Investigating Electromagnetic Power Transfer Ratio of Circular Polarizing Planar Metasurface Lens

ChangHyeong Lee*, DaJung Han*, Muhamad Kamran Khattak*, Sungtek Kahng*

ABSTRACT

We designed an antenna structure with the circular polarization metamaterial superstrate which increases the directivity of the primary antenna as a lens. The metamaterial superstrate removes the necessity of the array antenna and complicated feed. Plus, it provides the Fabry-perot cavity with the circular polarization. With regard to the primary antenna, a CRLH antenna is adopted to have the size-reduction from the conventional half-wavelength patch antenna

Key Words : Metamaterial; EM Power Transfer; Circular Polarization Gain Increase.

Ⅰ. Introduction

There are a number of ways to avoid the densely populated feed for the conventional array antenna, and the superstrate covers one patch antenna to increase the radiation aperture and directivity[2-4]. The planar electromagnetic band-gap (EBG) antenna is realized with periodically stacked dielectric slabs[2]. Fabry-Perot cavity antenna is applied to the Ku-band[3]. Not only a superstrate but also a substrate is used to maximize the directivity, but the volume of the entire geometry tends to be bigger[4].

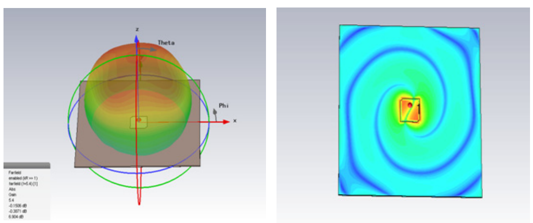
In this paper, the energy focusing superstrate is designed to increase the directivity and create the circular polarization when the linear polarized field from the primary antenna passes the metamaterial superstrate, compared to other antennas in the same category. Furthermore, the primary antenna is a CRLH antenna which shows the -1st resonance mode(LH), and the zeroth order resonance(ZOR) along with the positive resonance modes(RH). By combining the metamaterial primary antenna with the lens-like superstrate, the directivity and antenna gain are increased and the linear polarization from the bottom changes to the circular polarization at the top and the far-field.

Ⅱ. priamary radiator and metasurface lens

1.Primary radiator

First, an LHCP radiator is designed in the form of a microstrip patch. This will be employed as the primary source for the complete antenna structure. It will be shown that this EM-wave exciter should have a circular polarization and the consequent polarization of the metasurface has to coincide with that from the primary source.

Fig. 1(a) presents the far-field pattern of the patch antenna as well as the rotating electric field over the radiator. In Fig. 1(b), the return loss indicates the impedance match with the resonance frequency at the 5 GHz-WLAN service region. At this frequency, the axial ratio for the desirable CP function is observed along the elevation angle axis.



(a) (b)

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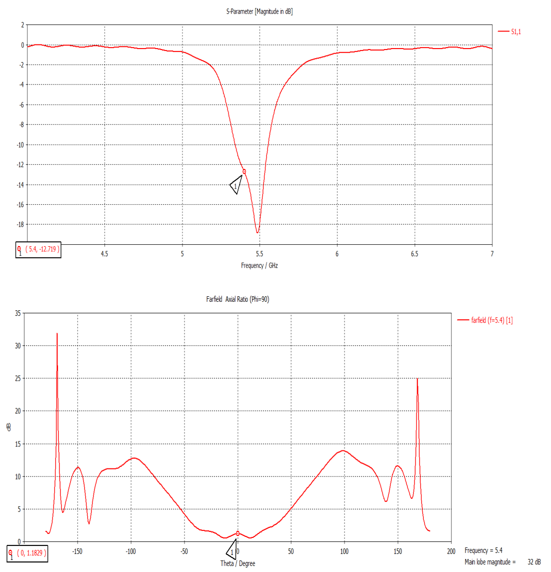
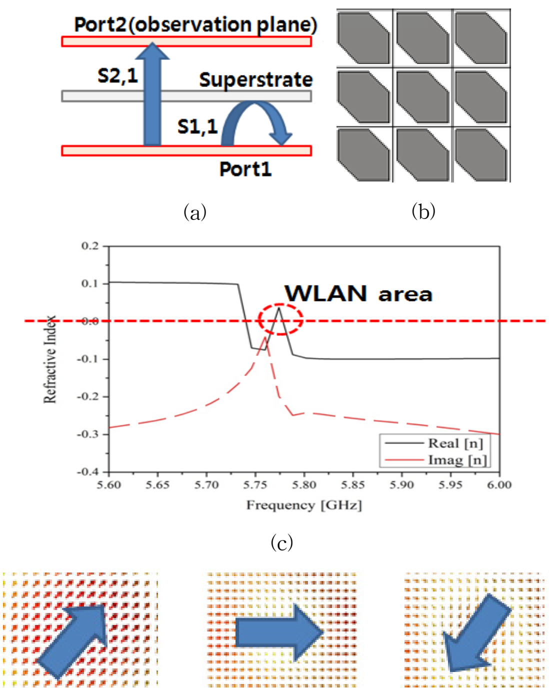


