Circular Loop Antenna Examples

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***Abstract*—Various examples of circular loop antennas are illustrated.**

I. Introduction

In the implementation of a circular loop antenna, the input impedance matching to 50Ω is a challenge for antenna designers; therefore, they overcome this issue by taking different approaches to the antenna design.

II. Loop Antenna Examples

A. Circular Loop Antenna with Balun Transformer and a Step Change in Loop Width:

The proposed antenna [1] has outer radius of 43mm and inner radius of 40mm having loop width of 3mm. C-shaped structure of circular loop antenna has step change to its outer radius of 45mm and inner radius of 33mm having loop width of 12mm from angle 100° to 260°. The Fig. 1 shows the proposed antenna.

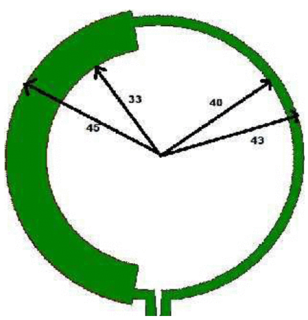

Fig. 1. The proposed antenna

The VSWR values in terms of frequency of the proposed antenna with the impedances of 50Ω, 80Ω, and 100Ω are shown in the Fig.2.

The impedance of 80Ω gives better results; therefore, a Balun is needed to ensure the unbalanced to balance transformation of the proposed antenna and to match the impedance. Balun transformer of 50Ω to 80Ω is used and merged with the proposed antenna at 80Ω and then balun transformer is fed with 50Ω. The VSWR of proposed antenna with balun transformer of 50Ω to 80Ω is shown in the Fig. 3.

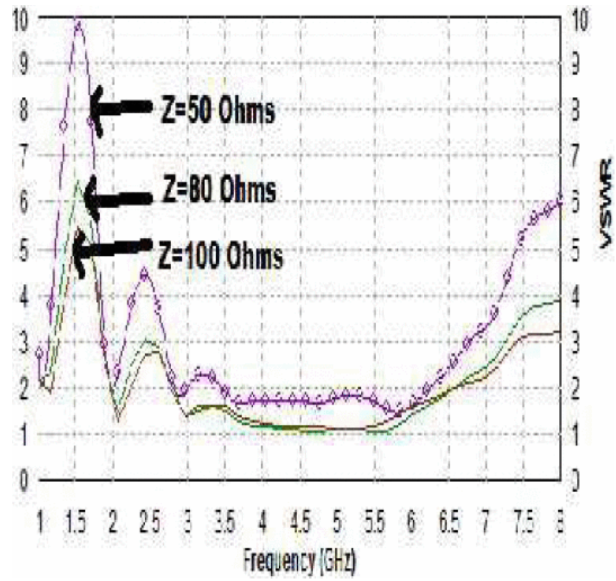

Fig. 2. The VSWR of proposed antenna at 50Ω, 80Ω, and 100Ω impedances

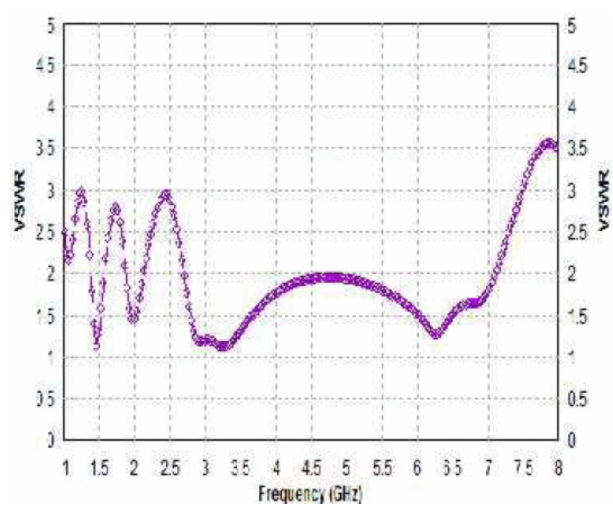

Fig. 3. The VSWR of proposed antenna with the balun transformer

A C-shape structure circular loop antenna was presented and demonstrated that by introducing C-shape to the left arm of the printed circular loop antenna and tapering to coupled transmission lines gives impedance bandwidth of 2.7 GHz. The proposed antenna is merged with Balun transformer50Ω to 80Ω having impedance bandwidth of 4.4 GHz which gives excellent performance and can be used for various application

B. Circular Loop Antenna with 8 Feed Points:

The proposed antenna [2] is composed of a conductor strip loop of inner radius $r = 19.09mm$ whose strip width is $w = 1.5mm$ and thickness of $h = 12mm$ which is shown in the Fig. 4.

