Low-Profile Dual-Band Antenna based on Meta-Surfaces

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Abstract

A prototype for a dual-band metamaterial-inspired antenna is presented. The antenna consists of a dual-band dipole placed between two meta-surfaces, which are tuned to operate at both dipole bands. In this way, the dipole radiates at a different half-space at each frequency band. Antenna gains as high as 6.1dB and 7.6dB have been measured at the low- and high-frequency bands, respectively, while keeping a low-profile of 0.152λ at the lowest resonant frequency.

1. Introduction

One of the most successful applications of the metamaterial paradigm has been the use of meta-surfaces for enhancing the radiation properties of planar antennas [1]. In particular, meta-surfaces based on grid of cut and continuous wires [2] have been successfully employed to enhance the radiation properties of dipoles antennas [3]. Essentially, the operating principles consist of confining the near-field produced by the primary source on the meta-surface area. In this way, the area with uniform illumination is augmented, thus obtaining a higher gain while keeping excellent aperture efficiency. The radiation mechanism is based on strong magnetic dipole moments excited in the meta-surface. Furthermore, as the meta-surface is placed very close to the antenna, profiles as low as 0.1λ~0.15λ can be obtained. Moreover, since the near field is inherently confined in the meta-surface, these structures have also been applied to reduce the mutual coupling in antenna arrays [4].

In this contribution, the same meta-surface is employed to design a dual-band antenna which radiates at a different half-space at each frequency band. Basically, a dual-frequency dipole is placed between two meta-surfaces tuned to both dipole frequency bands. In this way, each meta-surface acts as a superstrate at one frequency band and as a reflecting plane at the other frequency band, enhancing the dipole antenna gain, and switching the direction of radiation at each frequency band.

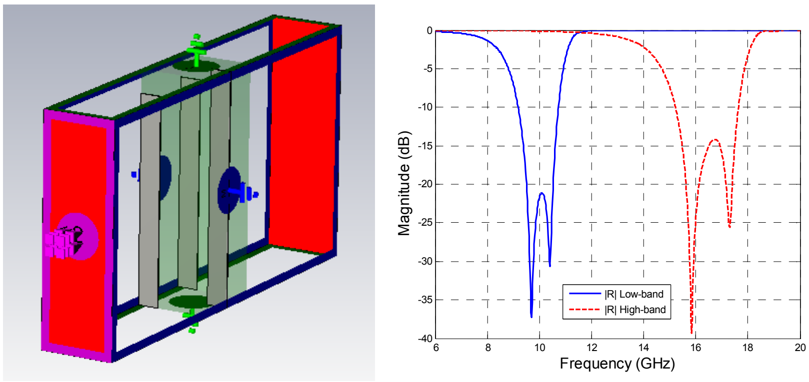
2. Antenna Prototype

In the first place, two meta-surfaces have been conveniently scaled to operate at the low- and high-frequency bands. Fig. 1 shows the simulated reflection coefficients for both meta-surfaces, which have been analyzed by using CST commercial software. The unit cell model is also represented in Fig. 1 for the sake of clarity. As shown, the meta-surface are characterized by a pass-band which corresponds with frequencies where the currents in the grids of wires are oscillating out of phase creating strong magnetic dipole moments.

A dual-band dipole has been designed in order to feed both meta-surfaces. The top and back views of the fabricated antenna are represented in Fig. 2. Essentially, the dipole consist of a outer envelop acting as a low-frequency dipole and a inner high-frequency dipole [5]. The measured antenna return loss is represented in Fig. 2. As shown, the dipole is well-matched at both frequency bands and three different resonant frequencies can be identified. One resonant frequency is located in the low-frequency band, which corresponds with currents oscillating along the outer envelop in a dipole-like fashion. Conversely, two resonant frequencies are obtained at the high-frequency band: the first one corre-

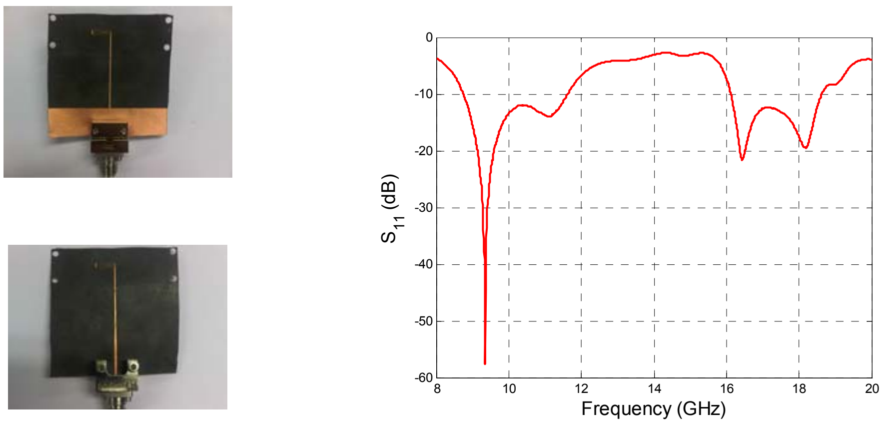
ISBN 978-952-67611-0-7

sponding with currents oscillating along the inner dipole, and the second one with currents oscillating around the outer envelop as in a loop antenna.



