# Aperture Coupled Microstrip Antenna with Three Resonants

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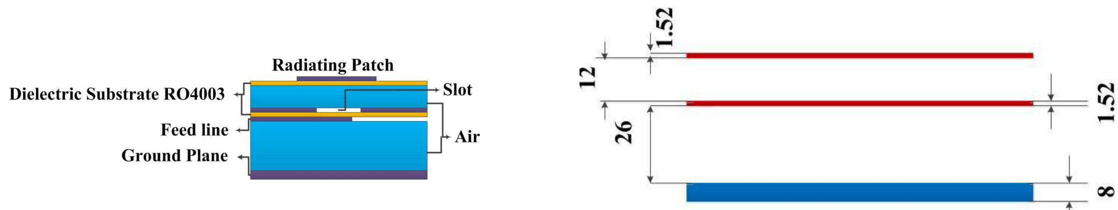
**Abstract**— This paper presents improved aperture coupled microstrip antenna with three resonants which its bandwidth has been enhanced due to vary the current distributions. There is a compromise between radiation characteristics and the bandwidth. Radiation patterns indicate the appropriate propagation pattern of antenna is between 1.3 GHz to 2.3 GHz frequency band which clarifies a bandwidth more than 53%. There is bandwidth enhancement up to this limit by utilization of multiple radiating elements. The antenna operates in both linear and circular polarization (1.64 GHz to 1.76 GHz for less than 3 dB Axial Ratio). The simulated results done by two methods, i.e., Finite Element Method (FEM) and Finite Difference Time Domain (FDTD) collaborated by two full-wave softwares ANSYS HFSS and CST MWS have good agreements with the measurement ones.

## 1. INTRODUCTION

The microstrip antennas have many applications due to their planar structures and mechanical formations, but they suffer from narrow bandwidth. Many procedures have been done for bandwidth enhancement and different methods proposed; although these methods decrease the antenna propagations [1]. Conventional methods for increasing the bandwidth of these antennas are categorized in three general groups: bandwidth enhancement by feeding network, variation in patch's physical structure and material connected with feeding network and the patch. Many types of microstrip antennas such as rectangular, circular, semi-circular and triangular patches have been investigated with mathematics concepts in [2]. The basis of current structure's design has been adopted from aperture coupled microstrip antenna which introduced in [3]. The general purpose of this paper is enhancement of aperture coupled microstrip antenna bandwidth as much possible as it can; consequently the radiation characteristics of an end-fire antenna have been observed here. Fundamental discussion of current paper is achieving three resonants in the antenna by employing one radiating element which it is contrary with other two resonants aperture coupled microstrip multiple radiating element antennas. As a result, optimum energy coupling methods have been considered for a patch [4–7]. One $H$ form slot has been created which it is responsible for controlling the coupling energy on patch. Also, the size increasing in slot structure causes to create a degree of freedom for bandwidth enhancement. With variation on patch structure by cutting both sides (clipping the edges), it is possible to add the degree of freedom for controlling of $S_{11}$ antenna parameter. Nevertheless, the current distribution form in the patch changes which this causes to multiple controlling in antenna bandwidth; Consequently, the bandwidth enhancement is achieved more than 53%. Certainly, it is necessary to draw attention to this point that multiple radiating elements used in aperture coupled antennas have bandwidth enhancement up to this limit [8] and many procedures have been done in this field [9]. Next section presents aperture coupled microstrip antenna design and its important parameters.

## 2. ANTENNA STRUCTURE AND ITS DESIGN PRINCIPLES

Side view of designed physical structure of aperture coupled microstrip antenna has been illustrated in Fig. 1. The center frequency of this L-band aperture antenna is 1.7 GHz which has many applications such as global positioning system (GPS), satellite communications, and etc.. The circular polarization (CP) of this antenna has many advantages for communication systems like robustness with respect to the link attenuation, decreasing the multipath distortion, increasing the capability of delivering the signals, etc.. In the other hand, the horizontal linear polarization (HLP) is predominant in broadcast communications such as TV and FM and the vertical linear polarization (VLP) is applicable for radiating a radio signal in all directions such as widely distributed mobile units and two-way earth to earth communications in the frequency range above 30 MHz. In the proposed antenna, the radiating element is the upper metal patch. Therefore, the effective coupling parameters are antenna feeding network, slot and patch dimensions. Indeed, the degree of




(a) (b)

Figure 1: Side views of aperture coupled microstrip antenna.

freedom for broadbanding of aperture coupled microstrip antennas is its feeding network which it consists of a probe or microstrip line that causes bandwidth enhancement about 5% to more than 15% [10, 11]. So, fundamental cases engaged with the bandwidth and radiation characteristics of microstrip antennas can be studied as below:

