micro strip antenna has following dimension parameter

**Dimension Details-**

Ground dimension is 80mm × 80mm.
Conductor thickness t=0.035 mm. Dielectric thickness is 0.7874mm

On ground plane DGS dimension –

(1) Inner ground cylinder of radius is 2mm and four rectangular slots are cut. Each has dimension 
    \( L=7.597\) mm, \( W=2\) mm

(2) Outer DGS etched has dimension 
    \( R_1-R_2=11.894\) mm.

The measured values of defected ground structure dimensions for the size reduction are mentioned in the above description. The dimensions in terms of inner ground cylinder, four rectangular slots and outer etched defected ground structure are specified.

Now for patch, annular outer patch has radius 20 mm.

And \( R_1-R_2 \) = 6 mm.

Lower cut on this circular strip is of 6 mm.

Now for inner patch has radius 10mm

Feed line (inset gap feeding) has dimension

\( L=30.18\) mm
\( W=2.413\) mm
Gap is 0.3mm

**Inductance & Capacitance-calculation**

In case of antenna with reduced dimensions

\( L_{dm} = 1.0209\) nH, \( C_{dm} = 10.1613\) pf
CHAPTER 5  DESIGN ANALYSIS OF SINGLE BAND MICRO STRIP ANTENNA FOR ENHANCING THE IMPEDANCE BANDWIDTH

Table 5.5  Size reduction due to DGS and DMS

<table>
<thead>
<tr>
<th>Antenna Description</th>
<th>Radius(mm)</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional antenna (without DMS)</td>
<td>38.02265</td>
<td>48</td>
</tr>
<tr>
<td>Antenna embedded with DGS and DMS (with tuned location)</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

From the above table, the size of conventional and proposed antenna indicates the values of radius of both the antennas and percentage reduction. By using the size reduction technique, the overall size of the proposed antenna is compressed to 48%.

Return loss versus Frequency graph

The return loss of the micro strip antenna and operational frequency graph indicates the important parameters of the micro strip antenna. The bandwidth of the micro strip antenna can be calculated using return loss versus frequency graph.

The standard value for the return loss should be -10dB and parameters can be calculated. Where parameter values can be calculated at -10dB return loss, bandwidth and the voltage standing ratio are the important parameters which can be calculated with the help of the graph which is between return loss and the frequency. The simulated results in the below figure is mentioned in the pink color graph line and measured values are mentioned in brown color graph line. The graph increases in the negative side when the frequency increases and after the threshold value, with the increase in frequency, the return loss increases in a positive side.
Figure 5.9  Measured impedance bandwidth of compact CMSA

The impedance bandwidth of compact circular micro strip antenna is calculated from the Figure 5.9 above.

Simulated results from the Figure 5.9
When the above mentioned dimensions of proposed antenna are simulated on electromagnetic simulator environment, the proposed antenna operates at 1.565Gz with impedance bandwidth of 313.2 MHz on -10 dB which correspond to 1.29 VSWR, which is much more with regard to the reference antenna. The return loss of proposed antenna comes to 43.04 dB.
The results have been calculated from the Figure 5.9.
Return loss at \( f_0 \) =43.04dB 
Voltage standing wave Ratio (VSWR) at \( f_0 \) =1.29 
Bandwidth at -10dB= 313.20MHz

**Calculation of Inductance & Capacitance-**
In case of antenna with reduced dimensions
\[ L_{dm} = 1.0209nH \]
\[ C_{dm} = 10.1613pf \]

The values of various parameters of designed micro strip antenna like return loss, voltage standing wave (VSWR) ratio and bandwidth at -10dB from the graph are given above and the calculated values of resistance and capacitance after applying DGS and DMS are also mentioned.

**Measured results from the Figure 5.9**
When the above mentioned dimensions of antenna are measured, the proposed antenna operates at 1.5608 GHz with impedance bandwidth of 313.11 MHz on -10 dB which correspond to 1.0458 VSWR, which is much more with regard to reference antenna. The return loss of proposed antenna comes to 41.20 dB. The results have been calculated from the figure 5.9.

