Dual Frequency Dual Polarization Microstrip Slotted Antenna On A Single Layer:-
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Abstract:-
Some designs of slot antenna's are explored keeping in mind the requirement for miniature wireless services like one in Bluetooth, Biomedical implants, Mobile phones etc. A modification to prevailing design is tried out and comparable results are obtained with less complexity. The antenna was designed using ADS simulation tool. The proposed antenna is capable of generating dual resonant frequencies with dual perpendicular polarizations.

Introduction:-
In recent years the demand for broad-band antennas has increased for use in high frequency and high speed data communication. Printed antenna's are economical and can be accommodated in the device package. Microstrip antennas are best form of printed antennas because they are light weight, low profile, low cost, ease to analyze and fabricate and are compatible with the integrated circuit.

This project report discusses some types of slotted antenna simulated and a finally tested with the simulation and experimental results.

1) Cross Slot Microstrip Antenna:
In cross slot microstrip antenna the two separate operation frequencies are obtained with orthogonal polarisation planes and the impedance matching for the two frequencies can be obtained using a single probe feed. Figure:-1 below shows the layout of the cross slot MSA. Table:-1 highlights the design parameters and frequency measured from the simulations.
still remains unchanged.

Fig:.-2 Dependence of resonant frequency on the length of slot with $W = 1\text{mm}$.

Table:.-1 Design parameters summary:-

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_1$ First Resonant Frequency</td>
<td>1.85 GHz</td>
</tr>
<tr>
<td>$F_2$ Second Resonant Frequency</td>
<td>2.37 GHz</td>
</tr>
<tr>
<td>$L$</td>
<td>37.7mm</td>
</tr>
<tr>
<td>$W$</td>
<td>28.4mm</td>
</tr>
<tr>
<td>Slot Width $W$</td>
<td>1mm</td>
</tr>
<tr>
<td>Slot Length</td>
<td>8mm</td>
</tr>
<tr>
<td>$F_2/F_1$</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Figure:.-3 shows the radiation pattern and the S11. From the plot of S11 its clear that the patch exhibit dual frequency response.

<table>
<thead>
<tr>
<th>$m_1$ freq=1.829GHz</th>
<th>$m_2$ freq=2.360GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{dB}(\text{second_mom_a..S}(1,1))=-15.012$</td>
<td>$\text{dB}(\text{second_mom_a..S}(1,1))=-7.971$</td>
</tr>
</tbody>
</table>
2) Square slot with stub loaded slots:

For enhanced area reduction central slot with extended arms can be used. By exciting the patch using a coaxial probe feed along the diagonal line of the square patch, it is expected that dual frequency operation based on the two resonant frequencies of the perturbed TM(10) and TM(01) modes can be generated. Figure:-4 shows the layout of the square slot antenna. Table:-2 tabulates the design parameters and simulated results.
Table:-2 Summary of Design and simulation results of antenna layout above:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width of Square MSA patch</td>
<td>40mm</td>
</tr>
<tr>
<td>Width of square slot</td>
<td>13mm</td>
</tr>
<tr>
<td>Length of Stub</td>
<td>12mm</td>
</tr>
<tr>
<td>Width of stub</td>
<td>1.6mm</td>
</tr>
<tr>
<td>F1</td>
<td>3.7 GHz</td>
</tr>
<tr>
<td>F2</td>
<td>4.1GHz</td>
</tr>
</tbody>
</table>

Figure:-5 S11 for square slot MSA.

Figure:-6 below shows the radiation pattern of antenna. From figure:-5 it is evident that this kind of structure even though gives good return loss but does not give good bandwidth. One of the reason can be improper impedance match at the feed point. But important thing is that it gives return loss of -25dB at high frequency like 4 GHz.

3) Liu and Wu design:

Before trying out with this design, few other slot antennas where also attempted like U-slot antenna. But they are difficult to fabricate by hand. Liu and Wu suggest a scheme for single layer dual polarised slotted patch antenna as shown in figure:-7. It yields very good return loss but at cost of increased complexity. The modification suggested latter on and which was fabricated avoids such complexity and exploits the fact that as slot length tends to zero highest resonant frequency can be attained. The Liu and Wu design adds extra L-shaped slots to reduce the polarisation loss from multiple reflection between transmitting and receiving polarisations at arbitrary angles. This design is suitable for application to modern wireless communication systems.
Linear Polarization  
Circular Polarization

Figure: 6 Polarisation pattern for square slot MSA

Fig: 7 Liu and Wu architecture for slotted single layer MSA
**Dimensions:**

**L-shaped slots:**

W = 1.5mm L = 9mm. Spacing from adjacent radiating walls is 1.5 mm.

The square patch for L-shaped slot is 12mm X 12mm.

**Main Resonating patch:**

W = L = 14.5mm. With stub arms of dimension 3.06mm X 3.06mm. The slots in the main patch are used to capacitively couple the power from port1 and port 2.

The dimensions of coupling slots is 1mm X 3mm.

Figure:- 8 shows the polarisation and the return loss for the Liu and Wu design.

