Design of Out-of-Phase Power Divider Fed Endfire Antenna with Wide Bandwidth

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Abstract—A novel wideband periodic endfire antenna is presented. Broad bandwidth is realized by using a parallel strip line (PSL) feed and dipole elements. A coupling between two microstrip lines on the top and bottom substrate layers through a slot in the common ground plane, and a transition from two microstrip lines to a parallel stripline are used to achieve an wideband operation. The regular dipole shape is modified to a quasi-rhombus shape by adding two triangular patches. Using two dipoles helps maintain stable radiation patterns close to their resonance frequencies. A modified array configuration is proposed to further enhance the antenna radiation characteristics and usable bandwidth. The proposed antenna provides endfire radiation patterns with high gain, high front-to-back (F-to-B) ratio,wide beamwidth in a wide bandwidth of the 130%

Keywords—stirp line; wideband; endfire antenna; out-of-phase divider;

I. INTRODUCTION

Microstrip antennas have been popular for decades because they exhibit a low profile, small size, lightweight, low manufacturing cost, high efficiency, and an easy method of fabrication and installation. Furthermore, they are generally economical to produce since they are readily adaptable to hybrid and monolithic integrated circuits fabrication techniques at radio frequency (RF) and microwave frequencies. The Yagi–Uda antenna, first published in an English language journal in 1928[1], has been used extensively as an endfire antenna. However, only limited success has been achieved at adapting this antenna to microwave/millimeter-wave operation.

In[2],[3] , the antenna was first demonstrated by Y.Qian et al. and further optimized for increased bandwidth. The antenna is realized on a high dielectric-constant substrate with a microstrip feed. Unlike the traditional Yagi–Uda dipole design, we employ the truncated microstrip ground plane as the reflecting element, thus eliminating the need for a reflector dipole, resulting in a very compact design compatible with any microstrip-based monolithic-microwave integrated-circuit (MMIC) circuitry.

In these applications, there is a particular interest to obtain an increased operational bandwidth of the array; hence, the need for wideband antenna element. The microstrip-fed quasi-Yagi antenna consists of a half-wavelength dipole and an approximately quarter-wave-length rectangular director to increase the gain and improve the F-to-B ratio. A wide operational bandwidth of 48% was demonstrated in the X-band[4],[5]. Researchers have suggested modifications to this antenna that improved its bandwidth. By replacing the dipole and the director of the quasi-Yagi antenna by a bow-tie the bandwidth can improve to 60%, and reduce the antenna size by 20%[6]. Further research resulted in a novel microstrip-fed printed antenna, called printed Lotus antenna, with a modified balun[7],[8]. The printed Lotus provides up to 60% bandwidth with fairly low return loss level. However, the balun in these designs is based on a half-wavelength delay line, which is designed at the center frequency. This narrowband delay line limits the bandwidth of the antenna as reported in[8]. In addition, the radiation patterns are deteriorated at the higher frequencies, which decreases the usable antenna bandwidth.

In this paper, we present out-of-phase power divider with ultrawide bandwidth connected to the feedline of the double rhombus antenna. The proposed antenna employs two substrates with a common ground plane. A coupling between two microstrip lines on the top and bottom substrate layers through a slot in the common ground plane, and a transition from two microstrip lines to a parallel stripline are used to achieve an wide bandwidth operation. The antenna with the phase shifter is operating in a wide bandwidth between 2.3GHz and 12GHz, with stable radiation patterns. This design is used in a modified 2-element array, and the return loss, coupling and radiation patterns are presented. The simulation and analysis for the presented antennas are performed using the commercial computer software package Ansoft High Frequency Structure Simulator (HFSS), which is based on the finite element method. Measurements of the return loss and coupling are also conducted for verification of the simulation results.

II. ANTENNA DESIGN

The proposed antenna is printed on a woven glass closth (FR4) substrate with a dielectric constant of 4.4, a conductor loss (tanδ) of 0.0023 and a thickness of 20mil (0.5mm). The detailed geometry and parameters of the proposed antenna are illustrated in Figure1. Many parameters are introduced in the proposed antenna design which may add more complexity to the design, but they give us more flexibility to tune the antenna to match different design requirements.

The geometry of the proposed antenna is shown in Figure 1. The antenna consists of two major parts: the periodic endfire antenna part and the out-of-phase power divider part. The structure of the periodic endfire antenna part is designed based on[9]. The main objective of this antenna is to provide 2.3GHz-12GHz bandwidth. The dimensions of this antenna where selected so that the lengths of the long and short dipoles are half wavelength at 2.3GHz and 12GHz, respectively for this antenna to cover the targeted bandwidth. Then the dimensions are optimized based on numerical results until we obtained the final dimensions for the design that covers the aforementioned frequency range. The dimensions are revealed in Table 1.