**Measured results are**
From the above figure it can be observe that
Operating Frequency \( f_0 \) =1.5608GHz 
Return loss at \( f_0 \) =41.20dB 
Voltage standing wave Ratio (VSWR) at \( f_0 \) =1.0458 
Bandwidth at -10dB= 313.11MHz
Calculation of Inductance & Capacitance-
In case of antenna with reduced dimensions
\[ L_{dm} = 1.0209 \text{nH}, \quad C_{dm} = 10.1613 \text{pf} \]

The values of antenna’s lumped parameters such as the inductance and the capacitance can be calculated from the proposed formulation and these parameters also directs towards the reduced dimensions of the micro strip antenna. The values of inductance and capacitance should be in such a manner that the size of the antenna can be reduced and performance of other parameters can be enhanced.

**TABLE 5.6  Simulation and measured results of proposed antenna**

<table>
<thead>
<tr>
<th>ATTRIBUTE</th>
<th>SIMULATED RESULTS OF PROPOSED ANTENNA WITH DGS AND DMS</th>
<th>MEASURED RESULTS OF PROPOSED ANTENNA WITH DGS AND DMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>RESONANT FREQUENCY (GHz)</td>
<td>1.565</td>
<td>1.5608</td>
</tr>
<tr>
<td>RETURN LOSS (dB)</td>
<td>43.04</td>
<td>41.20</td>
</tr>
<tr>
<td>VSWR (At ( f_0 ))</td>
<td>1.29</td>
<td>1.0458</td>
</tr>
<tr>
<td>BANDWIDTH (MHz) (At -10 dB)</td>
<td>313.20</td>
<td>313.11</td>
</tr>
</tbody>
</table>

The simulated results of the proposed antenna with DGS and DMS and measured results of the proposed antenna with DGS and DMS are shown in the above table and it is observed that there is no major variation between the simulated results and the measured results in some parameters.
5.4.3 Comparison of Performance of both the antennas

When the performance of conventional antenna without DGS and DMS and the proposed antenna embedded with DGS and DMS on the tuned location is observed, it can be seen that both the antennas are operating at almost same resonant frequency but impedance bandwidth is different. The antenna with DGS and DMS can increase the bandwidth from 0.48% to 20% and the size of antenna can be reduced to 48% as given Table 5.5. The measured parameters of the proposed micro strip antenna are tabulated in Table 5.7. When the proposed antenna is designed according to the technique which has been used in the proposed antenna design, the various parameters like bandwidth, resonant frequency, VSWR and return loss can be calculated.

Table 5.7  Comparison of performance of both antennas

<table>
<thead>
<tr>
<th>Conventional antenna (without DGS/DMS)</th>
<th>Resonant frequency (GHz)</th>
<th>Return Loss (dB)</th>
<th>VSWR At (f0)</th>
<th>Bandwidth (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.5659</td>
<td>19.87</td>
<td>1.226</td>
<td>7.49</td>
</tr>
<tr>
<td>Antenna embedded with DGS and DMS</td>
<td>1.5608</td>
<td>41.20</td>
<td>1.0458</td>
<td>313.11</td>
</tr>
<tr>
<td>(From Measured Results and tuned location)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The performance of the reference antenna and the proposed antenna is compared in the above Table 5.7.

The values of reference antenna (without DGS and DMS) are:

- Resonant Frequency = 1.5659 GHz
- Return Loss = 19.87 dB
- VSWR = 1.226 \( f_0 \)
- Bandwidth = 7.49 MHz

The values of proposed antenna (with DGS and DMS) are:

- Resonant Frequency = 1.5608 GHz
- Return Loss = 41.20 dB
- VSWR = 1.0458 \( f_0 \)
- Bandwidth = 313.11 MHz

The result in Table 5.6 and Table 5.7 indicates the circular micro strip antenna with DGS and DMS can increase impedance bandwidth from 0.48% to 20% and the size of the antenna has been reduced to 48%.

Table 5.6 indicates the proposed antenna with different attribute values. Here, in this table, the values of the proposed antenna, which has been designed with the technique of DGS and DMS are specified. The result of the proposed antenna is in terms of simulated form and in measured form.

In Table 5.7, the comparison of performance of reference antenna without DGS and DMS and the proposed antenna with DGS and DMS has been calculated.

5.5 **Additional Simulated Graphs of Conventional (Reference) Micro Strip Antenna**

Some additional graphs of simulated results of reference (conventional) micro strip antenna are also studied for various other parameters.
Figure 5.10 S-Parameter magnitude (S11) vs frequency graph for reference micro strip antenna

The Figure 5.10 indicates the graph between S parameters (magnitude) and frequency for the reference antenna. It is observed from the graph that as the frequency increases, the magnitude of the S parameter decreases. But, after reaching some lever, the magnitude of the S parameter starts increases with the increase in frequency further. The peak value at the downward side graph indicates that value of frequency which can be known as resonant or operating frequency.
Figure 5.11 VSWR vs frequency plot for reference micro strip antenna

The Figure 5.11 specifies the graph for reference antenna, between the voltage standing wave ratio VSWR and the frequency in GHz. It is studied from the graph that at frequency 1.569GHz, the value of voltage standing wave ratio is 1.226 at f₀.

