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YAGI-UDA MICROSTRIP PATCH ANTENNA FOR C-BAND AND X-BAND APPLICATIONS

PRATEEK KHURANA, RAJAT ARORA & NAVAID ZAFAR RIZVI

School of Information and Communication Technology, Gautam Buddha University,
Greater Noida, Uttar Pradesh, India

ABSTRACT

This paper describes an antenna structure that combines Yagi-Uda array concept and Microstrip Patch Antenna. This maybe used for mobile and satellite communication, global positioning system and radar applications. The comparative simulation study of an Omni-directional 4-element Yagi-Uda microstrip patch antenna has been done on HFSS software in C-band and X-band configurations, at a central frequency of 5.2 GHz and 10.2 GHz respectively. A maximum power gain of 35dB was obtained for C-band Antenna. Thus simulation results obtained from software implementation were studied and analyzed comprehensively.

KEYWORDS: Yagi Uda Array, Microstrip Patch Antenna, Fabrication, HFSS, C-Band, VLSI

I. INTRODUCTION

A large number of research activities have been conducted on the subject of wireless communications that uses microwave bands [1, 2]. Most of the wireless networks employed today are using omni directional antennas [3]. The first Yagi-Uda antenna design in microstrip structures was suggested by Huang in 1989 [4]. The antenna proposed by the researcher had four patches that were electromagnetically coupled to each other.

A maximum gain of 8 dB was achieved. This kind of proposed arrangement has a number of advantages over single microstrip antennas like increased gain and directivity. The components of a simple microstrip Yagi antenna are shown in Figure 1. This includes a driven patch element and a few parasitically coupled reflectors and director patch element [5].

In a conventional Yagi-Uda dipole array, the driven element is responsible for coupling of electromagnetic energy through space into the parasitic dipoles to obtain a directional beam. In microstrip Yagi array this electromagnetic energy is coupled from the driven patch to the parasitic patches through both space and surface waves in the substrate [5]. In this paper an attempt has been made to design a Yagi-Uda microstrip patch antenna that operates at a central frequency of 5.2 GHz and 10.2 GHz for C-band and X-band respectively, with a high directivity. The power obtained for C-band configuration was 35 dB.

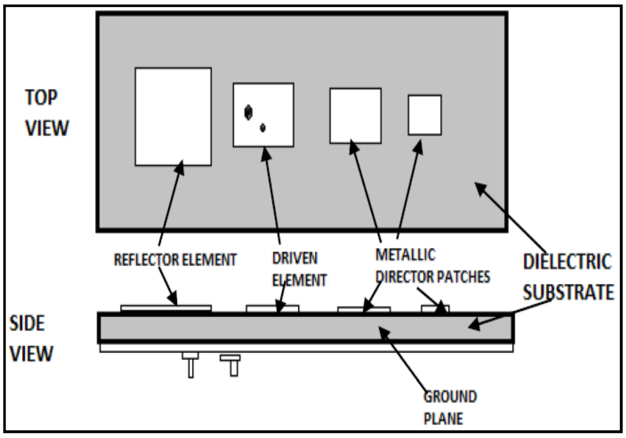

Figure 1: Microstrip Yagi-Uda Configuration

This value of power gain obtained is quite higher than the estimated gain values of a number of similar designs proposed earlier [7, 10]. This high power gain is a desirable characteristic for mobile and satellite communication, global positioning system and radar applications. A software simulation of the Yagi-Uda microstrip patch antenna in both X-band and C-band was carried out using ANSYS HFSS (high frequency structural simulator). It has capability to model RF and microwave frequency and offer multiple solutions for high frequency electromagnetic field simulations. Radiation patterns and polar plots for simulated designs are obtained depicting the bandwidth, central frequency, power gain of the design under consideration.

The Yagi-Uda microstrip patch antenna has been simulated in the C-band obtaining a central frequency of 5.2 GHz and in the X-band obtaining a central frequency of 10.2 GHz. This designworks considerably both as a transmitter and receiver with high gain. In the next section, the design parameters for various components of the antenna used in HFSS simulation are described in detail. Further, section III explains the HFSS simulation results of the antenna both in the X-band and C-band configurations.

