

# Planar circular loop antennas with self-biased magnetic film loading

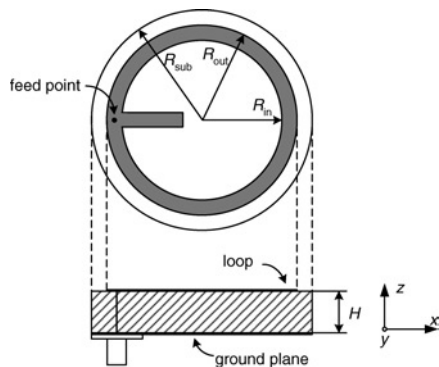
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A circular loop antenna with self-biased magnetic film loading at 1.7 GHz is presented. The proposed circular loop antenna is realised by cascading a microstrip loop and a tuning stub. Self-biased NiCo-ferrite magnetic films were used to tune the working frequency of the loop antenna. Three different cases of antennas with films loading were designed and analysed. Antennas with self-biased magnetic films loading working at 1.7 GHz with a tuning range of 50–400% of the antenna bandwidth were achieved.

**Introduction:** In modern wireless communication systems, the need for antennas with small size, low profile, light weight and easy fabrication has been continuously growing [1]. Circular loop antennas have been of great interest to many researchers and engineers in recent years [2–6] because circular loop antennas have much smaller circumference compared with those circular patch antennas. Also they can radiate either a linearly polarised wave in the far-field zone or a circularly polarised wave by disturbing the symmetry of the loop. The substrates of planar antennas play a very important role in antenna miniaturisation. In particular, antenna substrates with larger relative permeability can lead to antenna miniaturisation, enhanced bandwidth, tunable centre frequency, polarisation diversity, and beam steering [7–8].

To be practically feasible in miniature antenna applications, such as handheld wireless communication devices, where battery power and space for electronics are at a premium, it is important for antenna substrates to comprise of self-biased magnetic materials, in which no external bias magnetic field is needed. Magnetic thin films provide a unique opportunity for achieving self-biased magnetic patch antenna substrates with  $\mu_r > 1$  at  $> 1$  GHz frequencies. The strong demagnetisation field for magnetic thin films,  $H_{\text{demag}} = 4\pi M_s$ , allows for a self-biased magnetisation with high ferromagnetic resonance (FMR) frequencies (up to several GHz), which are essential for microwave devices.

In this Letter, we present circular loop antennas with NiCo-ferrite self-biased magnetic films loaded on the top of the antenna, under the ground plane and both on the top and under the ground plane. The fabricated antennas with self-biased magnetic films showed a large radiation frequency tunability of about 50–400% of the –10 dB bandwidth. These magnetic antennas can be made conformably at a low cost near room temperature.



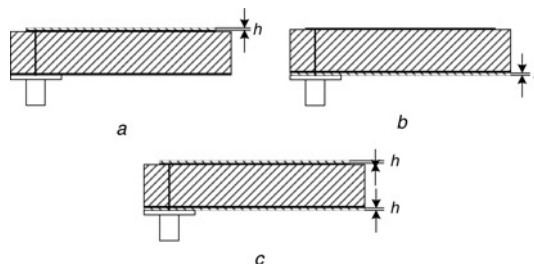
**Fig. 1** Geometry of proposed circular loop antenna

$R_{\text{sub}} = 14$  mm,  $R_{\text{out}} = 12.4$  mm,  $R_{\text{in}} = 11.4$  mm,  $L = 6.22$  mm,  $H = 1.27$  mm

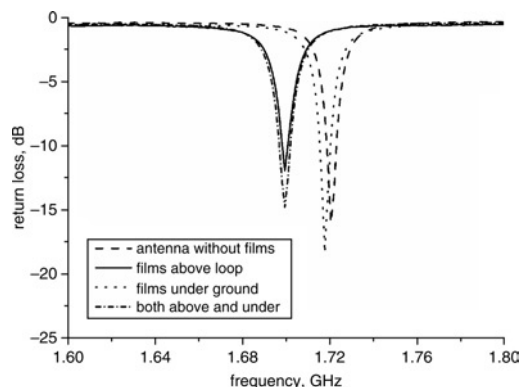
**Antenna configuration:** Fig. 1 shows the schematic top view and side view of the circular loop antenna. This antenna consists of a microstrip loop and a tuning stub. Both the microstrip loop and the tuning stub are realised by patterning copper cladding on the top surface of the dielectric substrate. The feed point is located on the junction of the tuning stub and the microstrip loop with a distance of 0.5 mm to the outer edge of the loop. The radius of the outer ring is 12.4 mm, and the inner ring is 11.4 mm, the length of the tuning stub is 6.22 mm with a width of 1 mm. We adopted Rogers RT/duroid 6010 as the substrate in both simulations and fabrications, which has a relative permittivity of 10.2 and thickness of 1.27 mm. The proposed circular loop antenna is

designed and simulated with the help of a High Frequency Structure Simulator (HFSS 10.0).

**Numerical and experimental results:** Three circular loop antennas with ferrite films were designed and fabricated as follows. First, a ferrite thin film of thickness 2  $\mu\text{m}$  was introduced just above the microstrip loop, as indicated in Fig. 2a. Second, a 2  $\mu\text{m}$ -thick ferrite film was added just under the ground plane, as shown in Fig. 2b. In this case, the ferrite film has the same size as the ground plane. Combining the above two cases, we also designed an antenna with two layers of ferrite film, in which one layer is just above the loop, and the other under the ground plane as shown in Fig. 2c. The measured return loss of four antennas is plotted in Fig. 3. The return loss curves in Fig. 3 were measured under the condition that all the geometrical dimensions of the antenna remained the same, only the ferrite films were added at different positions.



**Fig. 2** Circular loop antenna with a film above the loop (Fig. 2a); circular loop antenna with film under ground plane (Fig. 2b); films both above loop and under ground plane,  $h = 0.002$  mm (Fig. 2c)



**Fig. 3** Measured return loss against frequency for four different cases

From Fig. 3 we can see that the central resonant frequency of the non-magnetic antenna is about 1.72 GHz, and the –10 dB bandwidth is 5 MHz. When a ferrite film is added above the loop antenna, the resonant frequency shifts down to 1.70 GHz. This indicates a tuning range of 20 MHz relative to the non-magnetic antenna, or equivalent to approximately 400% of the bandwidth. When a ferrite film is added just under the ground plane, we observe that the resonant frequency is 1.717 GHz, a shift of about 50% of the antenna bandwidth relative to the non-magnetic circular loop antenna, and with a slightly enhanced  $S_{11}$  peak magnitude of –18.2 dB, indicating better impedance matching. When two ferrite films are added above the micro-strip loop and under the ground plane at the same time, this moves the resonant frequency further down to 1.70 GHz again with a  $S_{11}$  peak magnitude of –15 dB. Clearly, the antenna loaded with ferrite film can indeed miniaturise the geometrical dimensions effectively, as demonstrated by shifting down the resonance.

**Conclusions:** Four circular loop antennas with/without ferrite films were fabricated and analysed. The fabricated magnetic antennas with self-biased magnetic films can realise a tuning range of 50 to 400% of the antenna bandwidth, which shifts from 1.72 to 1.717 and 1.70 GHz, respectively, indicating that self-biased magnetic films do lead to minimised antennas by shifting down the resonance frequency.

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