CHAPTER 4

MODIFIED ELECTROMAGNETIC COUPLING TECHNIQUE FOR BANDWIDTH ENHANCEMENT

4.1 INTRODUCTION

In this chapter a new concept of modified proximity coupled antenna with slot is introduced to achieve wide bandwidth. Also a microstrip line tuning stub fed rectangular slot antenna is investigated for ultra wide bandwidth.

As discussed earlier, it is possible to increase the absolute bandwidth of microstrip patch antenna by simply using thicker substrates. This however, introduces several problems. The first is the excitation of surface waves, which distorts the normal radiation pattern and introduces additional loss. The second is the excitation of higher order modes which introduces further distortions on the pattern and impedance characteristics. The third is that the feed probe (extension of inner conductor of the coaxial line) introduces a series reactance almost proportional to the substrate thickness and hence the lead inductance becomes significant with respect to the antenna radiation resistance for thick substrates and therefore prevents proper matching.

In view of the above problems, electromagnetic coupling has been studied as a possible feed technique for electrically thick microstrip antennas. In general, 9% to 15% bandwidth has been reported earlier [68-70] in electromagnetic coupled stacked patch configuration.
4.2 A WIDE BAND MODIFIED PROXIMITY COUPLED ANTENNA WITH NARROW SLOT IN THE MICROSTRIP FEED AND THE GROUND PLANE

A new concept of proximity coupled antenna with slots is investigated for wide impedance bandwidth at a center frequency of 7.4 GHz.

4.2.1 Design and simulation

The rectangular patch dimensions are calculated as per available theoretical equations. The patch substrate has a dielectric constant of $\varepsilon_r = 9.8$ and thickness 2.54 mm. The microstrip feed substrate has a dielectric constant of $\varepsilon_r = 2.55$ and thickness 1.5748 mm.

In this proximity coupled antenna, a narrow slot is cut in the microstrip feed line and is located at a position approximately $\lambda/4$ from the other end of input feed. Another narrow slot is cut in the ground plane, which is below the feed line, at the same position as the slot in the microstrip feed line. Its dimension is slightly greater than the dimensions of the slot in the feed line. The centers of both the slots are kept at the same location for maximum coupling. The patch is located above the feed in such a way that the center of patch is exactly above the center of slot or slightly offset for maximum coupling. The offset is less than 1.5 mm. The top view and the side view of the antenna structure is shown in Figure 4.1 (i) and (ii).
Fig 4.1. Antenna Configuration

This configuration is simulated in ANSOFT HFSS V9.2.1 and optimized.

The simulated return loss plot is shown in Figure 4.2.

Fig 4.2. Simulated return loss plot

The return loss plot shows an impedance bandwidth (VSWR ≤ 2) of 2.2GHz (6.4-8.6GHz) that corresponds to 30% impedance bandwidth. The wide bandwidth achieved is due to the multiple resonances introduced by the
combination of slot in the microstrip feed and the ground plane. The close resonant loops in the Smith chart as in Figure 4.3 reveals the presence of multiple resonances. When there is no slot in the ground plane, the resonant loop becomes wider thereby reducing the bandwidth. The length and width of the slot in the ground plane play a major role in the impedance matching over the whole frequency range.

![Simulated Smith Chart](image)

**Fig 4.3. Simulated Smith Chart**

The radiation pattern obtained for this antenna configuration is hemispherical in the elevation plane as shown in Figure 4.4. The back lobe is due to the slot in the ground plane. The average gain of the antenna is $2\text{dB}_a$. 
(i) Frequency 6.6GHz

(ii) Frequency 7.5GHz
4.2.2 Fabrication and measured results

The patch is printed on a 100 mil thick substrate of $\varepsilon_r = 9.8$, the feed line with slot is printed on a 60 mil substrate of $\varepsilon_r = 2.55$. The two substrates are assembled with the help of fasteners. The front view and rear view of the realized antenna photographs are shown in Figure 4.5 (i) and 4.5(ii) respectively.
The measured return loss plot is shown in Figure 4.6(i). The 10 dB points are at 6.2 GHz and 8.34 GHz, which give an impedance bandwidth of 2.34 GHz which corresponds to 31.6 % of the centre frequency. The Smith chart is shown in Figure 4.6(ii). It is observed that resonant loops are formed due to multiple resonances of the optimum patch parameters.

