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Research Article

A Compact Efficient Yagi-Uda Patch Antenna with EBG Structure

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Abstract

The paper describes a design of planar three-element Yagi-Uda antenna for 1-3 GHz band. The structure has been optimized for a maximum directivity and maximum gain and other performance parameter by include the air gap of 1.5cm and simulated by IE3D Software. This Yagi antenna consisted of the driven element, a reflecting element and a directing element. We measured the gain of the purposed antenna is 5.8dB.

Keywords: *Yagi-Uda antenna, Directivity, Gain, Antenna Efficiency, Radiation Efficiency.*

1. Introduction

Antennas are devices that transmit or receive electromagnetic waves. If an antenna is receiving a signal it converts the incident electromagnetic waves into electrical currents; if it is transmitting it does the opposite. Antennas are designed to radiate (or receive) electromagnetic energy with particular radiation and polarization properties suited for its specific application. The Yagi-Uda antenna is basically an arrangement of dipoles in such a way that the whole system provides a directional antenna beam in desired direction. That's why some times it is called a directional antenna system. The Yagi antenna's overall basic design consists of a resonant fed dipole (John D. Kraus et al,1997) (the fed dipole is the driven element). The Yagi-Uda antennas are directional along the axis perpendicular to the dipole in the plane of the elements, from the reflector toward the driven element and the director(s). Typical spacing's between elements vary from about 1/10 to 1/4 of a wavelength, depending on the specific design. The lengths of the directors are smaller than that of the driven element, which is smaller than that of the reflector(s) according to an elaborate design procedure. These elements are usually parallel in one plane, supported on a single crossbar known as a boom. The Yagi antenna is a directional antenna which consists of a dipole and several parasitic elements. The parasitic elements in a Yagi antenna are the reflectors and the directors. A Yagi antenna typically has only one reflector which is slightly longer than the driving element (dipole) and several directors, which are slightly shorter than the driving element. The Yagi antenna is said to be directional because it radiates power in one direction allowing it to transmit and receive signals with less interference in that particular direction. Figure 1 is a diagram of the general configuration of a Yagi antenna.

The driven element of a Yagi-Uda patch is the feed point where the feed line is attached from the transmitter to the Yagi to perform the transfer the power from the transmitter to the antenna. A dipole driven element will be resonant when its electrical length is ½ of the wavelength of the frequency applied to its feed point (Sun, B.H et al,2009). The feed point is on the canter of the driven element. **The directors** are the shortest of the parasitic element and this end of the Yagi is aimed at the receiving station. It is resonant slightly higher in frequency than the driven element, and its length will be about 5% shorter, progressively than the driven element. The length of directors can vary depending upon the director spacing. The numbers of directors that can (length) of the supporting boom needed by the used are determined by the physical size design. The directors are used to provide the antenna directional pattern with gain. The amount of gain is directly proportional to the length of the antenna array not by the number of directors used. The spacing of the directors can range from 0.1 to 0.5wavelengths or more and will depend largely up on the design specification of the antenna (Balanis, C.A et al,1997). **The reflector** is the element that is placed at the rear of the driven element (The dipole). Its resonant frequency is lower, and its length is approximately 5% longer than the driven element. Its length will vary depending on the spacing and the element diameter. The spacing of the reflector will be between 0.1 wavelengths and 0.25 wavelengths (H. Yagi et al,1928). Its spacing will depend upon the gain, bandwidth forward/backward ratio, and side lobe pattern requirements of the final antenna design. The length and

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spacing between the elements which we are taken to design the antenna are shown in the Table 1.

