



## Broadside Radiation based on Even-mode Spoof Surface Plasmon Polaritons Excited by Slot in AMC Ground Plane

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### Abstract

In this paper, a broadside antenna based on even mode of spoof surface plasmon polaritons (SSPP) using artificial magnetic conductor (AMC) ground plane is proposed. Slot in AMC ground plane is used for first time to excite even mode of SSPP in horizontally placed corrugated metal strip while maintaining low profile. Planar configuration of the proposed design is possible due to the horizontal E-field of slot in AMC ground. The in-phase resonating even mode currents of both the SSPP strips contribute for radiation in broadside direction. The proposed antenna offers 89% radiation efficiency with 6.7 dBi gain with low profile of only  $0.068 \lambda$  (where  $\lambda$  is free space wavelength at resonance frequency of 3.2 GHz.)

### 1. Introduction

Spoof surface plasmon polaritons (SSPP) waves are Surface Plasmon like waves at microwave frequencies which can be achieved using subwavelength corrugations in metallic strips [1]. Recently, SSPP based antenna is the alluring topic for researchers [2-4]. There are two modes of SSPP: 1) Even mode and 2) Odd mode [5].

Even mode of SSPP is used for resonant antenna [5-7]. In [5] and [6], even mode SSPP is excited by near-field of printed monopole over metallic ground plane. In [7], even mode of SSPP is excited by nearby placed printed monopole over rectangular Artificial Ground Plane. The simplest technique to excite even mode of SSPP is to use printed monopole in proximity to corrugated metallic strip. The near-field from the monopole gets coupled to SSPP strip as even mode of SSPP, which induces first resonating mode current in the SSPP strip. That even mode current with the help of metallic ground or Artificial ground gets radiated in broadside direction. The common design strategy observed is to use monopole with ground to excite even mode of SSPP in corrugated metallic strip which is placed vertical over that ground.

However, overall profile of the antenna increases due to the height of the printed monopole and vertical placement of SSPP strip w.r.t. ground. Low profile design strategy for exciting even mode of SSPP current in corrugated metallic strip must be investigated.

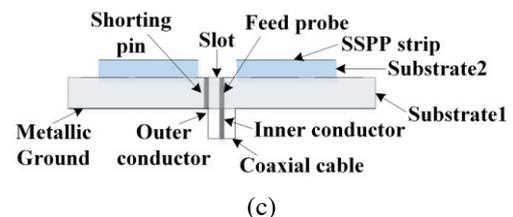
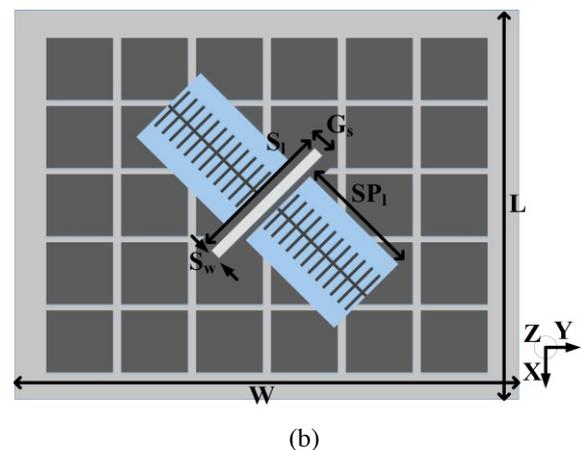
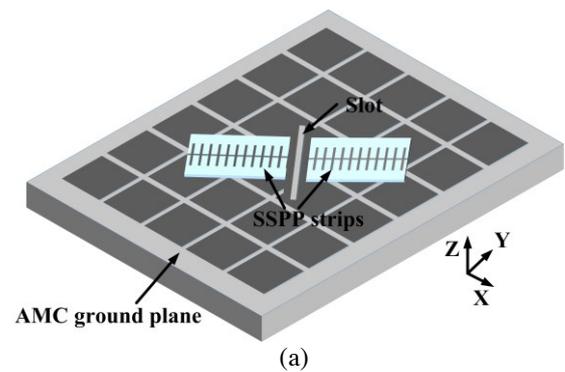


Figure 1. Geometry of the proposed antenna (a) Perspective view, (b) Top view and (c) Cross section view

In this paper, even mode of SSPP is excited using near-field of slot in AMC ground plane. Slot in AMC ground plane can give horizontal E-field which is favourable to excite even mode in SSPP strip. Horizontal placement of SSPP strip is possible due to the AMC ground plane which helps

in reducing overall profile of the antenna. SSPP strips are placed horizontally on both sides of slot. Even mode of SSPP strips' currents are in the same direction in both sides of slot which ultimately gives broadside radiation. To the best of the authors' knowledge, it is the first time that even mode of SSPP is excited by slot.

