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Ultrawideband Log-periodic Series-fed Printed Dipole Arrays Antenna

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Abstract

By replacing a printed dipole of quasi-Yagi antenna by a series-fed printed dipole arrays with planar trapezoidal toothed log-periodic structure, a new ultrawideband operation and end-fire radiation pattern are presented. The experiment results of the proposed antenna, determined from 10-dB return loss, larger than 121% of the center frequency that covers the ultrawideband applications band and end-fire radiation pattern.

1. Introduction

The microstrip quasi-Yagi antenna exhibits attractive features including low profile, low-cost, lightweight,ease of fabrication, and broadband operation. These features make the microstrip quasi-Yagi antenna attractive for use in various applications. An end-fire quasi-Yagi antenna which is broadband uniplanar structure has been proposed for the first time by Kaneda *et al.*[1], achieving bandwidth 48% and since then explored in several papers[2]-[3]. Several bandwidth-enhancement techniques for printed dipoles or quasi-Yagi have been proposed in the literature, replacing printed dipole driver by printed bow-tie[4], patches driver [5] and a log-periodic dipole arrays director [6], tiled dipole [7] and several director elements [8]. However, those antennas have impedance bandwidths generally less than 85% of the center frequency.

In this paper, the printed dipole of quasi-Yagi antenna as driver and director is replaced by a series-fed printed dipole arrays with planar trapezoidal toothed log-periodic structure, which results in an improvement in bandwidth and gain. This new design combines a series-fed printed dipole arrays [9] and planar trapezoidal toothed log-periodic structure [10].

2. Antenna Design

Fig. 1 shows the ultrawideband log-periodic series-fed printed dipole arrays antenna. The top metallization consists of three parts, the microstrip-to-CPS transition, the series-fed printed-dipole arrays, and planar trapezoidal toothed log-periodic structure. The truncated microstrip ground plane on backside of the substrate is used as a reflector element for the antenna. We explain the three parts separately in order to understand the ultrawideband characteristics of the antenna. Optimizing those three parts separately makes the optimization easier.

2.1 Microstrip-to-CPS balun

Coplanar strip (CPS) is a uniplanar transmission line and a microstrip balun is usually desired to provide efficient transition between the CPS and the microstrip lines. The balun is used to introduce a half-wavelength

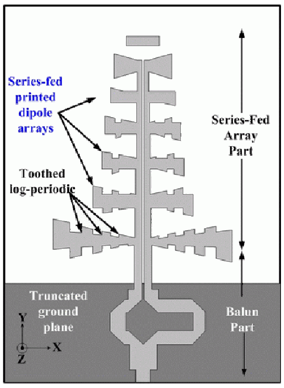
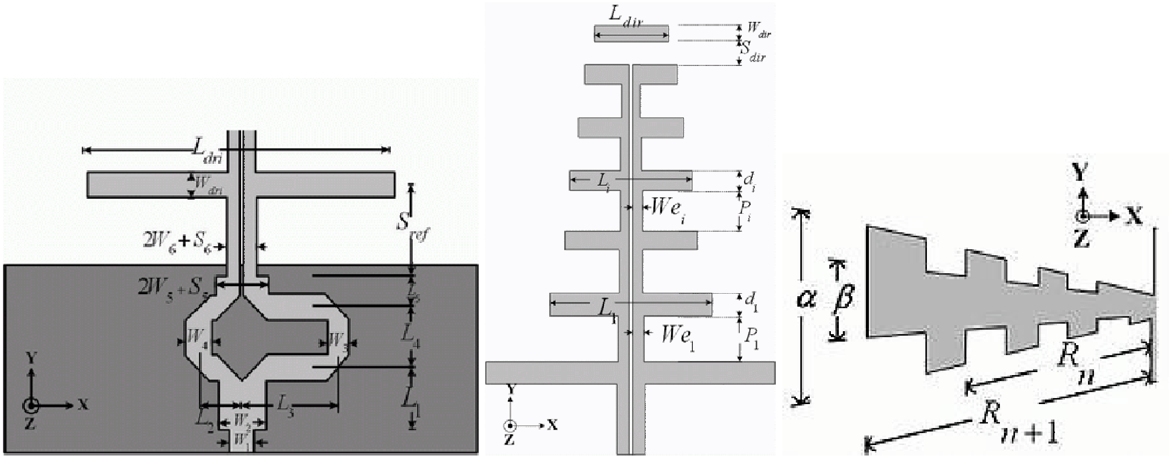


Figure 1: Schematic of the ultrawideband log-periodic series-fed printed dipole arrays antenna



(a) (b) (c)

