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An Enhanced Gain of Yagi-Uda Antenna with Folded Dipole for Amateur Radio VHF Band Application

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Abstract. This paper presents an enhanced gain of Yagi-Uda antenna with folded dipole for amateur radio Very High Frequency (VHF) band. The analysis is performed using CST Microwave Studio Suite software. The structure of this directional antenna integrates three main parts which are directors, reflectors and feeder point of 50 Ω. The performance of the proposed antenna has a tolerable reflection coefficient below -10 dB at 144.46 MHz. A maximum gain of around 14.03 dB with a good efficiency of 75.6% is achieved. The gain of the antenna increases up to 2% when added with 7 elements of reflector than with one element of reflector and enhanced significantly by 23.6% compared to the conventional Yagi-Uda antenna.

1. Introduction

An amateur radio is a non-commercial exchange of message using a wireless communication system that is established by the International Telecommunication Union (ITU) through International Telecommunication Regulation. It can be accessed in the specific RF frequency spectrum which is the very high frequency (VHF) frequency band to enable communication across the city and the region. In this paper, an amateurish radio is used to extend the communication range of the base station in the countrified area and to provide 100% coverage of the radio amateur system in Peninsular Malaysia. It is also to provide coverage for the present blind spots in the rustic areas and to provide a communication system that is robust for emergency, disaster and distress areas by using a high-gain antenna design. There are several themes that all antenna designers should know about the basic properties that must be acquired in order to get an efficient antenna. The fundamental properties are the matching impedance, bandwidth, radiation pattern and the most important is the gain1. Antenna gain is the ratio of the power required at the input of a loss-free reference antenna to the power-supply input of the granted antenna to produce, in a given direction and the identical field at the same distance. Yagi-Uda antenna is one type of antenna that developed in the 1920's[1]. In 1927 and 1928, respectively, Uda and Yagi published their paper on what today known as the Yagi-Uda antenna[2-4].

Yagi-Uda antenna is widely used due to inherent advantages of good directivity, high gain, low cost, simple structure and light weight[5-6].It also used by amateur radio group, but the problem is, the antenna that constructed from previous data cannot be used in wide range area especially in the rural area. Hence this paper proposed the new Yagi-Uda antenna design to upgrade the system, beside it can be used in wide range area. This antenna also can prevent the building of the more base station in order to reduce the financial problem. It also provides a free telecommunication application for the rural population as long as affordable since they are coming from low income group. Lastly it can provide a comprehensive solution for the emergency, disaster and distress solutions in the rural areas.

VHF band is widely used in a long range communication system, enabling communication across the cities and the rural regions. An amateurish radio that utilizes the VHF band is used to extend the communication range of the base stations in remote areas and provide 100% coverage of the amateur radio system in Peninsular Malaysia. The aim of the amateur radio is to offer secondary coverage during the harsh environment especially emergency, disaster and distress rural areas. Thus, it is important in designing the Yagi-Uda antenna for local communities in rural areas so as to channel the information in a wide range area through the amateurish radio VHF band. Yagi-Uda has been utilized by amateur radio group. However, such antenna is deprived of a wide coverage in rural areas, thereby, leading to poor communication links in that most needed areas. Thus, in this study, a new Yagi-Uda antenna is designed to achieve an enhanced gain with good impedance bandwidth at resonant frequency of 144 MHz.

2. Material and method

The proposal antenna is designed using electromagnetic solver, CST Microwave Studio Suite software. A directional simple 7 elements Yagi with 3.7 m boom length for the lower 144 MHz is modeled and designed. The dimensions of the optimized antenna structure are presented in Table 1.

