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Analysis of the Effects of Reflector and Director on a Half Wave Dipole's Directivity

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Abstract- **The rapid advancements in the field of antenna and microwave design has opened many new dimensions. This is only possible because of the developments of various highly efficient simulation tools that produce precise and truthful results. With the advancements in antenna design, complexity of the design is also increased. Designers sometimes ignore the simplicity and beauty of the old antenna designs. This paper is an attempt to re-assert the theory proved by H.Yagi and S. Uda in 1926 using modern tools. CST microwave studio is used for simulation of a 2 GHz half-wave dipole with a reflector and director in its vicinity. Such a high frequency of 2 GHz is used for the simulation because these are used a lot nowadays for various applications. The advantages of the design of Yagi-Uda antenna can be exploited in various modern antenna and their applications.**

***Keywords**: Half-wave dipole; wave reflector; wave director; directivity.*

I. INTRODUCTION

There are numerous applications where the need of a directional antenna comes into picture. Since more than 100 year there have been researches in the direction of making an antenna directional. One of the oldest methods to make an antenna directional is make a parasitic array out of it. In 1926, H.Yagi and S.Uda invented a parasitic array that successfully increased the directivity and bandwidth of a simple half-wave dipole [1]. A rod of equal or slightly longer length is placed quarter wave away from a half wavelength long vertical antenna. The current induced in it will be in phase or lag behind. This effect will make this rod a 'wave reflector'. If another rod of length less than quarter wavelength is placed quarter wave away on the other side of this arrangement, the current induced in this rod will lead. This effect will make this rod a 'wave director'. Reflector will reflect away the signal that comes out of the driven element. On the other hand, director pulls the electromagnetic wave towards it causing the radiation pattern to be single directional towards the director. To make the radiation pattern more directional one can put more directors on the same axis and plane. On the contrary only a single reflector is sufficient to cause directive action of radio wave.

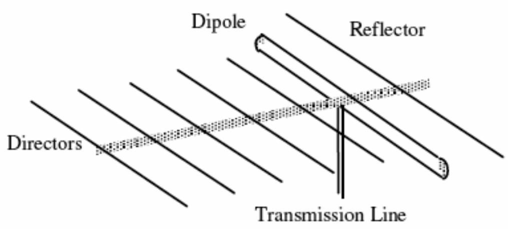

Figure 1. 7-element Yagi Uda antenna

II. ANTENNA DESIGN

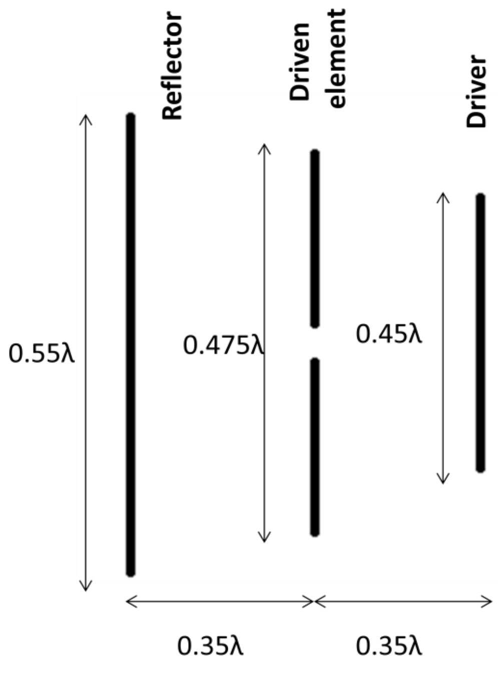

Figure 2. Antenna Dimensions

Operating frequency is 2 GHz. Hence wavelength is 147.78 mm. Driven element is kept 0.475 times of wavelength because only 95% of the dipole antenna radiates. Reflector length is 0.55λ and director length is 0.45λ. Separation between driven element and driver is 0.35λ and that between driven element and driver is also 0.35λ. Input impedance of a half wave dipole is 73Ω.

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Following table shows the dimensions of the antenna.

Table 1 Antenna Dimensions

Structure	Length (mm)
Driven Element	70.44
Reflector	76.85
Driver	66.50
Spacing	51.72

Antenna radius is taken as 0.001λ. Feeding gap is 1 by 200 time of the driven element length.

Firstly a simple half wave dipole antenna is constructed and its return loss, bandwidth and directivity are observed.

Secondly a reflector is kept 0.35λ away from the dipole. Results are observed again.

Lastly, a driver is placed 0.35λ away from the driven element on the same plane as the reflector and the results are observed.

III. SIMULATION RESULTS

A. Half wave dipole

Figure 3 shows the return loss plot of a simple half wave dipole resonant at 2 GHz.

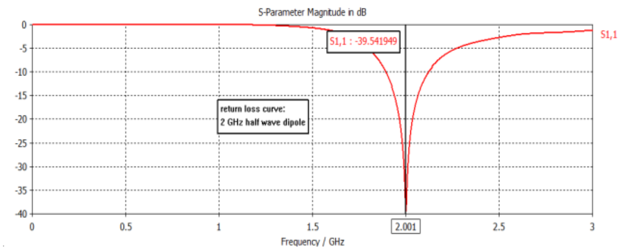

Figure 3. S11=-39.54 at 2 GHz (dipole only)

The half-wave dipole radiates omni-directionally, perpendicular to the length of the wire. Figure 4 shows that the radiation pattern is donut shaped as explained in standard text.

