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Gain Enhancement of a Base Station Antenna with Transmitting Metasurfaces

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***Abstract*—A gain enhanced base station antenna element with transmitting metasurfaces is proposed in the paper. Based on the conventional dipole patch antenna, the 2-layer metasurfaces with cross bow-tie are introduced for gain improvement, and also satisfy the boundary limitation of the original antenna. The magnitude and phase of the E-fields at the radiating aperture are more uniform by tuning the geometry of the unit cell of the metasurfaces, and hence higher gain is realized. The simulation shows that the metasurfaces effectively improve the gain by more than 1 dB within 5150~5850 MHz, and the radiation patterns of the proposed antenna remain stable.**

***Index Terms*—Base station antenna, gain enhancement, metasurfaces.**

I. Introduction

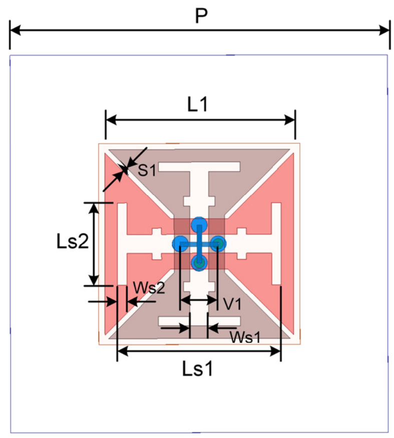
Dual-polarized patch dipole antennas have been widely applied in modern mobile communication systems, including the emerging 5G system, owing to the robust communication performance under complicated propagation environment in the urban area. Furthermore, dual-polarization provides individual transmission channels with almost the same space occupation, which is beneficial for MIMO processing. By modifying the radiating geometry and the feeding structure, several dual-polarized dipole antennas with good features have been proposed, such as the antenna with wideband and high port isolation [1, 2], stable radiation patterns [3], and independently controllable modes [4].

For a base station, the gain of the antenna is a key index that profoundly influences the communication quality. Higher gain is always desired with assigned space limitation. In [5] a shorting pin is introduced in the magneto-electric dual-loop antenna for higher gain, which is difficult to apply in dual-polarized antenna. Consisting of periodic structures, metasurfaces have been widely used for high gain beam-focusing [6, 7]. Considering the metasurfaces are able to enhance the gain for the radiating element, they are potential to apply in the base station antenna for higher gain, provided the introduced surfaces satisfy the practical space constraint of the base station.

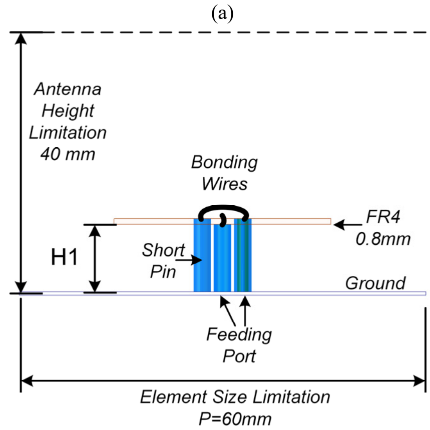
In this paper we will propose the transmitting metasurfaces to improve the gain of the original base station dipole antenna. Sharing the same transverse area, the metasurfaces are well integrate into the original antenna. The effect of the metasurfaces is discussed, and the simulated performances of the original and proposed antennas are depicted for comparison.

II. Original planar dipole antenna

A typical planar dipole base station antenna developed from [1] is discussed in this section, of which the geometry is depicted in Fig. 1. The dipole is fed by two 50Ω coaxial cables in the numerical simulation. The antenna works in 5150~5850 MHz, which covers the frequency band of IEEE 802.11a. Note that The antenna design is limited within the area of 60*60 mm^2 due to the assembly requirement, and the height needs to be lower than 40 mm as well.



(a)



(b)

Fig. 1 Geometry of the planar dipole antenna. (a) Top view, (b) left view. L1 = 31, S1 = 0.5, V1 = 6, Ls1 = 28, Ls2 = 13, Ws1 = 3, Ws2 = 1.5, H1 = 12, P = 60. All dimensions are in millimeters.