### 2.1. Dimensions and Dielectric Characteristics of Upper Section

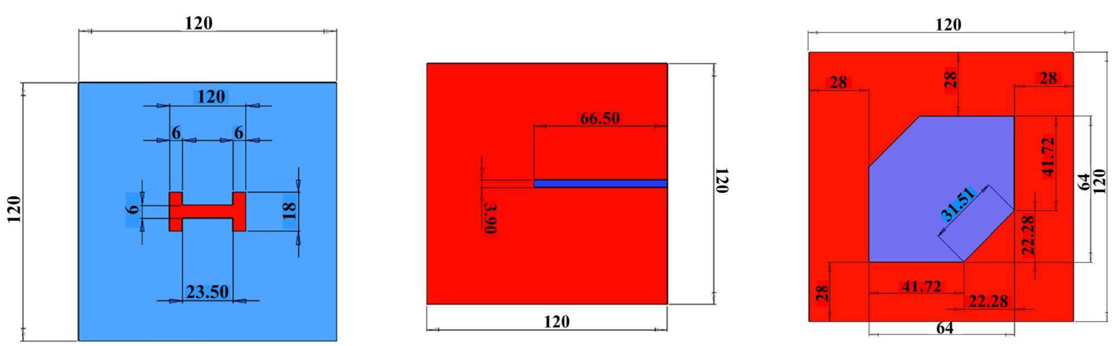
It is obvious that antenna radiatione and its bandwidth become so well as increase in the upper dielectric layer thickness and decrease in its relative permittivity coefficient [12], whereas coupling factor will be decrease. RO4003 substrate type is used with dielectric constant of $\epsilon_r = 3.38$ and thickness of 1.52 mm and its lower air layer thickness is equal to 12 mm. Employing the simple calculations [13], the $\epsilon_{eff}$ of this combined structure (RO4003 with air) is less than using merely dielectric. The air layer role is creating one degree of freedom for antenna bandwidth enhancement.

### 2.2. Dimensions and Dielectric Characteristics of Lower Section

In spite of energy coupling which performs from this line, increasing in dielectric constant and its thickness reduction is a reason for coupling improvement [14]. Also, the dielectric material type is RO4003 with constant of $\epsilon_r = 3.38$ accompanied by thickness of 1.52 mm. Thickness of each microstrip antenna layer has been shown in Fig. 1.

### 2.3. Dimensions and Characteristics of Feeding Network and Slot

Obviously, the feeding network has a direct relation with its characteristic impedance. If the impedance matching meets its requirements, the $S_{11}$ and antenna bandwidth parameters will be improved. The feeding network alignment must be vertical on slot without any deviations for improving coupled energy [14]. It is important to note that the feeding network length effects on bandwidth, too. In other side, the slot dimensions have direct effect on coupling and antenna radiation characteristics. Its structure is in $H$ form and vertical on feeding network alignment as mentioned above. The effect of slot dimensions on $S_{11}$ parameter is inevitable as presented in simulation. Slot and feeding network have been placed in two sides of RO4003 microstrip line and physical structure. Its dimensions have been shown in Fig. 2.




(a) (b) (c)

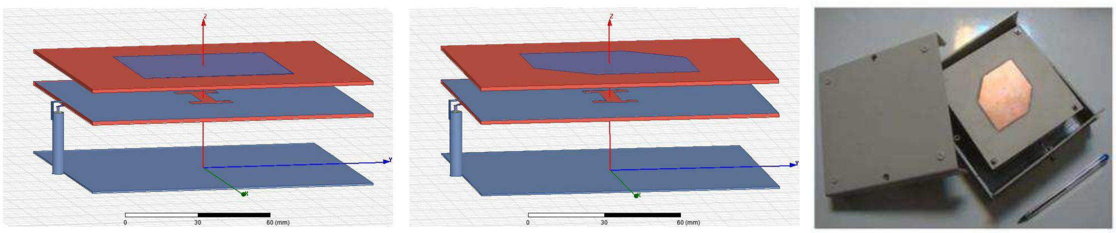
Figure 2: (a) Slot. (b) Feeding network and (c) patch characteristics (Dimensions in mm).

### 2.4. Dimensions and Characteristics of Patch (Radiation Element)

Patch dimensions have direct relation with resonant frequency and bandwidth of the antenna. The antenna bandwidth has been enhanced intensely due to clip in the patch edges and varies the current distribution well in order to create the third resonant. This operates notwithstanding transformation of linear into circular polarization by adjusting the exact dimensions and sufficient energy coupling of slot. In the next section, clipped patch effect has been presented by ANSYS HFSS (Frequency Domain) and CST MWS (Time Domain) softwares. The patch is placed in the center for optimum coupling [4]. Its characteristics and dimensions have been illustrated in Fig. 2.

