Novel Multilayer Structure Yagi-Uda Antenna

Kuo-Lun Hung[1,2] , Hsi-Tseng Chou[1,2], Kuei-Jen Lee[3]

[1] Department of Communications Engineering, Yuan Ze University, Chung-Li, Taiwan

[2] Communications Research Center, Yuan Ze University, Chung-Li, Taiwan

[3]Department of Communication Engineering, Oriental Institute of Technology, Pan-Chiao, Taiwan

1. Introduction

A Yagi-Uda (Yagi) antenna is a parasitic linear array of parallel dipoles used to generate end-fire beam formation. A traditional Yagi-Uda antenna consists of a driven element, a reflector, and one or more directors. This antenna structure is simple to build, lightweight, and low cost. The reflector and directors are not driven directly, but instead couple parasitically to the driver [1]. It is well known from antenna theory that the Yagi-Uda antenna is primarily used to achieve end-fire radiation by satisfying appropriate amplitude and phase conditions (equal amplitude and opposite phase) for the closely-spaced driven element, reflector, and the directors. Traditionally, Yagi antennas are designed using wire dipole or printed dipole antennas. In 1991, Huang presented a design of the Yagi antenna based on microstrip patches [2]. Recently, an interesting configuration of the printed Yagi antenna was presented in [3], which was modified and optimised in [4,5]. In this paper, a novel Yagi-Uda antenna is proposed as shown in figure 1. The driver and director are printed dipole place on different layer of printed circuit board (PCB), and the reflector is a conductive plan. Unlike traditional printed Yagi antenna which configuration cannot be changed after fabricate, multilayer structure provide more variation.

2. Antenna Design

Figure 1 and figure 2 are the structure of multilayer Yagi-Uda antenna. Each layer was made by PCB. Layer 2 is the driven element which is a dipole of approximately (slightly less than) a half-wavelength tuned to resonance. Layer 3 to N are directors. However, considerable improvements can be achieved if more directors are added to the array. Practically there is a limit beyond which very little is gained by the addition of more directors because of the progressive reduction in magnitude of the induced currents on the more extreme element. Usually most antennas have about 6 to 12 directors. Since the length of each director is smaller than its corresponding resonant length, the impedance of each is capacitive and its current leads the induced emf. The total phase of the currents in the directors is not determined solely by their lengths but also by their spacing to the adjacent elements. Thus, properly spaced elements with length slightly less than their corresponding resonant lengths acts as directors because they form an array with currents approximately equal in magnitude and with equal progressive phase shifts which will reinforce the field of the energized element toward the directors. Separation distance between the directors is 0.3λ to 0.4λ. However, the directors are not necessarily of the same length and the separation between the directors is not necessarily uniform for optimum design. Layer1 is a flat, conduct plane. In practice, the reflector is place on first element next to the driven element, and very little in the performance of a Yagi-Uda antenna is gained if more than one element are used as reflectors. Distance between the driven element and the reflector is smaller than the spacing between the driven element and nearest director. It is found to be near optimum at 0.25λ.

3. Simulation and Measurement Result

A preliminary design is performed without further optimization. The antenna was built and tested as shown in Fig. 3. The dimensions of antenna are as follow. Dipole length = 19 mm, length of director on layer 3 is 18.7 mm, distance between reflector and radiator is 0.25 λ, distance between radiator and director is 0.31 λ. The antenna is printed on 0.4 mm FR-4 substrate with dielectric constant 4.4. The computed and simulated reflection coefficients are shown in Fig.4. The simulation and measurement result of radiation pattern for y-z cut when directors number are five (N=7) at 5GHz are shown in Fig.5. Fig.6 shows the measurement result of antenna directivity variation with the number of directors. However, considerable improvements can be achieved if more directors are added to the array. Practically, there is a limit beyond which very little is gained by the addition of more directors because of the progressive reduction in magnitude of the induced currents on the more extreme elements.

Directors are put on the same layer as shown in figure 2. It is found that the directional characteristic is enhanced. The simulated radiation pattern when the number of directors are five at 5 GHz for y-z cut and x-z cut is shown in figure 8. The distance of d1 and d2 is designed with further optimization. The maximum directivity happen when the current induce on the directors are in phase. The dimensions are as follow, d1= 10 mm, d2 = 12 mm. The directivity of antenna is 12.81 dB.

4. Conclusion

A multilayer structure Yagi antenna was proposed and design. This new design maintains original advantage of Yagi antenna but multilayer structure provide more variation. Utilization of planar reflector is proposed to enhance directional characteristic.

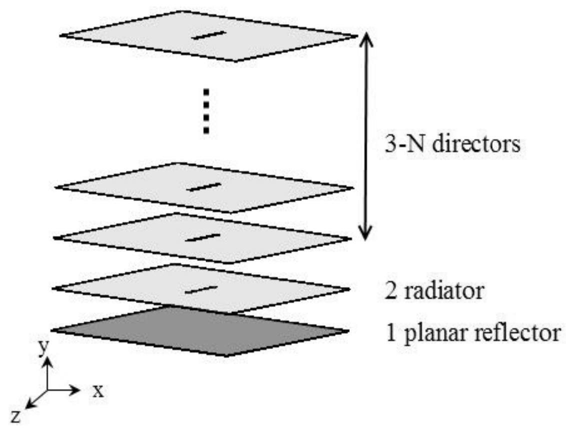

Figure 1. Structure of multilayer Yagi-Uda antenna

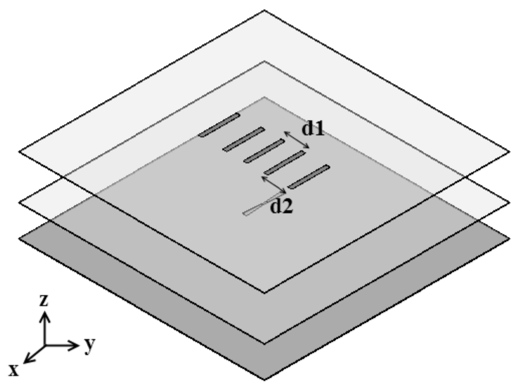

Figure2. Structure of multilayer Yagi-Uda antenna (directors on the same layer)

