Printed Lotus Antenna For Wideband Phased Array Systems

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A novel printed antenna fed by a microstrip line is designed for wideband application in the X-band. The antenna provides a wide bandwidth of over 60% relative to –10 dB, stable far field radiation characteristics in the entire operating band with relatively high gain, low cross polarization, wide beamwidth and good front-to-back ratio.

Introduction

Printed microstrip antennas are widely used in wireless communication systems. They exhibit a very low profile, small size, lightweight, low cost, and high efficiency and are easier to install. Furthermore, they are generally economical to produce since they are readily adaptable to hybrid and monolithic integrated circuits fabrication techniques at RF and microwave frequencies [1].

Among the most widely used printed antennas in wireless communications and phased array systems are printed dipoles and quasi-Yagi antennas fed by coplanar strip line (CPS), which are usually used to obtain an end fire radiation pattern. In order to feed this type of antennas, a microstrip-to-CPS transition that includes a 180^0 phase shifter (balun) is usually used [2]. The balun consists of a T-junction with one side of the microstrip line delayed by half wavelength to produce a predominantly odd mode for the CPS. An attractive quasi-Yagi antenna design that uses the transition in [2] is presented in [3-4] that exhibits wide BW (48%) and good radiation characteristics. The antenna consists of a half wavelength dipole as a driver and an approximately quarter wavelength rectangular director to increase the gain and improve the front-to-back ratio. While the driver and director are placed on one side of the substrate, the ground plane is placed on the other side and truncated to act as a reflector.

Recently, the authors showed that by replacing the dipole and the director by a bow-tie for the X-band operations, improvements in the bandwidth, antenna size, and radiation characteristics are obtained [5]. In this paper, a novel microstrip-fed printed Lotus antenna is presented for wideband phased array systems operating in the X-band. The return loss and far field radiation characteristics of these antennas are introduced. The simulation and analysis for the presented antennas are performed using the commercial computer software package, Ansoft HFSS, which is based on the finite element method. Verification for the computed return loss is performed using measurements and further computations using the commercial software Momentum of advanced design system (ADS) of Agilent

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Technologies. Fabrication tolerance analysis is also performed to predict the antenna performance sensitivity due to any small fabrication errors.

Printed Lotus Antenna Geometry and Dimensions

The proposed antenna is printed on a Rogers RT/Duroid 6010/6010 LM substrate of a dielectric constant of 10.2, a conductor loss (tan δ) of 0.0023, and a thickness of 25 mil (0.635 mm). The geometry, parameters and prototype of the proposed printed Lotus antenna are shown in Fig. 1. The antenna is defined by two ellipses. The smaller ellipse is located completely in one half of the larger ellipse. The larger ellipse has Rh1 and Rv1 as the semi horizontal and semi vertical axes, respectively. The smaller ellipse has Rh2 and Rv2 as the semi horizontal and semi vertical axes, respectively, and is rotated by an angle α. The vertical and horizontal distances between point P, shown in Fig. 1, and the smaller ellipse center point are L1 and W1, respectively. The parameter L2 defines the vertical dimension of the antenna, while L3 is the distance between the substrate edge and the antenna in the y direction and L4 is the length of the CPS. The CPS is connected to a microstrip feed line through a balun to introduce the odd mode at the edge of the CPS. The truncated ground plane acts as a reflector that helps suppressing back radiation.

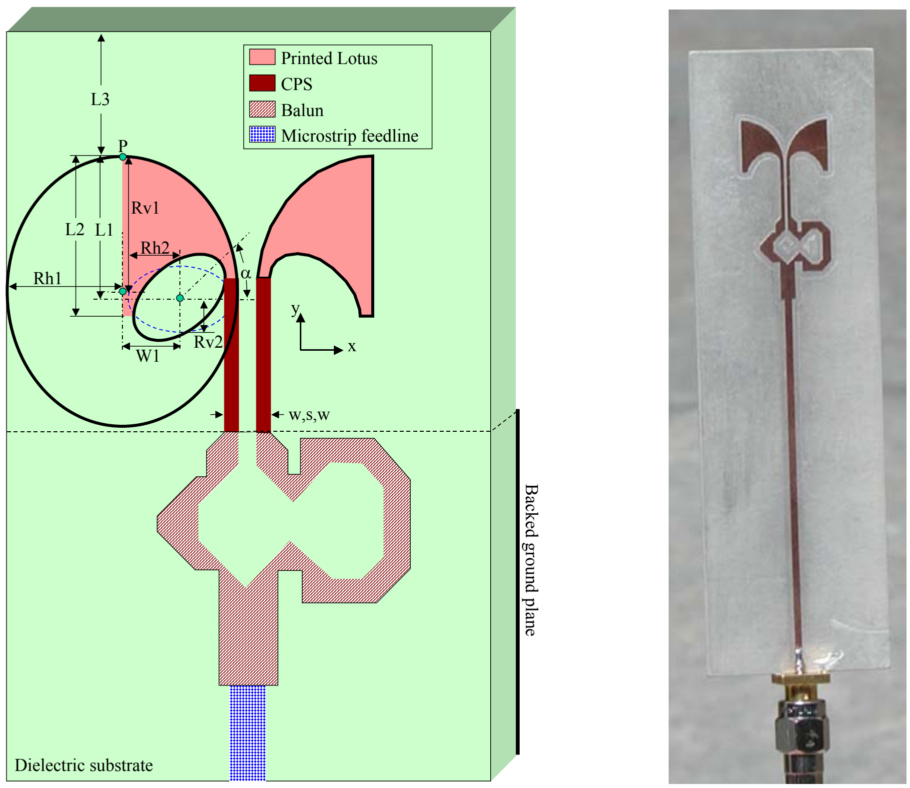
The parameters of the printed Lotus antenna are optimized for optimum bandwidth around 10 GHz. The designed antenna has Rh1, Rv1, Rh2, Rv2, L1, W1, L2, L3 and L4 equal to 3.4, 3.6, 1.57, 1.06, 3.87, 1.76, 4.2, 5.8 and 4.55 mm, respectively, with $\alpha = 41^o$, and the CPS dimensional parameters w and s are 0.3 and 0.2 mm, respectively, for an approximate characteristic impedance of 100 Ω. Figure 2 shows the dimensions in mm for the baluns, where the legend on the left side of the figure indicates the horizontal and vertical dimensions of the designated inclined lines by the symbols.