Table 1. Design Specification of QM7 Antenna

SPECIFICATION	VALUE
Length of Reflector (R)	0.482λ
Length of Driven Element(DE)	0.48λ
Width of Feed Element (FE)	0.009λ
Length of Director 1 (D1)	0.457λ
Length of Director 2 (D2)	0.446λ
Length of Director 3 (D3)	0.437λ
Length of Director 4 (D4)	0.430λ
Length of Director 5 (D5)	0.443λ
Spacing b/n Reflector and Driven Element	0.238λ
Spacing b/n Driven Element and Director 1	0.124λ
Spacing b/n Director 1 and Director 2	0.287λ
Spacing b/n Director 2 and Director 3	0.335λ
Spacing b/n Director 3 and Director 4	0.431λ
Spacing b/n Director 4 and Director 5	0.335λ
Diameter of elements	0.0014λ

Yagi–Uda antenna has a simple geometry. It can readily be designed and optimized by a numerical approach. However, certain design rules will help with initial design or design of general purpose antennas without optimization. The antenna consists of an array of parasitic elements that include a driven element, a reflector element and one or more director elements [5-7]. In dipole Yagi antennas, the reflector is about 1–2% larger than the driven element. Once the driven element is selected the reflector size can be chosen as stated. The reflector size also has a significant effect on the antenna front-to-back ratio and the input impedance. The directors exhibit capacitive impedance whereas the reflectors show inductive impedance[5,8-9]. The addition of several directors of appropriate length can further improve the directivity of a Yagi antenna[10]. In order to design the high gain antenna, the type of antenna and antenna requirement should be considered. The QM7 antenna as shown in Figure 1 and detail dimensions in Table 1 is a simple 7 elements Yagi with 3.7 m boom length for the lower 144Mhz SSB/MGM band. It exhibits a forward gain of 11.35 dBd; i.e. 13.5 dB forward gain over the isotropic radiator, while the F/R is about 12.5dB. It matches a 50 ohms impedance, and it is coupled to the 50 Ohm coaxial cable with the use of 1:1 balun.

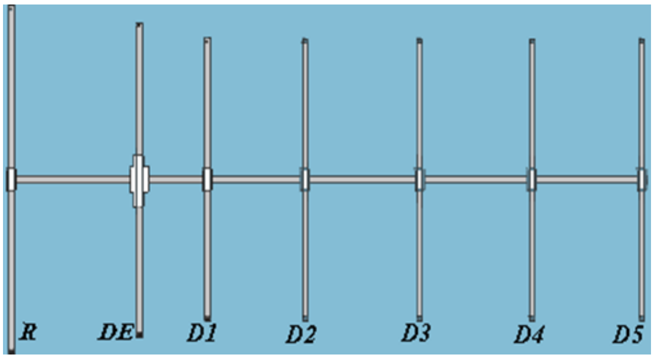

Figure 1. Simple 7 Element Yagi (QM7)

Yagi antenna consists of two parts; the combination feeder-reflector and the row of director elements. First step of designing Yagi-Uda is by adjusting the combination feeder-reflector for maximum gain in the forward direction, and noted that the adjustment remained optimum (within experiment error) even the row of directors was added. It was possible to retain the same adjustment of the feeder-reflector combination in successive experiments involving different rows of directors.

i) Folded Dipole

For the first, improvement of antenna was by adding folded dipole. A folded dipole is a dipole antenna with the ends folded back around and connected to each other, forming a loop. Folded dipole is "folded" back on itself, the currents can reinforce each other instead of cancelling each other out, so the input impedance will also depend on the impedance of a dipole antenna length. The folded dipole antenna has replaced the normal dipole antenna in some applications owing to its wideband impedance characteristics. Generally, a folded dipole antenna has a typical bandwidth between 10% and 30% of its center frequency[11-14].