## 3. RESULTS

There is a compromise between radiation characteristics and the antenna bandwidth. The three resonant frequencies effect on upper (due to patch), lower (due to slot) and mid (due to feeding network) frequency band of $S_{11}$ parameter, respectively. Of course, all of these resonants influence each other. The design and simulation procedures have been done by ANSYS HFSS and CST MWS softwares. Schematic (Fig. 3) and results of aperture coupled antenna are presented in the following:

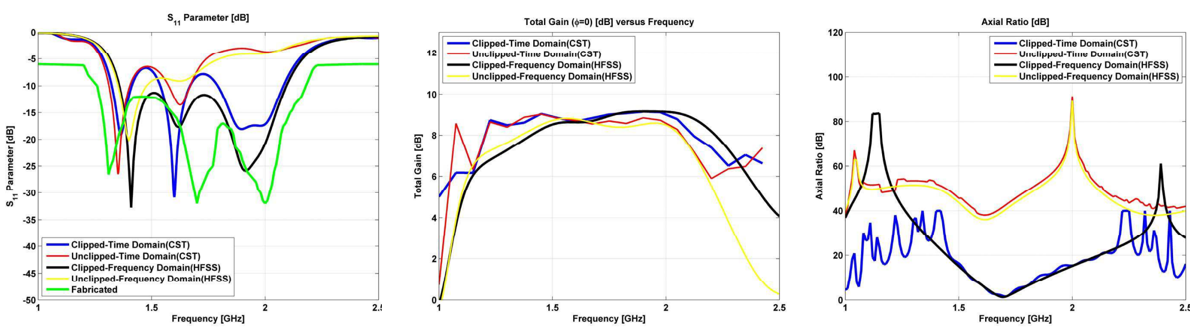


(a) (b) (c)

Figure 3: Aperture coupled microstrip antenna. (a) Unclipped Simulated. (b) Clipped Simulated. (c) Clipped Fabricated.

### 3.1. Return Loss

The $S_{11}$ parameter has been investigated with and without using clipped patch in order to investigate its effect on antenna bandwidth (Fig. 4).




(a) (b) (c)

Figure 4: (a) $S_{11}$ parameter, (b) total gain parameter and (c) axial ratio parameter at $\phi = 0$ and $\theta = 0$.

### 3.2. Gain Diagram

The gain of a conventional rectangular patch is in order of 7 dB. As shown in Fig. 4, aperture coupled antenna gain has been reached to 9 dB by employing mentioned methods.

### 3.3. Axial Ratio (AR) Diagram

The axial ratio parameter is defined for elliptical or circular polarization. It is defined by ratio of the magnitudes of the major and minor axis determined by the electric field vector. The axial ratio in the proximity of center frequency (1.7 GHz) shows that there is circular polarization in this band (Fig. 4).

### 3.4. Radiation Patterns

The simulated radiation pattern of the antenna has been presented versus angle of $\Theta$ (with respect to $z$ axis) for miscellaneous frequencies (Fig. 5). The measured radiation pattern results of aperture coupled microstrip antenna have been illustrated in Fig. 6 at 6 frequencies of 1.3 GHz, 1.5 GHz, 1.7 GHz, 1.8 GHz, 2.1 GHz, and 2.3 GHz, respectively. These measurement results are in good agreements with their simulation results.