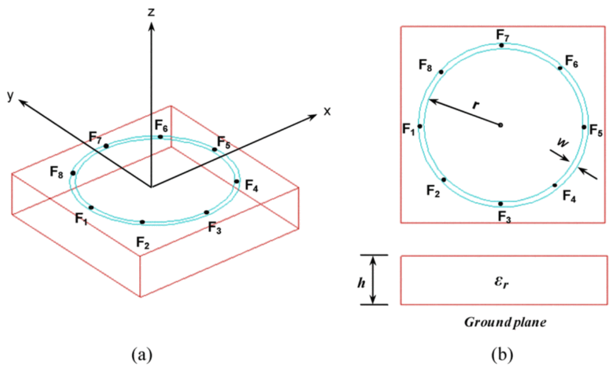

Fig. 4. Circular loop antenna with 8 feeds: (a) Perspective view and (b) Top and side view

The antenna is fed at 8 feeding points F_1, F_2, F_3, F_4,F_5, F_6, F_7, and F_8 which are placed symmetrically over the circular loop with an angular spacing of 45°. Due to the symmetrical shape of the antenna, except for the directions of the beam, the performance of antenna is the same for all the feed locations. Thus, only one feed configuration, F_1, is analyzed and all other configurations are assumed to yield the same results.

The antenna is analyzed for configuration F_1 and its return-loss for 50Ω input impedance is shown in Fig. 5. The antenna resonates at a frequency of $f_0 = 4.4GHz$. As shown in Fig. 5, antenna shows a -10 dB bandwidth of $550MHz$ range from $4.2GHz$ to $4.75GHz$.

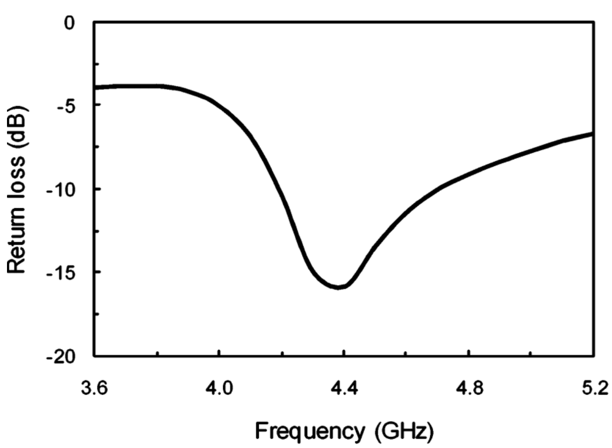

Fig. 5. Return Loss

C. Partitioned Circular Loop Antenna with Insertion of Five Capacitive Elements:

The loop of the proposed antenna [3] is partitioned into multiple segments and loaded with capacitive elements at selected locations so as to decrease phase variations in the current flow and thereby increase the radiation efficiency. A total of five capacitors are used to achieve stable current flow, resulting in phase variations of $< 12°$. A thin-wire circular loop antenna of radius $r = 7.0mm$, circumference $C \approx 44.0mm$ $(0.85\lambda_0)$ and wire segments of radius $a = 0.5mm$ was designed for operation at 5.8 GHz. A total of 24 nodes deforming 24 wire segments comprise the antenna geometry, as shown in Fig. 6.

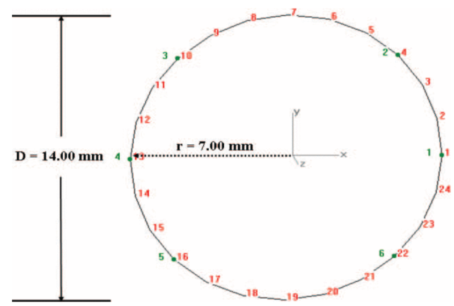

Fig. 6. Thin wire model of partitioned circular loop antenna with wire nodes (red) and lumped series ports (green) indicated

Five capacitive elements were inserted at the following node locations to cancel out the net inductance of the wire loop: 0.086 pF (nodes 4 and 22), 0.042 pF (nodes 10 and 16), and 0.047 pF (node 13). The antenna was simulated in transmission mode in free space from 1 to 10 GHz, resulting in an input impedance of $49.3 - j0.05\Omega$, a corresponding input admittance of $20.3 + j0.02mS$, and a return loss of 43.4 dB at 5.8 GHz, as shown in Fig. 7.

