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A Three Element Yagi Uda Antenna for RFID Systems

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***Abstract*— This paper presents a simple broad band printed Yagi Uda antenna operating at a resonant frequency of 400 MHz that can be used for Ultra High Frequency (U.H.F) applications like Radio Frequency Identification (R.F.I.D) Systems. The antenna is horizontally polarized and consists of a dipole, a reflector and a set of three directors which are placed 3 m above the ground. The impedance bandwidth of the proposed antenna is about 21.5 % and the maximum gain in the pass band frequency range is 16.3 dBwith a return loss of -19 dB.The design formulas and various antenna parameters like Return loss, Voltage Standing Wave Ratio (V.S.W.R), Input impedance, Gain etc of the proposed antenna is observed and the simulation is carried out using an electromagnetic simulation tool , CADFEKO. The results show that the designed antenna is well suited for Ultra High Frequency applications like RFID systems.**

***IndexTerms*—Printed YagiUda antenna, Reflectors, Directors, Driven element, Parasitic elements, CADFEKO.**

I. INTRODUCTION

Yagi Uda antenna was discovered by ShintaroUda and Hidetsugu Yagi and was simply known as the Yagi antenna. It is a highly directional antenna that consist of an array of dipoles (Driven Element) and a set of parasitic elements behind the driven element having more than one director and a reflector that improves the radiation properties of the antenna when properly aligned. It is a highly directional antenna in the sense that it radiates greater power in one direction thereby reducing the interference from all other sources. Yagi Uda antenna is very widely used due to various advantages like low cost, high gain, easy structure etc. During the early days of its discovery the antenna was mainly used in Televisions but later, such antennas found applications in all other fields like Radars, RFID’s, Satellites etc. Yagi Uda antenna can also be used for radio frequency identification in which a tag attached to an object will be identified at the radiofrequencies. Such tags may contain much useful information and may emit microwave or ultra high frequency waves.

A Driven element or Dipole is the point where the feeding is provided. The feeding is usually provided towards the centre of the dipole so that maximum power transfer takes place from transmitters to antennas. A dipole is said to be resonant when its length is half the wavelength of operation. The dipoles need not be always linear in structure, it may be folded also. The geometry of the dipole greatly determines the gain of the antenna in forward and backward directions. Each of these dipole elements are arranged on a supporting boom structure.

The field provided by the driven element induces currents in the parasitic elements of the array through mutual coupling and determines most of the parameters of the antenna. The shortest parasitic element is called a Director. It is a highly resonant structure and operates at a frequency less than the driven element. Directors provide a directional position to the structure with high gain. The length of a director is less than that of a driven element and may vary each time depending on the spacing between the directors which is of the range 0.1-0.5λ. The number of directors used may depend on the physical size of the antenna and increasing the number of directors may enhance the directivity (Gain) of the antenna. The length and spacing of a director has significant effect on the forward and backward gain and provides the antenna with a directional radiation pattern. Directors are the most important elements present in the array.

A reflector is usually placed at the ends of the driven element. The length of a reflector is more than that of a driven element but its frequency of operation is less than the driven element. The length of a reflector depends on the dimensions of each element in the array whereas the spacing between the reflectors will be of the order of 0.1-0.25λ. The length and spacing of a reflector also affects the gain and input impedance of an antenna.

The reflector and the director are designed to be in parasitic mode, since no feeding is provided to these elements. These elements may vary the radiation properties of the driven element. Varying the length between the driven element and parasitic element causes the radiation pattern to be reversed in the array. A low cost Yagi Uda antenna operating at short range (1-100 m) Radio Frequency Identification System operating in the Ultra High frequency (UHF) bands (300MHz – 3000 MHz) is proposed in this paper. Section II discusses the proposed antenna design while section III analyses the results and the paper end with a conclusion in section IV.

II. ANTENNA DESIGN

The geometry of the proposed antenna is shown in Fig 1. It consist of a dipole, reflector and a set of 3 directors designed to operate at a resonant frequency of 400 MHz and is said to be horizontally polarized. Table I shows the parameters of the designed antenna. A port is attached to the middle of the dipole element and is fed by a voltage source.