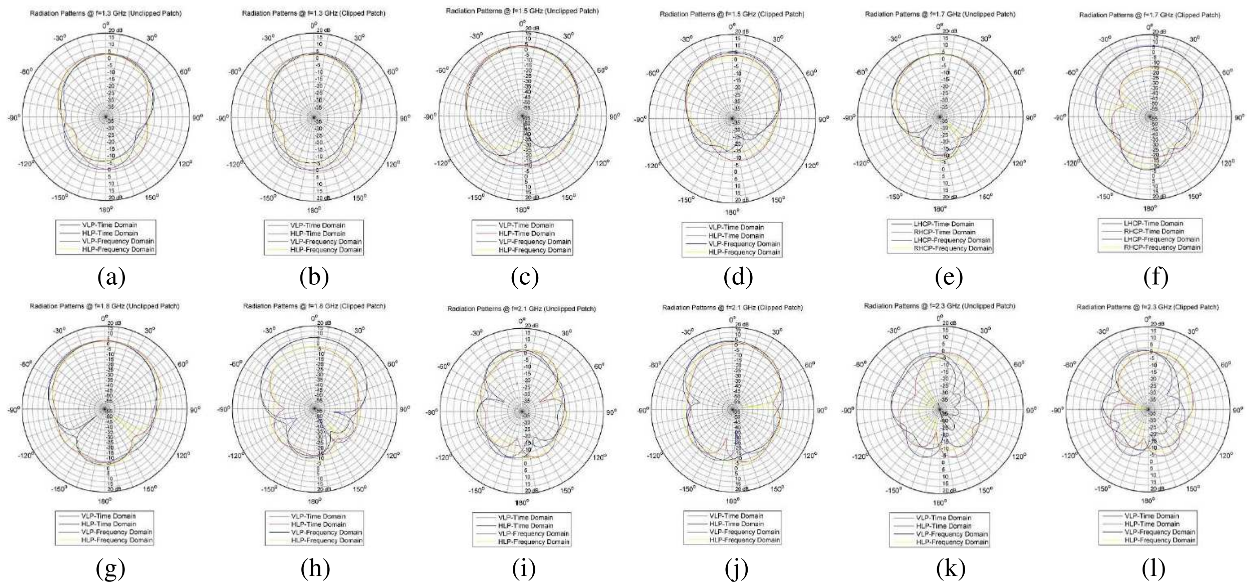


Figure 5: Simulated Radiation Patterns (a) unclipped (1.3 GHz), (b) clipped (1.3 GHz), (c) unclipped (1.5 GHz), (d) clipped (1.5 GHz), (e) unclipped (1.7 GHz), (f) clipped (1.7 GHz), (g) unclipped (1.8 GHz), (h) clipped (1.8 GHz), (i) unclipped (2.1 GHz), (j) clipped (2.1 GHz), (k) unclipped (2.3 GHz), (l) clipped (2.3 GHz) patches.

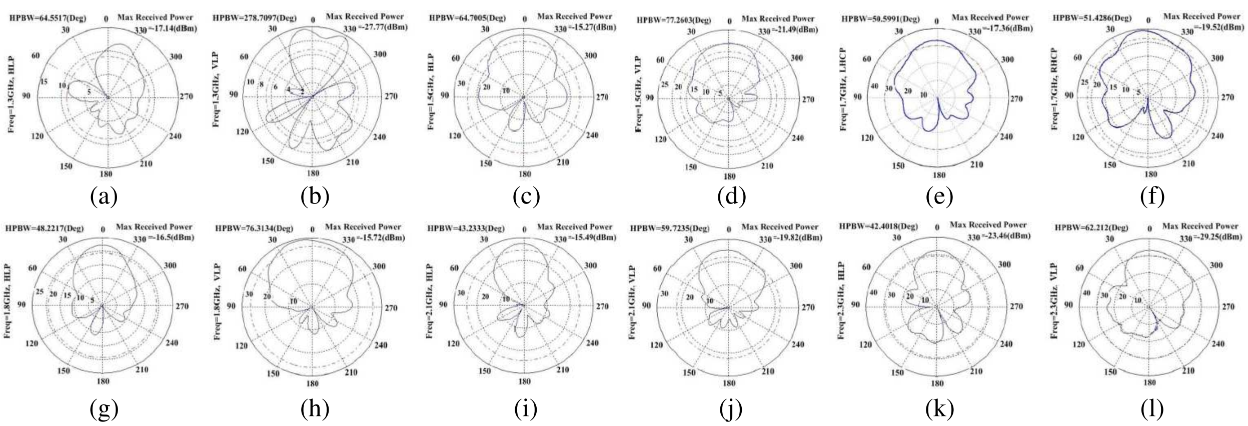


Figure 6: Measured Radiation Patterns (a) HLP (1.3 GHz), (b) VLP (1.3 GHz), (c) HLP (1.5 GHz), (d) VLP (1.5 GHz), (e) RHCP (1.7 GHz), (f) LHCP (1.7 GHz), (g) HLP (1.8 GHz), (h) VLP (1.8 GHz), (i) HLP (2.1 GHz), (j) VLP (2.1 GHz), (k) HLP (2.3 GHz), (l) VLP (2.3 GHz).

## 4. CONCLUSION

This paper presented improved aperture coupled microstrip antenna with three resonants. The bandwidth enhanced due to clip in the patch edges and varied the current distribution well in order to create the third resonant. There was a compromise between radiation characteristics and the antenna bandwidth. These two factors were optimized in simulated and fabricated samples. Radiation patterns indicated the appropriate propagation pattern of antenna was between 1.3 GHz to 2.3 GHz frequency band which clarified bandwidth more than 53% by using certain method in the novel one radiating element. Of course, there was bandwidth enhancement up to this limit by utilization of multiple radiating elements. The simulated results which had been done by two methods, i.e., Finite Element Method (FEM) and Finite Difference Time Domain (FDTD) collaborated by two full-wave softwares ANSYS HFSS and CST MWS had good agreements with the measurement ones.

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