Filtering Balun Based on Spoof Surface Plasmon Polariton

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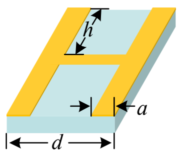
***Abstract*—In this letter, a filtering balun based on spoof surface plasmon polariton (SPP) structure is proposed. This filtering balun is mainly composed of periodic H-shaped spoof SPP structures and two microstrip-slotline cross-coupling structures. Owing to the intrinsic 180º phase difference between two output ports of microstrip-slotline cross-coupling structure and the high-efficient odd mode transmission property of the spoof SPP structure, a balun with filtering capabilities operating around 2 GHz has been realized and verified.**

Keywords—Balun; microstrip-slotline; spoof surface plasmon polaritons (SPP).

I. Introduction

The filtering balun is a single-circuit block assembling balun with filtering capabilities. It can realize not only the transition from unbalanced signal to the balanced one, but also a selective transmission of targeted signal in the objective operating frequency band. They have extensive applications in modern microwave systems with the advantage of multifunction, compact size, etc. Therefore, a variety of methods have been proposed to achieve filtering balun or improve the performances [1]-[3], among which the Marchand balun and its derivative coupled-line forms are the most popular approach to design a filtering balun [1]. Besides, a new approach to realize a microstrip filtering balun is proposed in [2] by utilizing the standing-wave property of an open-circuited half-wavelength microstrip line. Moreover, a filtering balun based on the intrinsic 180º phase difference between two output ports of the microstrip-slotline cross-junction is proposed in [3]. However, most of them are limited to use conventional microwave transmission line.

Recently, ultrathin-thickness spoof surface plasmon polariton (SPP) structures have attracted much attention due to its unique features in microwave region. It can realize a high-efficiency transmission of electromagnetic (EM) wave with a single layer conductor and a high constraint of EM wave to its surface. In addition, an important advantage of spoof SPP is that the dispersion characteristics and spatial confinement properties can be designed and controlled by the geometric parameters of the arrayed elements. Therefore, various types of spoof SPP transmission lines [4] and microwave components, including bandpass filter [5], coupler [6], antenna [7] and so on, have been developed. Nevertheless, few works use this type of structure for the design of filtering balun.



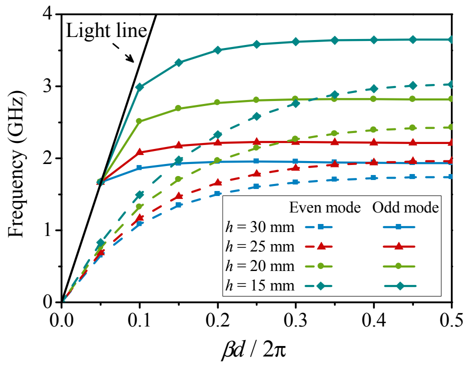


Fig. 1. (a) The schematic of spoof SPP structure, (b) the dispersion curves of the proposed SPP structure with different parameter *h*.

In this letter, a new balun with filtering capabilities is proposed based on the spoof SPP structure. By utilizing the odd mode dispersion supported by the spoof SPP transmission line and the intrinsic electric field distribution of the microstrip-slotline cross-coupling structure, a 180º phase difference between the two output ports can be realized. Meanwhile, it can achieve efficient conversion of EM wave from microstrip line to slotline. The symmetric H-shaped spoof SPP structure is employed to support odd-mode transmission, and to realize filtering capability by its cut-off frequency [8]. Because of the ***E***-field discription of odd-mode is similar to the one of slotline, the EM wave can be well transited between them by properly constructing the transition structure. For demonstrating the concept, a filtering balun operating around 2 GHz is designed.

II. Analysis of the Proposed Filtering Balun

A. Analysis of the symmetric H-shaped spoof SPP structure

The basic symmetric H-shaped spoof SPP structure is composed of a thin metal strip on top of a dielectric substrate. The unit cell structure is shown in Fig. 1(a) with parameters of depth *h*, width *a*, and lattices constant *d*. Previous works

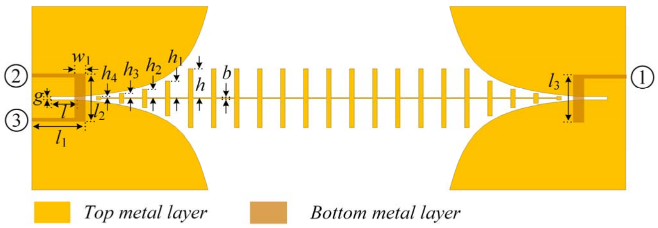


Fig. 2. The configuration of the proposed filtering balun.

demonstrate that either side of the corrugated metal strip can support well confined spoof SPPs. The spoof SPP waves propagating along this symmetric structure will split into two modes: even mode and odd mode [8], and the dispersion characteristics of the spoof SPP structure are shown in Fig. 1(b). Here, the parameters d and a are chosen as 10 mm and 1 mm, respectively. It concludes that parameter h can have an apparent influence over the cut-off frequency of the spoof SPP structure, and the cut-off frequencies will increase as h decreases both for the even mode and odd mode. It should be mentioned that the ***E***-field distribution of odd mode is similar to that of slotline. Therefore, it provides a direct coupling of the EM wave propagation between the slotline and the spoof SPP structure. In addition, the dispersion curves of the proposed spoof SPP structure under different modes have a cut-off frequency, which can realize a filtering capability in the process of the EM wave propagating.

