

Metamaterial Spiral-shaped Antenna

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A conventional spiral antenna (H. Nakano, K. Nogami, S. Arai, H. Mimaki, and J. Yamauchi, "A Spiral Antenna Backed by a Conducting Plane Reflector," *IEEE Antennas Propag.*, vol. 34, no.6, June 1986) has a current with a positive propagation phase constant ($\beta > 0$) and is called a natural spiral antenna. The natural spiral antenna does not produce a circularly polarized (CP) wave when the antenna height (i.e., the distance from the conducting ground plane to the spiral arms) is less than 0.1λ with λ being the free space wavelength at the operating frequency. On the other hand, a different spiral antenna that has a current with a negative propagation phase constant ($\beta < 0$) radiates a single CP beam in the broadside direction, even when the antenna height is extremely small, e.g., on the order of 0.03λ . Such a spiral antenna is called a *metamaterial (MTM) spiral antenna* (H. Nakano, J. Miyake, M. Oyama, and J. Yamauchi, "Metamaterial Spiral Antenna," *IEEE Antennas Wireless Propag. Lett.*, vol. 10, 2011). This paper presents CP multibeam radiation from an antenna composed of low-profile MTM spiral-shaped arms. Multibeam radiation increases the communication capabilities of the antenna and broadens its fields of application.

Fig. 1(a) shows an MTM antenna made of a single curved arm printed on a dielectric substrate. The antenna is made of numerous N-type meta-atoms (H. Nakano, T. Abe, and J. Yamauchi, "Planar Reconfigurable Antennas Using Circularly Polarized Metalines," *IEEE Antennas Wireless Propag. Lett.*, vol. 18, May 2019). The length and thickness of the meta-atom are 0.08λ and 0.026λ , respectively, at design frequency f_{DSN} , which is selected to be lower than the meta-atom transition frequency, f_0 , i.e., $f_{\text{DSN}} < f_0$. The antenna is excited from point F. Point T is the arm end, which is connected to the ground plane (below the dielectric substrate) through Bloch impedance Z_{Bloch} . Fig. 1(b) shows the 3-D radiation beam at frequency f_{DSN} .

Based on the abovementioned results, we array four MTM curved antennas to construct an MTM spiral-shaped antenna, as shown in Fig. 2(a), where one of F_i ($i = 1, 2, 3, 4$) is used as the feed point. T_i ($i = 1, 2, 3, 4$) are the arm ends. Fig. 2(b) shows the principal left-handed CP radiation field component, E_L , when each feed point is excited in turn. It is found that four beams are created, where each E_L has a half-power beamwidth of approximately 130 degrees. Further analysis reveals that the gain is approximately 4 dBi, and scattering parameter S_{ii} is small, as desired: less than -20 dB.

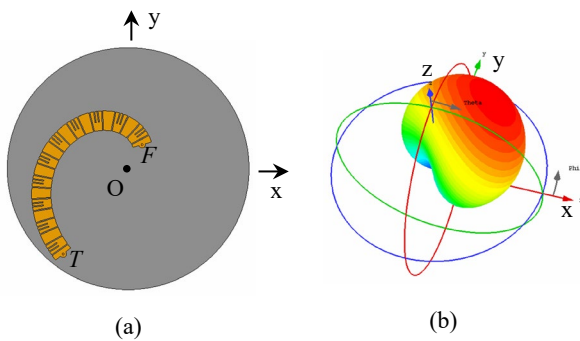


Figure 1. MTM curved arm

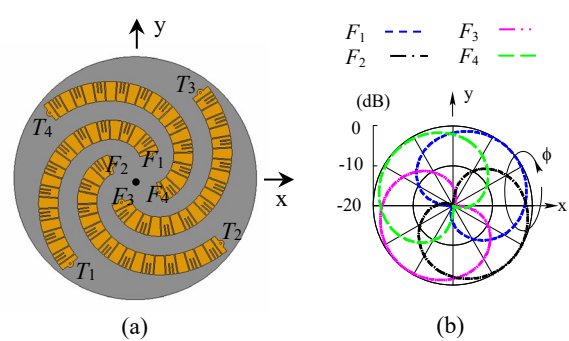


Figure 2. MTM spiral-shaped antenna