Novel Planar Wideband Omni-directional Quasi Log-Periodic Antenna

Heng-Tung Hsu, *Senior Member, IEEE*, James C. Rautio*, *Fellow IEEE*, and San-Wen Chang

Nearson Marketing Group, 10F, No.33, Tien-Mei 3rd Street , Hsinchu, Taiwan, R.O.C
*Sonnet Software Inc., 100 Elwood Davis Road, North Syracuse, NY 13212, USA

***Abstract*—In this paper, a novel and simple wideband planar omni-directional antenna is proposed. The simultaneously wideband and omni-directional characteristics of the proposed structure are achieved by adding two mutually-coupled elements to the conventional dipole antenna. This newly proposed structure is able to extend the bandwidth (VSWR ≤ 2:1, at UHF band) to 30% compared to simple dipole antennas while maintaining an omni-directional radiation pattern with maximum gain of 2.2dBi.**

***Index Terms*—Antennas, dipole antennas, omni-directional.**

I. Introduction

COMPACT, very low-cost printed antennas with both wideband and omni-directional characteristics are desired in modern communications systems. Dipole antennas have been popular candidates in many systems for their uniform omni-directional coverage, reasonable gain, and relatively low manufacturing cost. Despite the advantages mentioned above, dipole antennas suffer from relatively narrow bandwidth, about 10% for VSWR ≤ 2:1. This bandwidth problem has limited their application in modern multi-band communication systems. In addition, nearby objects easily detune the dipoles because of the limited bandwidth of operation.

Antenna arrays have been excellent solutions for operating bandwidth expansion [1-3]. With optimum arrangement of the radiating elements, high operating bandwidth can be achieved at the expense of small beam width, large physical size and relatively complex feeding structures. To further make the antennas compact-sized, low-profile and easily integrated into communication systems, several techniques have been developed including folded-dipole [4], inverted-L based [5], fat dipole[6], monopole based [7-11], etc. The main effort has been devoted to minimize the reactive part of the antenna impedance and optimize match at the input port of the antenna.

In this paper, the new quasi log-periodic antenna structure is presented. This simple structure consists of a regular half-wavelength dipole with two mutually-coupled stubs. Compared to the conventional half-wavelength dipole, the bandwidth of this new structure can be extended to 30% without sacrificing the uniform omni-directional radiation pattern. The excellent performance achieved through this simple structure has created itself great potential for applications in tag antennas of Radio-Frequency Identification (RFID) systems. In the following sections, the design with parametric study of the antenna is presented. Full wave 3D EM simulation is also performed and radiation patterns of the proposed structure are discussed.

II. Quasi Log-periodic Antenna

Fig. 1(a) shows the structure of the quasi log-periodic antenna. Compared to the conventional half-wavelength dipole antenna as shown in Fig. 1(b), two additional mutually-coupled stubs are symmetrically connected to the original dipole. These two coupling stubs generate an additional resonance that tends to cancel the reactive part of the dipole impedance to achieve expanded bandwidth. As can be seen, this structure has a low profile and can be easily fed by a coaxial feed from the center of the structure. Three major parameters including the length of the stub (*a*), the

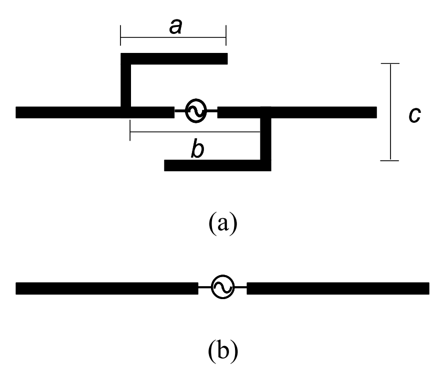


Fig. 1. (a) Structure of the proposed quasi log-periodic antenna and (b) Structure of the conventional half-wavelength dipole.

