Planar Waveguides Based on Spoof Surface Plasmon Polaritons Supported by Two-conductor Transmission Lines

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***Abstract*—This work presents two waveguides based on spoof surface plasmon polaritons (SSPPs) supported by two-conductor transmission lines. Smooth and simple transition is achieved without employing flaring ground. Two prototypes of SSPP waveguides are fabricated for demonstration. Both simulations and measurements validate the efficient excitation and propagation of SSPPs supported by two-conductor transmission lines (TLs) which greatly simplify the design of transition. The proposed waveguides can find significant potential applications in plasmonic circuits at microwave frequencies.**

***Keywords*—SSPPs; waveguide; metamaterials**

I. INTRODUCTION

Recently, ultrathin corrugated metallic strips on flexible films, which are termed as conformal surface plasmons (CSPs) [1], are proposed to propagate SSPPs efficiently on planar path. However, most of SSPP structures are based on single-conductor transmission lines [2,3], which is difficult to be employed directly in planar microwave circuits mainly constructed by two-conductor TLs. Usually, the transition between SSPP structure and two-conductor TLs are based on flaring ground which is very complicated to design.

In order to overcome the limitation caused by the flaring ground, SSPPs supported by two-conductor TLs have been proposed [4,5]. The addition of ground planes can greatly simplify the design of transition while remaining the dispersion characteristics of SSPPs. In this paper, two SSPP waveguides with different kinds of grooves are proposed. The transitions are both with simple geometry and built by gradient grooves which avoid using flaring ground. For demonstration, two prototypes of SSPP waveguides are fabricated. Both numerical and experimental results validate the high-efficiency excitation and propagation of SSPPs.

II. SSPP WAVEGUIDE WITH RECTANGULAR GROOVES

Fig. 1(a) shows the schematic configuration of the SSPP waveguide with rectangular grooves, the sketches of each region are given in Figs. 1(b)-1(d). The length of the three regions are L_1=10 mm, L_2=40 mm and L_3=40 mm, respectively. Region I is a coplanar waveguide (CPW) with H=10 mm, g=0.4 mm and W=20 mm. Region III is the SSPP structure and the geometry parameters are as follows: d=5 mm, a=1 mm and h=4 mm. Region II in Fig. 1(c) is the transition with gradient grooves. The groove depth h varies from h_1=0.5 mm to h_8=4 mm with a step of 0.5 mm.

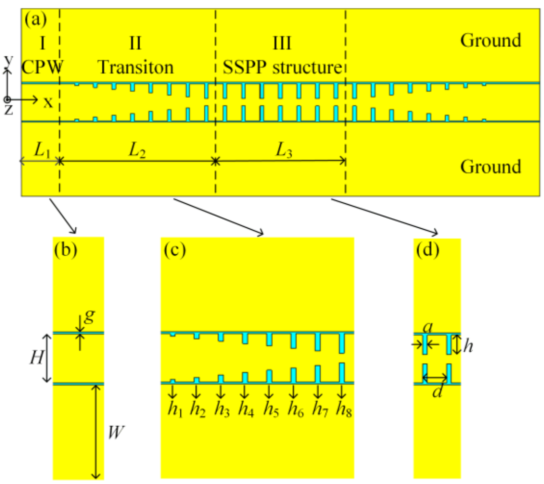

Fig. 1. The schematic configuration of the SSPP waveguide with grooves. (a) Top view of the structure. (b) Region I: CPW. (c) Region II: Transition. (d) Region III: SSPP structure.

Fig. 2 shows the comparison of simulated and measured results. The photograph of the fabricated prototype is shown in the inset of Fig. 2 as well. It can be seen that the tested results exhibit good agreement with simulations at low frequencies, i.e. below 7.2 GHz, which demonstrate the excellent matching of momentum and impedance. The measured cut-off frequency is nearly 10.4 GHz. The return loss is almost less than -10 dB up to about 7.2 GHz. When the frequency increases, the measured results become worse gradually due to the serious impedance mismatch caused by connectors and soldering imperfections. Nevertheless, improved low-frequency performance can be achieved which validates the high-efficiency excitation and propagation of SSPPs.

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than -0.86 dB while the return loss is lower than -13.62 dB which indicates excellent low-frequency performance. All the results obtained above verify the efficient propagation of SSPPs and the bandwidth improvement.