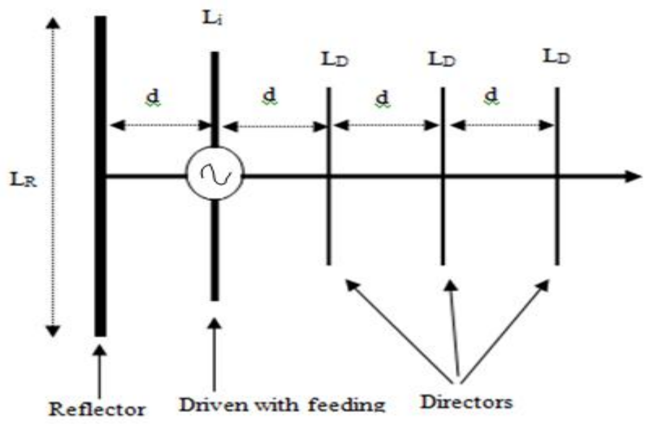

Figure 1. Geometry of the proposed antenna

The general rules of design for a Yagi Uda antenna operating at 400 MHz is given by

Reflector Length, $L_R = 0.477 \text{ X } \lambda$ (1)

Active Element Length, $L_i = 0.451 \text{ X } \lambda$ (2)

Director Length, $L_D = 0.422 \text{ X } \lambda$ (3)

Spacing between elements, $d = 0.25 \text{ X } \lambda$ (4)

Where $\lambda = \frac{c}{f}$

Where λ is the wavelength in metres, c is the velocity of light in freespace ($3x10^8$m/s), f is the operating frequency in MHz.

TABLE I PARAMETERS OF THE PROPOSED ANTENNA

Parameters	L_R	L_i	L_D	d
Value (mm)	0.357	0.338	0.316	0.187

When the director is placed close to the driven element its length should increase but does not decrease when they are moved away from the driven element. Length of the array is considered to be most important than the actual number of elements present in the array. The position of first director element and the spacing of reflectors decides the matching of the Yagi. Antenna gain depends on the number of array elements. As the number of elements increases, the gain increases provided the elements are not separated far apart and they are equal in length. Fig 2 shows the three dimensional view of the designed antenna using CADFEKO.

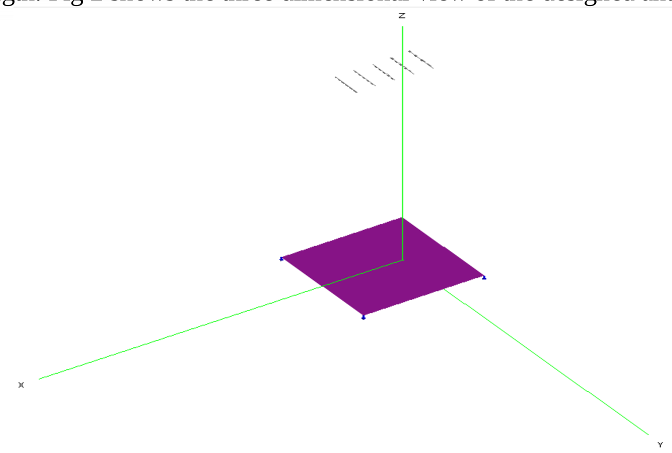

Figure 2.Antenna designed using CADFEKO

III. RESULTS AND DISCUSSION

The proposed antenna is simulated using CADFEKO and various parameters such as Return loss, VSWR, Gain, Input impedance etc are observed.

Fig 4 shows the return loss of the Yagi Uda antenna that operates at a frequency of 400MHz. Return loss indicates the amount of power lost to the load and does not return as radiation. If Pr and Pi indicates the power reflected and suppied by the source respectively,

$$\text{Return Loss} = 10\log\frac{P_r}{Pi} \qquad (5)$$

The bandwidth of the antenna is measured from the return loss curve. The Yagi Uda antenna has an impedance bandwidth of 84 MHz with return loss <-10 dB.

Impedance Bandwidth is given by

$$\text{Impedance Bandwidth (\%)} = \frac{f_h - f_l}{f_c} \text{X} 100 \qquad (6)$$

$$\text{Where} \quad f_c = \frac{f_l + f_h}{2} \qquad (7)$$

Where f_l, f_h and f_c are the upper cut off, lower cutoff and centre frequencies of the antenna with return loss <-10dB.