In fact the standing wave ratio is the indication to the received energy with or without loss. The system for transmitting power (radio frequency power) is effectively efficient or not depends somewhat on this parameter. The practical value of VSWR should be very low. The higher value vitiates the enactment of the communication system.

The graph for finding VSWR is very simple and can be studied easily. The value finding is easy.

Smith Chart

Smith chart is a contrivance for the circuits which can handle very high frequency. The applications which entail very high frequency; the smith chart is the good option for calculating or finding the values of various parameters.
The smith chart in Figure 5.12 shown above is powerful tool for calculating reference antenna’s parameters.

The smith chart epitomizes that the impedance of antenna vary with the variation in the frequency. In the above figure the impedance of S parameter (reflected) which is of complex in nature is shown within the indicating range of frequencies. In this plot the scale used for indicating values is basically a normalized impedance scale. Many problems of the transmission line require the need for the characteristic impedance so smith chart scale requires a scale of normalized impedance. The characteristic impedance’s preferable value is 50 ohm. In the above figure the parameter frequency is mentioned in the GHz and impedance ranges are also designated.
The reference antenna’s phase versus frequency in GHz graph is displayed in Figure 5.13. Basically the graphs showed above reveals the performance of the reference antenna in terms of phase change with respect to frequency. The phase in S parameters is represented in degrees on the vertical axis and the frequency in GHz scale is cited on horizontal axis. At the resonant frequency of 1.569 GHz the change of phase occurs in the displayed shape manner. The range of the phase scale is from 0 to 180 degrees in the upward positive side and the range of scale of phase is 0 to-180 degrees in downward side. The phase disparity or deviation according to the GHz frequency is presented above. The variation of the phase is very less before the reference antenna’s resonating frequency but after attaining the resonating frequency there is an abrupt change in the phase. The value on the scale of the phase goes on increasing or decreasing as the variation in the frequency occurs.
The real part of the V/A matrix coefficient in revealing the impedance is shown in Figure 5.14

![Real Part of V/A Matrix Coefficient in Z vs Frequency Graph](image)

**Figure 5.14** Real part of V/A matrix coefficient in Z vs frequency graph for reference antenna

In directly above mentioned figure the frequency is on the flat scale in GHz and values of the impedance are measured on the straight up shown in the figure scale. The value of the real part of the impedance varies according the change in the frequency. But from the figure above it can be said that before reaching the resonant frequency of the reference antenna the variation in the impedance is very very small. The preferred value for the impedance in most of the cases is almost 50 ohm. So in the above figure, at resonant frequency the value of the impedance touched is at some higher value. After attaining the peak positioned value the graph starts decreasing. As the frequency of the micro strip antenna fluctuates, the fluctuations in the impedance are seen at the resonant frequency.
The impedance parameter is an imperative parameter in knowing the performance of the microstrip or any other type of the antenna and it depends on the circuit signals which are in terms of voltage and current.

**Figure 5.15** imaginary parts of V/A matrix coefficient in Z vs frequency graph for reference antenna

The imaginary part of the V/A matrix coefficient in stating the impedance is shown in the above figure which is different from the real part impedance. In straight directly above cited figure, it is seen that the frequency lies on the plane horizontal scale in GHz and beliefs of the impedance are revealed on the plane vertical up shown in the figure scale. The imaginary part of the impedance of V/A Matrix fluctuates conferring to the change in the frequency.
Right from the image shown in the figure above it can be concluded that the imaginary impedance varies between imaginary and non-imaginary values. As the given frequency varies, a variant in the impedance is observed. The impedance basically fluctuates before and after the resonant frequency. The value which is very much common in the desired list or in many applications is around fifty ohm. But here the maximum value that has been obtained is from the figure is less than thirty ohm. After accomplishing the high sited value the graph in the figure flinches decreasing and as the frequency further changes, a change in the impedance is also seen.

