A Small and Thin Metasurface Loop Antenna

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Abstract - **Novel metasurface-backed loop antenna is proposed for ISM-band wearable devices. The antenna is printed on a small-area and thin substrate the bottom of which is designed to get the characteristics of artificial magnetic conductor(AMC) for acceptable antenna performances and robustness over human skin contact. The advantages and validity of the structure are verified by full-wave simulation and experiments.**

***Index Terms* — Printed loop antenna, Metasurface.**

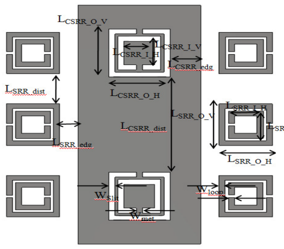
1. Introduction

The electromagnetic bandgap(EBG) structure has been adopted to horizontal wire antennas near PEC for miniaturization[1-4]. Yang et al place a dipole off the edge of a pair of 4-by-3 periodic mushrooms[1]. The mushroom EBG works for 8 GHz, stops S_{11} from severe deterioration at the aforementioned frequency, and keeps the radiation pattern close to the omni-directional one. Abkenar use 7-by-7 mushrooms over a large area to generate the stopband for the surface wave from 11 GHz to 14 GHz[2-4].

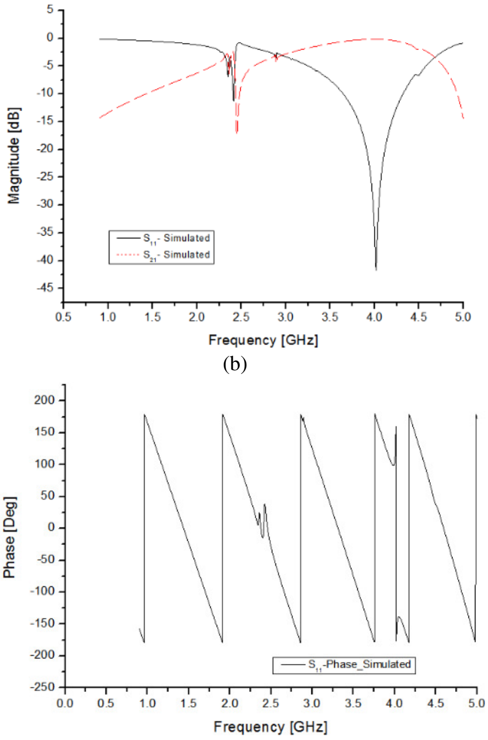
In this paper, a thin metasurface-combined loop antenna is proposed for the radiated fields in the 2.4GHz band as a relatively low frequency like the compact and thin AMC[5]. One layer of FR4 substrate has a loop printed on its top and CSRR-embedded metal ground on its bottom. Two complimentary split ring resonators (CSRRs) are formed on the metal region which possibly is shared with electronic circuits, and this geometry is tuned to have AMC properties. The AMC-backing structure retrieves the characteristics of the printed loop that would face the critical deterioration in S_{11} and radiation with the PEC bottom.

2. A Thin AMC and combination to a loop

The geometry of the AMC surface is now proposed for 2.4GHz, needing an aperiodic shape with truncated edges for practicality. Differing from the arrays of dogbones or patches in others', a new AMC should be an alternative form as the follows.



(a)



(b)

(c)

Fig. 1. A novel AMC surface (a) Geometry (b) Reflection and transmission coefficients in the plane-wave incidence test (d) Phase of Reflection coefficient in the plane-wave incidence test