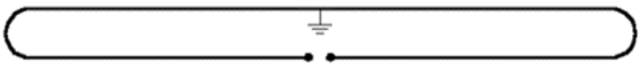

Figure 2. Simple Folded Dipole

ii) Reflector

The next step was improving the antenna reflector. An antenna reflector is a device that reflects electromagnetic waves. Antenna reflectors can exist as a standalone device for redirecting radio frequency (RF) energy, or can be integrated as part of an antenna assembly. Parameters that can directly influence the performance of an antenna with integrated reflector: dimensions of the reflector (big ugly dish versus small dish), spillover (part of the feed antenna radiation misses the reflector), aperture blockage (also known as feed blockage: part of the feed energy is reflected back into the feed antenna and does not contribute to the main beam), illumination taper (feed illumination reduced at the edges of the reflector), reflector surface deviation, defocusing, cross polarization, feed losses, antenna feed mismatch and non-uniform amplitude/phase distributions. These antennae are simulated under various design of reflector. The results of gain, reflection coefficient, directivity and efficiency are tabulated in Table 2.

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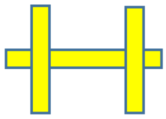
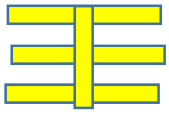
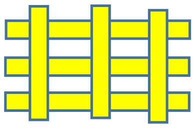
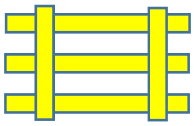
Table 2. Comparison of QM7 Yagi-Uda Antenna for Different Design of Reflector

	Reflector Design	Gain (dB)	Reflection Coefficient (-dB)	*D**	*E**
1		13.81	12.246	13.72	81.09
2		13.82	11.272	13.69	78.51
3		13.44	11.907	13.03	79.01
4		13.77	11.265	13.64	78.03
5		13.73	11.38	13.57	80.43
6		14.03	11.40	13.62	75.54
7		14.03	11.406	13.62	75.56

**D*: Directivity; **E*: Efficiency

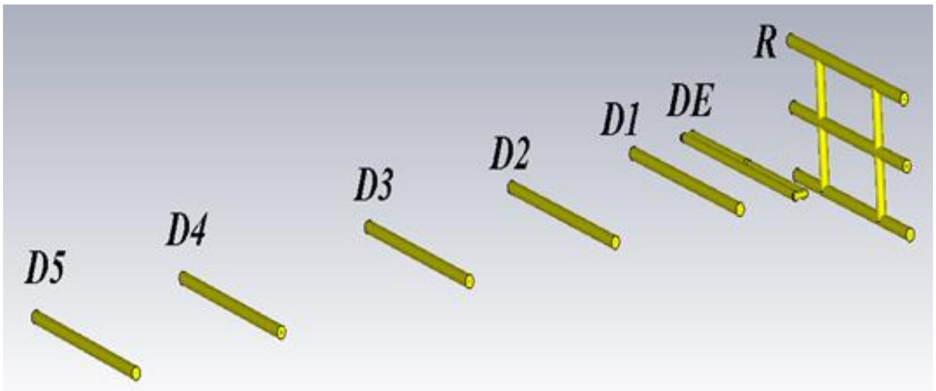
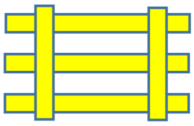


Figure 3. Perspective View for Propose Yagi Uda Antenna

Table 3. Comparison of QM7 Yagi-Uda Antenna and Propose Yagi-Uda Antenna.

Reflector Design	Gain (dB)	Reflection Coefficient (-dB)	D*	E*
	13.81	12.246	13.72	81.09
	14.03	11.406	13.62	75.56

3. Result and Discussion

From the simulated results in Table 2, reflector design no.1 shows the results of QM7 antenna after adding folded dipole. Gain, efficiency, directivity and reflection coefficient of reflector design 1 are shown in Figure 4, Figure 5, Figure 6 and Figure7 respectively. The optimized result after improving reflector is Reflector Design no. 7. The performance of reflector antenna design no. 7 is shown in Figure 7, Figure 8, Figure 9 and Figure 10 respectively.