Figure 5.16  Magnitude of V/A matrix coefficient in Z vs frequency graph for reference antenna
In the above cited or revealed figure the frequency is in GHz on the horizontal scale and tenets of the impedance which are restrained are on the vertical up figure scale. The value of the measured impedance diverges depends on the deviation in the frequency. Then from the above figure it can be believed that before the attainment of the resonant frequency of the reference antenna the impedance disparity or variation is in different way as compared to the real impedance graph variation. The favored value in maximum of the cases for the attained impedance is practically fifty ohm. So according to the above figure the value of the impedance gladdened at some higher value at resonant frequency. After achieving the topmost placed value the impedance graph starts decreasing. As the microstrip patch antenna’s frequency varies, the variation in the impedance is observed at the resonant frequency. The parameter (impedance) is an essential parameter in expressive the performance.

Figure 5.17 Phase of V/A matrix coefficient in Z vs frequency graph for reference antenna
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The antenna which is known as reference antenna whose phase of V/A matrix has been recorded for different frequencies for the performance. So the graph which is between frequency and the phase is shown in the above mentioned figure. Fundamentally the graphs presented directly above in Figure 5.17 exposes the enactment of the reference micro strip antenna in terms of change in phase of the antenna change with respect to change in frequency. The phase representation in S parameters graph is in degrees on the vertical or the upward affiliation and the frequency in GHz measure is mentioned on horizontal or straight axis. The phase changes according to the change in frequency but when reaches at the resonant frequency of the reference antenna at 1.569 GHz the variation of phase happens in the exhibited form way. The assortment of the phase scale is from zero to 180 degrees in the vertical upward side and the range of scale of phase is 0 to 180 degrees in downward side. The change in the phase is according to the GHz frequency as mentioned above. Initially the variation in the phase is in a smaller amount with the frequency change but after achieving the resonating frequency there is a sudden variation in the phase. The scale of the goes on increasing or decreasing as the variation in the frequency occurs.

5.6 Additional Simulation Graphs of Proposed Micro Strip Antenna

Several supplementary graphs of proposed microstrip antenna’s simulation results have also been studied for many other parameters. The Figure 5.18 specifies the diagram between S parameters (magnitude) and the specified frequency in GHz for the proposed antenna. It is perceived from the diagram that when the frequency increases, there is a decrease in the magnitude of the S parameter. But when the frequency increases and reaches the resonant frequency then the magnitude of the S parameter jumps and upturns with the frequency progress. The bottom most value at the downward side graph point to that value of frequency which is basically known as operating frequency.
Figure 5.18 S-Parameter (S11) vs frequency graph for proposed micro strip antenna

The Figure 5.18 specifies the diagram between S parameters (magnitude) and the specified frequency in GHz for the proposed antenna. It is perceived from the diagram that when the frequency increases, there is a decrease in the magnitude of the S parameter. But when the frequency increases and reaches the resonant frequency then the magnitude of the S parameter jumps and upturns with the frequency progress. The bottom most value at the downward side graph point to that value of frequency which is basically known as operating frequency.
Figure 5.19  VSWR vs frequency plot for proposed micro strip antenna

The Figure 5.19 states the graph for VSWR calculation for the proposed antenna. The graph is between the frequency in GHz and voltage standing wave ratio VSWR. It is observed from the figure that at frequency 1.565GHz, which is basically a resonant frequency of the antenna, the value of voltage standing wave ratio is 1.29.

Actually the VSWR or Voltage Standing Wave indicates whether the received energy is with or shorn of loss. This parameter is very effective for finding that the method or system for transporting the energy (radio frequency power) is excellently proficient or not. The voltage standing wave ratio should have a very low value for system to be efficient. The VSWR with higher side values of the range indicates the communication system is not working properly. So the performance of the system also depends upon this parameter. In the above graph the value is 1.29 which indicates that the system is better but not ideal for the radiation loss.
The Smith chart displayed in Figure 5.20 shown above is potent contrivance for computing the parameters of the proposed antenna here. Basically a Smith chart is a setup or an effective tool for handling the high frequency type. The calculation of the various parameters can be done for the systems which require very high frequency applications. So this is the good alternative graphical method for finding the various parameters value for the antenna system.

