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Design of planar dual band Yagi antenna for energy harvesting application

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Abstract

In this project, a planar dual band yagi antenna array is proposed for energy harvesting application. Here the substrate used is FR-4(lossy) with dielectric constant of 4.3. Using the microstrip feed line the extra balun as a part of the feed network, required in the conventional microstrip yagi antenna can be avoided. The antenna was designed to operate at two frequencies i.e. 1.8GHz and 2.4GHz. The predicted, simulated and practical results are shown to be in good agreement.

Index Terms—Antenna array, energy harvesting, microstrip feed line, yagi-uda antenna, balun.

1. INTRODUCTION

Recent advances in RF energy-harvesting technology have made self-sustainable devices feasible. The major concern for these devices is typically the battery life and replacement. Applying RF energy-harvesting technique to them can significantly extend the battery life and sometimes even avoid the need for a battery. The ambient RF power is a good potential candidate for the energy supply as it is widely broadcast from numerous reliable electromagnetic resources. However, since the power density of the ambient RF power is extremely small, it is very challenging to design RF energy-harvesting systems with satisfying RF-to-dc power conversion efficiencies (PCEs).

2. ANTENNA BASICS

Antennas are used for **converting** conducted electromagnetic waves into electromagnetic waves freely propagating in space and vice versa. The name is derived from the field of zoology, where the term antennae (Latin) is used to designate the

long thin feelers of insects.

The oldest existing antennas, eg those used by *Heinrich Hertz* in 1888 in his first experiments for proving the existence of electromagnetic waves, were neither physically nor functionally separated from high-frequency generators, and up to the present day resonant circuits are taken as models for illustrating certain antenna characteristics. It was not until around and after 1900 that antennas were clearly separated and regarded an independent unit in a radio system as transmitting and receiving stations were set up.

Antennas have the function of converting one type of wave into another. The direction of energy conversion is irrelevant as far as the principle of operation and the understanding thereof are concerned. The transmitting and the receiving antenna can therefore be looked at in the same way (reciprocity principle), and the parameters described below are equally valid for transmission and reception. This also applies if the parameters are in some cases measurable only for transmission or for reception or if their specification appears to be meaningful only for one of these modes. Active antennas are the only exception: being pure receiving antennas, they are non-reciprocal. Apart from that, a clear distinction between transmitting and receiving antennas must be made if, for example, the maximum transmitter power is to be taken into account. This is however irrelevant to the characteristics and the principle of operation.

Antennas can be classified in several ways. One way is the frequency band of operation. Others include physical structure and electrical/electromagnetic design. In that we are going to discuss about yagi uda antenna.

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A. YAGI UDA ANTENNA

Another antenna design that uses passive elements is the Yagi antenna. This antenna, illustrated in figure(1.4), is inexpensive and effective. It can be constructed with one or more (usually one or two) reflector elements and one or more (usually two or more) director elements.

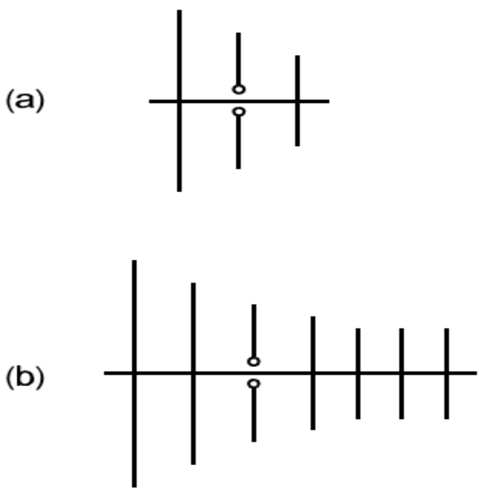

Fig 1. The Yagi antenna (a)Three elements and (b)Multiple elements

3. BASIC FORM OF YAGI UDA ANTENNA ARRAY

The Yagi antenna design has a dipole as the main radiating or driven element. Further 'parasitic' elements are added which are not directly connected to the driven element. These parasitic elements pick up power from the dipole and re-radiate it. The phase is in such a manner that it affects the properties of the RF antenna as a whole, causing power to be focused in one particular direction and removed from others.

The parasitic elements of the Yagi antenna operate by re-radiating their signals in a slightly different phase to that of the driven element. In this way the signal is reinforced in some directions and cancelled out in others. It is found that the amplitude and phase of the current that is induced in the parasitic elements is dependent upon their length and the spacing between them and the dipole or driven element.