II. DESIGN AND CONSTRUCTION

Table 1: Design Parameters for Different Components in C-Band

Components	Position (X mm, Ymm, Zmm)	X-Size (mm)	Y-Size (mm)	Z-Size (mm)
Substrate	0, 0, 0	16	20	0.508
Feed Line	8, 0, 0.508	0.5	20	0.05
1st Reflector	3.8, 6, 0.508	9	0.5	0.05
2nd Array	4.5, 9, 0.508	7	0.5	0.05
3rd Array	5.5, 12, 0.508	5	0.5	0.05
4th Array	6.6, 14, 0.508	3	0.5	0.05
Airbox	0, 0, 0	16	20	4.794

Similar to the conventional Yagi-Uda dipole antenna, the microstrip Yagi-Uda antenna has a driven element which is also called a feed element. Apart from this there is a reflector element and a number of director elements. A 3-Dimensional representation of the antenna has been shown in Figure 2 that was implemented on ANSYS HFSS software. This figure clearly shows the substrate, feed line, reflector element and 3 arrays which act as the director element. The function of reflector element is to force the electromagnetic energy generated from feed line towards the director elements which increase the overall directivity of the antenna design.

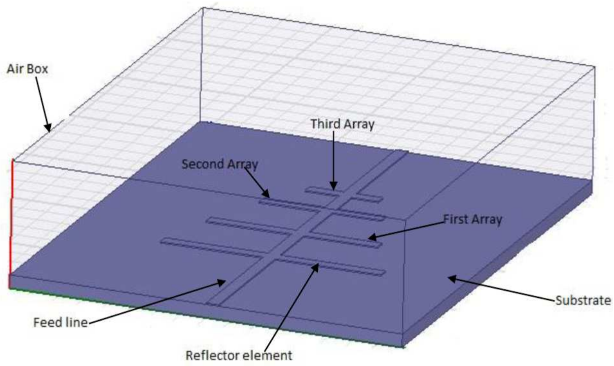

Figure 2: Antenna Design on HFSS Software

The Yagi-Uda microstrip patch antenna design was implemented on HFSS software in both C-band and X-band. The simulation results obtained are described in section III. The design parameters were different for both X-band and C-band implementations. The design parameters for C-band implementation are summarized in Table 1. In HFSS, "Rogers RT/duroid 5880" was selected as the material for substrate formation. This material has a relative permittivity of 3.2 and relative permeability of 1. For feed line, reflector element and the 3 arrays, the material used was "pec" with a relative permeability and permittivity of 1. The airbox is made up of air with a relative permittivity of 1.0006 and relative permeability of 1.0000004.

Table 2: Design Parameters for Different Components in X-Band

Components	Position (X mm, Ymm, Zmm)	X-Size (mm)	Y-Size (mm)	Z-Size (mm)
Substrate	0, 0, 0	8	14	0.508
Feed Line	8, 0, 0.508	0.5	14	0.05
1st Reflector	3.8, 6, 0.508	5	0.5	0.05
2nd Array	4.5, 9, 0.508	4	0.5	0.05
3rd Array	5.5, 12, 0.508	2.5	0.5	0.05
4th Array	6.6, 14, 0.508	1	0.5	0.05
Airbox	0, 0, 0	8	14	2.794

The design parameters for X-band implementation are summarized in Table 2. The simulation results of X-band working of antenna are described in section III. If complex fabrication techniques are available, both the proposed designs can be fabricated easily.

A number of attempts to increase the directivity have been done in past like perturbation procedures [8] and the use PBG structures [12]. However, quite better results were obtained by using an airbox in the HFSS implementation.

III. SOFTWARE SIMULATION

ANSYS HFSS software was used to carry out the simulation of proposed antenna design. HFSS is a high performance electromagnetic field simulator for3-D volumetric passive modeling. A very refined graphical user interface is presented to the user. It can be used to calculate parameters such as central frequency, radiation pattern and to judge the directivity of the antenna. HFSS also gives the freedom to select material for forming the various components of the antenna design. The results obtained from the simulation of the antenna design in HFSS are shown in section V. Simulations of two antenna designs were performed, one in C-band and another in X-band, as shown in Figure 4 and Figure 5 respectively. Both the antenna designs were simulated extensively and XY plot to obtain central frequency, radiation pattern, 3-D plot and polar plot were inspected. It was found that for X-band configuration, the central frequency obtained was 10.2 GHz.