## 2. Antenna Geometry

Figure 1 shows the antenna geometry which contains three main parts: (1) AMC ground plane, (2) Slot and (3) Two corrugated metallic strips. One side of the slot in AMC ground is fed by cylindrical wire probe i.e. feed probe that has been extended from inner conductor of the coaxial cable and other side of the slot is shorted to metallic ground through metallic via i.e. shorting pin as shown in Figure 1(c) [8]. The Metallic ground is shorted to the outer conductor of co-axial cable. Diameter of the feed probe is 1 mm. Diameter of shorting pin and diameter of inner conductor are same as diameter of feed probe. The length of the feed probe and shorting pin is 6 mm. Diameter of the outer conductor is 4 mm. Distance between shorting pin and feed probe in  $\Phi = 45^\circ$  direction is 1.9 mm. The Substrate used for coaxial cable is Rogers 4003C. The co-axial fed slot and horizontally placed corrugated metallic strips are oriented along  $\Phi = 45^\circ$  on the AMC ground as shown in Figure 1(b).

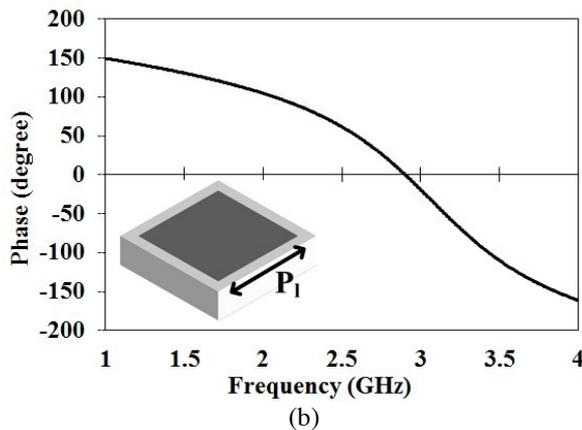
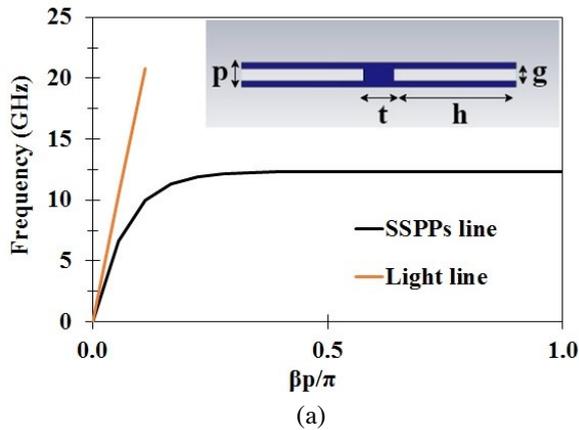


Figure 2. (a) Dispersion curve (Inset: SSPPs unit cell) (b) Reflection phase vs. frequency (Inset: AMC unit cell)

TABLE 1. Dimensional values (In Millimeters)

h	g	t	p	$S_w$	$G_s$
4	0.4	0.5	0.8	1.5	2.5
$P_1$	$S_1$	$SP_1$	W	L	
11	27	18	77	65	

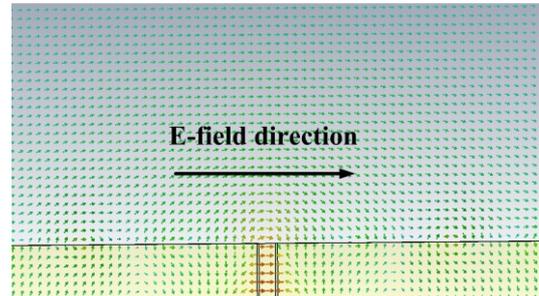


Figure 3. E-field configuration of the slot in AMC ground plane at 3.2 GHz

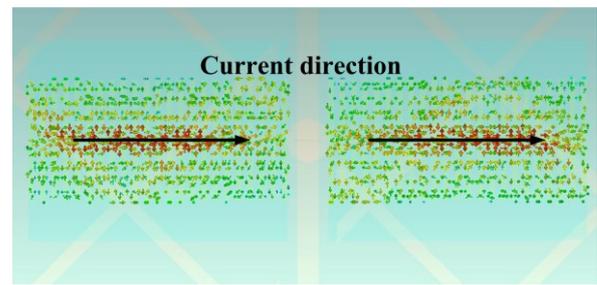


Figure 4. Even mode of SSPP currents in SSPP strips fed by slot in AMC ground at 3.2 GHz.

