Effects of Ground Planes on a Six Element Yagi-Uda Antenna

John Maxwell Dunn
Department of electrical, Computer, and Energy Engineering
ECEN 2420
Boulder, Colorado, USA

***Abstract*—This paper will explore how ground planes affect the radiation pattern of a 6 element Yagi-Uda antenna. Using FEKO, a Yagi-Uda antenna was created from specifications in Yagi-Uda Antenna Design[1]. Then, far-field simulations were used to tune the antenna to 7.04Mhz, the center frequency for a NorCal 40A radio. Finally, radiation patterns and other antenna parameters with different ground planes were compared.**

I. Introduction

Although Yagi-Uda antennas are largely used in frequencies ranging from 30Mhz to 3Ghz, the simplicity of its design makes it a viable choice for the purpose of this paper, which is to observe changes in radiation power and other antenna parameters when ground planes of differing permittivity and conductivity are added.

In a Yagi-Uda antenna, there are four types of elements. The first is the driving (sometimes called feed) element, which consists of a half-wave dipole. This element is electrically isolated from all other elements in the antenna. The second element is called the reflector. Its primary purpose is to reflect the radiation pattern towards the third elements, called the directors. The role of the directors are to focus the radiation patterns in to a directional lobe. Lastly, a boom element connects all but the driving element down the antenna's length. In order to tune the antenna to 7.04Mhz with no ground plane, the Driving Element Length must be changed from a perfect dipole, or a 0.5 ratio, to a 0.467 ratio.

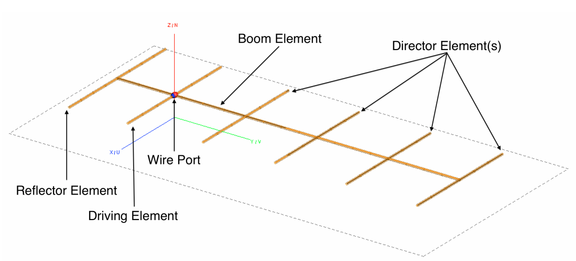

Fig. 1. Components of a Yagi-Uda Antenna.

II. Design Specifications

The antenna designed in this paper uses values given by "Yagi-Uda Antenna Design" [1]. All the specifications are given as a coefficient to the wavelength (1) of the center frequency. In this case, the $f_c = 7.04$ Mhz and $c = 3.0 \times 10^8 \frac{m}{s}$.

$$wavelength = \lambda = \frac{c}{f_c} = 42.6 \text{ [m]} \tag{1}$$

Notice in Table I the elevation of this antenna is 21.31 meters tall. This is highly impractical, but for the purposed of this paper, it will do just fine.

Dimension	Ratio	lambda*Ratio [m]
Driving Element Length*	0.467	19.89
Reflector Element Length	0.482	20.54
Director (1) Element Length	0.428	18.24
Director (2) Element Length	0.420	17.89
Director (3) Element Length	0.420	17.89
Director (4) Element Length	0.428	18.24
Reflector Spacing	0.2	8.522
Director Spacing	0.25	10.65
Elevation	0.5	21.31

TABLE I
Specifications of the Yagi-Uda Antenna [1].

III. Simulation of Antenna

When the antenna is constructed in FEKO using the specifications in Table I, the radiation patterns follow the images shown in Fig. 2. The ground planes shown have the parameters detailed in Table II[2]. It can be seen that the greater the "quality" of the ground plane, meaning higher in permittivity and conductivity, the higher the resultant angle (Fig 3) of the main lobe and the higher power outputted.

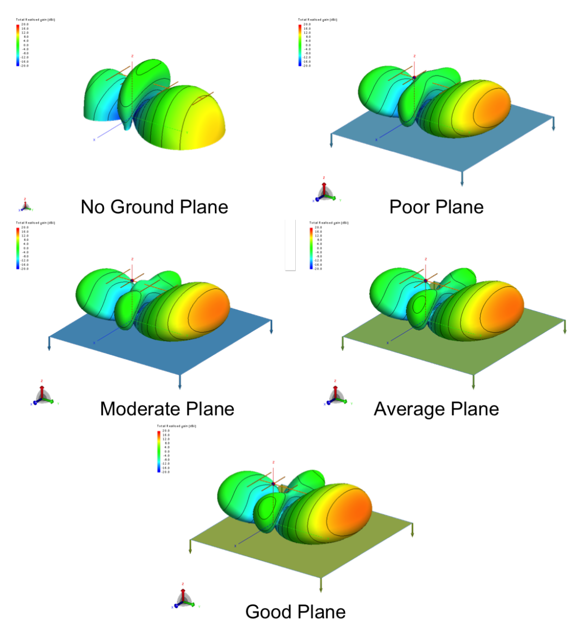

Fig. 2. Full 3D radiation patterns of the designed antenna.