Figure 2: Schematic of the proposed antenna parts (a) microstrip-to-CPS, (b) the series-fed printed dipole arrays, and (c) planar trapezoidal toothed log-periodic structure

delay, which is required to obtain the odd mode in the coupled microstrip line while suppressing the even mode and establish a impedance matching between the balanced (dipole) and unbalanced (feed) elements of the antenna. The balun is designed for the center frequency at 6 GHz, which creates 180^o phase difference between the coupled microstrip lines and offers a good impedance matching. Next, the length of driver (L_{dri}) and distance from the driver to the reflector (S_{ref}) are sensitive elements. The antenna's design frequency and its operational bandwidth will be affected by these two parameters. Therefore, the length of the driver would be optimum when it is about a guide-wavelength and the distance between the driver and the reflector is about a quarter guide wavelength. A description of the microstrip-to-balun is provided in Fig. 2(a). A prototype has been designed using FR-4 substrate ($\epsilon_r = 4.4$ and tan $\delta = 0.022$). The thickness of the substrate is 1.6 mm. The optimization of the balun is also done with the full-wave simulation. After a few optimization processes, the structural parameters of the balun are as follows (unit: millimeters): L_{dri}=38.6, L_1=7.208, L_2=5.424, L_3=12.124, L_4=7.332, L_5=3.5424, S_{ref} =11.2, S_5=S_6 =0.6, W_{dri}=3.016, W_1=3.016, W_2=5.832,W_3 =2.616, W_4=3.216, W_5=3.016 and W_6=1.608.

2. 2 Series-fed Printed Dipole Arrays

The modified quasi-Yagi antenna adopted new driver and director elements consists of changing the tradition dipole director elements to a pair of series-fed printed dipole arrays in order to achieve maximum bandwidth. The proposed series-fed printed dipole array is fed to the terminals of the longer element by using a direct connection between the strip dipoles. This excitation method gives the phase progression for endfire radiation because the CPS line does not support the even mode, which enables us to suppress the undesired mode excited in the coupled microstrip line. We use a series-fed technique [7] that the operation bandwidth is restricted to the lengths of the longest (for the lowest frequency) and the shortest (for the highest frequency) dipole elements of the antenna arrays. The end of the series-fed is a parasitic director. Its dimensions are designed for the end of operation frequency. The parasitic director element on the top plane simultaneously directs the antenna propagation toward the end-fire direction, and acts as an impedance matching element. The dipoles with different lengths and director are printed on the same side of the dielectric substrate and are connected directly through a straight CPS as shown in Fig. 2(b). The series-fed arrays' dimensions are (unit:millimeter) P_1=6.88, P_2=5.66, P_3=5.4, P_4=4.75, P_5=4.39, d_1 =3.0, d_2=2.71, d_3=2.52, d_4=2.51, d_5=2.71, L_1=21.4, L_2=17.8, L_3=16.2, L_4=14.2, L_5=12.2, L_{dir}=7.2, W_{e1}=1.50, W_{e2}=1.3, W_{e3}=1.2, W_{e4}=1.0, W_{e5}=0.95, W_{dir}=2.216 and S_{dir}=3.284.

2. 3 Planar Trapezoidal Toothed Log-periodic Structure

The antenna is based on the well-known log-periodic antenna scaling principle. Following this basis, the antenna displays a periodic behaviour with frequency logarithm. The structure of the proposed antenna is shown in Fig. 2(c). The printed dipoles are periodically scaled with the longer element designed for the lower resonant frequency and the shorter on for the hiher frequency. The antenna dimensions follow the periodictly relationship : if f_1 and f_2 are one period apart, they will be related to geometric ratio (τ) by

$$\Delta = \ell n(f_2) - \ell n(f_1) = \ell n(\frac{1}{\tau}) \tag{1}$$

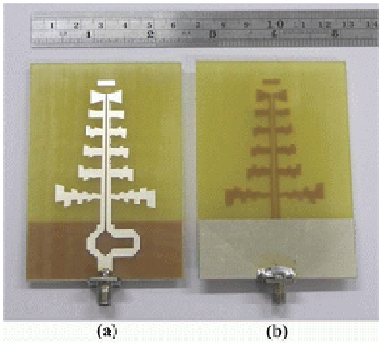
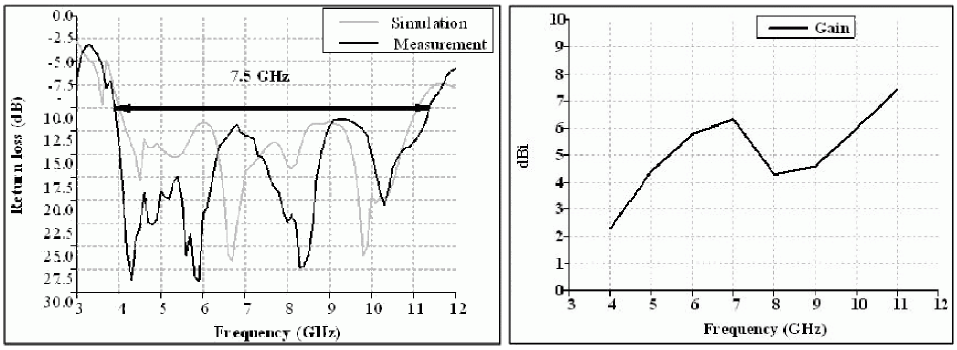


Figure 3: Photograph of the proposed antenna (a) front-side (b) back-side



(a) (b)

Figure 4: (a) Measured and simulated return losses and (b) measured gain of the proposed antenna

