CHAPTER-4

Design of High Gain Microstrip Patch Antenna
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Introduction... Gain enhancement using microstrip array antenna... High gain planar multi-resonator broadband MSA

4.1 INTRODUCTION

The need of the microstrip patch antenna is increased due to the increasing requirement of wireless communication. They are suitable for many applications due to their simple structure, low profile, cost effective and Omni directional radiation patterns [1,2]. But their applications are limited due to low gain and narrow bandwidth characteristics of them. The compatibility of multiple communication systems and the prolongation of the communication distance demand the improvement of bandwidth and gain. There are few techniques to develop the gain of the microstrip antenna, described in the journal [1,2], also there are few journals where the gain enhancement methods have been presented using multiple superstrate materials [3,4]. Actually there are some problems for using the superstrate materials above an antenna which may affect the antenna’s basic performance characteristics, i.e. gain, radiation resistance and efficiency. There are few ways to obtain the high gain and the broad band antenna such as loading some slots/slits on the radiating patch or ground plane[5], appropriate choice of the thickness of the substrate [6], partial ground planes[7,8], using a parasitic element or a diminished surface-wave antenna [9-11], cavity backed slotted antenna [12] and double layer array antenna [13]. Improvement of the gain and the bandwidth of the antenna also depend on the dimensions and shapes of the patch and the ground plane. Selecting an appropriate size of ground plane will provide better bandwidth and also increase the gain of the antenna. However, the gain of above mentioned previously reported dual-band, single-fed antennas are less than 6 dBi [14-30], even for a planar compact-element arrays [31]. The gain of the microstrip antennas reported in [32-35] are much higher, but also less than11 dBi.

This chapter presents the progress of a microstrip antenna to increase the gain. Higher gain is obtained by using microstrip array antenna and Multi-resonator Broadband MSA. The designed antenna is simulated using Method of Moment (MOM) based ANSOFT designer.
software version 2.2. The designed antenna is fabricated and measured. A good matching is observed between the simulated and measured input impedance ($S_{11}$), gain, VSWR and radiation pattern of the antenna. Experiments are done using standard microwave test bench. The simulated and experimental results show the gain up to 14dBi using a U shaped multi-resonator monopole antenna. The designed microstrip patch antenna is single layered and is very easy to design and fabricate.

4.2 GAIN ENHANCEMENT OF A MICROSTRIP ARRAY ANTENNA: Design (1)

4.2.1 Introduction

In this work [35] a simple array antenna with four circular patches on a square ground plane has been presented. These four radiating patches are fed by four coaxial probes. This designed array antenna has been fabricated and measured. The minimum reflection coefficient at resonant frequency is -13.54dB. The practical bandwidth at -10dB is 8.15GHz. The novelty of the work is that a high gain of 11dBi is obtained by this designed array antenna.

4.2.2 Antenna Design

Fig 4.1 shows the designed array structure. The designed antenna contains four circular shaped radiating patches on a square shaped ground plane. Each circular patch has radius of 5mm. The dimension of the square ground plane is 50mm×50mm. The array antenna is fabricated on an FR4_epoxy dielectric substrate with a thickness ($h$) of 1.6 mm, relative permittivity $\varepsilon_r = 4.4$.

![Fig.4.1- Design of the array antenna](imageurl)
The antenna is excited by coaxial probe feed. The position of the feeding point is chosen to obtain best impedance matching. For best matching of input impedance, the four radiating patches are placed in that position with respect to ground plane of the antenna which has been shown in the Fig.4.2. The element spacing of this array antenna was 1.16 \( \lambda_0 \) at 14 GHz to minimize coupling. The proposed antenna has been designed in Ansoft designer software. Fig.4.2 represents the picture of the fabricated array antenna.

![Fig.4.2- Fabricated array antenna](image)

- **4.2.3 Measurement**

  For this investigation, proposed array antenna has been fabricated on an FR4-epoxy dielectric substrate. The experimental arrangement is done using a standard microwave test bench for the radiation pattern and gain measurement of the fabricated array antenna. The measurement of Reflection coefficient is done using Agilent made Network analyzer. Fig 4.3 shows the plot of the measured results.

- **4.2.4 Result and Discussion**

  Reflection Coefficient Vs Frequency plot for the simulated and measured values have been shown in Fig 4.3 for the designed array antenna. The measured bandwidth at -10dB is 8.15GHz. The antenna gain is very high which is around 11dBi at 13.8GHz frequency. The achievement of this simple antenna is novel one. The Simulated and Measured
Fig.4.3- Simulated and Practical Reflection Coefficient Vs Frequency plot of the array antenna

Gain Vs Frequency Plot has been shown in Fig.4.4. The normalized values of simulated and practical radiation patterns have been shown in Fig.4.5 to Fig.4.8.

Fig.4.4- Simulated and Practical Gain Vs Frequency plot of the array antenna
Fig. 4.5 - Simulated and Practical E plane Co, Cross Radiation pattern plot at 9GHz frequency.