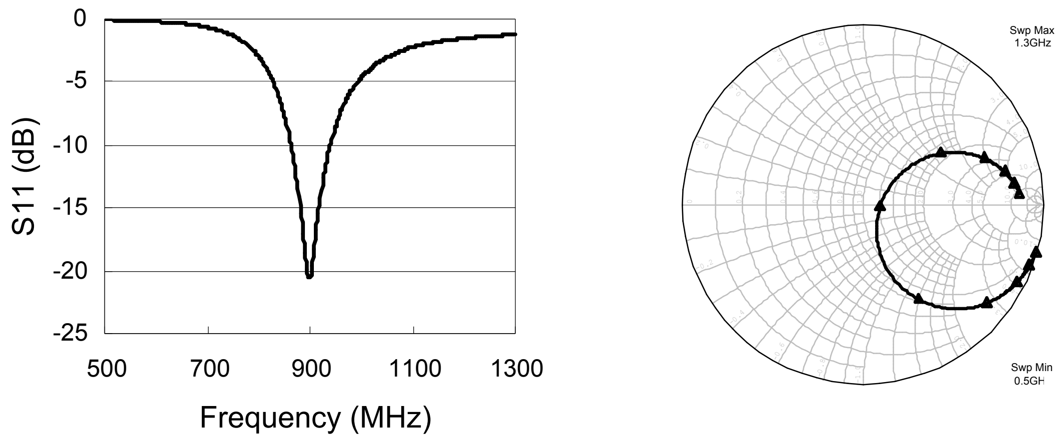


Fig. 2. Simulated S_{11} and impedance of regular half-wavelength dipole on a 0.4mm FR-4 substrate ($\varepsilon_r = 4.2$).

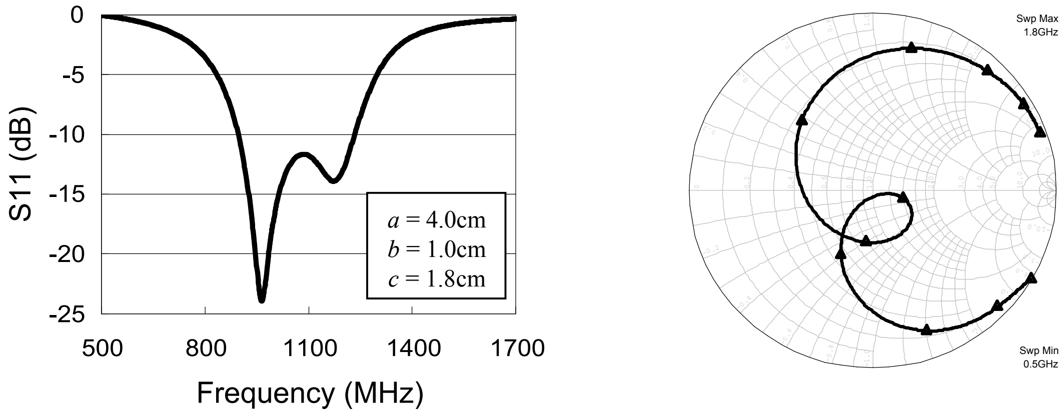


Fig.3. Simulated S_{11} and impedance of the quasi log-periodic antenna on a 0.4mm FR-4 substrate ($\varepsilon_r = 4.2$).

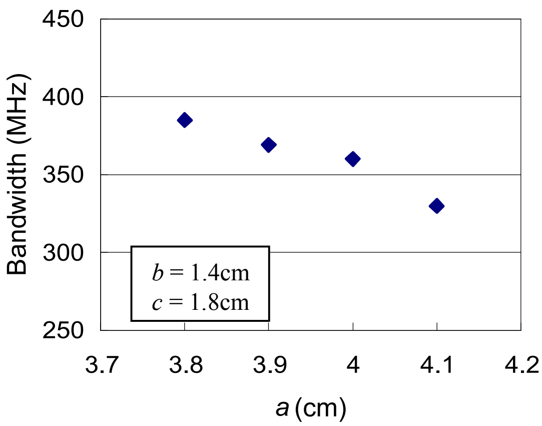
horizontal separation between the stubs (*b*) and the vertical distance between the stub and the dipole (*c*) need to be adjusted for optimal performance.

