Bandpass Filter Using Half-Mode Substrate Integrated Plasmonic Waveguide

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***Abstract* – A bandpass filter based on hybrid spoof surface plasmon polaritons (SSPPs) and half-mode substrate integrated waveguide (HMSIW) is proposed. The filter consists of a traditional HMSIW structure and an E-type slot array etched on the top metal layer of the HMSIW to support SSPP modes. The passband of the filter can be adjusted by changing the dispersion characteristics, which can be realized by tuning the parameters of the unit cell. The simulation results show that the proposed structure has great filter characteristics within a passband from 3.05 to 3.65GHz with high return loss (> 15dB), low insertion loss (< 1dB) and high out-of-band rejection (> 40dB).**

***Index Terms* — spoof surface plasmon polaritons (SSPPs), half-mode substrate integrated waveguide (HMSIW), dispersion curve.**

I. INTRODUCTION

Surface plasmon polaritons (SPPs) are highly confined surface electromagnetic (EM) waves that propagate along the interface of metal and dielectric and decay exponentially along the direction vertical to the interface in the optical band. However, the nature SPPs at the microwave band do not exist due to metal approximately behaves as perfect electric conductor (PEC) [1]. In order to realize highly confined surface EM wave at microwave band, the concept of spoof surface plasmon polaritons (SSPPs) is presented in [2], which shows similar characteristics with SPPs at microwave band. Recently, various structures that support SSPP modes have been reported [3]-[7].

Substrate integrated waveguide (SIW) has been widely used in the field of microwave technology because of its advantages of low loss, low profile, slight crosstalk, etc. However, SIW has a disadvantage of its large lateral width. To realize the size compactness but keep the characteristics of SIW, the concept of half-mode SIW (HMSIW) is presented in [8].

In this paper, a novel bandpass filter (BPF) using an E-type-slotted HMSIW-SSPP structure is proposed. The dispersion characteristics of the SSPP unit cell are studied and analyzed, and it shows that the low and high cut-off frequencies can be adjusted by tuning the width of HMSIW and slot parameters. Finally, the frequency responses of the proposed filter are simulated, with a good bandpass filtering effect and out-of-band rejection.

II. HALF-MODE SUBSTRATE INTEGRATED PLASMONIC WAVEGUIDE

A half-mode substrate integrated plasmonic waveguide is constructed, consisting of an HMSIW and an embedded E-type slot array on the top metal layer as the SSPP structure. The configuration of the proposed HMSIW-SSPP unit cell is shown in Fig. 1. The yellow and green area denote the copper with thickness t_1 = 0.018 mm and Rogers 5880 substrate with relative dielectric constant ε_r = 2.2, loss tangent $\tan\delta$ = 0.0009 and thickness t_2 = 0.127 mm, respectively. The width of the HMSIW (W), length of the unit cell (p) are set as 14.5 mm and 4 mm, respectively. The diameter of the metalizing via-holes (d) is 0.4 mm, and the center-to-center spacing of the adjacent via-holes (g) is 0.5 mm. The parameters of the E-type slot are set as follows: l = 7 mm, t_x = 1.7 mm, t_y = 6.5 mm, and w_s = 0.2 mm.

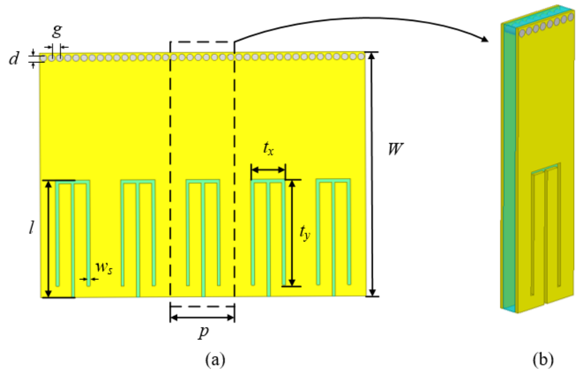

Fig. 1. Schematic view of proposed HMSIW-SSPP waveguide. (a) Top view. (b) 3D view of the proposed unit cell.

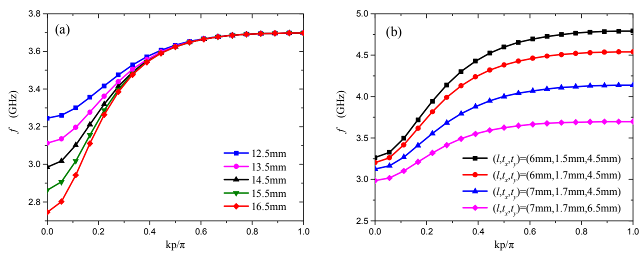

Fig. 2. Dispersion curves of the proposed unit cell (a) with different W. (b) with different combinations of l, t_x and t_y.

To better understand the characteristics of the proposed HMSIW-SSPP structure, its dispersion relation is analyzed. The dispersion curves for the fundamental SSPP mode of the proposed unit cell with different values of *W*, and different combinations of *l*, t_x and t_y are shown in Fig. 2(a) and 2(b), respectively. It can be discovered from Fig. 2(a) that the low cut-off frequency of the proposed unit cell decreases as *W* increases while the high cut-off frequency remains the same. From Fig. 2(b), it can be seen that the low and high cut-off frequencies are both changed by tuning the parameters of the E-type slot. Therefore, the proposed BPF's passband can be adjusted by tuning the width of HMSIW and the parameters of the E-type slot array.