(c)

Fig. 1. Primary source (a) Field pattern (b) Return loss (c) Axial ratio

1.2 Metasurface lens and fed by the primary source

In order to bring an improvement to the gain of the single patch, a metamaterial superstrate can be thought of. Particularly, the superstrate is required to have zero or negative refractive index to work as a lens



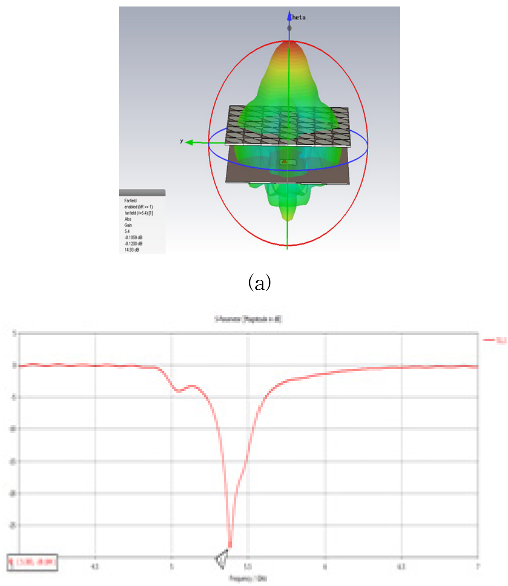
(a) (b)

(c)

(d)

Fig. 2. Metasurface design (a) Top-view of the periodic geometry (b) Side-view of the plane-wave test setup (c) Refractive index (d) Checking the CP

Fig. 2(a) is the proposed metasurface. This is inserted in the plane-wave test configuration as in Fig. 2(b). S-parameters from the plane-wave test are converted to the refractive index as in Fig. 2(c) where zero and negative values appear and judge to create higher directivity. Fig. 2(d) tells the linearly polarized plane-wave is converted to the CP as desired. Now, the metasurface lens combined with the primary source



(a)

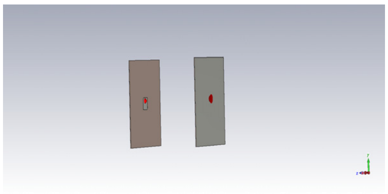
(b)

Fig. 3. Metasurface lens combined antenna (a) Bird's eye-view of the full geometry (b) Return loss

Fig. 3(a) presents the complete structure made up of the primary source and the metasurface is the proposed metasurface. As checked, the gain reaches 14 dBi resulting in an improvement of over 8 dB from the single patch. This is also based on the unchanged impedance match as given in Fig. 3(b). As temporary conclusion, the proposed structure plays a role of a lens as a planar geometry in enhancing the gain

Ⅲ. checking the EM power coupling by this antenna

In this section, we investigate how the proposed antenna can introduce positive effects to the EM power transfer between the TX and RX agents in a radio system placed in the near and intermediate regions.