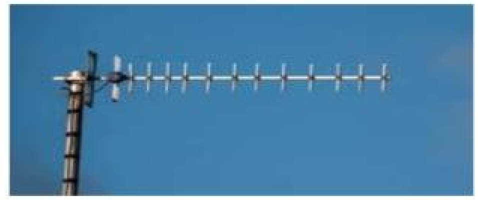

Fig 2.Yagi Uda antenna showing element types

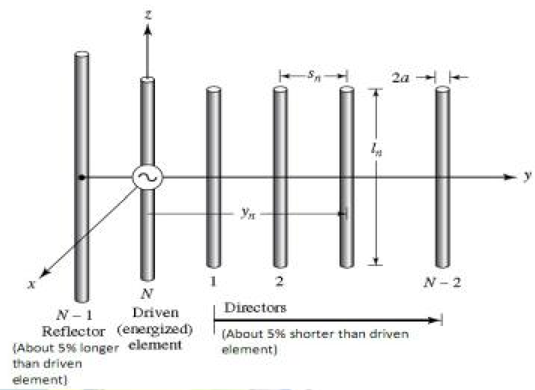

Fig 3.Typical Yagi Uda antenna configuration

There are three types of element within a Yagi antenna:

(i) **Driven element:** The driven element is the Yagi antenna element to which power is applied. It is normally a half wave dipole or often a folded dipole.

(ii) **Reflector :** The Yagi antenna will generally only have one reflector. This is behind the main driven element, i.e. the side away from the direction of maximum sensitivity. Further reflectors behind the first one add little to the performance. However many designs use reflectors consisting of a reflecting plate, or a series of parallel rods simulating a reflecting plate. This gives a slight improvement in performance, reducing the level of radiation or pick-up from behind the antenna, i.e. in the backwards direction. Typically a reflector will add around 4 or 5 dB of gain in the forward direction.

(iii) **Director:** The director or directors are placed in front of the driven element, i.e. in the direction of maximum sensitivity. Typically each director will add around 1dB of gain in the forward direction, although this level reduces as the number of directors increases.
The antenna exhibits a directional pattern consisting of a main forward lobe and a number of spurious side lobes. The main one of

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these is the reverse lobe caused by radiation in the direction of the reflector. The antenna can be optimized to either reduce this or produce the maximum level of forward gain. Unfortunately, these two do not coincide exactly, and a compromise on the performance has to be made depending upon the application.

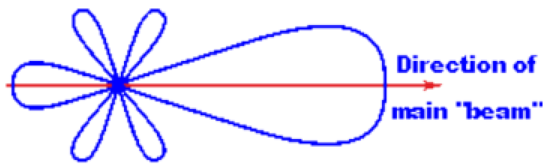


Fig 4.Radiation pattern of Yagi Uda antenna

4. LIMITAIONS OF YAGI UDA ANTENNA

The major limitations of yagi uda antenna are its gain and bandwidth is limited. For high gain levels, the antenna becomes very long. So, we prefer planar form of yagi antenna for energy harvesting.

5. NEED FOR PLANAR QUASI YAGI ANTENNA

An ideal planar antenna should have some characteristics like

- Good radiation characteristics such as well defined pattern, good front to back ratio and low cross polarization.
- Wide frequency bandwidth.
- Small as possible to easy integration with microwave integrated circuits.
- Simple and low cost fabrication.

The planar printed quasi-Yagi antenna has almost all these characteristics. However the bandwidth of conventional quasi-Yagi antenna is narrow. To overcome this limitation, various methods are proposed in literature and now very good bandwidth is achieved. Another limitation of Quasi-Yagi antenna is it can't provide a high gain owned by Yagi- Uda antenna. Various methods to enhance the gain of the Quasi-Yagi antenna are also highlighted in literature.

The classic Yagi-Uda antenna is a popular and widely used antenna since its origin. It is because of its simplicity, low cost, directional radiation pattern and relatively high gain. The antenna consists of linear array of parallel dipoles forming a parasitically coupled array as shown in figure.

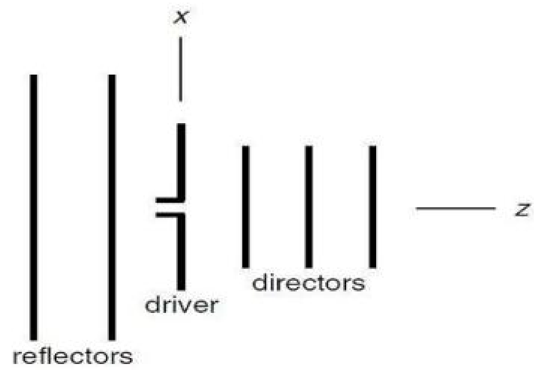
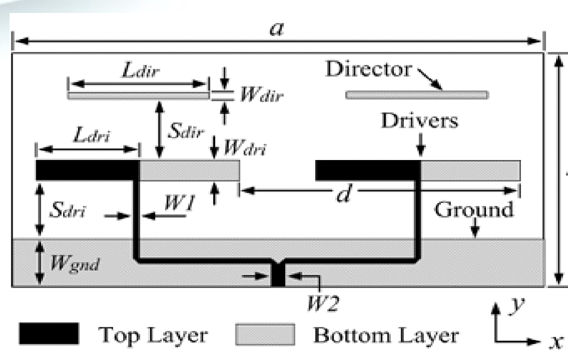


Fig 5.Layout of classic Yagi -Uda Antenna

6. PROPOSED DESIGN

A. 1X2 QUASI YAGI SUB-ARRAY DESIGN

Due to the size limitation of the fabrication, the design starts from a 1×2 subarray. Fig. 1(a) and (b) gives the top and side views of the proposed quasi-Yagi subarray, which is fabricated on a 62-mil-thick FR-4 substrate with a dielectric constant of 4.3. The top and bottom metallization comprises a microstrip feedline, two double-sided parallel-strip feedlines, two dipole elements (drivers), two directors, and a conductor plane. The conductor plane can be treated as a virtual ground plane and acts as the reflector element for the two antenna ele-ments, which makes the subarray radiate forward and obtain a good front-to-back ratio [5]. Using the microstrip feedline, the extra balun as a part of the feed network, required in the con-ventional microstrip quasi-Yagi antenna [5], can be avoided.