Besides, the dispersion characteristics of the proposed unit cell and conventional HMSIW-SSPP unit cell with an I-type slot are compared. The proposed unit cell and the conventional unit cell have an identical size, and the dispersion curves are shown in Fig.3. The results show that the proposed unit cell has lower cut-off frequencies, which means the proposed unit cell has higher propagation constant and more slow-wave effect than conventional I-type slot.

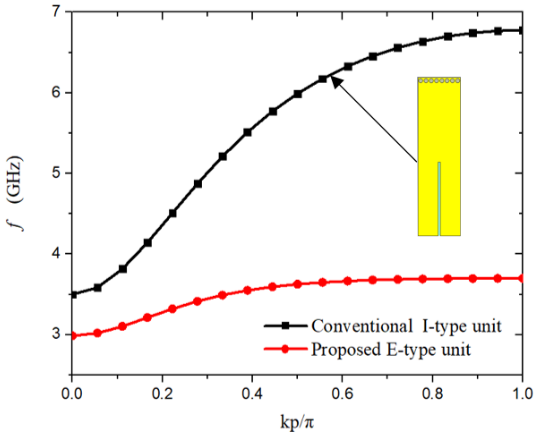

Fig. 3. Dispersion curves of the proposed HMSIW-SSPP unit cell and conventional HMSIW-SSPP unit cell.

III. Bandpass Filter Application

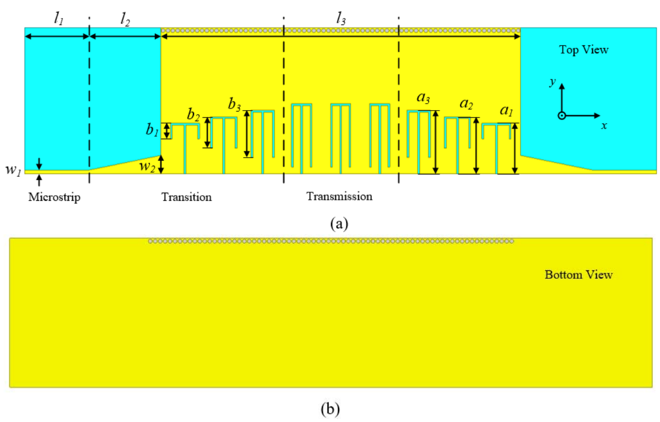

Fig. 4. Schematic view of proposed filter. (a) Top view. (b) Bottom view.

The configuration of the proposed BPF is shown in Fig. 4. The filter consists of microstrip part, transition part and HMSIW-SSPP transmission part. In the transition part, a tapering microstrip line and three gradient E-type slots are used for matching the impedance between 50-Ohm microstrip line and HMSIW-SSPP structure. The parameters of the filter are set as follows: l_1 = 6.5 mm, l_2 = 7.5 mm, l_3 = 36.9 mm, w_1 = 0.37 mm, w_2 = 1.9 mm, a_1 = 5 mm, a_2 = 5.7 mm, a_3 = 6.3 mm, b_1 = 1.6 mm, b_2 = 3.23 mm, b_3 = 4.87 mm.

To study the properties of the filter, its S-parameters are calculated by frequency-domain simulation of CST Microwave Studio. As shown in Fig. 5, the proposed BPF processes good bandpass characteristic with $|S_{21}| > -1$ dB and $|S_{11}| < -15$ dB from 3.05 GHz to 3.65 GHz, and excellent out-of-band rejection with $|S_{21}| < -40$ dB.

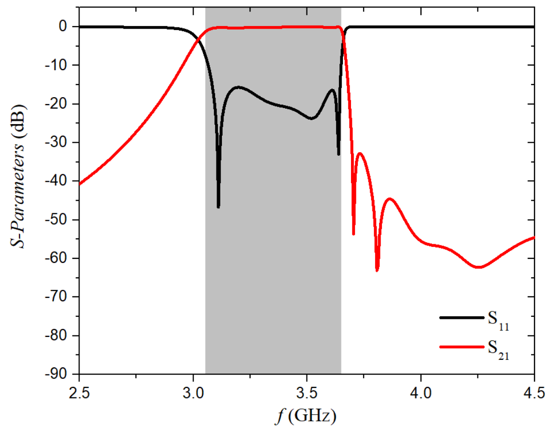

Fig. 5. Simulated S-parameters of the proposed filter.

IV. Conclusion

In this paper, a BPF based on the concepts of SSPP and HMSIW is proposed and analyzed. The low and high cut-off frequency of the proposed filter can be adjusted, and the E-type slot has a more slow-wave effect than the conventional I-type slot. The simulated results show that the filter possesses a bandwidth of 3.05-3.65 GHz with a return loss of more than 15 dB and an insertion loss of less than 1 dB. The out-of-band rejection level is less than 40 dB. The proposed filter not only has a great filtering feature but also facilitates fabrication and integration with other circuits.

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