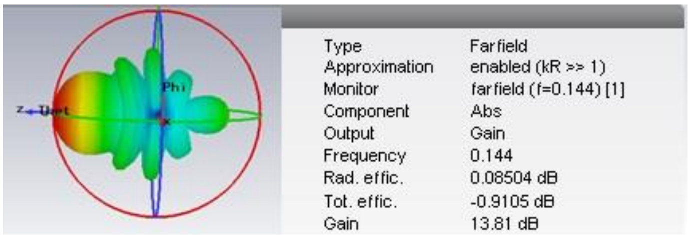


Figure 4. Gain Reflector Design 1

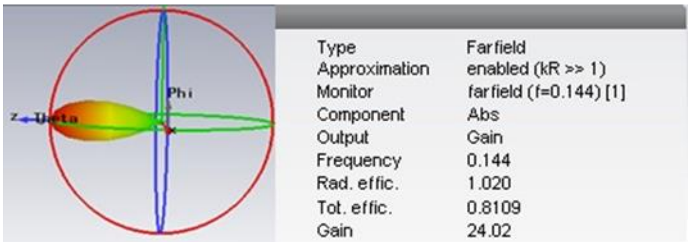


Figure 5. Efficiency of Reflector Design 1

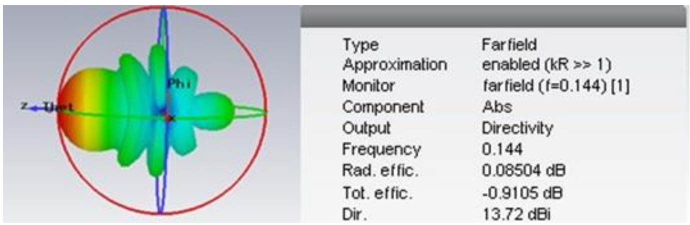


Figure 6. Directivity of Reflector Design 1

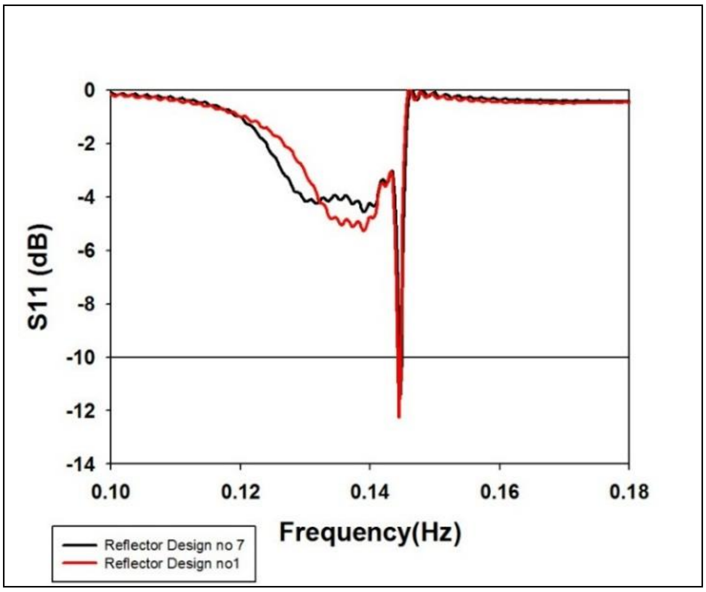


Figure 7. Reflection Coefficient of Reflector Design 1 and 7

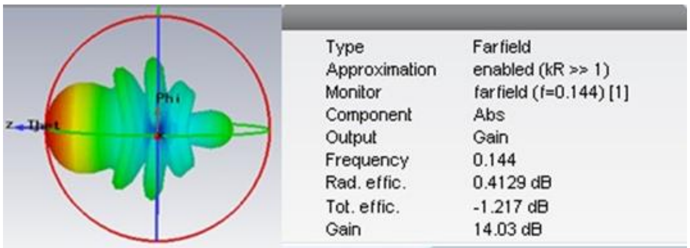


Figure 8. Gain Reflector Design 7

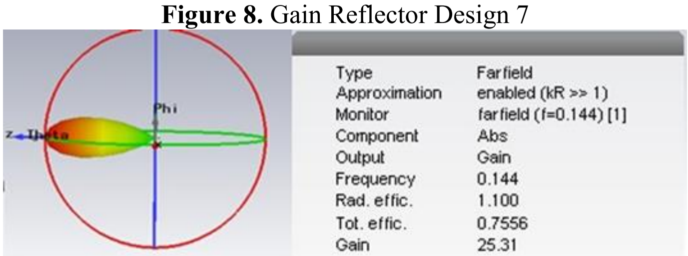


Figure 9. Efficiency Reflector Design 7

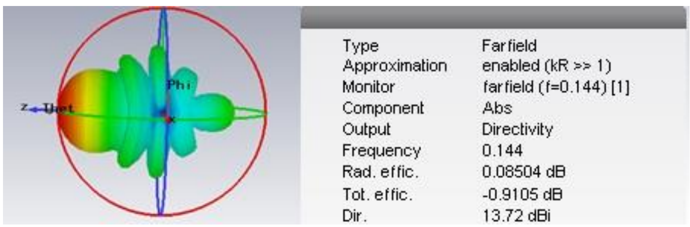


Figure 10. Directivity Reflector Design 7

Referring to Table 2, the result shows the reflector design affects the antenna performance in terms of gain significantly. The additional of reflector design no. 7 as shows in Figure 3 improved the gain from 11.35 dB to 14.03 dB. There are two principle ways in which the far-field pattern of a Yagi-Uda array may be "tuned" or adjusted for a particular frequency. One way is to vary the director spacing while holding the element length and reflector's spacing constant. The second method is to vary the director length while holding all other parameters fixed. Either one of these methods will have a considerable effect on the gain and far-field patterns. On the other hand, the usual effects of altering the reflector spacing or length are mostly to change the level of the back lobes and to control the impedance of the array. Further, changing the length of the driven element will have a negligible effect, on the pattern4. In this experiment, the priority is more on changing the reflector design and it will change the level of back lobe and to control the impedance. It is known that reflector is to redirect electro-magnetic (EM) energy, generally in the radio wavelength range of the electromagnetic spectrum. So with the new improvement of Reflector no 7, it is possible to redirect more EM to