III. Numerical Analysis and Results

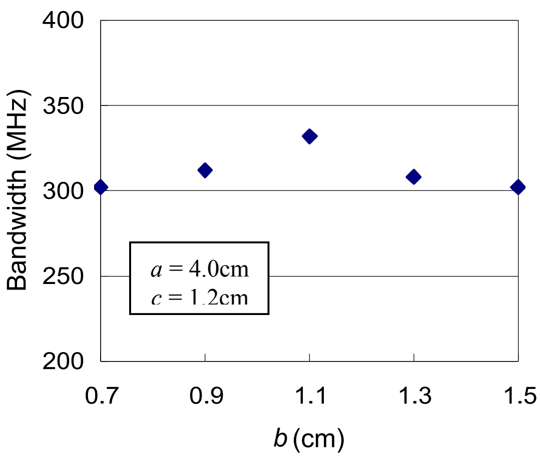
Numerical analysis is performed using Sonnet ®, a planar 3D Method of Moments based electromagnetic analysis. Since we are dealing with an open-boundary problem, the top and bottom covers of the shielding box are removed during simulation. Also, the side walls are placed far away from the radiating antenna so as not to perturb the antenna performance.

Fig. 2 shows the simulated performance of a regular half-wavelength dipole on a 0.4mm FR-4 ($\varepsilon_r = 4.2$) substrate centered at 900MHz. The total length of the half-wavelength dipole is 14.1cm. A VSWR $\leq$ 2:1 bandwidth of 78 MHz is observed. Figure 3 shows the typical response of the quasi log-periodic antenna on the same substrate. The dimensions chosen are a = 4.0 cm, b = 1.0 cm and c=1.8 cm; with the same length of 14.1 cm used for the half-wavelength dipole. The VSWR $\leq$ 2:1 bandwidth has been significantly increased to 338 MHz, which is about 4 times that of a conventional dipole. Note that the center frequency is also increased due to the expanded bandwidth of the structure. However, this increase in center frequency can easily be compensated through the length adjustment of the half-wavelength dipole. Further length reduction of the structure can also be achieved by introducing appropriate capacitive loading to the structure. Parametric study was performed on the three major parameters to investigate the dependence of the bandwidth expansion on each parameter. The results of parametric study are plotted in Fig. 4.

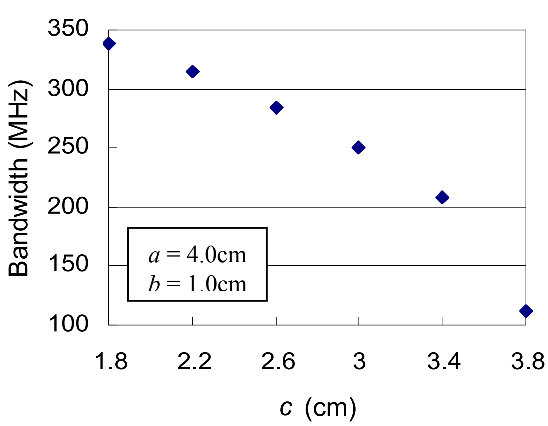
Fig. 5 shows the real and imaginary parts of the antenna impedance for the quasi log-periodic structure. For comparison purposes, those of the regular dipole are also included in the figure. The main reason for the limited bandwidth of the conventional dipole antenna is the drastic increase in antenna reactance with frequency. This is typically the case when the operating frequency goes beyond the resonant frequency for regular dipoles as shown in Fig. 5.



(a)



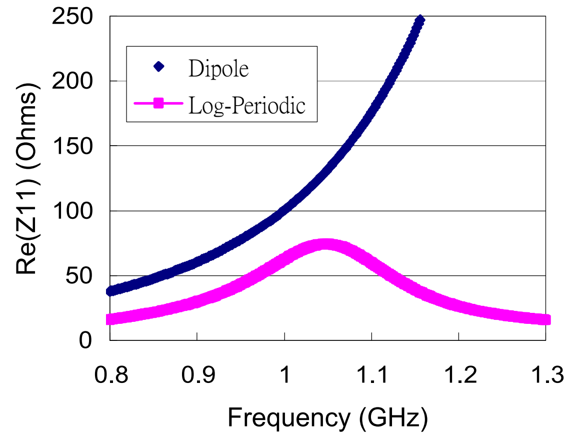
(b)