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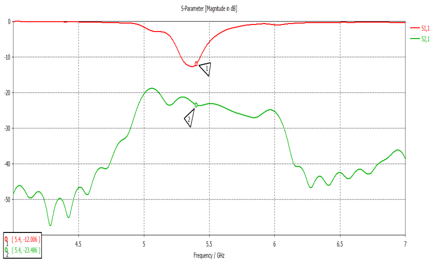

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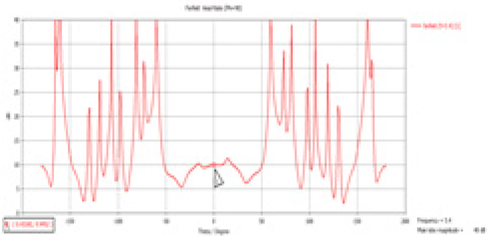
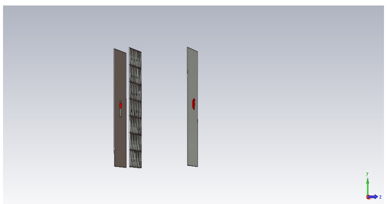


(c)

Fig. 4. 1 CP TX and 1 CP RX without the metasurface (a) Configuration (b) Transfer coeffient and return loss (c) Axial ratio

Firstly, a single CP radiator and another CP radiator become the TX and RX agents in an intermediate region another than the far-field zone as seen in Fig. 4(a). The level of the power transfer from the TX to the RX is around -25 dB in Fig. 4(b). The axial ratio is degraded from the case of an isolated antenna, since the near-field EM interaction is relatively active. Secondly, we add the metasurface to only the TX to improve the performance.



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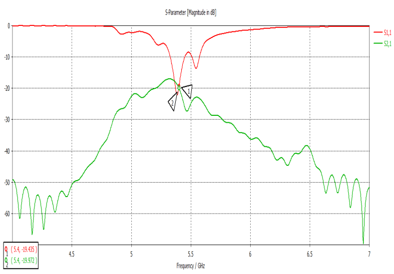

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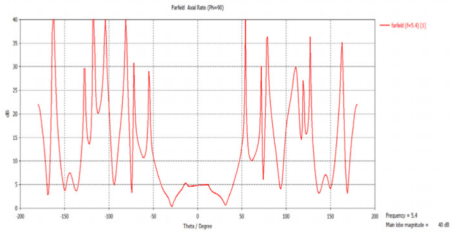
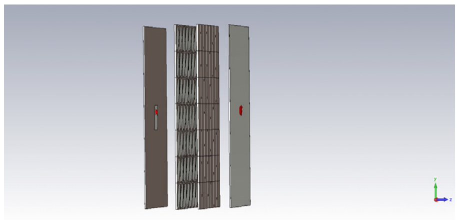


(c)

Fig. 5. 1 CP TX with the metasurface and 1 CP RX without the metasurface (a) Configuration (b) Transfer coeffient and return loss (c) Axial ratio

The suggested metasurface is placed in front of the TX, but The RX has no supporting structure as shown in Fig. 5(a). More wireless power is transferred by around 6 dB in Fig. 5(b). The axial ratio becomes better than before.



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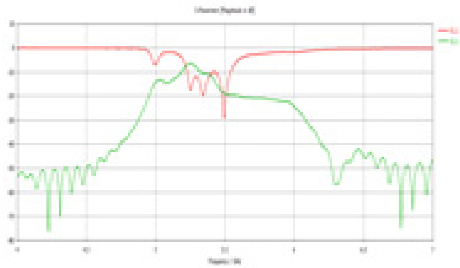

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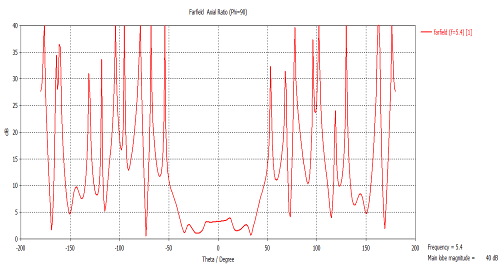

(c)

Fig. 6. Both the TX and RX with the merasurfaces (a) Configuration (b) Transfer coeefient and return loss (c) Axial ratio

Finally, the metasurfaces are given to both the TX and RX antennas as in Fig. 6(a). Fig. 6(b) shows the wireless power transfer is improved by 15 dB compared to the first case due to the function of the planar lens. This also helps the axial ratio of the system to meet the CP condition.

Ⅳ. conclusion

A CRLH antenna with the circular polarized metamaterial superstrate is presented. The superstrate behaves like a lens to the primary antenna increasing not only the directivity and gain of the antenna but also introduces circular-polarization to the linearly polarized field originating from the primary antenna. The superstrate also improves the gain of the wireless power system.

Ⅴ. Acknowledgment

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