For C-band configuration the central frequency obtained was 5.2 GHz. From this it may be clearly seen that both the antenna designs work properly in the intended microwave frequency bands. The XY frequency plot, 3-D plot and polar plot for X-band configuration have been shown in Figure 6, 7 and 8 respectively. Similarly for C-band configuration, the 3 plots are shown in the Figure 9, 10 and 11 respectively.

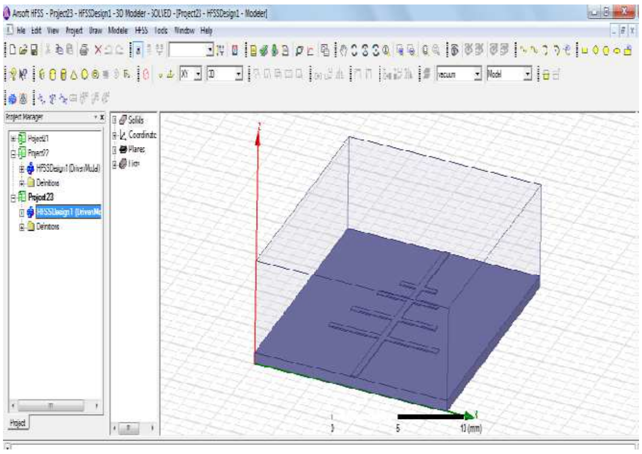

Figure 3: HFSS Antenna Design in C-Band

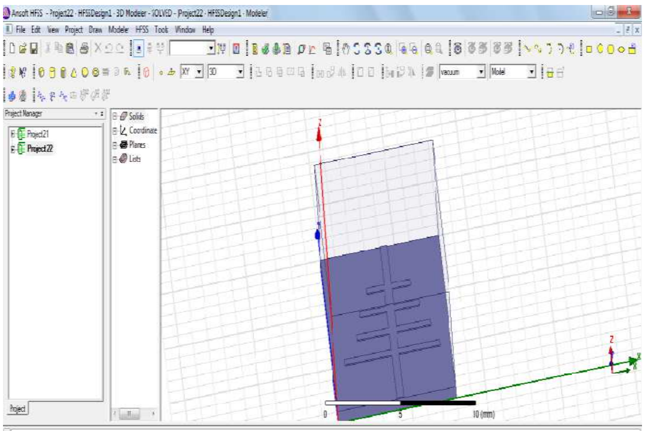

Figure 4: HFSS Antenna Design in X-Band

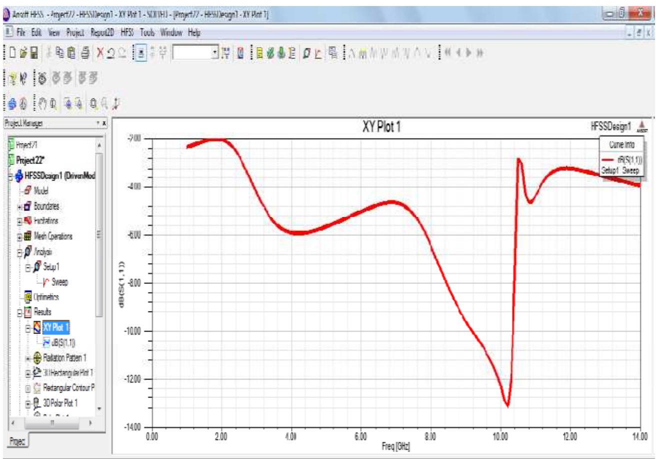

Figure 5: XY Frequency Plot for X-Band Configuration

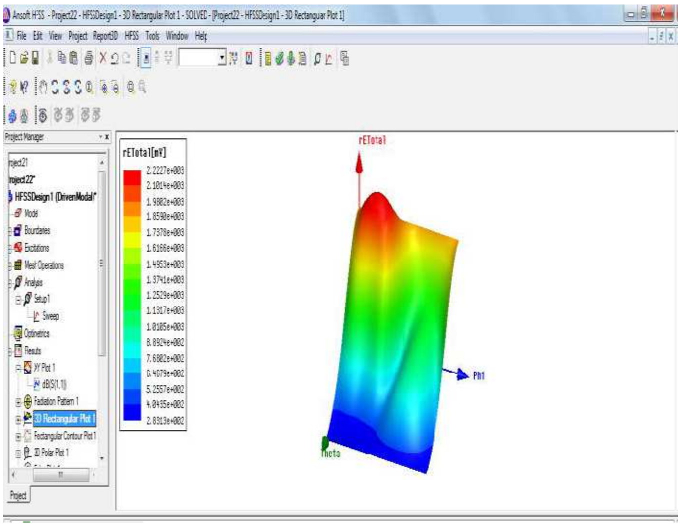

Figure 6: 3-D Plot for X-Band Configuration

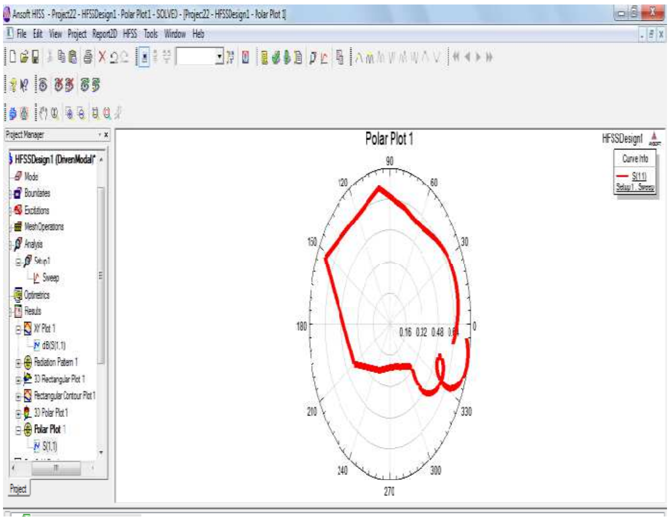

Figure 7: Polar Plot of X-Band Configuration

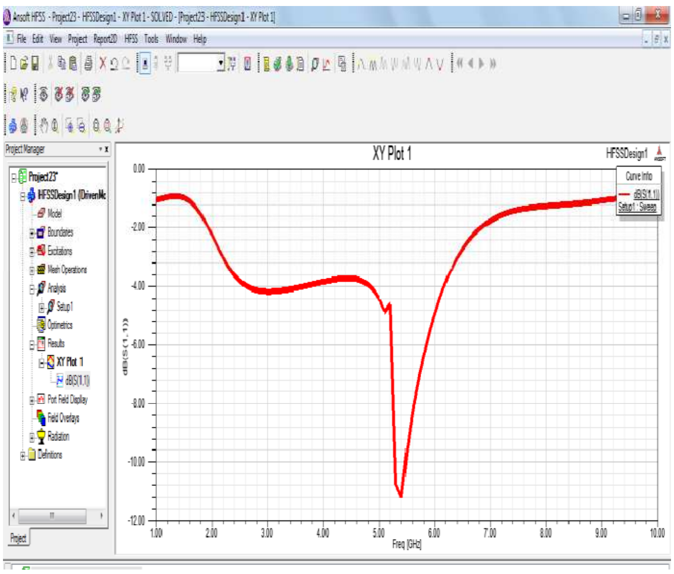

Figure 8: XY Frequency Plot of C-Band Configuration

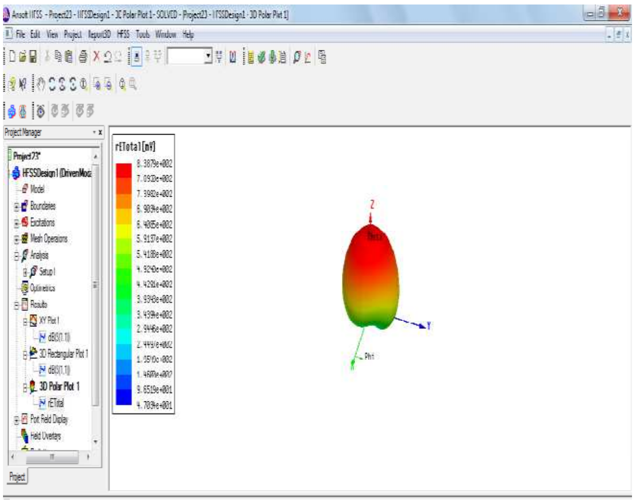

Figure 9: 3-D Plot of C-Band Configuration

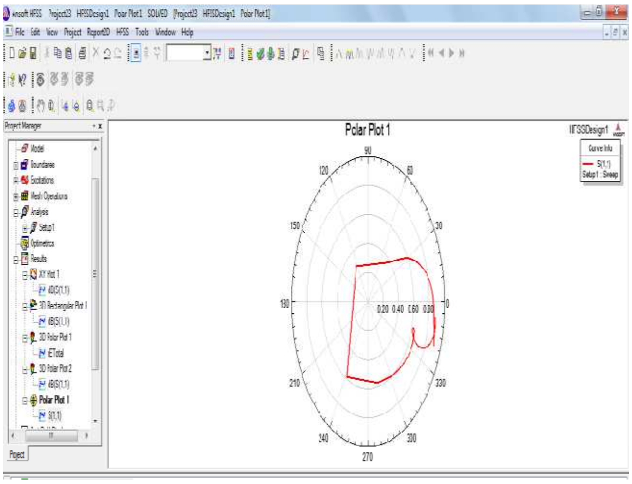

Figure 10: Polar Plot of C-Band Configuration