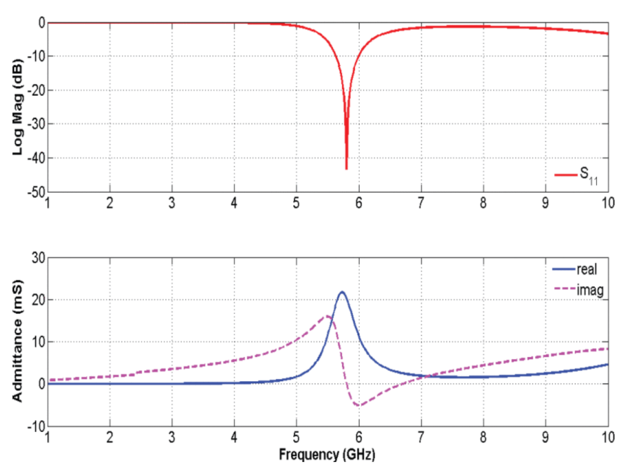

Fig. 7. Simulated return loss and input admittance for the thin wire partitioned circular loop antenna (5.8 GHz)

The simulated current magnitude and phase on the thin wire loop antenna, with and without lumped capacitors, are plotted in Fig. 8. The total phase shift with capacitive loading is on the order of 12°, which indicates good stability of the current phase over the entire length of the loop.

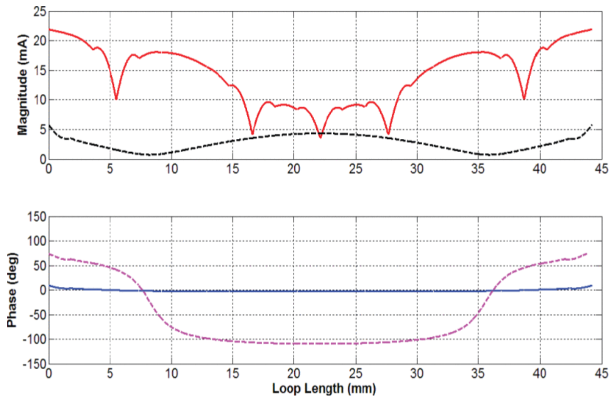

Fig. 8. Simulated current magnitude and phase on thin wire circular loop antenna with (solid) and without (dashed) lumped capacitors (5.8 GHz)

D. Bi-circular Loop Antenna with Plane Reflector:

The design of the proposed bi-circular loop antenna which combines with the plane reflector [4] uses two layers of substrate with length W (86.11 mm) and width H (66.98 mm) and there is a gap d between two substrates. At the first layer, consisting of the front side and back side, there is double half-loop copper strip-line with radius R. The two double half-loops are connected with a link, with radius r, becomes the double full loop. The front side double half-loop and the back side double half-loop have different polarization. The copper patch width w is 2.00 mm and 0.03 mm thickness. On the other hand, the second layer consists of copper patches on the entire surface. The geometry of the antenna is shown in the Fig. 9.

Coaxial feed line structure contains a copper core with a radius value a1is 0.63 mm, the value of a2 is 2.11 mm and the outer copper thickness is 0.66 mm, thus the value of a3 is 2.77 mm.
At the 2.45 GHz frequency ($\lambda_0 = 122.36mm$) and dielectric constant of Teflon, for phase matching, the length l of the coaxial feed line can be determined by following equation

$$l = \frac{1}{2}\lambda_g = \frac{\lambda_0}{2\sqrt{\epsilon_r}}$$

From the equation, the value of l is $42.21mm$.

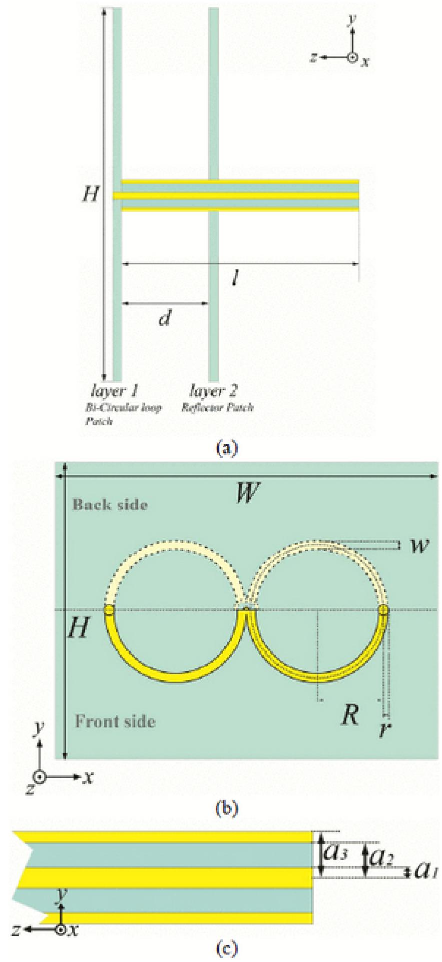

Fig. 9. Design of bi-circular loop antenna with plane reflector and coaxial feed line, (a) side view, (b) front view of layer 1 substrate, and (c) side view of coaxial feed line