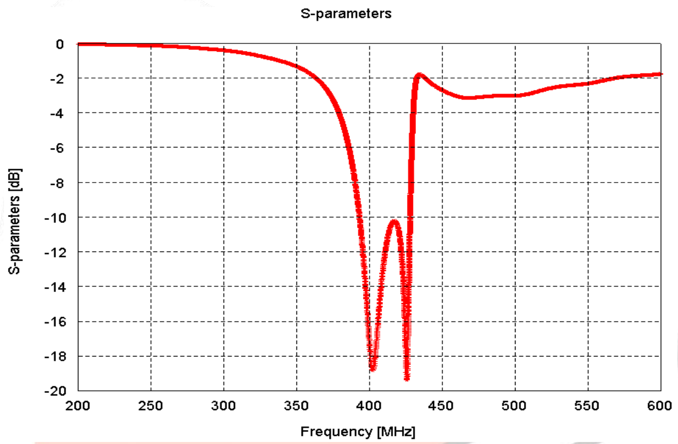

Figure 3. Return loss of the proposed antenna

VSWR of the Yagi Uda antenna is less than 2 for all the frequencies between 400 and 440 MHz and is shown in fig 4. VSWR describes the level of impedance matching to a radio or transmission line of 50Ω to which it is connected. It is expressed in terms of Reflection coefficient Γ and is given by

$$\text{VSWR} = \left[\frac{1+\Gamma}{1-\Gamma}\right] \qquad (8)$$

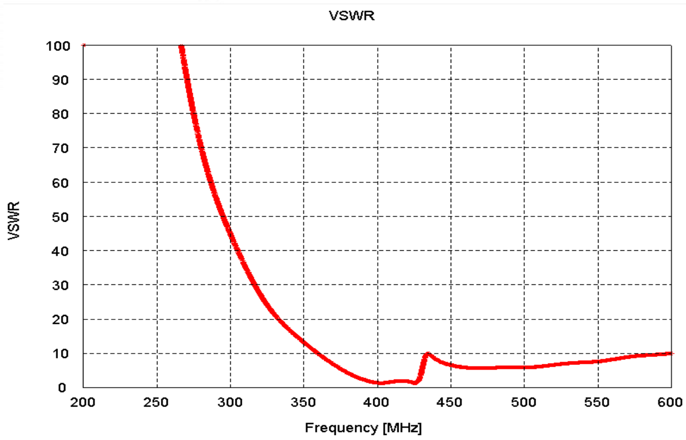

Figure 4 VSWR of the designed antenna

Fig 5 shows the 3D plot of gain (in dB) of the Yagi Uda antenna element at 400 MHz. The observed gain at resonant frequency of the proposed antenna is 16.3 dB which is shown in fig 6. Antenna gain is the ability of an antenna to direct radiations in a particular direction. Gain of an isotropic antenna is unity.

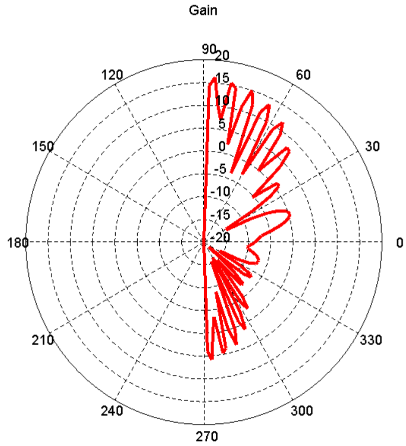

Figure 5. 3-D plot of gain of the antenna at 400 MHz

The radiation pattern plot of the Yagi Uda antenna in E plane (XZ) and H plane (YZ) at 400 MHz is plotted in fig 6 a) and 6b)) and fig 6c) shows a 3 dimensional view of the pattern.

Antenna radiation pattern is defined as a graphical representation of radiation of an antenna as a function of space co-ordinates and is usually expressed in terms of far field pattern.

