HIGH GAIN AND COAX FED MODIFY RECTANGULAR MICROSTRIP ANTENNA DESIGN FOR X BAND APPLICATION

*[1]İsa ATAŞ, [2]Teymuraz ABBASOV, [3]M. Bahattin KURT, [3]Hüseyin ACAR

[1] Dicle University, Diyarbakır Vocational School, Diyarbakır, Turkey

[2]İnönü University, Engineering Faculty, Electrical-Electronics Engineering, Malatya, Turkey

[3] Dicle University, Engineering Faculty, Electrical-Electronics Engineering, Diyarbakır, Turkey

*Corresponding author; E-mail: isaatas21@gmail.com

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Abstract: *This study presents a design of coax-fed rectangular microstrip antenna operation in different applications within the context of X-bands. High gain and radiation pattern characteristics are obtained by using coax-fed network technique. The Rogers Kappa was chosen as a substrate material for the designed patch antenna with a dielectric constant of 4.38, and a height of 2.4 mm. Simulation results are obtained and examined by using the High Frequency Structure Simulator (HFSS) software. The simulated results indicate the band from 8.2GHz to 11.7 GHz (return loss < −10 dB) and produce a gain of 6.53 dB at 8.7GHz and 11.65 dB at 11GHz, respectively.*

Key words: *microstrip antennas, coax-fed, gain, directivity, high gain.*

1. Introduction

Nowadays, researches on microstrip antenna especially focuses on size reduction, increasing gain, wide bandwidth (BW), multiple functionality and system-level integration [1], [2]. Microstrip Antenna (MA) which are used in many field such as mobil communication, wireless internet, satellite and misille navigation, radar systems and biomedical applications have a good credit in meeting these requirements among the other antenna types [3]. However MA have some disadvantages such as low gain and narrow BW. These bad characteristics of MAs have been tried to improve by using different methods such as choosing special dielectic material, modifying the geometric configuration, etc. MA was firstly mentioned conceptually by Deschamps(1953), and later a patent was taken for a MA by Gutton and Baissinot. Because of not existing of good dielectric substrates, first practical MA was developed by Howel and Munson at the beginning of 1970 [4].

1.1. Feeding Methods

MAs have two feeding techniques. These are contacting and non-contacting feeding. Feeding technique affects the antenna input impedance and radiation characteristics, and therefore, is an important design parameter [5].

1.1.1. Contacting Feeding

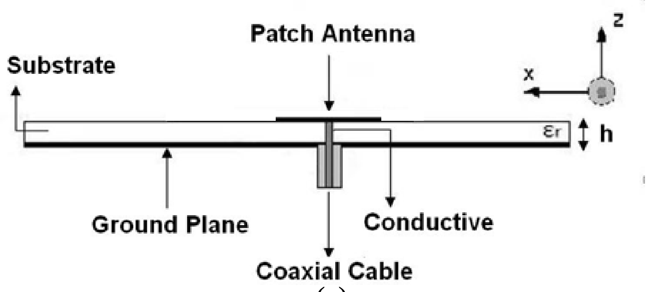
In this method, the Radio Frequency power is fed directly to the radiating patch using a microstrip line or coaxial element. Microstrip line feed is one of the easier methods to design and fabricate as it is just conducting strip connecting to the patch and therefore can be considered as extension of the patch [5], [6]. The most important advantage of this method is to maintain its planar structure. By controlling the inset position, solving matching problem is get easier. The disadvantage of this method is that as substrate thickness increases, surface wave and spurious feed radiation increases, which limit the BW for practical designs [3]. Coaxial Probe feed where the inner conductor of the coax is attached to the radiation patch while the outer conductor is connected to the ground plane, are also widely used. Advantages of this method is easy to fabricate and match, and it has low spurious radiation. The disadvantages of this method is having narrow BW and more difficult to model, especially for thick substrates ($h > 0.02\lambda_0$) [3]. For thick substrates, which are generally employed to achieve broad BW, both the above methods of direct feeding the MA have problems. In the case of a coaxial feed, increased probe length makes the input impedance more inductive, leading to the matching problem. For the microstrip feed, an increase in the substrate thickness increases its width, which in turn increases the undesired feed radiation. Also, both the microstrip feed line and the coaxial probe possess inherent asymmetries which generate higher order modes which produce cross-polarized radiation. To overcome these problems, noncontacting (indirect) feeds, discussed below, have been introduced [3], [6].