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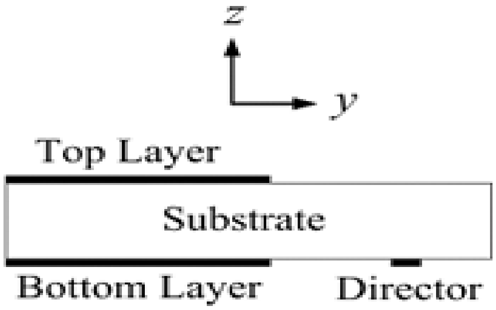

Fig 6. Top view and side view

DESIGN PARAMETERS:

PARAMETER	VALUES
Length of driven element(Ldri)	28mm
Width of driven element(Wdri)	2mm
Length of director(Ldir)	25mm
Width of director(Wdir)	0.5mm
Length of ground(a)	140mm
Width of ground(Wgnd)	20mm
Length of substrate(a)	140mm
Width of substrate(b)	100mm
Dielectric constant	4.3

Fig 7. Design parameters

The above design can be simulated in computer simulation technology (CST) software and s –parameter, gain, directivity etc. can be analyzed. The figure below shows the simulated results.

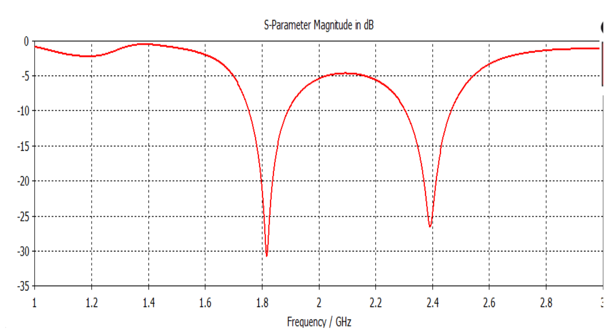

Fig 8.S-Parameters Graph of 1X2 sub-array

The designed antenna operates in dual band i.e., at frequency 1.8 GHz and 2.4 GHz with gain of 6.3 dB and 7.2 dB respectively. Christo Ananth et al.[3] discussed about E-plane and H-plane patterns which forms the basis of Microwave Engineering principles.

B. GAIN ENHANCEMENT USING 1X4 ARRAY

A 1 × 4 quasi-Yagi array can be formed by simply connecting two 1 × 2 subarrays together with a T-junction power divider. The photographs of the 1 × 4 array are shown in Fig. 3. The distance between each element is equal to that of the previous subarray. In this way, the array has more flexibility to switch between 1X4 and 2X2 topologies.

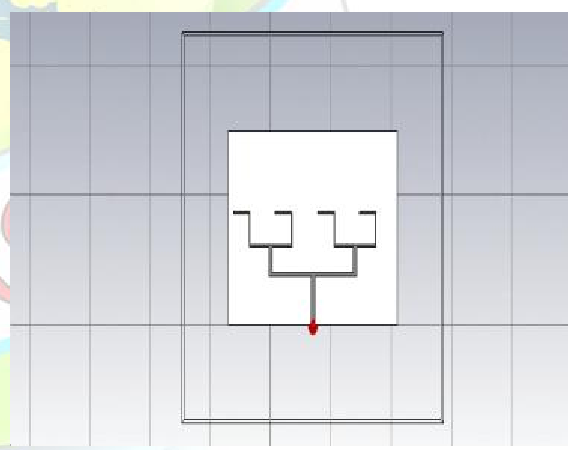

Fig 9. Front view of 1X4 quasi yagi array.

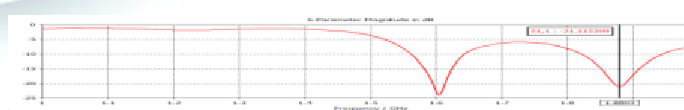

Fig 10. S-parameter for 1X4 array

It is observed that by using 1X4 yagi array the gain has been improved when compared to1X2 subarray.

7. CONCLUSION

A 1X2 yagi antenna array is designed to operate in dual band i.e at frequencies 1.8 GHz and 2.4 GHz with gain of 6.3dB and 7.2 dB respectively.This antenna can be use for energy harvesting application. Further gain can be enhanced by using 1x4 array.

8. FUTURE WORK

The above designed antenna can be connected to a rectifier circuit using suitable matching network .The antenna receives the RF power, and the rectifier converts it into dc power. In this way, it can be used for energy harvesting applications by collecting the energy from ambient environment.

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