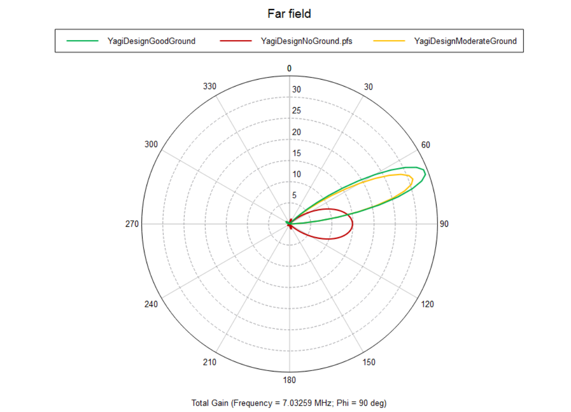

Fig. 3. This H-Plane cut shows how the resultant angle and gain of the main lobe increases with ground quality.

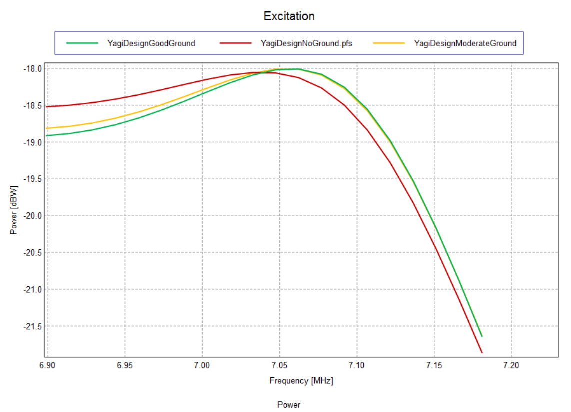

Fig. 4. Source power with respect to frequency. As the quality of the ground planes increase, the center frequency shifts higher and the maximum magnitude of the source power increases.

Ground Plane	Permittivity (ϵ)	Conductivity (σ)
None	N/A	N/A
Poor	4.5	0.001
Moderate	4	0.003
Average	12.5	0.0075
Good	13	0.015

TABLE II
GROUND PLANE PARAMETERS

IV. Fabrication Considerations

While this antenna is an excellent model for directional antenna design, it is not ideal for frequencies as low as 7.04 Mhz. If this antenna were to be constructed, there would have to be some important design considerations to make it physically practical.

Foremost, the size of the antenna would be fairly massive. At 51.12 meters in length and 20.54 meters in width, it would take up about a fourth of a soccer field. Additionally, the antenna would be positioned 21.31 meters in the air, which is a feat of engineering unto itself. To mitigate the size issue, support structures made out of non-conductive materials like PVC piping would have to be installed to stabilize each element.

A way to shrink the antenna size would be to implement ferrite core elements and use thicker wire elements. This would increase the radiation resistance and allow for the ends of all elements to be significantly trimmed.

The last consideration is the tuning of the antenna. As shown in Fig 4, the center frequency changes when different grounds are applied. Therefore, depending on the ecosystem surrounding the antenna, the Driving Element Length ratio would have to be altered. Typically ranging from (0.42:0.48)λ.

V. Conclusion

This paper presents the effects of varying ground planes on a six element Yagi-Uda antenna. The Yagi-Uda antenna is a highly directional antenna, consisting of driving, reflecting, and directing elements (Fig. 1). It's primary operation is between 30 Mhz and 3 Ghz, but here it is used for a 7.04 Mhz signal, which results in some size issues.

Despite this, it was shown that as the quality of the ground plane increases, meaning higher values for permittivity and conductivity, the radiation pattern of the antenna changes quite a bit. All lobes of the pattern are forced upward in the H-Plane (Fig. 3) with increasing resultant angle and the magnitude of their gain increases proportionally. A surprising discovery was that as the quality of the ground plane increases, the center frequency shifts to higher frequencies.

In the future, other antenna designs might be considered for use, including a horn antenna or a loop antenna. These designs might be more suited for lower frequencies.

References

[1] ”Yagi-Uda Antenna Design.” Yagi-Uda Antenna. N.p., n.d. Web. 26 Apr. 2014. ¡http://www.antenna-theory.com/antennas/travelling/yagi3.php¿.

[2] ”Soil Dielectric Properties.” Soil Dielectric Properties. N.p., n.d. Web. 28 Apr. 2014. ¡http://home.earthlink.net/ w6rmk/soildiel.htm¿.