From the above results it can be seen that for the C-band configuration the central frequency is 5.2 GHz. This high frequency of operation is suitable for a number of RF applications. This frequency of operation is even higher than the stable antenna designs proposed earlier, that were working around 2.4 GHzin S-band and 1.5 GHz in L-band [9, 11 and 13]. The value of gain achieved is also higher than the similar designs proposed earlier, working at nearly same frequency of operation [6].

IV. EXPERIMENTAL RESULTS

The results obtained from the software simulation are thoroughly studied in this section. The parameters that were considered for study of software simulation results are central frequency of operation, maximum power obtained and directivity. The results from software implementation were accurate and similar to the proposed design. The antenna was reflecting in the range of 0-360̊, thus behaving like an omni-directional antenna for the C-band configuration and the range obtained for the X-band configuration was 0-120̊.

For C-band configuration, the implemented antenna design was found to be an omni-directional antenna and so it may be widely used for mobile and satellite communication applications. The central frequency obtained for C-band configuration was 5.2 GHz and that for X-band configuration was 10.2 GHz. A total of 6 lobes were obtained from radiation pattern that include 1 major lobe, 1 minor lobe and 4 side lobes. While a total of 4 lobes were obtained for the X-band configuration with 1 major lobe, 1 minor lobe and 2 side lobes.

This result clearly depicts that the antenna radiates perfectly for the C-band configuration with high gain and directivity but for the X-band configuration it shows a low directivity. The bandwidth that was obtained from the radiation pattern of the simulated results was 9 GHz for X-band configuration and 12 GHz for C-band configuration. This bandwidth obtained is approximately 3 times higher than the bandwidth resulted in planar microstrip Yagi array antenna proposed by J. Huang [4]. Thus Yagi-Uda microstrip antenna in the C-band configuration has a high bandwidth as compared to X-band configuration.

V. CONCLUSIONS

It may be seen from the above results that when the concepts of Yagi-Uda dipole antenna and a Microstrip patch antenna are interlinked, a much high performance antenna in terms of gain and directivity is obtained that may be used for wide range of applications in fields of mobile communication, satellite communication, RFID,GPS, Radar communication etc. It is both light weight and high profile and also does not involve a high manufacturing cost. Further, the operational parameters of antenna may be optimized by various algorithmic tools like GA etc.

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