Printed Lotus Antenna Characteristics

The return loss is measured using the network analyzer HP 8510C, and computed using HFSS. A comparison between the measured and calculated return loss are shown Fig. 3 (a). A very good agreement is obtained with a slight increase in the –10 dB BW from 57% to 60% and in the –15 dB BW from 52% to 55.5%. The small discrepancies between measurement and simulation around 10 GHz are due to the imperfect fabrication and the SMA coaxial connector transition. However, one should note that these differences are well below the –15 dB level; thus, the simulations and measurements predict a wideband range of operation for this antenna.

The radiation patterns at 10 GHz are shown in Fig. 3 (b). The beam width is 74^o and 143^o in the E and H-planes, respectively. The maximum gain is around 5.7 dB and the front-to-back ratio is 17.9 dB. The cross polarization level is –26 and –29 dB in the E and H-planes, respectively, considering only the angles defined by the

3 dB beamwidth. The stability of the radiation pattern is examined by computing the radiation patterns at 8, 10 and 13 GHz, which cover the entire operating band. The antenna shows good pattern stability, and the gain is found to vary from 4.2 to 5.7 dB. These characteristics make this antenna a very good candidate for phased array systems.



(a) (b)

Fig. 1. Printed Lotus antenna (a) geometry and parameters, and (b) prototype.

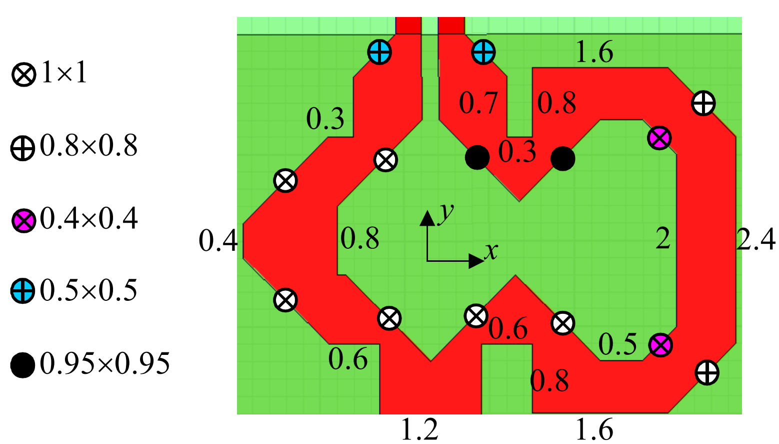
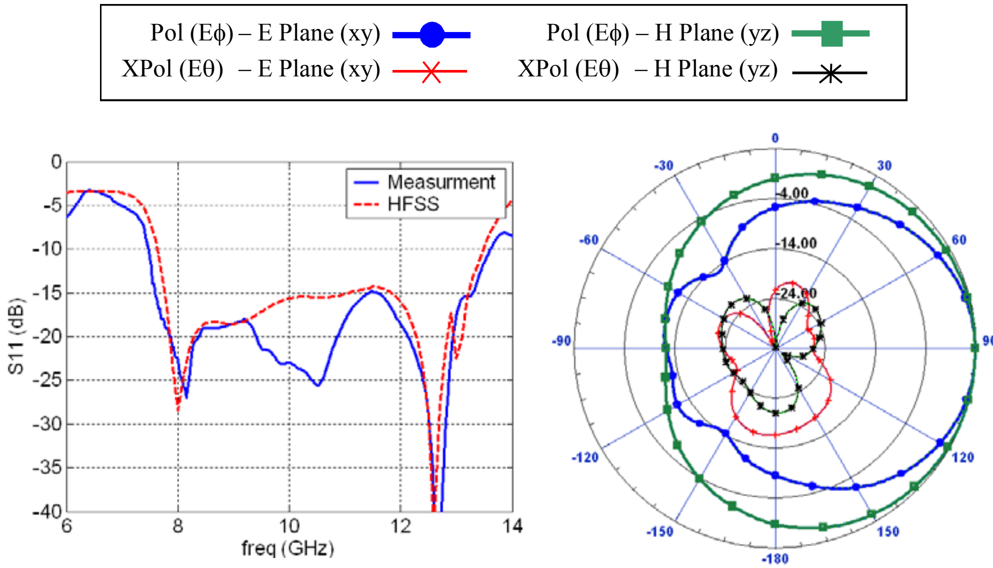


Fig. 2. Dimensions in mm for the balun.



(a) (b)

Fig. 3. Printed Lotus antenna (a) return loss, and radiation patterns at 10 GHz.

Conclusion

The printed Lotus antenna fed by microstrip line through a modified phase shifter is presented. The antenna has a wide bandwidth of 55.5% relative to –15 dB and 60% relative to –10 dB. In addition to being very small in size, the antenna exhibits stable far field radiation characteristics over the entire operating band with relatively high gain, low cross polarization, very wide beamwidth and high front-to-back ratio.

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