Fig. 4.6 - Simulated and Practical H plane Co, Cross Radiation pattern plot at 9GHz frequency.
Fig. 4.7- Simulated and Practical E plane Co, Cross Radiation pattern plot at 13GHz frequency.

Fig. 4.8- Simulated and Practical H plane Co, Cross Radiation pattern plot at 13GHz frequency.

Fig. 4.9- Simulated result of 3D Radiation pattern of the array antenna at 9GHz frequency.
From these figures it has been shown that the radiation patterns of the array antenna are good. Fig 4.9 shows the 3D view of the simulated radiation pattern of the antenna at 9GHz frequency, which is also very good.

4.2.5 Conclusion

The practical bandwidth of the antenna at -10 db is 8.15GHz. But which is very significant to mention here that the peak gain of the very simple antenna is 11dBi. Both simulated and measured gain of the antenna are better than 6dBi throughout the frequency region 9GHz to 14 GHz. Practical gain is always around 1dBi less than simulated gain. This may be for the connector or cable loss. Generally microstrip antenna suffers from two disadvantages. They are low gain and narrow bandwidth. Several number of research works have been presented for broad banding or achieving high gain by different methods. Here both broad banding and high gain have been achieved simultaneously. Moreover the simulated and practical radiation patterns are good. These antennas are extensively used in the field of mobile or satellite communication.

4.3 HIGH GAIN PLANAR MULTIRESONATOR BROADBAND MSA: Design(2)

4.3.1 Introduction

This work presents the planar multiple resonator technique using microstrip patches for high broadband and gain operation. Only a single patch is excited through the microstrip line feed and other patches are coupled parasitically. The multiple resonators have been coupled which is realized by using a small gap i.e. less than 2h between the patches. The mechanism for this type of broadband and high gain technique is that a patch positioned near to the fed patch gets energized through the coupling between the two patches which is called parasitic patch. The superposition of the responses of the three resonators take place, then a high gain and wide bandwidth are obtained. The resulting broadband microstrip antenna also has much increased antenna size than a single rectangular microstrip antenna.

4.3.2 DESIGN OF THE NOVEL ANTENNA DEVELOPED

The designed antenna shown in Fig.4.10 is fabricated on FR4-epoxy dielectric substrate with dielectric constant $\varepsilon_r= 4.4$, loss tangent of 0.02 and thickness ($h$) 1.6mm. The basic antenna structure contains three unequal sized U shaped patch, a feed line and a slotted ground plane. The patch has a width 2mm. The patch is excited through a feed line of width 3mm and length 22mm.
as shown in Fig 4.10. The position of the feeding point is chosen to obtain the best impedance matching. A conducting slot loaded ground plane of width 22mm and length 32mm is placed on the dielectric substrate. The gaps between U parasitic elements are 2mm and the distance between T slots in the ground plane is 7mm. The position of the T slots has been shown in the Fig.4.10. The upper most and lower most sides of the T slots are placed at a distance 5mm from the upper and lower boundary of the ground plane, which is aligned in the X axis and 5.5mm right side from the left side boundary of the ground plane. The dimensions of patch and slots are given in Table 4.1. The layout of the antenna is drawn in the Ansoft designer software.

Fig.4.10- Design of the Proposed Antenna
Table 4.1
Specifications of the Proposed Antenna
(All Dimensions are in mm)

<table>
<thead>
<tr>
<th>Dimension of Patch in mm</th>
<th>Dimension of Slot in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>U₁</td>
<td>U₂</td>
</tr>
<tr>
<td>Height(H)</td>
<td>H₁= 7</td>
</tr>
<tr>
<td>Length(L)</td>
<td>L₁= 8</td>
</tr>
<tr>
<td>Width(w)</td>
<td>W₁ = 1</td>
</tr>
</tbody>
</table>

➢ 4.3.3 Fabrication and Measurement

For this investigation, the designed antenna has been fabricated on an FR4-epoxy dielectric substrate. Fig.4.11 shows the picture of the fabricated antenna. The measurement of Reflection coefficient has been done using Agilent made Network analyzer. The practical results have been plotted in Fig.4.12. The arrangement of radiation pattern and gain measurement of the fabricated antenna are done using a standard microwave test bench. The fabricated antenna is placed in receiving position. An Agilent microwave source is connected to the transmitting horn antenna shown in Fig.4.12.
An Agilent Power meter is connected to the designed receiving antenna. The measurement of reflection coefficient and gain of the fabricated antenna are done at zero degree angle with the transmitting antenna with U patch in vertical direction.
4.3.4 Result and Discussion

4.3.4.1 Reflection Coefficient

Prototype of this designed antenna has been fabricated and measured. From Fig.4.13 it has been observed that adding extra parasitic element introduces very important effect on the antenna characteristics like bandwidth and gain. Adding a U shape parasitic element on the left side of the center U type patch exhibits 0.04GHz, 0.55GHz, 0.77GHz, 0.66GHz, 0.58GHz and 0.39GHz bands where as for only center U type patch antenna the obtained bands are 0.66GHz, 1.62GHz, 0.39GHz and 0.35GHz. Introducing U shape parasitic element on the right side of the center U type patch we obtained 0.11GHz, 0.64GHz 1.29GHz and 0.7GHz bands. Then further increase of bandwidth has been obtained using both side parasitic elements with center U type patch. This antenna has been fabricated and its parameters are measured.