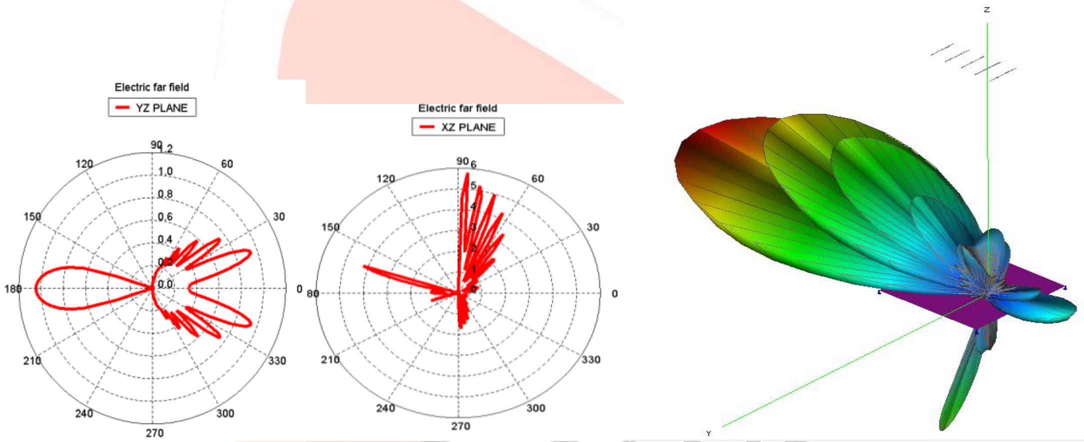

Figure 6. a) Radiation pattern in XZ plane b) Radiation pattern in YZ planeC) 3D view of Radiation pattern at 400 MHz

Fig 8 plots the impedance graph of the Yagi Uda antenna. It is observed that the input impedance of the Yagi Uda antenna at centre frequency of 400 MHz is 52 Ω which is very close to 50Ω. Hence good impedance matching is achieved between the antenna and the transmitter and maximum power is transferred.

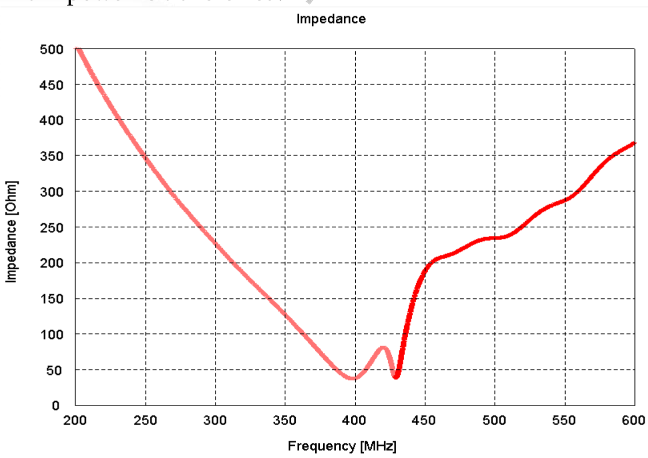

Figure 7. Impedance plot of the antenna

Current distribution plot at 400 MHz is illustrated in fig 8. Most of the radiation fields are concentrated near the dipole element since it acts as the driven element.

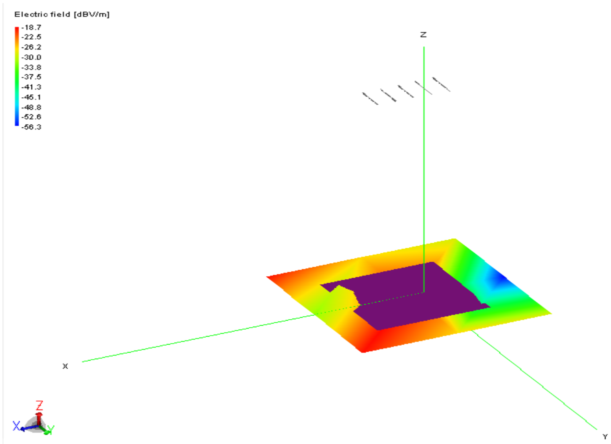

Figure 8. Current distribution of the antenna at 400 MHz

IV. CONCLUSION

A printedYagi Uda antenna with 3 directors, a reflector and a driven element is designed using CADFEKO software. The antenna operates in the Ultra High Frequency Band (300-3000 MHz) and the bandwidth of operation can be increased by increasing the reflector length and by reducing the director length. Effect of these antenna elements on various antenna parameters are observed and evaluated. A return loss of -19 dB , gain of 16.3 dB, and VSWR<2 is achieved for the proposed antenna when operated at 400 MHz. so the designed antenna is well suited for RFID systems operating in the Ultra High Frequency bands.

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