1.1.2. Non - Contacting Feeding

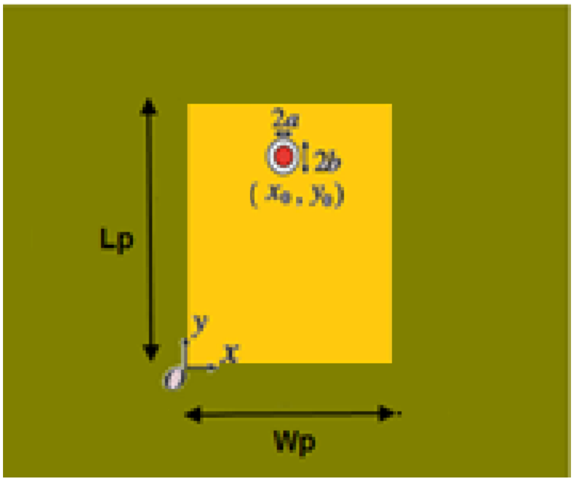
The electromagnetic coupling is also known as proximity coupling. The feed line is placed between the patch and the ground plane, which is separated by two dielectric media. The advantages of this feed configuration include the elimination of spurious feed-network radiation. The disadvantages are that the two layers need to be aligned properly and that the overall thickness of the antenna increases [3]. Another method for indirectly exciting a patch employs aperture coupling. In the aperture-coupled MA configuration, the field is coupled from the microstrip line feed to the radiating patch through an electrically small aperture or slot cut in the ground plane. Similar to the electromagnetic coupling method, the substrate parameters of the two layers can be chosen separately for optimum antenna performance. This feeding method gives increased BW [6]. We chosen the coaxial probe feed because of its simple to match and easy to fabricate properties. In Fig. 1, proposed coaxial fed MA was shown.

1.2. Methods of Analysis

There are many methods of analysis for MAs. The most popular models are the transmission-line, cavity, and full wave (which include primarily Finite Element, Finite Difference Time Domain, and Moment Method). The transmission-line model is the easiest of all, it gives good physical insight, but is less accurate and it is more difficult to model coupling. Compared to the transmission-line model, the cavity model is more accurate but at the same time more complex. However, it also gives good physical insight and is rather difficult to model. In general when applied properly, the full-wave models are very accurate, very versatile, and can treat complex geometries [3]. In this study, we used High Frequency Structure Simulator [7] (HFSS) which is widely used in antenna design and employ the full-wave finite element method for analyzing the electromagnetic structures.



(a)



(b)

Figure 1. Coaxial feed microstrip antenna (a) side view (b) top view.

2. Methods

2.1. Design of Rectangular Microstrip Antenna

Microstrip antennas manufactured with printed circuit technology are comprised of a conductor radiating on the upper surface and a ground conductor containing an insulator on the lower surface of the insulating material having a low-loss thin layer [8]. Since the numeric values obtained as simulation results of theoretical calculations are not in desired levels, some parameters are manually changed to achieve appropriate results. "Rogers Kappa-438" is selected as insulating material of the antenna designed in this study and a dielectric constant (ε_r) of 4.38, an insulating copper thickness (t) of 0.035 mm and a dielectric height (h) 2.4mm are taken. Physical parameters of the antenna designed with a center frequency of 10GHz are calculated with equations (1-6) used in transmission line model [3] [6] and demonstrated below.

$$W = c_o\sqrt{\frac{(\varepsilon_r + 1)}{2}} / 2 f_r \tag{1}$$

$$\varepsilon_{eff} = \left[\frac{\varepsilon_r + 1}{2}\right] + \left[\frac{\varepsilon_r - 1}{2}\right]\sqrt{\frac{1 + 12h}{W}} \tag{2}$$

$$\Delta l = 0.412h \frac{(\varepsilon_{eff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{eff} - 0.258)(\frac{W}{h} + 0.8)} \tag{3}$$

$$L = \left[\frac{c_o}{2 f_r \sqrt{\varepsilon_{eff}}} \right] - 2\Delta l \tag{4}$$

$$x_0 = \frac{W_p}{2} \tag{5}$$

$$y_0 = \frac{L_p}{2\sqrt{\varepsilon_{eff}}} \tag{6}$$

In the transmission line formula, ε_r is dielectric constant of insulating material, ε_{eff} effective dielectric value of insulating material, C_o light speed, *fr* resonance frequency, *h* thickness of insulating material and ΔL line expansion. The probe feed point is located at (x_0, y_0), and antenna input impedance is chosen as 50 Ω. Table 1 below demonstrates the output and input parameters of rectangular coax-fed antenna.