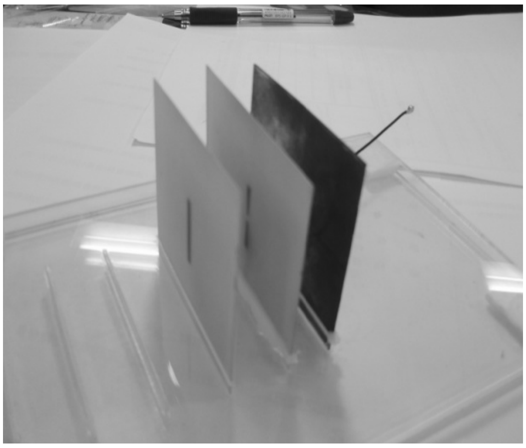

Figure 3. Picture of multilayer Yagi-Uda antenna

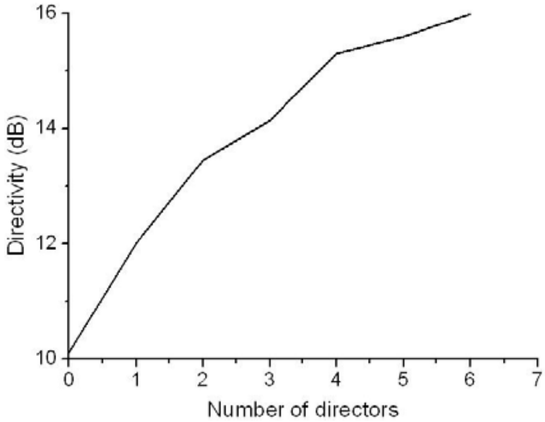

Figure 6. Variation of Directivity

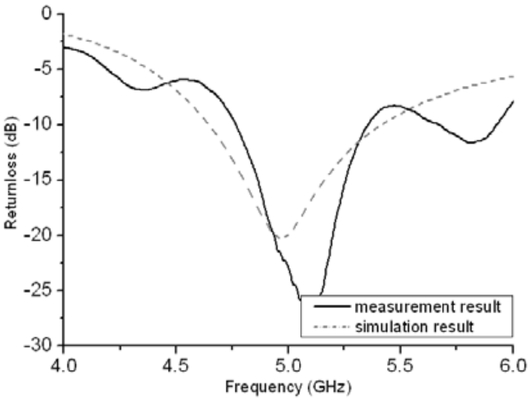

Figure 4. Return loss

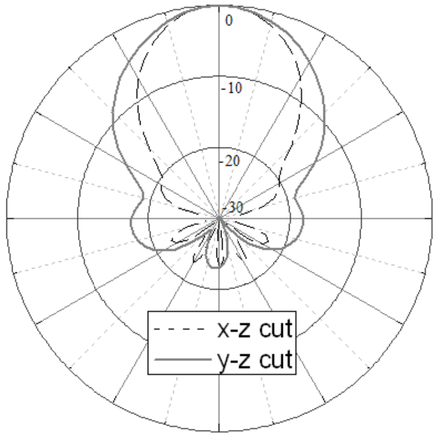

Figure 7. Radiation pattern(x-z cut, y-z cut)

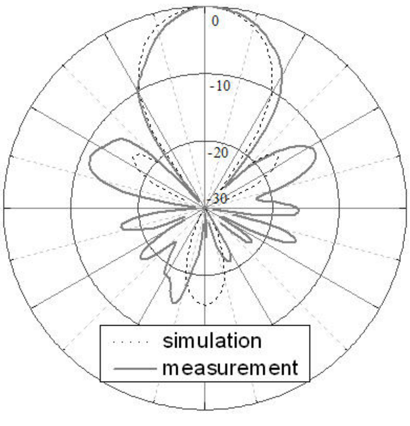

Figure 5 . Radiation pattern N=7

References

[1] Stutzman, W.L., and Thiele, G.A.: 'Antenna theory and design (Wiley, New York, 1998, 2nd edn.)

[2] Huang, J., and Densmore, A.C.: 'Microstrip Yagi array antenna for mobile satellite vehicle applications', IEEE Trans. Antennas Propag. 1998, 39, pp. 024–1030

[3] Qian, Y., et al.: 'Microstrip-fed quasi-Yagi antenna with broadband characteristics', Electron. Lett., 1998, 34, pp. 2194–2196

[4] Deal, W.R., et al.: 'A new quasi-Yagi antenna for planar active antennaarrays', IEEE Trans. Microw. Theory Tech., 2000, 48, (6), pp. 910–918
[5] C. A. Balanis, Antenna Theory: Analysis and Design, 3rd Ed., Wiley-Interscience, 2005