Elliptical Metasurface Cloaks for Decoupling and Cloaking of Microstrip Monopole Antennas at 28 GHz and 39 GHz for 5G Wireless Applications

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Abstract— **In order to curtail mutual coupling between two closely spaced microstrip monopole antennas operating at frequencies 28 GHz and 39 GHz, the concept of electromagnetic cloaking is applied by utilizing elliptical metasurfaces. In this paper, we show that by enveloping the monopole antennas with the specifically engineered metasurface cloaks, not only is there a significant reduction in the mutual electromagnetic interaction but also restoration in the radiation patterns are observed, as if the antennas were completely isolated from each other. The decoupling effect is seen in the reduction of mutual S-parameters. This enables the antennas to radiate independently even though they are placed in a very close proximity.**

Keywords*— *Microstrip monopole antennas, elliptical metasurface cloaks, mantle cloaking, reduction of mutual coupling

I. Introduction

In recent years, the phenomenon of electromagnetic invisibility has been an object of remarkable interest that led to a significant research in the area. To achieve electromagnetic invisibility, various methods have been proposed such as transformation optics, transmission-line networks, and plasmonic cloaking, among others. Considering the fact that these techniques require bulky volumetric metamaterials, they may not be convenient for antenna applications with limited space availability. To deal with the aforementioned concern, the concept of mantle cloaking was introduced. It utilizes scattering cancellation method, wherein an ultra-thin metasurface creates anti-phase surface currents that results in suppression of the dominant scattering mode of the object to be cloaked. This was first wrought for cylindrical objects using thin patterned metasurfaces at GHz frequencies [1], [2]. It is of great interest to accommodate compact antenna configurations for various applications, such as MIMO, radar detection, mobile communications, etc. However, designing antennas with a very small separation between them degrades antenna performance and thus to resolve this issue, the mantle cloaking method has also been used to suppress the electromagnetic interaction between neighboring antennas [3], [4]. The metasurface cloak not only negates the mutual coupling but also restores the radiation properties of the antennas in such a way that it seems as if the antennas were completely isolated from each other. Recently this approach has also been applied to printed monopole antennas [5].

In this paper, cloaking and decoupling effect is determined for two closely spaced printed monopole antennas designed to operate at frequencies 28 GHz and 39 GHz (shown in Fig. 1). We have demonstrated that when the antennas are wrapped by the elliptical metasurfaces (shown in Fig. 2), they are decoupled from each other and at the same time, their radiation patterns are restored as if they were two isolated antennas radiating independently.

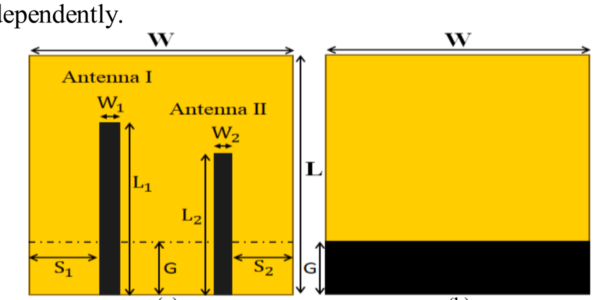

Fig. 1: (a) Top-view and (b) Bottom-view of printed monopole antennas I & II operating at frequencies f_1=28 GHz and f_2=39 GHz, respectively.

II. Elliptical Metasurfaces for Monopole Antennas

We take into consideration two microstrip monopole antennas - I and II with resonant frequencies at f_1=28 GHz and f_2=39 GHz, respectively printed on a dielectric substrate (L=7.5, W=6.75, h=0.13, and ε_r=2.2). All the geometrical parameters exhibited in Figs. 1 and 2 are in mm. The dimensions for the configuration in Fig. 1 are as follows: L_1=3.81, W_1=0.428, S_1=2.089, L_2=3.39, W_2=0.308, S_2=1.5, and G=1.821. We

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analyze each of the antennas in the isolated scenario and then consider the coupled case wherein the antennas are separated by a distance of 2.42 mm (which is either 0.226 λ_1 or 0.315 λ_2). When these antennas are placed in close proximity, it is observed that the interference generated due to mutual coupling, deteriorates the radiation properties of both the antennas (affirmed by the plots in Fig. 3).

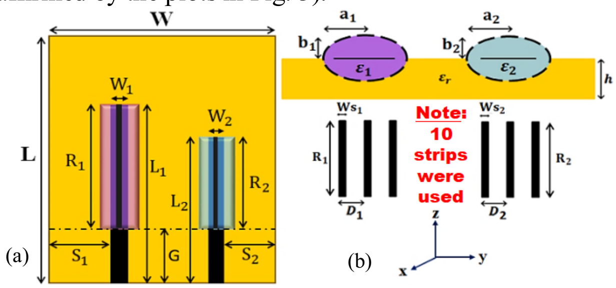

Fig. 2: (a) Top-view and (b) Front-view of cloaked printed monopole antennas.

We then proceed on to integrate the monopole antennas with the elliptical metasurfaces (Fig. 2). The cloak for each antenna is fabricated as per the following dimensions: R_1=1.9896, Ws_1=0.0375, a_1=0.2357, b_1=0.0982, ε_1=3.73, D_1=0.1094, R_2=1.5686, Ws_2=0.0231, a_2=0.1692, b_2=0.0705, ε_2=12.51, and D_2=0.0785. Now, when the antennas are placed close to each other, the appropriately designed elliptical metasurfaces enable to decouple the two antennas and reinstate their gain patterns (demonstrated in Fig. 3).