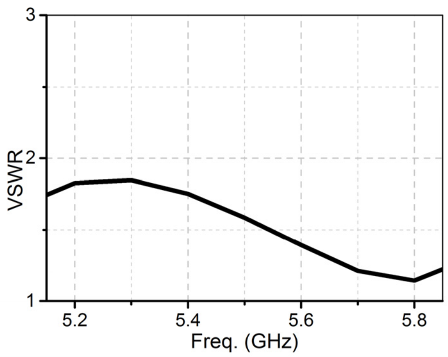


Fig. 2 Simulated standing wave ratio (VSWR) of the dipole antenna.

Two bow-tie patches with a H-shaped slot are printed on the bottom and the top faces of the radiating substrate, respectively. The outer conductor of each feeding cable is soldered at the middle of the bow-tie, while the inner conductor is connected to the short pin on the opposite side by a bonding jumper wire. The parameters of the bow-tie patch are tuned for impedance matching. The simulated VSWR (standing wave ratio) of the antenna stays below 2.0 within the designated band, as depicted in Fig. 2.

III. Gain-Enhanced Antenna with Metasurfaces

Transmitting metasurfaces is introduced for gain enhancement of the original base station antenna, which is composed of 2-layer substrates and printed circuits, as depicted in Fig. 4 (a). The two layers are with a layer spacing of *H3*, which is slightly lower than a quarter wavelength, while the bottom layer is above the original patch with a distance of *H2*. Each layer has the same geometry and consists of a cross bow-tie, of which the top view is shown in Fig. 3. Note that the two patches are placed back-to-back to increase the distance in between, in order to exploit the limited space. Different from other reported metasurfaces, the proposed one should satisfy the boundary limit of the base station antenna. The periodicity *Pm* is selected to be 20 mm, 1/3 length of size limit of the antenna element, which allows 8 unit cells to surround the original patch in the upper space, as shown in Fig. 4 (b).

The working mechanism of the metasurfaces can be explained by Fig. 5. Consider the aperture that 30 mm above the original patch dipole as the radiating aperture, where the E-fields at the edge are with about 60-degree phase delay than the fields at the middle as shown in Fig. 5 (a). This is a result of the spherical wave propagation in the free space. Utilizing the beam focusing concept of transmitarrays [7], the gain increases if the fields at the radiating aperture are uniform in magnitude and phase. And the 8 surrounding unit cell are possible to compensate the original phase delay at the edge.

The parameters of the unit cell are optimized for gain improvement, in which the bow-tie is tuned to be near but not at the resonance. Uniform radiating field is achieved when the unit cell is appropriately selected as given in Fig. 5 (a), and therefore gain enhancement is realized.

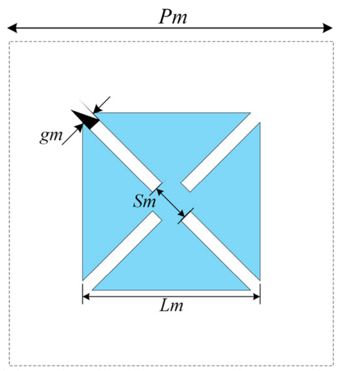
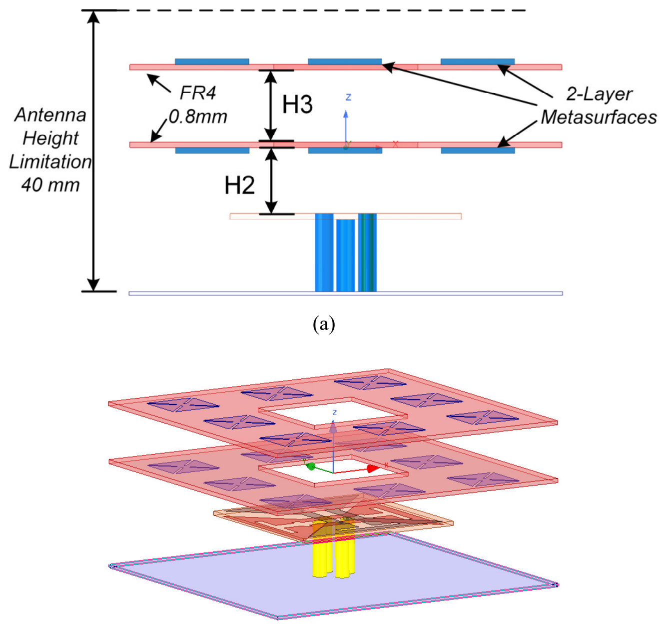


Fig. 3 Top view of the unit cell of the proposed metasurfaces. Pm = 20, Lm = 10, gm =1, Sm = 3. All dimensions are in millimeters.