B. *Analysis of the microstrip-slotline cross-coupling structure*

The whole structure of the filtering balun is illustrated in Fig. 2, where the microstrip-slotline cross-coupling line at input port 1 is stretched beyond the slotline area, whereas the microstrip-slotline cross-coupling line output area are separated into two identical ports. The cross-section of ***E***-field distributions for three ports are schematically shown in Fig. 3. It is clear that 180º phase difference at the two output ports (port 2 and port 3) can be obtained from the anti-parallel field distributions, which could benefit the design of the balun.

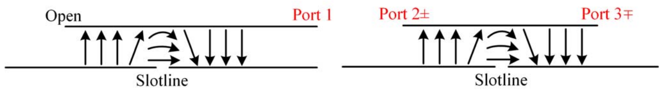


Fig. 3. The cross-section view of ***E***-field distributions in the microstrip-slotline cross structure.

III. SIMULATED RESULTS

Based on the aforementioned analysis, we have designed a filtering balun on a F4B substrate with thickness of 0.8 mm and dielectric constant of 3.5 and a loss tangent of 0.001. To realize a high-efficient EM wave transmission from slotline to spoof SPP structure, gradually changed spoof SPP structures is employed, as shown in Fig. 2. The operating frequency of the filtering balun is designed at 2 GHz. As observed from Fig. 1(b), the parameter h should be adjusted to 25 mm. The optimized geometric parameters of the filtering balun are l = 6 mm, l_1 = 13.3 mm, l_2 = 19 mm, l_3 = 19 mm, g = 0.4 mm, h_1 = 14 mm, h_2 = 7 mm, h_3 = 3.6 mm, h_4 = 1.8 mm, w_1 = 3.8 mm and b = 0.5 mm. The simulated S-parameters of the designed filtering balun are shown in Fig. 4. The 3 dB frequency bandwidth is about 12.5% with respect to the center frequency. The in-band insertion loss is about 0.9 dB, and the return loss is better than 12 dB. The simulated amplitude and phase differences between the two output ports are plotted in Fig. 5. The gray region expresses the passband. It can be clearly observed that the phase difference between the two output ports varies within 180º±3º and amplitude difference is always less than 0.1 dB in the designed passband. We will discuss the fabrication and experimental verification in the presentation in detail.

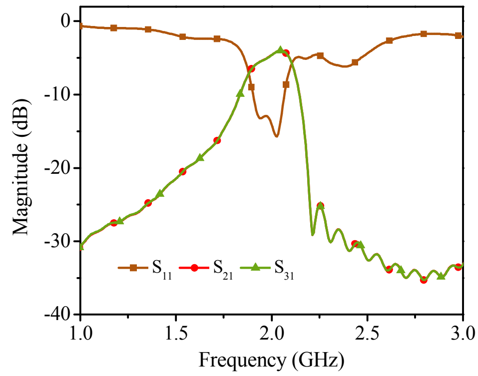


Fig. 4. The simulated S-parameters of the proposed filtering balun.

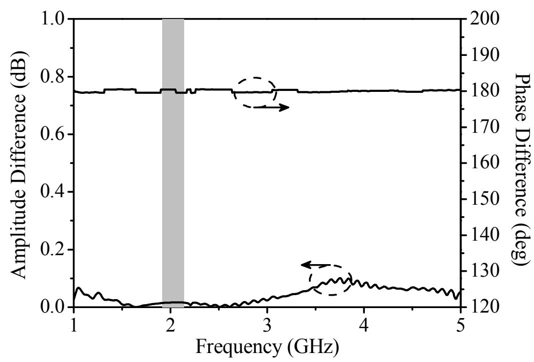


Fig. 5. Simulated amplitude and phase differences between the two output ports.

IV. CONCLUSIONS

This paper provides a new method to design a filtering balun based on spoof SPP structure. Utilizing odd mode propagation and the microstrip-slotline cross-coupling structure, a 180º phase difference between the two output ports can be realized. Meanwhile, the symmetric H-shaped spoof SPP structure can realize filtering capability by its cut-off frequency adjustable upon its groove height and maintain a high-efficient transmission of EM wave. Based on these features, a filtering balun is designed and verified with good performances. It is believed that the proposed concept may provide good alternative design for future communication systems.

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