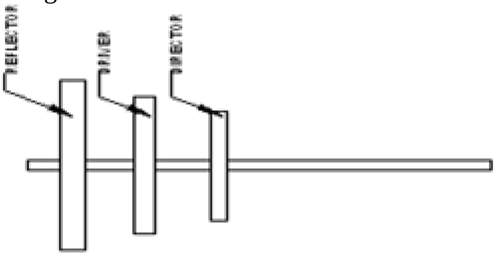

Figure 1: Proposed Yagi-Uda Patch Antenna

2. Proposed YAGI-UDA Patch Antenna

Table 1: Length and spacing between the elements

Element	Length	Separation
Reflector	0.55λ	0.1λ
Driver	0.50λ	0.1λ
Directors	0.45λ, 0.40λ, 0.35λ	0.1λ

The dimensions of the purposed Yagi antenna are illustrated in Figure 2. First we design the ground plane. The dimension of is (14.15*14.15 cm). Then above the ground plane we include1.5cm air gap and above the air gap we design EBG (electromagnetic band gap). EBG is of mushroom-type. Dielectric layer (3.27) is positioned between the lower surface of the antenna and upper part of the EBG. The thickness of the EBG plane is 0.77 cm. The three compact Yagi-Uda antenna is designed first for 1.6 GHz in free space. A driver is fitted on the centre of the patch. The distance between the driver and the director is 0.61 cm and the distance between the driver and the reflector is 0.54 cm. The EBG ground plane is designed with procedure similar to (J. M. Bell et al,2004). Both Yagi and EBG structure, including patches, columns, and the bottom ground plane, are made of copper.

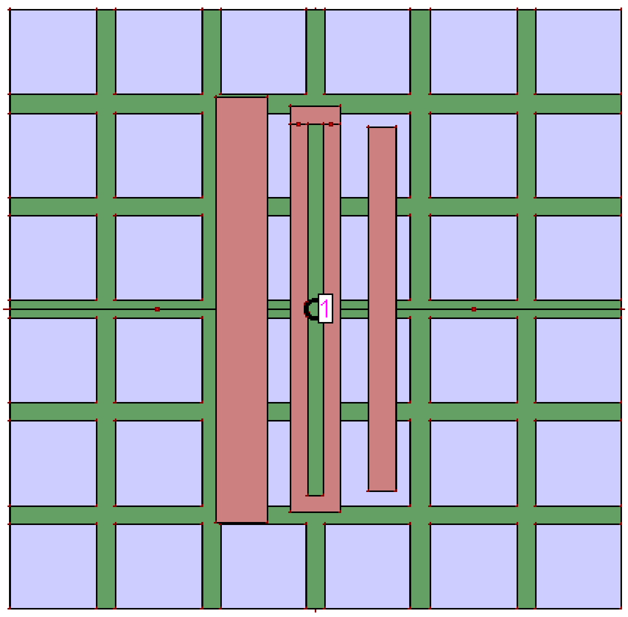

Figure 2(a): Compact-Efficient Yagi-Uda Antenna

The dimensions of three elements of compact Yagi-Uda antenna are shown in the above Figure2 (b).

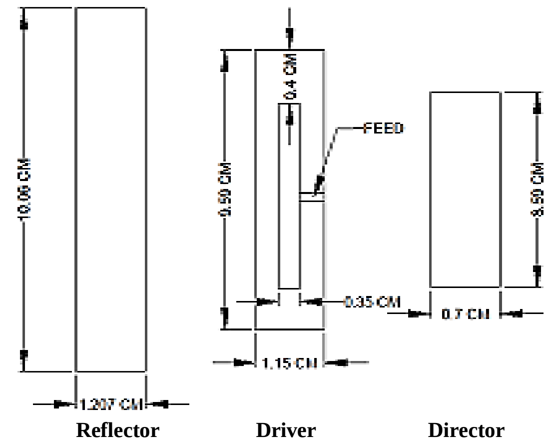

Figure 2(b) Elements of Yagi Antenna

3. Simulated Results and Comparisons

The proposed Yagi-Uda antenna with EBG and with air gap structure shown in Fig. 2 and it has been studied and simulated. Similarly other geometries with difference air gap simulated and we get best results in 1.5cm air gap. The results show that the performance parameters of Yagi-Uda antenna with EBG with air gap structure is better include air gap. The S_{11}<-20dB from 2-3 GHz.