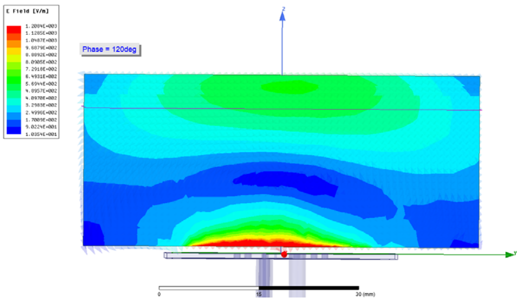
(a)

(b)

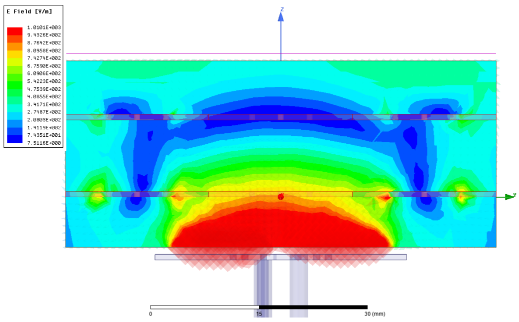
Fig. 4 Geometry of the proposed antenna with metasurfaces. (a) Profile view, (b) perspective view. H2 =8, H3 = 10. All dimensions are in millimeters.

The radiation patterns of the original and the proposed antenna are compared in Fig. 6. It is observed that the patterns are similar to each other in spite of some minor differences, which indicates that the metasurfaces do not degrade the side lobe performance. Fig. 7 shows the simulated gain response with and without the metasurfaces. The original antenna is with the gain of 11.1 dB in average, while the proposed one has the average gain of 12.2 dB. Comparing the curves it is validated that the proposed antenna with transmitting metasurfaces enhanced the gain by about 1.1 dB.

Two 2×2 antenna arrays based on the original and proposed antenna are designed and fabricated, respectively. The measured results of the samples will be further presented in the conference.



(a)



(b)

Fig. 5 Simulated E-field distribution of (a) the original dipole antenna and (b) antenna with the proposed transmitting metasurfaces.

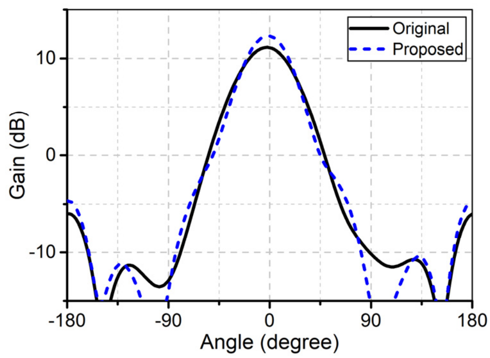


Fig. 6 Simulated radiation patterns of the original antenna and the proposed antenna.

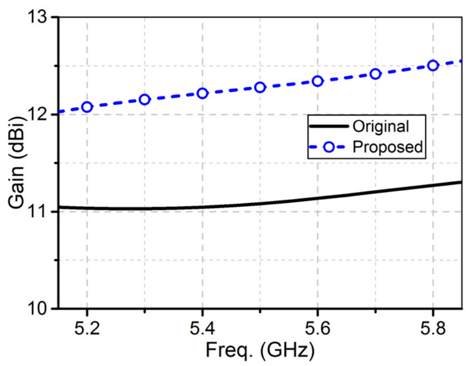


Fig. 7 Simulated gain vs. frequency of the original antenna and the proposed antenna.

IV. Conclusion

This paper proposes a gain enhanced base station antenna element with transmitting metasurfaces. An original dipole patch antenna working at 5150~5850 MHz is first simulated and discussed. In order to improve the gain under the assigned boundary limitation, the 2-layer metasurfaces with cross bow-tie are introduced. The E-fields of both antennas are depicted to explain the gain enhancement by the metasurfaces. By tuning the geometry of the unit cell, the metasurfaces effectively improve the simulated gain by about 1.1 dB. The proposed antenna is potential to apply in the base station array that requires strict space limitation.

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