The impedance of the proposed micro strip antenna which works on the GHz frequency has been premeditated with the service of smith chart. In the figure mentioned above the reflected s-parameter impedance on the smith chart is basically complex in nature in the given range of frequencies.
In this chart, normalized values of impedance on the scale of smith chart are used for impedance scale. Normalized impedance scale is very much required in many transmission line problems because the value of the parameter characteristic impedance is required in many transmission line problems. For plotting the impedance values properly in the chart, the normalized values of impedance are required for proper plotting within range. The desirable value for characteristic impedance is 50 Ohm in almost all applications related to microstrip antenna. In the above displayed graph the frequency is given particularly in the GHz and ranges of impedance are also mentioned.

**Figure 5.21** Phase vs frequency graph for proposed antenna
The phase versus frequency in GHz graph of the projected antenna where the frequency is in GHz and the phase is in degrees is exhibited in Figure 5.21. Mainly the graphs presented above exposes the enactment of the proposed micro strip antenna in relations of changes occurs in phase with respect to the frequency. The upward side plane in the vertical, the phase values in s-parameters are epitomized in degrees and the frequency in GHz scale is quoted on horizontal axis. As the frequency changes the change in the parameter phase in degrees has also been seen. Before and after the resonant frequency value i.e 1.565 GHz the variation in the phase transpires in the shape shown in graph. The phase scale range is from 0 to -180 degrees in the lower or downward scale (negative side) and the range of scale of phase is 0 to +180 degrees in upper or positive scale. The phase inconsistency or deviance according to the frequency is presented in the graph. The value of the phase goes on growing or falling as the deviation in the frequency happens.

![Real Part of V/A Matrix Coefficient in Z vs Frequency Graph](image)

**Figure 5.22** Real part of V/A matrix coefficient in Z vs frequency graph for proposed micro strip antenna
In the above mentioned figure (Figure 5.22), the frequency in GHz unit is on the horizontal axis and impedance values are mentioned on the vertical up axis as shown in the figure scale. The variation in the impedance values differ according to the variance in the frequency values. It is observed from the above revealed graph that before attaining the resonant frequency of the proposed antenna, the impedance value variations are very nominal. The desired value for the micro strip antenna’s impedance in almost all the cases is 50 ohm. Hence, in the above diagram, the value of impedance is observed near to 50 ohm at given resonant frequency which is quiet ok. The graph in the figure starts in the decreasing side after the attainment of the upper most value of the resonant frequency. A fluctuation in the impedance value occurs whenever there is any change in the frequency of the micro strip antenna.

It is an effective parameter for calculating the performance of a communication micro strip antenna and it relies on the current and voltage of the circuit.

Figure 5.23  Imaginary part of V/A matrix coefficient in Z vs frequency graph for proposed micro strip antenna.
The graph shown in Figure 5.23 reveals the information about the imaginary part of the V/A matrix in the Z-coefficient or impedance coefficient versus frequency. The graph shown in the figure changed from the real part impedance.

It is observed from the figure that the frequency is on the horizontal axis in GHz and V/A matrix coefficient in impedance is on the vertical axis as reflected in the figure. Whenever the change in frequency occurs, the values of V/A matrix coefficient will vary accordingly.

The above graph fluctuates between imaginary and non-imaginary values. After reaching the resonant frequency, the graph starts decreasing towards the imaginary side.

Figure 5.24  Magnitude of V/A matrix coefficient in Z vs frequency graph for proposed micro strip antenna
In the figure 5.24, the magnitude of V/A matrix coefficient in impedance \( Z \) versus frequency change is displayed. Here also, the frequency is on the flat axis in GHz and the magnitude of the impedance (V/A matrix coefficient is displayed on the perpendicular axis. The variation of the impedance according to the variation in frequency is shown in the graph above. The graph studied for real impedance is somewhat different from the graph attained here. The desired value of impedance that is 50 ohm has been seen at the resonant frequency in the graph. In most of the cases, the impedance 50 ohm is desired. But as seen from the figure that the value of impedance further increases after the resonant frequency and then starts decreasing after attaining the maximum value.

**Figure 5.25** Radiation pattern for E-plane of proposed micro strip antenna for directivity at 1.5608GHz
The figure 5.25 is basically a smith chart for finding an understanding the radiation pattern of the E plane of proposed antenna for directivity at 1.5608 GHz. The two lobes of radiation pattern are shown in the figure above. The calculations are done at the farfield at frequency 1.5608. The following observations have been obtained: The resonant frequency is 1.5608 GHz, main lobe magnitude is equal to 4.2 dBi, main lobe direction is 5.0 degree and angular width at 3 dB is equal to 77.3 degree.