Fig 4.5. Photograph of the antenna

Fig 4.6 (i). Measured Return loss plot
The measured values are compared with simulated results and good agreement is obtained.

4.3 ULTRA WIDEBAND MICROSTRIP LINE FED RECTANGULAR SLOT ANTENNA

A microstrip line fed rectangular slot antenna with U shape tuning stub is studied for wide impedance bandwidth centering at 7.2 GHz.

The antenna structure is shown in Figure 4.7(i). The top view is depicted in Figure 4.7(ii). The RT duroid substrate has a dielectric constant of $\varepsilon_r=3.5$ and loss tangent 0.0019. The thickness of substrate is 60 mil and the dimension is 100mm x 100mm. A rectangular slot of dimension 31.9mm x 20.9mm is etched at the centre of one side of the ground plane (1/2 ounce thick copper) of dielectric substrate. A microstrip line terminated by a U shaped stub of width 15.5mm x length 8mm is etched on the other side of the dielectric substrate. L,W Fig 4.6 (ii). Measured Smith Chart
and ML denotes the length, width of the slot and length of the microstrip line respectively. The rectangular slot is the radiating aperture.

**Fig 4.7 (i) Antenna configuration**

**Fig 4.7 (ii). Top view of antenna configuration  Geometry of microstrip fed slot antenna**

**Antenna Parameters**

Substrate $\varepsilon_r=3.5$  Thickness 1.524 mm L=20.9 mm W=31.9 mm ML=40.8 mm WS=15.5 mm LS=8 mm WV=2 mm LH=1 mm
The configuration is simulated in ANSOFT HFSS v 9.2.1. The simulated return loss plot is shown in the Figure 4.8 (i). It is seen to provide an impedance bandwidth (VSWR \( \leq 2 \)) of 7.2GHz (2.5-9.7GHz) that corresponds to 118%. The ultrawide bandwidth is due to multiple resonances introduced due to the combination of slot and U shaped tuning stub. The close resonant loops in the Smith chart as shown in Figure 4.8 (ii) reveal that multiple resonances are indeed present.

![Simulated Return loss plot](image)

**Fig 4.8 (i).** Simulated Return loss plot
The length and width of the horizontal and vertical arms play major roles in the impedance matching over the entire frequency range. The width of the vertical arms of the stub helps to maintain the resonant loop close to the center. When the width is increased or decreased the resonant loop becomes larger. The length of the vertical arm also plays a similar role in the impedance matching of the antenna. The length of the vertical arms and the width of the horizontal arms are optimized in the same light. The length of the microstrip feed line is chosen such that there is a gap of 1mm between the slot edge and the end of microstrip feed line or start of the stub so that maximum coupling occurs between the feed and the slot. This gap length is found to be invariant even when the size of the ground plane increases. The radiation patterns obtained for this antenna are bidirectional as shown in Figure 4.9.
(i) Frequency 2.7GHz

(ii) Frequency 4.5GHz

(iii) Frequency 6.5GHz
The average gain of the antenna as obtained from simulation is 2 dB.

The antenna is fabricated on a 100mm x 100mm x 1.524 mm substrate with \( \varepsilon_r = 3.5 \). The measured return loss plot is shown in Figure 4.10.
The 10-dB points are at 2.3GHz and 9.4 GHz, which give an impedance bandwidth of 121%. The Smith chart is shown in Figure 4.11.

Fig 4.11 Measured Smith chart

The measured values are compared with simulated results and good agreement is obtained.
4.4 CONCLUSION

The reported new design of proximity coupled antenna with a slot in the microstrip feed and the ground plane provided bandwidth of better than 30% compared to conventional proximity coupled antenna.

An ultra wide band antenna fed by a microstrip line terminated by a U shaped tuning stub is reported. The bandwidth achieved with this antenna is approximately 121 %. The antenna has bi-directional radiation pattern. These antennas find applications in UWB radar, broad band wireless communication and imaging radars.