Fig. 1(a) is the shape of the proposed AMC surface. As briefly stated before, the metal plane in the middle of the bottom of one-layer 0.8mm-thick FR4 substrate has two CSRRs. This metalized area is a real-estate for electronic circuits, if needed, and its bisection line between the centers of the CSRRs will be aligned with the electric-field polarization of the plane-wave here and the direction of the loop to be printed in a later stage. As a method to investigate the AMC characteristics of a surface of interest, the reflection coefficient of the incident plane-wave illuminated on to the structure under test is obtained as the function of frequency, and should present the value of 1. The suggested surface is placed in the plane-wave test setup and the vertically polarized E-field and the transverse magnetic field are launched toward the device under test. The reflection coefficient comes to have 0-dB in magnitude and 0-degree in phase at 2.4GHz as shown in Fig.'s 2(b) and (c) with 1.00 mm, 1.00 mm, 0.7 mm, 0.7 mm, 0.5 mm, 2.0 mm, 0.8 mm, 0.9 mm, 0.65 mm, 0.57 mm, 0.3 mm, 0.62 mm 0.2 mm, 0.2 mm and 0.2 mm as $L_{CSRR\_O\_V}$, $L_{CSRR\_O\_H}$, $L_{CSRR\_I\_V}$, $L_{CSRR\_I\_H}$, L_{CSRR_edg}, L_{CSRR_dist}, $L_{SRR\_O\_V}$, $L_{SRR\_O\_H}$, $L_{SRR\_I\_V}$, $L_{SRR\_I\_H}$, L_{SRR_edg}, L_{SRR_dist}, W_{Slit}, W_{met} and W_{loop}, respectively. The potential advantages of the metasurface proposed in the previous section are examined in the combination with a loop. The antenna is intended to work at the 2.4-GHz band whose wavelength imposes a heavy restriction on holding many HIS cells within the limited space such as handset phones, smart wrist-watches, zigbee or blue-tooth modules. The characteristics of a small-area loop antenna are investigated for three different cases.

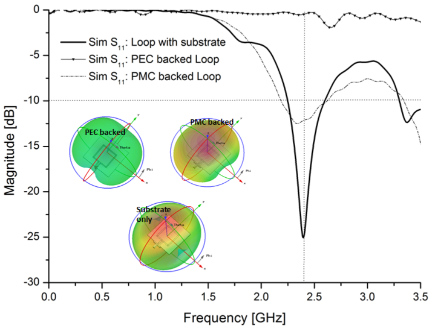
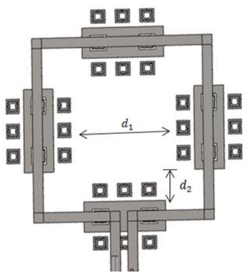
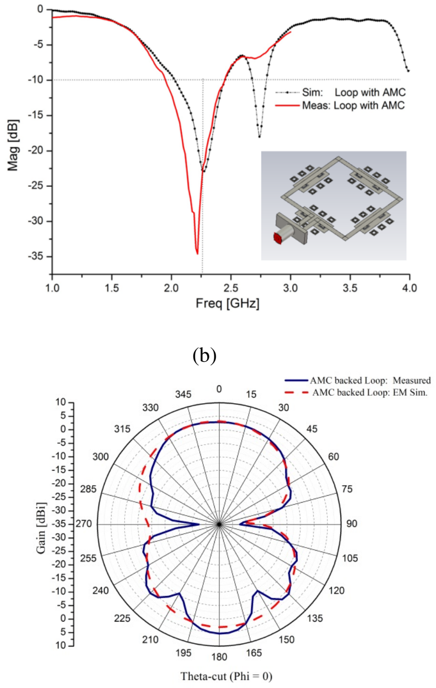


Fig. 2. Three cases are compared : S_{11} of the loop alone, PEC-backed printed loop and AMC-backed loop-antenna cases. Insets are far-field patterns in accordance with the three cases.

Firstly, the aforementioned loop as the reference source has the resonance at 2.4 GHz as the dip of S_{11} curve in Fig.2(a). The inset of the figure is the 3D-view of radiation pattern which is omni-directional with the gain of 2.2 dBi. Secondly, the PEC is placed behind the loop as in Fig.2(b). From the data of the return loss, the resonance frequency is nowhere to be found, and it is meaningless to talk about the radiation. Nonetheless, the third case where the loop is printed on the thin metasurface brings us a different outcome. In Fig. 2(c), the dip returns to the S_{11}-plot, which means the resonance condition is met and the antenna can radiate the electromagnetic power. Though the antenna gain is 2.0 dBi at 2.4 GHz lower than that of just the loop by 0.2 dB, their radiation patterns are very similar and the use of the AMC surface can improve the antenna performance significantly from the loop above the ground-plane. The antenna is fabricated and its experimental results are obtained.



(a)



(b)

(c)

Fig. 3. Implemented structure and experimental results (a) Geometry (b) S_{11} (c)Far-field pattern

As is seen in Fig. 3, the simulated results agree well with the experimental ones for the geometry in Fig. 3(a). The S_{11} in Fig. 3(b) and antenna pattern in Fig. 3(c) work as intended.

Acknowledgment

This work was supported by ICT R&D program of MSIP/IITP[2014-044-047-001, Dev. of radio services Antenna for the future Using Hybrid propagation medium].

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