Fig.4.13- Comparative study of Simulated Reflection Coefficient Vs Frequency plot of the Center U, Center U & Right sided U and Center U & Left sided U antenna

The Fig.4.13 implies that the slot insertion on the ground plane has significant effect on the bandwidth of the antenna. From this figure it has been found that a significant increase of bandwidth i.e. 0.72GHz BW has been increased to 2.02GHz and 1.51GHz BW increases to 6.72GHz when two T shaped slots have been loaded on the ground plane.
The comparative study of the simulated and practical results of the Reflection Coefficient Vs Frequency plot for the proposed antenna has been shown in Fig.4.14. From this figure it has been noticed that the two results are almost in agreement. From this results it has been concluded that the antenna has dual impedance bandwidth of 2.36GHz (2.46GHz-4.82GHz) and 6.16 GHz (6.24GHz-12.4GHz) practically and 2.02GHz (2.68-4.7) GHz and 6.72GHz (5.86-12.58) GHz by simulation. So practically the percentage impedance bandwidth of the antenna is 64.8% and 66.09%. Both simulated and practical results show that the gain of this antenna is high which is around 14dBi.
4.3.4.2 Gain

Fig. 4.15- Comparative study of Simulated Gain Vs Frequency plot of the Center U, Center U & Right sided U and Center U & Left sided U antenna

The simulated gain of the reference antenna, slotted antenna and measured peak gains of the fabricated patch antenna at various frequencies have been plotted in Fig. 4.16.

Fig. 4.16- Simulated and Practical Gain Vs Frequency plot of the antenna
According to Fig.4.15 the peak gains of the antennas with center U, parasitic U shape element on left side and parasitic element on right side are 7.83dBi, 10.52dBi and 10.1dBi respectively. As shown in Fig.4.16, the practically achievable maximum peak gain is 14 dBi and maximum simulated gain is 12dBi at the frequency of 10GHz. From this figure it is found that the simulated data almost follow the measured data.

**4.3.4.3 Radiation Pattern**

The radiation patterns of the designed antenna are studied at different frequencies. The simulated and practical normalized radiation patterns of the antenna are plotted in E-plane and H-plane at 4.2GHz and 10GHz frequencies. The co-polarization and cross-polarization radiation patterns of the antenna are presented as shown in Fig.4.17 to Fig.4.20 for the E-plane and the H-plane. The simulated and practical radiation patterns are compared and they agree in both the E-plane and the H-plane. The fabricated antenna produces almost symmetrical radiation pattern with maximum gain of 14dBi at 10GHz frequency. The half-power beam widths (HPBWs) in the E and H planes are almost 62° for each case.

![Simulated and practical E plane Co, Cross Radiation pattern of the antenna at 10GHz frequency](image)

**Fig.4.17**- Simulated and practical E plane Co, Cross Radiation pattern of the antenna at 10GHz frequency
Fig.4.18- Simulated and practical H plane Co, Cross Radiation pattern of the antenna at 10GHz frequency

Fig.4.19- Simulated and practical H plane Co, Cross Radiation pattern of the antenna at 4.2GHz frequency
Fig. 4.20 - Simulated and practical E plane Co, Cross Radiation pattern of the antenna at 4.2GHz frequency

Fig. 4.21 - Simulated Axial Ratio Vs Frequency Plot
Axial ratio of the designed antenna is plotted in Fig.4.21. Throughout the frequency range axial ratio is less than 2. So, the proposed antenna is circularly polarized. Fig. 4.22 shows the 3D view of the radiation pattern of the antenna.

**4.3.4.4 VSWR**

VSWR Vs frequency plot is shown in Fig.4.23. The value of the VSWR is 1.02 at 4.21GHz frequency.
4.3.5 Conclusion

A circularly polarized three unequal sized U shaped microstrip line fed slotted ground plane antenna has been presented in this article. High gain and dual broad band characteristics have been obtained from this antenna which is applicable for long distance communication systems. From the practical result it is noticed that the antenna shows two broadband ranging from 2.46GHz to 4.82GHz and 6.24GHz to 12.4GHz resulting in percentage bandwidth of 64.8% & 66.09%. A maximum gain of 14dBi (measured) and 12dBi (simulated) have been got using this simple proposed antenna. The measured result of the fabricated antenna shows good agreement with the simulated data. The axial ratio of the antenna is less than 2 which is shown in the Axial ratio Vs Frequency curve. So, it is circularly polarized. The practical radiation patterns also follow the simulated patterns. This achievement is done using a simple monopole microstrip antenna with slotted ground plane.

4.5 REFERENCES