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**Figure 8:**

Upper plots show S11 & S22 & lower left is E-co and right is E-cross polarisation.
4) Modified Single layer Dual frequency dual polarisation single layer slotted antenna:-

After getting hands-on with various slotted antennas and learning how they behave, a new idea of reducing complexity and still maintaining the performance was coined. In Liu and Wu design one needs external microstrip lines to match the feed. The design which is proposed here is probe feed and hence can very easily be matched. Figure:-9 shows the layout of the proposed simulated slotted MSA.

**Design Procedure:-** The design procedure adopted here is inspired from the method suggested by Jennifer Bernard et.al for the design of the U-slot antennas.

![Fig:-9 Modified Single layer slotted MSA.](image)

- \( f_{m1} = 2.594 \text{GHz} \)
  - \( \text{dB} \) at step 1, mode 1, S1.1 = 31.164
- \( f_{m2} = 5.858 \text{GHz} \)
  - \( \text{dB} \) at step 1, mode 1, S1.1 = 26.733
- \( f_{m3} = 2.594 \text{GHz} \)
  - \( \text{dB} \) at step 1, mode 2, S2.2 = 31.143
- \( f_{m4} = 5.858 \text{GHz} \)
  - \( \text{dB} \) at step 1, mode 2, S2.2 = 26.506

Figure:-10 S11 and S22 for layout shown in fig:-9
Note the improvement in F2/F1 ratio from all the other designs. With Liu and Wu design the F2/F1 = 6.451 GHz / 2.563 GHz = 2.52. With the modified design F2/F1 = 5.85 GHz / 2.59 GHz = 2.25

![Image](image_url)

**fig:-11** E-Co(Left) and E-cross polarisation (right) for the new modified antenna.

**Step-1** Select the substrate and permitivity. Use the equation below to make sure that the thickness of the substrate is at least greater than T if the operating wavelength is $\lambda_{\text{res,3}(\text{air})}$ (This the wavelength corresponding to the center frequency.)

$$T \geq 0.06 \frac{\lambda_{\text{res,3}(\text{air})}}{\sqrt{\varepsilon_r}}.$$  

**Step-2** Find the length as below

$$B + 2\Delta B \approx \frac{v_0}{2\sqrt{\varepsilon_r f_{\text{res,3}}}}$$

**Step-3** Calculate Width as below

$$A = 1.5(B + 2\Delta B)$$

**Step-4** Find the effective permittivity and fringing length using the following

$$\varepsilon_{\text{eff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left(1 + \frac{12T}{A}\right)^{-1/2}$$

$$2\Delta B = 0.824T \frac{(\varepsilon_{\text{eff}} + 0.3) \left(\frac{A}{T} + 0.262\right)}{(\varepsilon_{\text{eff}} - 0.258) \left(\frac{A}{T} + 0.813\right)}$$

**Step-5** Find the actual length by subtracting the fringing length.
Step-6: Select the thickness of the L-slot in the design based on the equation below

\[
B = \frac{v_0}{2\sqrt{\varepsilon_{\text{eff}} f_{\text{res3}}} \cdot 2\Delta B}
\]

Step-7 Calculate the length of the slot using the equation below. Note that the length calculated above is the length of the square patch on which L-slot is made and not the actual length.

\[
D = \frac{v_0}{\sqrt{\varepsilon_{\text{eff}} f_{\text{res2}}}} - 2 \left( B + 2\Delta B - E \right)
\]

Step-8 Select the arm length of L-slot using equation below. Note that it is very near to value of D and the difference is due to the thickness of the slot i.e.due to 'E'.

\[
\frac{C}{D} \geq 0.3 \quad \text{and} \quad \frac{C}{D} \geq 0.75
\]

Step-9 Now for the second resonance the effective permitivity and the length are different. Evaluate that using the equation below:

\[
\varepsilon_{\text{eff}(pp)} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left( 1 + \frac{12T}{D - 2F} \right)^{-1/2}
\]

\[
2\Delta_{B-E-H} = 0.824T \frac{(\varepsilon_{\text{eff}(pp)} + 0.3) \left( \frac{D-2F}{T} + 0.262 \right)}{(\varepsilon_{\text{eff}(pp)} - 0.258) \left( \frac{D-2F}{T} + 0.813 \right)}
\]

Step-10 To find the distance of the L-slot from the radiating walls use the following equations

\[
H \approx B - E + 2\Delta_{B-E-H} - \frac{1}{\sqrt{\varepsilon_{\text{eff}(pp)}}} \left( \frac{v_0}{f_{\text{res4}}} - (2C + D) \right)
\]

Finally, verify that the sum of C+H+E is less then the the length i.e. 'B'. If this condition gets violated then go back to equation which gives value of C and re-calculate the value of 'C'.

**Experimental Results and Conclusion:-**

The antenna was fabricated and the S11 and the radiation pattern was obtained as shown in figure:-12. It certainly surpasses the one shown in paper with hand fabrication. Hence, as future step if further improvements are sorted than much better dual polarised antenna can be obtained from the design shown in this report. A solid well proof design steps are highlighted in this report which can enable any kind of future research on the same design.
Fig. 12 Radiation pattern and S11 for the fabricated antenna.
References:-


4)”Design of Symmetric Slot Antenna For Dual Frequency Dual Polarization Operation”, G.S Binoy e.t.al.

5) “A Single Layer Dual Frequency rectangular microstrip”, Chen JS & Wong, Microwave & Optical Technology.


7)”Antenna Propagation and Wave Theory”, Balanis.