Table 1. Inset Fed Microstrip Antenna Parameters

Inputs	
Solution Frequency (fr)	10GHz
Substrate Thicknes (h)	2.4mm
Loss Tangent (tanδ)	0.005
Dielectric Constant (ε_r)	4.38
Conductor thickness (t)	0.035mm
Outputs	
Patch Width (W)	8.9mm
Patch Length (L)	5.4mm
Substrate Width	70mm
Substrate Length	70mm
SMA inner Radius (2a)	1.28mm
SMA outer Radius (2b)	4.1mm
Probe feed (xo)	3.75mm
Probe feed (yo)	2mm
Microstrip line impedanc (Z_0)	50Ω

3. Results and Findings

Simulation results of the designed antenna obtained by using HFSS simulation program are presented in this section. The return loss (RL) of the proposed antenna is shown in Figure 2. When simulation results are analyzed based on (<10 dB) RL criterion, it was observed that the maximum radiation of proposed antenna was primarily in 8.7GHz frequency and in 11GHz frequencies. At 8.7GHz operating frequency of the proposed antenna VSWR value was obtained as 0.5dB and RL value was obtained as -34.00dB. At 11GHz operating frequency of the proposed antenna VSWR value was obtained as 2dB and RL value was obtained as -18.59dB.

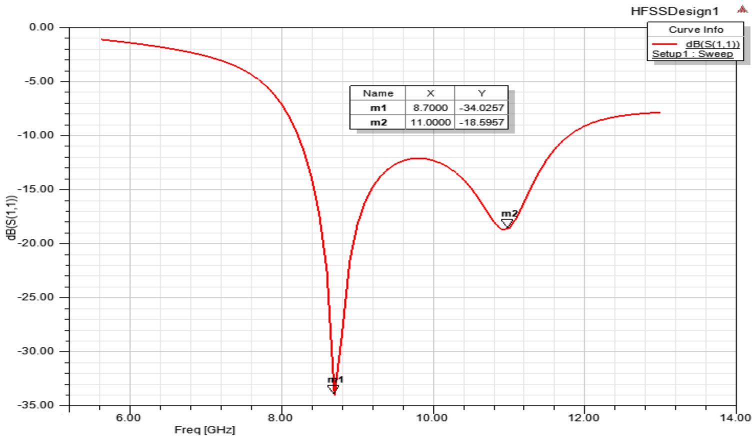


Figure 2. RL Characteristic of the Proposed Antenna

In Figure 3, VSWR characteristic of simulated antenna is given. Figure 4 shows all possible impedances in the frequency range (8 GHz–12 GHz) of the antenna on the Smith Chart, and from figure part of these impedances that fall into VSWR≤2 circle are seen.

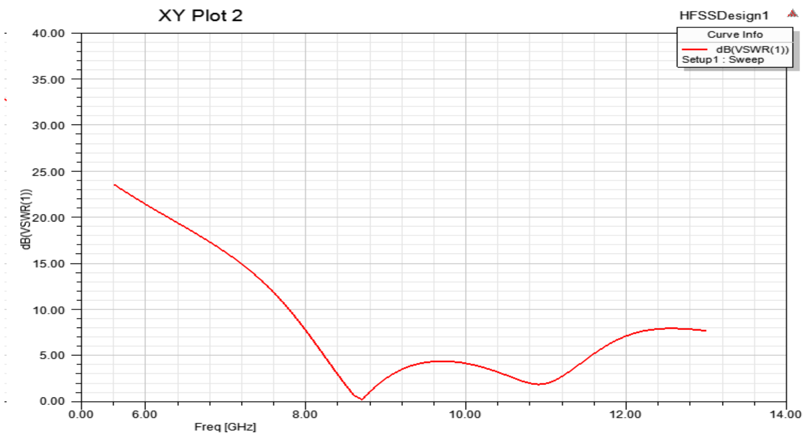


Figure 3. VSWR characteristic of proposed antenna.