The substrate used for SSPP strip is Rogers 4003C (substrate 2:  $\epsilon_r = 3.38$ ,  $\tan\delta = 0.0027$ ) with thickness of 0.25 mm. The AMC ground plane contains array of  $5 \times 6$  square metal patches over grounded dielectric Rogers RT6002 (substrate 1:  $\epsilon_r = 2.94$ ,  $\tan\delta = 0.012$ , thickness = 6 mm). Copper is used as metal with thickness of 0.018 mm. The unit cells of SSPP strips and AMC ground are shown in Figure 2. The two SSPP strips are placed symmetrically on both sides slot as shown in Figure 1(b). The optimized dimensions of the proposed antenna are shown in Table 1.

## 3. Results and Discussion

Figure 2(a) shows dispersion curve of the SSPPs unit cell which indicates higher propagation constant than the light line. Figure 2(b) shows in-phase reflection of normal incident wave on AMC ground. The horizontal placement of SSPP strips are possible due to the in-phase reflection of linearly polarized incident waves from the two SSPP strips. The near-field of the slot in AMC ground is used to excite first order resonating even mode in SSPPs strip which can be seen from E-field distribution of slot in AMC ground at 3.2 GHz in Figure 3. Even mode of currents are excited in both SSPP strips with same phase and direction as shown in Figure 4.

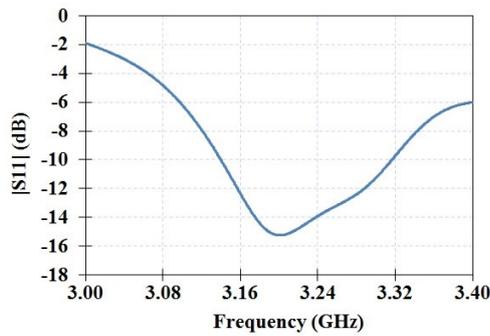


Figure 5. Simulation result of  $|S_{11}|$  vs. frequency

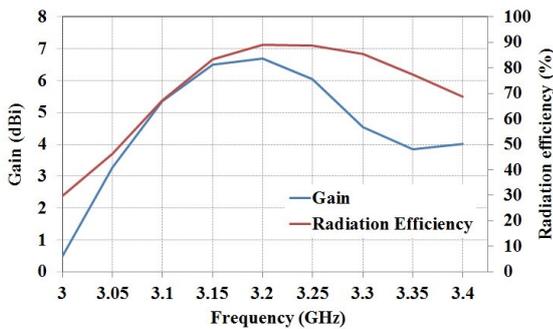


Figure 6. Simulated radiation efficiency and gain of the proposed antenna

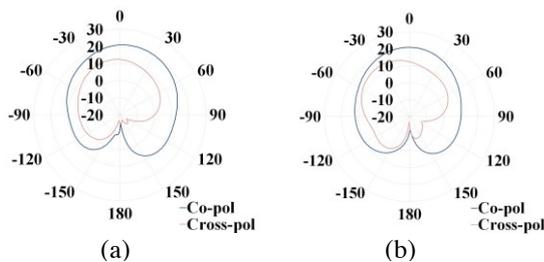


Figure 7. Far-field pattern at 3.2 GHz in (a) E-plane (b) H-plane.

As shown in Figure 4, two in-phase currents of two symmetrically placed SSPP strips give constructive interference of fields in broadside direction, which gives broadside radiation. Figure 5 shows  $|S_{11}|$  versus frequency plot of the proposed antenna. The proposed antenna shows resonant frequency at 3.2 GHz with 175 MHz 10-dB impedance bandwidth. Figure 6 show broadside gain of 6.7 dBi and radiation efficiency of 89 % at 3.2 GHz. Figure 7 shows broadside radiation in far-field patterns. The proposed antenna has only 6.4 mm ( $0.068\lambda$ , where  $\lambda$  is wavelength at resonance frequency of 3.2 GHz.) overall height.

#### 4. Conclusion

A broadside antenna based on SSPPs using AMC ground plane is proposed. Even mode of SSPPs is excited using

slot in AMC ground plane for very first time. Even mode of SSPP is excited while maintaining low profile configuration of the proposed antenna design. The horizontal placement of SSPP strips are possible due to the in-phase reflection property of linearly polarized incident waves from the two SSPP strips as well as E-field configuration of slot in the AMC ground plane. The radiation in broadside direction is the result of the constructive interference of in-phase radiation from both the SSPP strips. The proposed antenna offers 89% radiation efficiency with 6.7 dBi gain at 3.2 GHz resonant frequency.

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