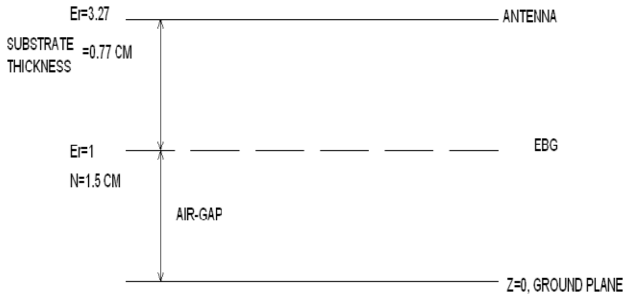

Figure 2 (c): Side View of antennal layer

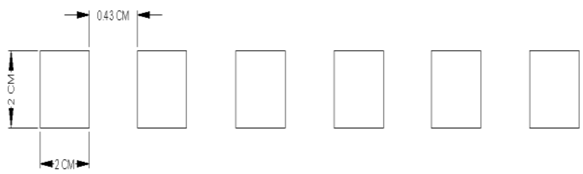

Figure 2(d) Side view of EBG

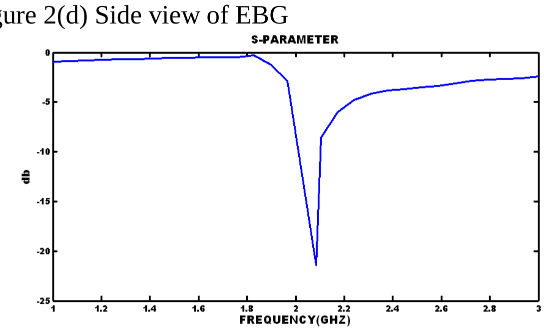

Figure 3: Frequency vs S_{11} Parameter.

(i) S-parameters- S-parameters describe the input-output relationship between ports (or terminals) in an electrical system. For instance, if we have a communication system with two radios (radio 1 and radio 2), then the radio terminals (which deliver power to the two antennas) would be the two ports. S_{11} then would be the reflected power radio 1 is trying to deliver to antenna 1. S_{22} would be the reflected power radio 2 is attempting to deliver to antenna 2. And S_{12} is the power from radio 2 that is delivered through antenna 1 to radio 1. Note that in general S-parameters are a function of frequency (i.e. vary with frequency). S_{21} represents the power received at antenna 2 relative to the power input to antenna 1. The most commonly quoted parameter in regards to antennas is S_{11}. S_{11} represents how much power is reflected from the antenna, and hence is known as the **reflection coefficient** (sometimes written as gamma or return loss). If S_{11} = 0 dB, then all the power is reflected from the antenna and nothing is radiated. If S_{11} = -10 dB, this implies that if 3 dB of power is delivered to the antenna, -7 dB is the reflected power.

(ii)Directivity: The d**irectivity** is a fundamental antenna parameter. It is a measure of how 'directional' an antenna's radiation pattern is. An antenna that radiates equally in all directions would have effectively zero directionality, and the directivity of this type of antenna would be 1 (or 0 dB). Directivity is the ability of an antenna to focus energy in a particular direction when transmitting, or to receive energy better from a particular direction when receiving. In a static situation, it is possible to use the antenna directivity to concentrate the radiation beam in the wanted direction. However in a dynamic system where the transceiver is not fixed, the antenna should radiate equally in all directions, and this is known as an Omni-directional antenna.

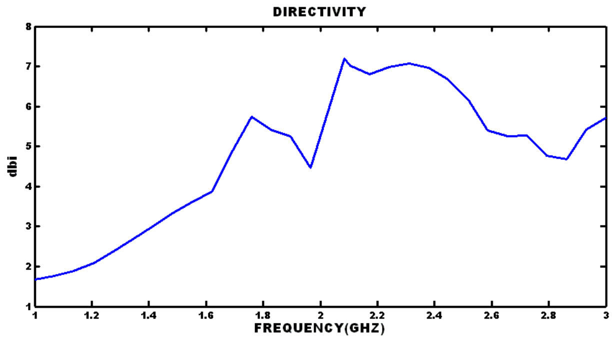

Figure 4: Field directivity vs frequency.