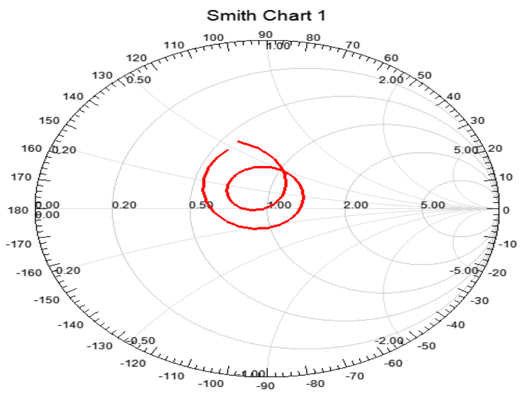
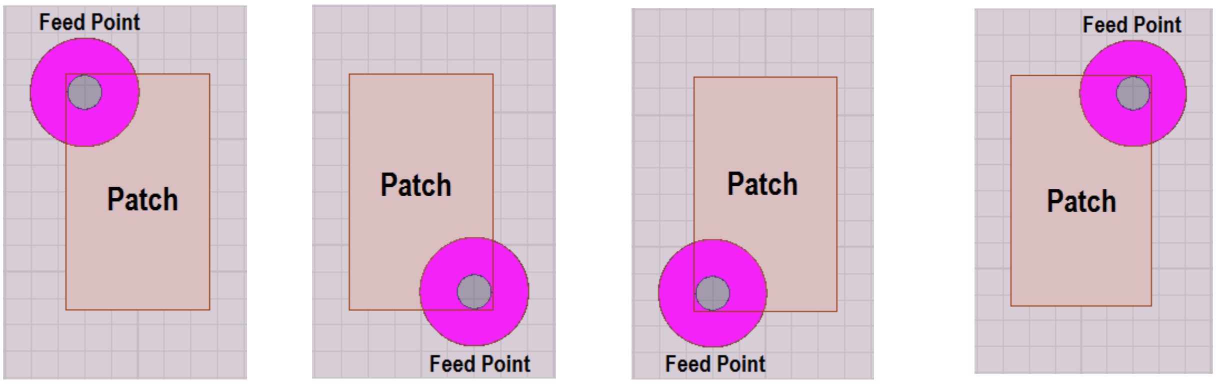


Figure 4. Changing of Input Impedance on Smith Chart.

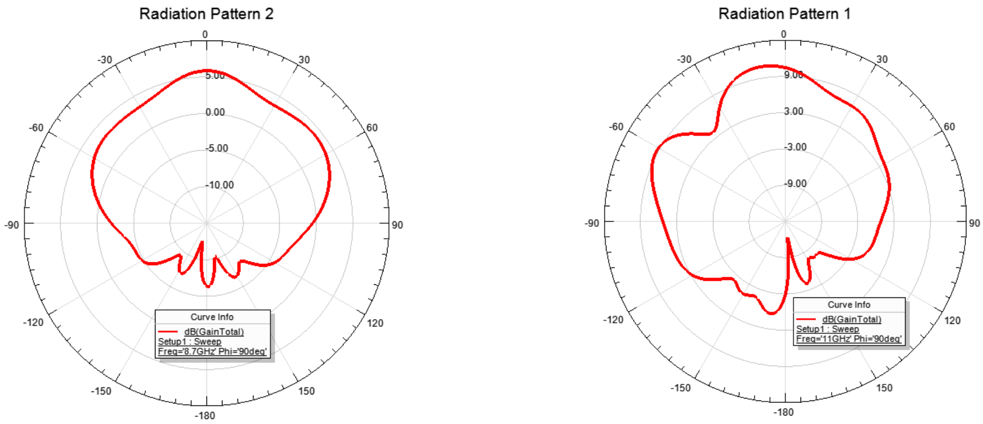
It has been observed that the gain value is changed by shifting the feed point of the patch. The relationship between the feed shape and the gain at the corner points of the patch is shown in Figure 5.



(a) (b) (c) (d)

Figure 5. Geometry structure of patch antenna at different feed points
(a) (-3.75,-2) gain=9.46dB (b) (3.75,2) gain=11.65dB (c) (-3.75,2) gain=9.08dB (d) (3.75,-2) gain=8.82

In Figure 6, the E–Plane (phi=90º) 2D radiation pattern of proposed antenna with resonance frequencies 8.7GHz and 11GHz are shown.



(a) (b)

Figure 6. Radiation Pattern E-Plane Graphs (a) 8.7GHz (b) 11GHz

4. Conclusion

In this study, a linearly polarized, high gain antenna that can operate in the X band is designed and simulated. The antenna shows the best radiation pattern when catches the appropriate high gain. In our study, 11.65dB gain was obtained at the frequency of 11GHz. The gain of the antenna at the feed point (xo=3.75, yo=2) and the return value behaved appropriately. The designed microstrip antenna is small size and high gain and suitable for today's communication devices. It is aimed to fabricate the designed antenna and add measurement results in the next stage.

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