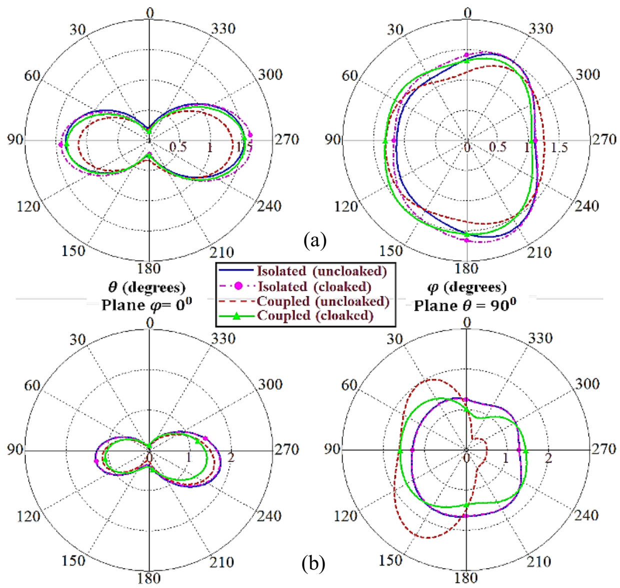

Fig. 3: Polar plots for (a) Antenna I operating at f_1=28 GHz and (b) Antenna II operating at f_2=39 GHz.

It can be deduced from Fig. 3 that the elliptical cloaks do not affect the properties of the antenna it is integrated to; its effects are reflected at the frequency of the neighboring antenna. In other words, the metasurface around Antenna I compels it to become a poor radiator at the resonant frequency of Antenna II and vice versa. This is validated by the E-field patterns and the total efficiency plot shown in Fig. 4 whereas the S-parameter plot (Fig. 4(c)) confirms the fact that the two antennas are completely decoupled at the resonant frequencies of one another.

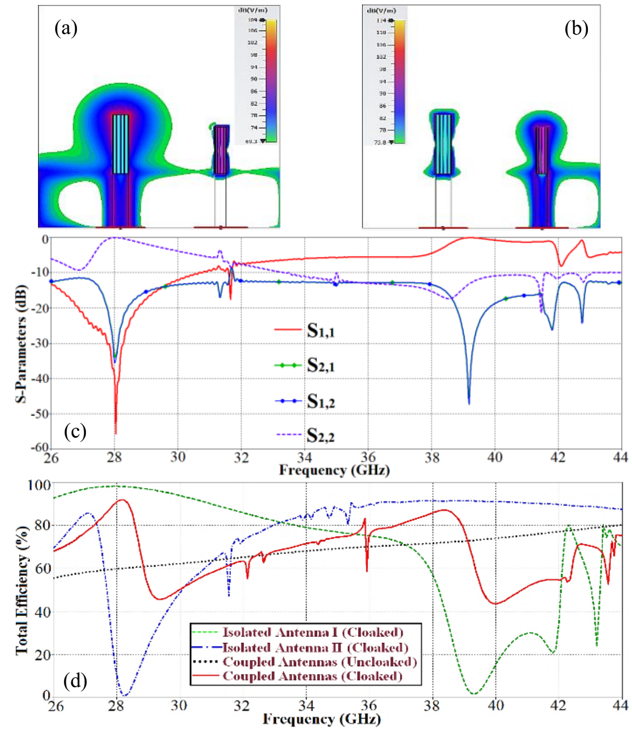

Fig. 4: (a) E-field for Antenna I (f_1=28 GHz), (b) E-field for Antenna II (f_2=39 GHz), (c) S-parameters for the cloaked coupled antennas, and (d) Total efficiencies.

III. Conclusion

In this paper, mantle cloaking is employed by using two engineered elliptical metasurfaces to reduce coupling between two microstrip monopole antennas placed in close proximity of each other. The presented simulation results substantiate the fact that the cloaks do not alter the radiation properties of the antenna they encase, instead the decoupling effects are noticed at the frequency of the other antenna placed in its vicinity. This design confirms that the properties of the antenna elements are restored by virtue of metasurface cloaks in a manner that they ostensibly radiate independently of each other.

References

[1] P. Y. Chen and A. Alù, “Mantle cloaking using thin patterned metasurfaces,” *Phys. Rev. B.*, vol. 84, p. 205110, 2011.

[2] Y. R. Padooru, A. B. Yakovlev, P.-Y. Chen, and A. Alù, “Analytical modeling of conformal mantle cloaks for cylindrical objects using subwavelength printed and slotted arrays,” *J. of Appl. Phys.*, vol. 112, no. 3, p. 034907, 2012.

[3] A. Monti, J. Soric, A. Alù, F. Billoti, A. Toscano and L. Vegni “Overcoming mutual blockage between neighboring dipole antennas using a low profile patterned metasurface,” *IEEE Antennas Wireless Propag. Lett.*, vol. 11, p. 1414–1417, 2012.

[4] H. M. Bernety and A. B. Yakovlev, “Reduction of mutual coupling between neighboring strip dipole antennas using confocal elliptical metasurface cloaks”, *IEEE Trans. Antenna Propag.*, vol. 63, no. 4, pp. 1554–1563, August, 2015.

[5] H. M. Bernety and A. B. Yakovlev, “Decoupling antennas in printed technology using elliptical metasurface cloaks”, *J. of Appl. Phys.*, vol. 119, no. 1, p. 014904, 2016.

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