Table 1. Antenna initial dimension in mm

L_f	L_1	L_2	L_3	L_4	L_5
18.5`	15.2	14	2.5	10	2
L_6	W_1	W_2	D_1	D_2	-
8	15.6	12.5	5	11	-

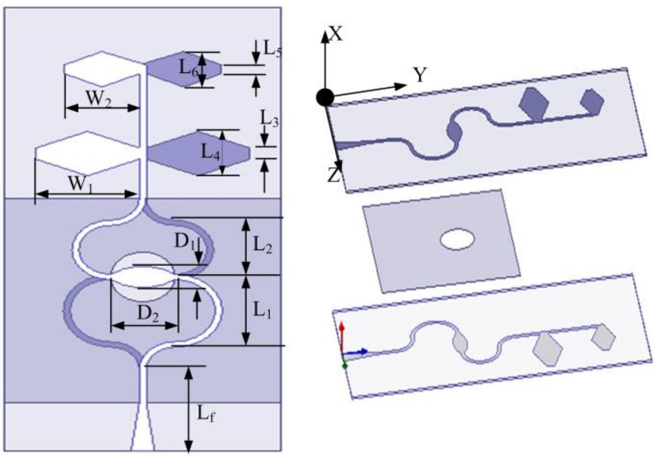

Figure.1 Antenna geometry and parameters

III. DESIGN RESULTS

The dimensions of the final design are chosen as in Table 1, A comparison between the computed VSWR and input impedance using HFSS and our FDTD code is presented in Fig. 2. Good agreement is observed which validates the design procedure using HFSS. The little differences betweenthe two results are because of using stair case in FDTD to model the transition part, which affects the results, especially at higher frequencies, where $\Delta x/\lambda$ is relatively high.

Both results show that the antenna operates over a wide range that extends from 2.3GHz to 12 GHz, which is 130%. The return loss level is less than -10 in almost the entire operating band. The average gain of the antenna is around 3dB-6dB, which is shown in Fig.2.The radiation patterns in the H- and E-planes for proposed tap monopole antenna are shown in Fig. 3, at 5GHz, 8GHz and 12 GHz.

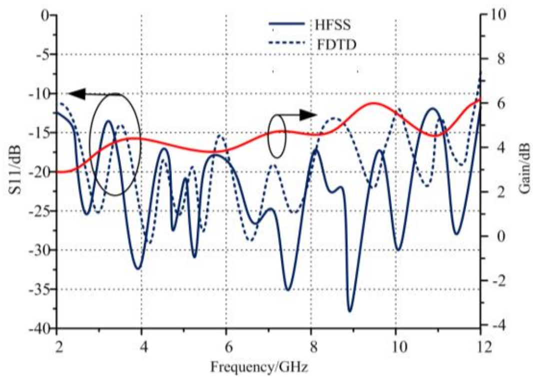

Figure. 2 Computed S11 and gain in endfire direction

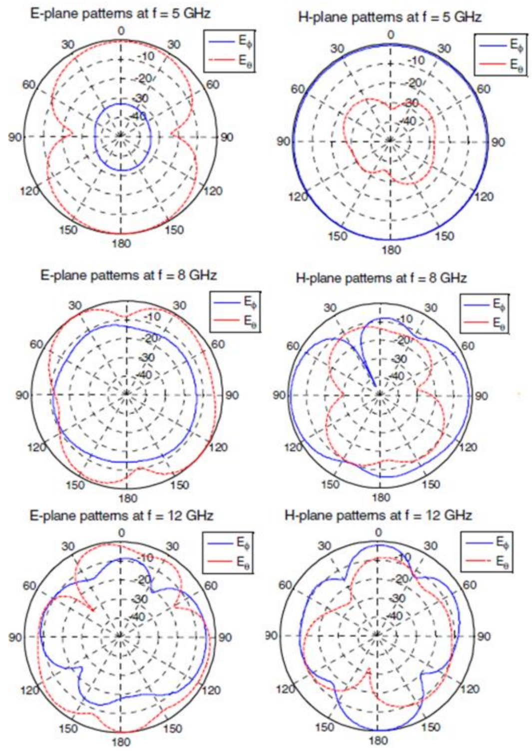

Figure 3 The computed co (Eθ) and cross (Eφ) polarized radiation patterns in the Eplane and H-plane

IV. CONCLUSION

This paper presents a design of a wide bandwidth endfire antenna with out-of-phase divider as feeding network. The proposed antenna exhibits an wide bandwidth of 2.3GHz-12GHz, with a low return loss level of less than -10dB, a high gain of 3dB-6dB. The presented antenna obtained a stable endfire radiation pattern. This antenna is a good candidate for UWB communication and phased arrays.

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