the destination. Next is to improve the pattern by changing the single driven element with a folded dipole element. As mentioned earlier, driven element is improved by replacing with folded dipole. The result at the reflection coefficient is maintained but the gain is improved. Figure 6 shows the result and it also shows that when using reflector design 7, the gain has improved, but the reflection coefficient is remaining same as the reflector design no. 1.

The additional of reflector design with 7 elements improves the gain significantly by 23.6% more than the conventional Yagi-Uda. This can be explained by two principles in which the far-field pattern of a Yagi-Uda array may be "tuned" or adjusted for a particular frequency. In this work, the priority focuses more on changing the reflector design and it will change the level of back lobe and control the impedance. The 10-dB impedance bandwidth resonates at 144.46 MHz and remains unchanged regardless the number of elements of reflector. The maximum gain of 14.03 dB is achieved for this proposed design at 144 MHz.

4. Conclusion

The aim of this work is to design a 144 MHz high gain Yagi-Uda Antenna for amateur. The high-gain antenna was designed using CST 2014 to overcome the lack of communication service in the rural area, especially during emergency, distress and disaster situation. Since the antenna will be used for the radio amateur application, the resonant frequency must be in the range of 144 MHz to148 MHz which is in the VHF frequency band. To improve the antenna, there was some tuning processes, such as adding folded dipole, parasite director antenna and lastly are improving the reflector antenna. The result was found to be promising with a gain of 14.03dB.The Reflector Design 7 have been chosen as the best design in improving the gain using reflector design method.

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