Typical designs of planar trapezoidal toothed log-periodic dipole have apex half angles (α) as

$$10^o \leqq \alpha \leqq 45^o \text{ and } 0.95 \geqq \tau \geqq 0.7 \tag{2}$$

Maximum value of frequency span (Δ) is related with minimum value of τ, as 0.7. In Fig. 2(c), the dimensions of planar trapezoidal toothed log-periodic are defined by the inverse of the geometric ratio τ are

$$\frac{1}{\tau} = \frac{l_{n+1}}{l_n} = \frac{R_{n+1}}{R_n} \tag{3}$$

Designing of log-periodic part has been described in [10] and hence it is not repeated here. From Fig. 2(c), the dimensions after adjustment are $\tau = 0.7$, the value of β is estimated as value of W_{dri} as 3.016 mm, and the other important value is α. Since the value of it is much, it is possible that the value interfere with truncated ground plane. Therefore 30^o (9.834 mm) was used after adjustment.

3. Simulation and Measurement Results

By putting the three parts individually optimized together, we can achieve moderately good performance. However, further optimization is required in order to achieve even better performance of the whole transition. The proposed antenna is fabricated on a FR-4 substrate with a dielectric constant of 4.4, a thickness of 1.6 mm, and a loss tangent of 0.022. Photograph of the proposed antenna are shown in Fig. 3. Measurements were carried out using an HP8510C network analyzer. Fig.4(a) plots both simulation and measurement results for input return loss. The simulated and measured bandwidths (return loss $\leqq$ 10 dB) that have consistent term are 118% and 121%, respectively that cover the ultrawideband band. Additionally, the gain of the antenna have been measured and its can be observed that the peak gains increase to more than 6 dBi at 7GHz and 11 GHz as shown in Fig 4(b).

The measured H-plane and E-plane radiation patterns are demonstrated in Fig. 5 and 6, respectively. For comparison, we selected the patterns at 5.0, 7.0, and 9.0 GHz, approximately corresponding to the lower end, center, and upper end frequencies of the operating band of the proposed antenna. The shape of the radiation patterns was found to be similar for all three frequencies. It can be observed that, as expected, the radiation patterns of higher frequencies are irregular because the balun does not have a 180^o phase difference to feed the printed dipole arrays.

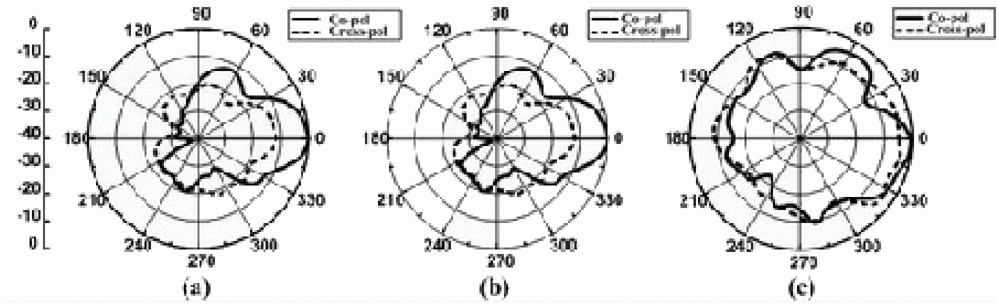


Figure 5: Measured the H-plane co- and cross-polarized radiation pattern of the proposed antenna (a) 5 GHz, (b) 7 GHz, and (c) 9 GHz

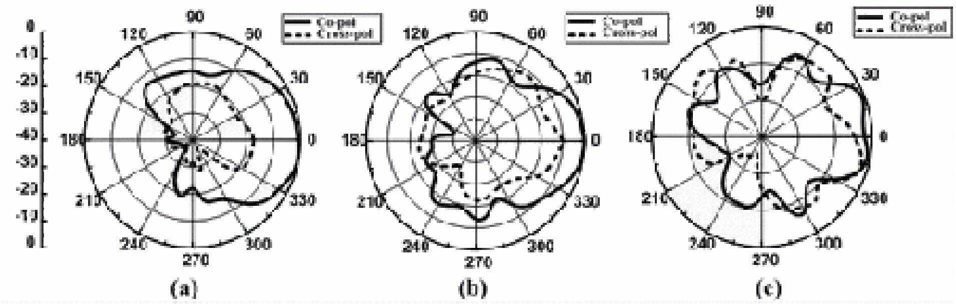


Figure 6: Measured the E-plane co- and cross-polarized radiation pattern of the proposed antenna (a) 5 GHz, (b) 7 GHz, and (c) 9 GHz

4. Conclusion

The ultrawideband log-periodic series-fed printed dipole arrays antenna has been proposed. The simulated and measured results from the dsigned antenna has been obtained. This new structure exhibits about 121% impedance bandwidth that covers the ultrawideband applications band. The radiation charecteristics of proposed antenna have also mesured at the selected frequencies, which represent the end-fire radiation pattern with a gain of about 3-7 dBi. Becuase of its ultrawideband operation, low cost, easy fabrication, and good radition patterns, the proposed antenna should be very useful in the ultrawideband communication systems.

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