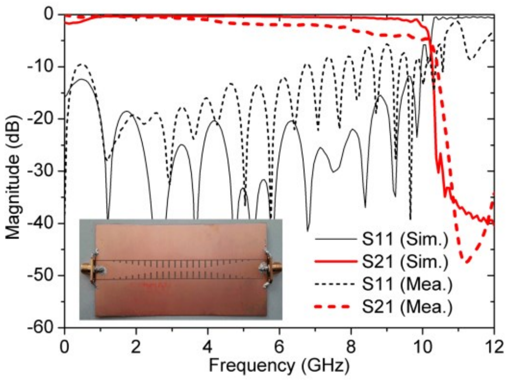

Fig. 2. Measured and simulated results of the SSPP waveguide with rectangular grooves. The inset is the photograph of the fabricated prototype.

III. SSPP Waveguide with Complementary Rectangular Grooves

The schematic configuration of the SSPP waveguide with complementary rectangular grooves is illustrated in Fig. 3. The sketches and detailed geometrical parameters of each region are given in Figs. 3(b)-3(d). Region I is a CPW with H_1=3 mm, g_1=0.15 mm and W=20 mm. Region III is the SSPP structure with complementary grooves. The dimensions are set as d=7mm, h=4mm and a=w_1=1mm. Region II in Fig. 3(c) works as a transition. Gradient grooves are employed with the groove depth varies from h_1=0.5 mm to h_8=4 mm with a step of 0.5 mm.

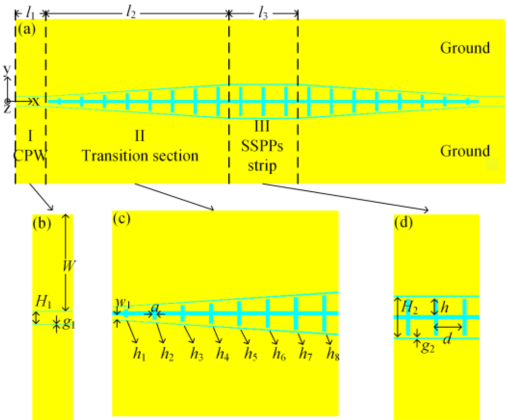

Fig. 3. The schematic configuration of the SSPP waveguide with complementary grooves. (a) Top view of the structure. (b) Region I: CPW. (c) Region II: Transition. (d) Region III: SSPP structure.

Fig. 4 illustrates the comparison of numerical and experimental results and the photograph of the fabricated prototype are shown in the inset. Satisfactory agreement is obtained which validates the good performance of the SSPP waveguide. The minor mismatch is mainly caused by soldering imperfection. The cut-off frequency of the waveguide is about 11.5 GHz. The measured insertion loss below 6.6 GHz is better than -0.86 dB while the return loss is lower than -13.62 dB which indicates excellent low-frequency performance.

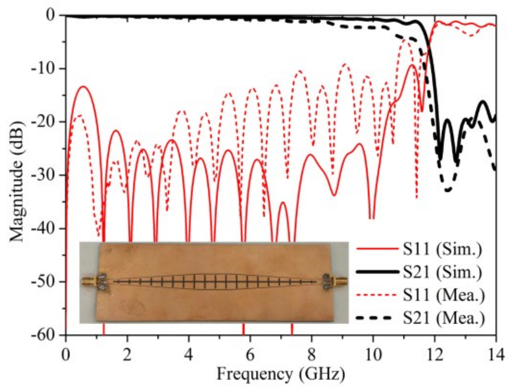

Fig. 4. Measured and simulated results of the SSPP waveguide with complementary rectangular grooves. The inset is the photograph of the fabricated prototype.

IV. Conclusion

In this paper, two SSPP waveguides with rectangular and complementary rectangular grooves are proposed. Smooth transition with simple geometry is employed to achieve excellent matching of momentum and impedance, avoiding using flaring ground. The addition of ground plane can both simplify the design of transition and improve the low-frequency performance. Two prototypes of the proposed waveguides are fabricated and measured to experimentally validate the high-efficiency excitation and propagation of SSPPs supported by CPWs. Such results can greatly accelerate the development of plasmonic circuits at microwave frequencies.

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