(iii) Gain: Gain is not a quantity which can be defined in terms of a physical quantity such as the Watt or the Ohm, but it is a dimensionless ratio. Gain is given in reference to a standard antenna. The gain of an antenna in a given direction is the amount of energy radiated in that direction compared to the energy an isotropic antenna would radiate in the same direction when driven with the same input power. Usually we are only interested in the maximum gain, which is the gain in the direction in which the antenna is radiating most of the power. An antenna gain of 3 dB compared to an isotropic antenna would be written as 3 dBi. The method of measuring gain by comparing the antenna under test against a known standard antenna (isotropic antenna), which has a calibrated gain.

(iv) Efficiency: The **efficiency** of an antenna relates the power delivered to the antenna and the power radiated or dissipated within the antenna. A high efficiency antenna has most of the power present at the antenna's input radiated away. A low efficiency antenna has most of the power absorbed as losses within the antenna, or reflected away due to impedance mismatch.

Conclusion: The paper describes a design of planar three-element Yagi-Uda antenna for 1-3 GHz band. The structure has been optimized for a maximum directivity and maximum gain and other performance parameter by include the air gap of 1.5cm and simulated by IE3D Software. This Yagi antenna consisted of the driven element, a reflecting element and a directing element. We simulated the gain of the purposed antenna is 5.8dB.

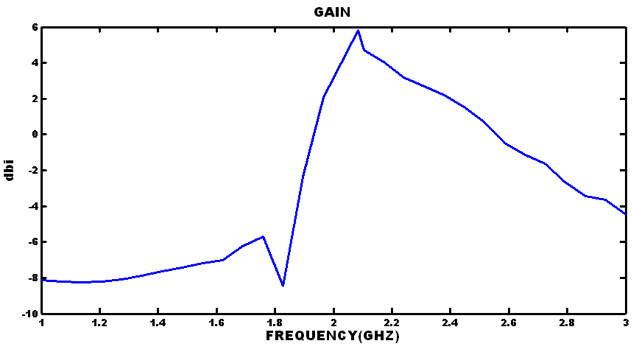

Figure 5:Total Field gain vs. Frequency

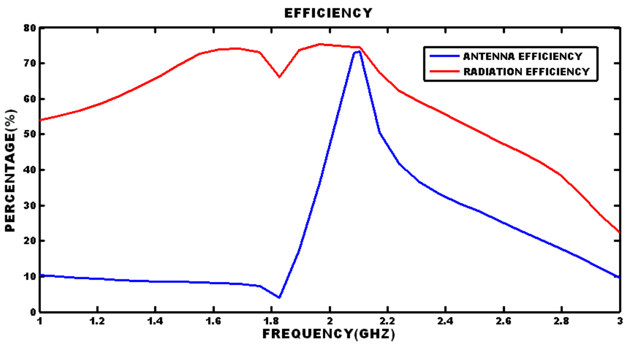

Figure 6: Efficiency vs. Frequency

This table show the variations of different performanceparameters (directivity, gain, antenna efficiency, radiation efficiency) with respect to frequency and we have noted these variations from the above graphs

Table 2: Performance parameter

Parameter	Simulated Results
Frequency (GHz)	2.083
$\|S_{11}\|$ (dB)	-21.42
Directivity (dBi)	7.19
Gain (dBi)	5.8
Antenna efficiency (%)	72.92
Radiation efficiency (%)	74

The above table of proposed antenna shows a bandwidth of 96 % with $S_{11} \leq$ -21 dB from 1 to 3 GHz. In above table shows much improvement in performance parameters over frequency band 1 – 3 GHZ. In the table shows the best results of proposed antenna at frequency of 2.083GHz.

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