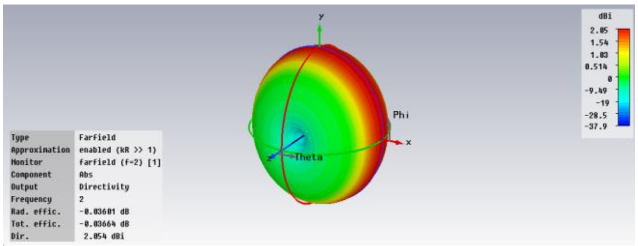

Figure 4. 3D radiation pattern of half wave dipole

In spherical coordinate system, the designed antenna is kept on the z-axis. So the radiation pattern is expected to be symmetrical along xy-plane. Polar plot keeping theta = 900 and varying phi is shown in figure 5.

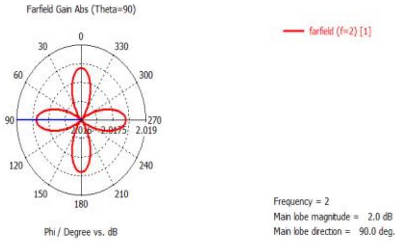

Figure 5. Polar plot of a half wave dipole antenna

1. *B. Half wave dipole with reflector*

Return loss of the antenna when a reflector is placed 0.35 wavelengths away is shown in figure 6.

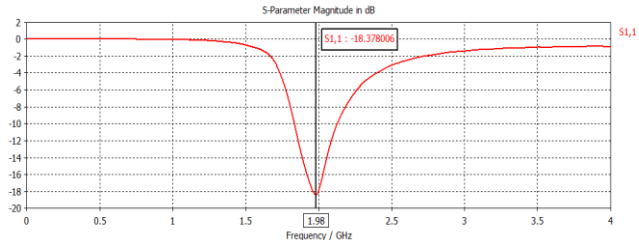

Figure 6. S11=-18.38 at 1.98 GHz (dipole with reflector)

We can see that placing a reflector along with the driven element increases the bandwidth significantly. Return loss is highly increased as compared to a simple dipole.

Effect on radiation pattern is that the radiation pattern shift away from the reflector increasing the directivity (Figure 7).

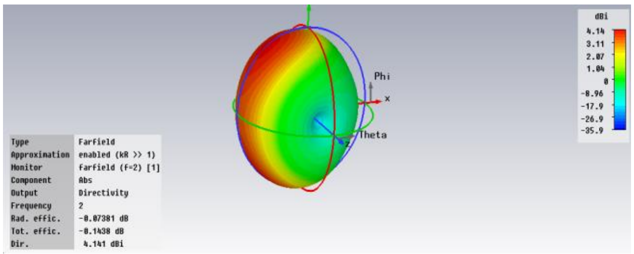

Figure 7. 3D radiation pattern of dipole with reflector

Polar plot of the antenna also shows the same information in figure 8.

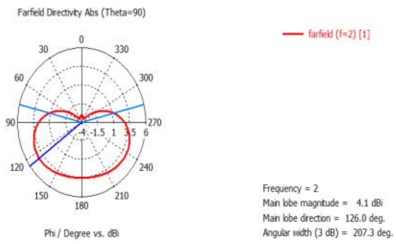

Figure 8. Polar plot of dipole with reflector

C. Half wave dipole with reflector and a director

To increase the directivity of the antenna one or more directors can be placed on the same plane as of driven element and reflector. From figure 9 it can be seen that the pattern which was already shifted away from the reflector moves more towards the director thus making the radiation pattern more directional.

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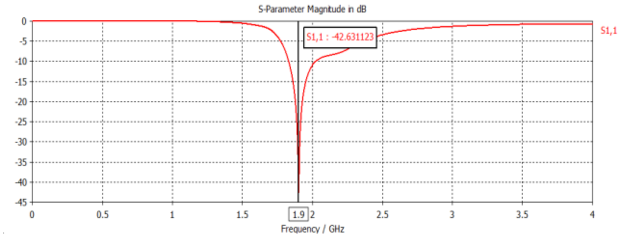

Figure 9. S11=-42.63 at 1.9 GHz (dipole with reflector and a director

The return loss is apparently improved when a director is placed. Consequently, the bandwidth is reduced again. But with placement of more director elements bandwidth can be increased again.

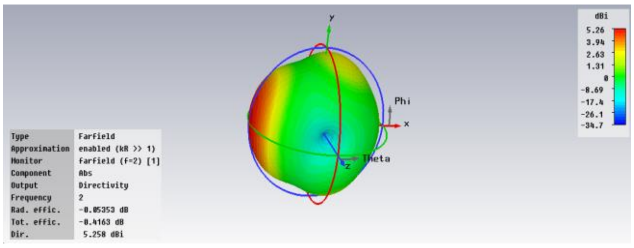

Figure 10. 3D radiation pattern of dipole with reflector and a director

Figure 10 and Figure 11 show that the directivity of the antenna is increased and it is highest where the director of the antenna is placed.

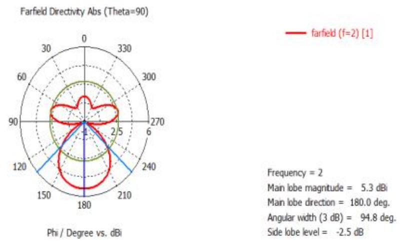

Figure 11. Polar plot of the dipole with reflector and a director

Table 2 shows the compilation of the results.

Table 2. Compiled results of 3 types of antenna

Parameter	**Simple dipole**	**Dipole with reflector**	**Dipole with reflector and director**
Return loss (dB)	-39.54	-18.38	-42.63
Directivity (dBi)	2.054	4.141	5.258
Bandwidth (MHz)	240	300	210

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