(a) (b)

Fig. 1. (a) Unit cell CST model. (b) Simulated reflection coefficients for the low-band and high-frequency band meta-surfaces.



(a) (b)

Fig. 2. (a) Top and back views of the dual-band dipole. (b) Measured antenna return loss.

This dual-frequency dipole has been placed between the two scaled meta-surfaces. An extensive parameter studio, not reported here for the sake of brevity, has been carried out in order to determine the optimal separation between the meta-surfaces and the antenna in order to obtain a good impedance matching while keeping a low profile. In the same way, the number of unit cells per meta-surface has also been optimized to obtain an enhanced gain while keeping good aperture efficiency.

The top and back views of the resulting prototype are depicted in Fig. 3. A meta-surface of 3x3 unit-cells has been employed in the low-frequency band, while a meta-surface of 5x5 unit cells has been employed for the high-frequency band. The total antenna thickness is of 0.152λ at the low resonant frequency. The frequency-domain behavior of the antenna return losses, gain at boresight and gain in the backward direction for both the low- and high-frequency bands are represented in Fig. 4. As shown, the antenna features a good impedance matching at both frequency bands. Furthermore, while the radiation is concentrated at boresight for the low frequency band, the energy is radiated in the opposite direction for the high-frequency band. In particular, the gain of the antenna dipole has been increased up to 6.1dB at the low frequency band, and two peaks of 7.6dB and 6.8dB gain appear at the high-frequency band. Moreover, front-to-back radiation ratio as high as 7.5dB and 12.5dB are obtained at the low- and high-frequency bands, respectively.

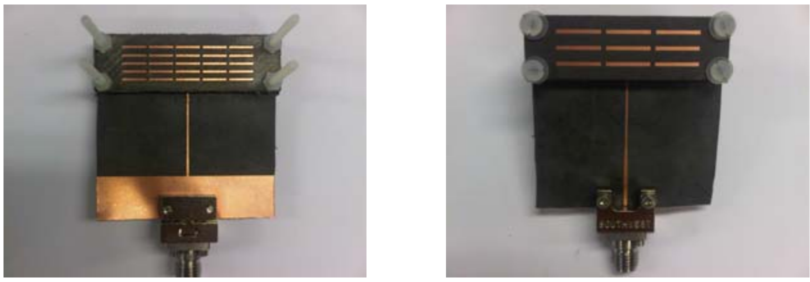
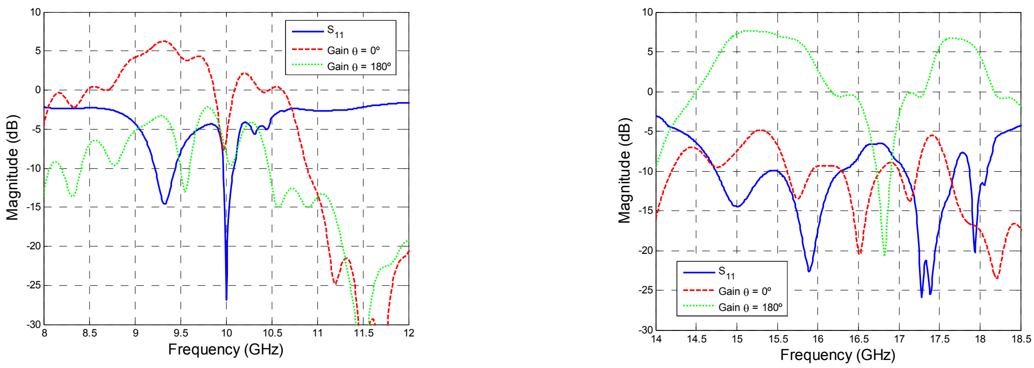


Fig. 3. Top and back views of the dual-band dipole with meta-surfaces.



(a) (b)

Fig. 4. Measured antenna performance in the (a) low and (b) high frequency bands.

4. Conclusion

A prototype for a dual-band metamaterial-inspired antenna has been presented. The designed antenna radiates at a different half-space at each frequency band. The radiation properties of the primary source have been enhanced measuring gains as high as 6.1dB and 7.6dB-6.8dB at the low- and high-frequency bands. Moreover, the antenna keeps a profile as low as 0.152λ and a good 50Ω impedance matching.

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