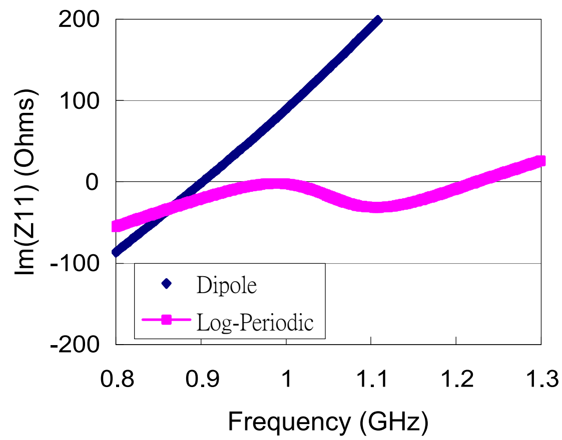
(c)

Fig. 4 Dependence of bandwidth on the major physical parameters of the structure.

However, we see in Fig.5 that the reactance of the quasi log-periodic antenna varies smoothly with frequency over the band of interest, which explains the bandwidth expansion phenomenon achieved by the added stubs. Also note that the reactance tends to become more capacitive compared to the regular dipole due to additional coupling induced by the stubs.



(a)



(b)

Fig. 5 The (a) real part and (b) imaginary part of the antenna impedance for the quasi log-periodic and regular dipole antennas.

Further investigation of the radiation pattern for the quasi log-periodic antenna is necessary. Several simulations are performed using CST Microwave Studio ™ based on Finite Integration Technique in Time Domain (FIT-TD). Fig. 6 shows the radiation pattern of the quasi log-periodic antenna at 1 GHz. The antenna has a maximum directivity of 2.2dBi and the 3dB beam width is observed to be 78.3 °. Excellent omni-directional coverage is observed. Fig. 7 shows the total efficiency as a function of frequency, exhibiting the wideband feature of the proposed antenna.

IV. CONCLUSION

A novel quasi log-periodic antenna is presented. This novel structure features a wide bandwidth compared to regular dipole antennas with excellent omni-directional coverage. Additionally, the low-profile and simple feed characteristics of the antenna make it easy to integrate with extremely low manufacturing cost.

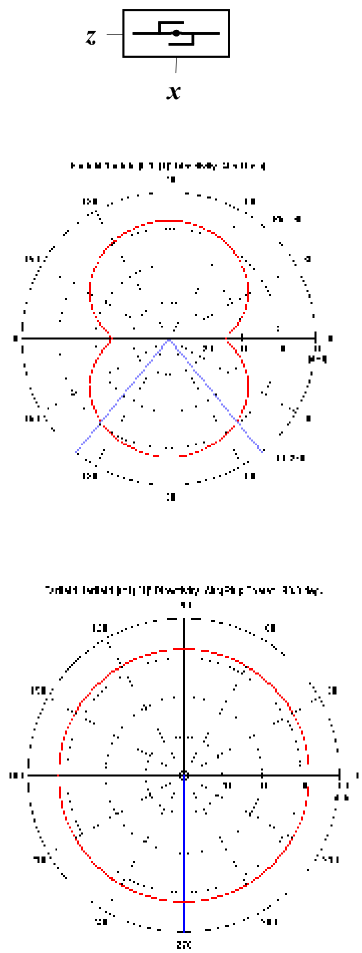


Fig. 6 The radiation pattern of the quasi log-periodic antenna

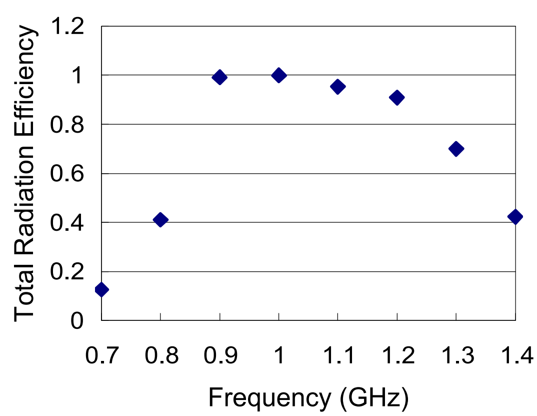


Fig. 7 Total efficiency versus frequency of the quasi log-periodic antenna

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