**Figure 5.26** Radiation pattern for E-Plane of proposed micro strip antenna for gain at 1.5608GHz

The figure 5.26 explains the smith chart to understand the radiation pattern of the E plane of proposed antenna for gain at 1.5608 frequencies. The observations are made at the farfield at frequency 1.5608. The following results are obtained:
The resonant frequency is 1.5608 GHz, main lobe magnitude is equal to 4.2 dB, main lobe direction is 5.0 degree and angular width at 3 dB is equal to 77.3 degree.

**Figure 5.27** Radiation pattern for E-plane of proposed micro strip antenna for E-field at 1.5608GHz

The figure 5.27 indicates the radiation pattern for the proposed antenna for E plane and for E field at the resonant frequency of 1.5608 GHz and the following values are observed:
The resonant frequency is 1.5608 GHz, main lobe magnitude is equal to 19.0 dBV/m, main lobe direction is 5.0 degree and angular width at 3 dB is equal to 77.3 degree.
The figure 5.28 shows the radiation pattern for the proposed micro strip antenna for axial ratio at 1.5608 GHz frequency and the following values are observed:

The resonant frequency is 1.5608 GHz, main lobe magnitude is equal to -73.9 dBi,
CHAPTER 5  DESIGN ANALYSIS OF SINGLE BAND MICRO STRIP ANTENNA FOR ENHANCING THE IMPEDANCE BANDWIDTH

The figure 5.29 measures the radiation pattern for the proposed micro strip antenna for E field at 1.5608 GHz frequency and the following results are obtained:

- Resonant frequency: 1.5608 GHz
- Main lobe magnitude: -6.8 dBm/2
- Main lobe direction: 5.0 degree
- Angular width at 3dB: 77.3 degree

**Figure 5.29** Radiation Pattern of proposed micro strip antenna for E field at 1.5608GHz
Figure 5.30  Radiation Pattern of proposed micro strip antenna for far field (max= 0dB) at 1.5608GHz

The figure 5.30 is basically for the radiation pattern for the proposed micro strip antenna for far field (max =0 dB) at 1.5608 GHz frequency and the following values are observed:
- The resonant frequency is 1.5608 GHz
- Main lobe magnitude shown in the figure is equal to 0.0 dB
- Main lobe direction is equal to 5.0 degree
- Angular width at 3dB is equal to 77.3 degree
5.7 Concluding Remarks

In this chapter, a new formula for bandwidth enhancement is developed and verified successfully by applying it to CMSA. This chapter embraces the design and simulation of two different circular shaped micro strip antennas. Firstly the reference or base microstrip antenna has been studied. The reference antenna without defected ground structure and defected micro strip structure has been designed with values as shown in the Table 5.1. The simulation and various results for different parameters have been analyzed from the different graphs. It has been concluded from the results of reference antenna that the bandwidth is very narrow. The proposed antenna with defected ground structure (DGS) and defected micro strip (DMS) has been analyzed and observed. The design parameters values have been mentioned in the table 5.2. The proposed antenna with DGS/DMS technology has improved bandwidth in comparison with the reference antenna without any etching. Various observations have been done for the proposed micro strip antenna also. The proposed micro strip antenna is very much in better in performance wise. The wide bandwidth and compact size as compare to reference antenna has been achieved by using the technique of DGS and DMS in the designed microstrip antenna.

A number of graphs of simulated results telling the micro strip antenna presentation are contrived and the conclusion of parameters of antenna showing the performances of antenna have also been studied and related on a electromagnetic simulator of 3 dimensional configurations. In the Initial part of this chapter the design methodology with proposed formulation is detailed. Afterwards the design and dimension and simulation of reference or conventional microstrip antenna with circular patch antenna and proposed circular patch micro strip antenna with or without the use of defected ground plane structure and defected microstrip organization is described. Finally at the end of the chapter the comparison of the conventional (reference) and proposed micro strip antenna with DGS and DMS technologies have been done successfully.
Various comparisons have been made and studied with the help of several other simulated graphs mentioned at the end of this chapter. The chapter is concluded with the experiment done and study of outcome in the form of result performance for both the microstrip antennas with and without DGS or DMS with simulated graphs with concluding statements. This chapter mainly divulges the suggested work for increasing the bandwidth and for reducing the size of microstrip patch antenna for single band configuration. Result in the table 5.5 & 5.7 shows that CMSA with DGS and DMS can improve the bandwidth from 0.48% to 20%. Meanwhile, utilizing size reduction techniques, the size of the antenna has been reduced to 48%.