At the best parameters result, the return loss graph is shown in the Fig. 10.

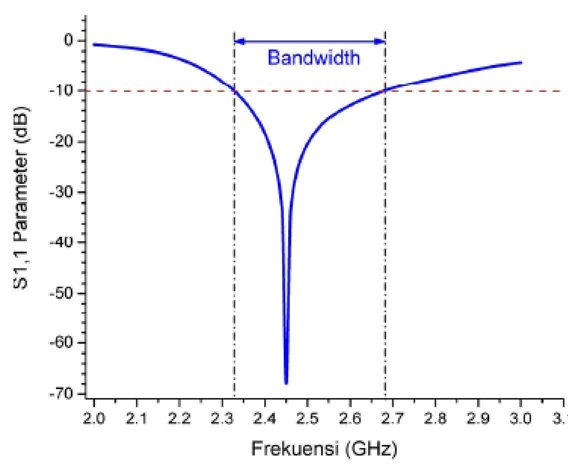

Fig. 10. The relation between frequency and $S_{1,1}$ -parameters on the best parameters result

E. Loop Antennas with a Parasitic Element and Broad-band Balun:

The proposed antenna [5] consists of two concentric coplanar wire loops (Loop 1 and Loop 2) placed above a ground plane at a height h. Loop 1 (the larger one), fed at $\phi = 0$ by a voltage source V_0(=1 volt), acts as a primary element, while Loop 2 (the smaller one) serves as a parasitic element. The size (or the radius r1) of Loop 1 is determined by the lower limit of an operating frequency band (its circumference is slightly longer than one wavelength at the lower frequency). By adjusting the size (or the radius r2) of Loop 2, the positions (at $\phi = \phi_1$ for Gap 1 and $\phi = \phi_2$ for Gap 2) of two gaps, and the height h, an optimal performance for the on axis (in the z direction) axial ratio can be achieved. The geometry of the antenna is shown in the Fig. 11.

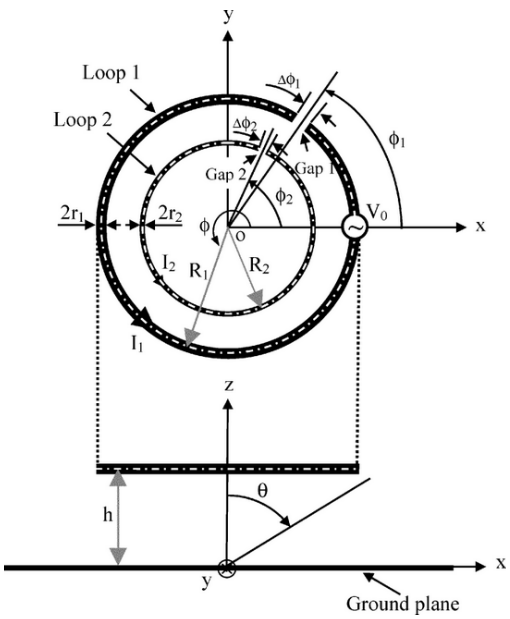

Fig. 11. Geometry of a circular-loop antenna with a parasitic circular loop

The frequency characteristics of the input impedance and gain are presented in Fig. 12. So, it can be seen that the input impedance is around $125 - j50\Omega$.

The further analysis is done only for the series- and parallel-fed dual rhombic loop antennas with a parasitic element. As expected, the parallel feed has a lower input resistance (about 50Ω) than that of the series feed ($< 100\Omega$). It is also observed that the series feed corresponds to a higher gain (about 10–11 dBi) than does the parallel feed. Therefore, the series feed is suitable for the applications in which the gain is most important while the parallel feed can find applications where the purity of polarization is the first priority. In the implementation, the support of a broad-band balun is considered. So, Fig. 13 presents the simulated and measured results for VSWR of the broad-band balun fed dual rhombic-loop antenna.

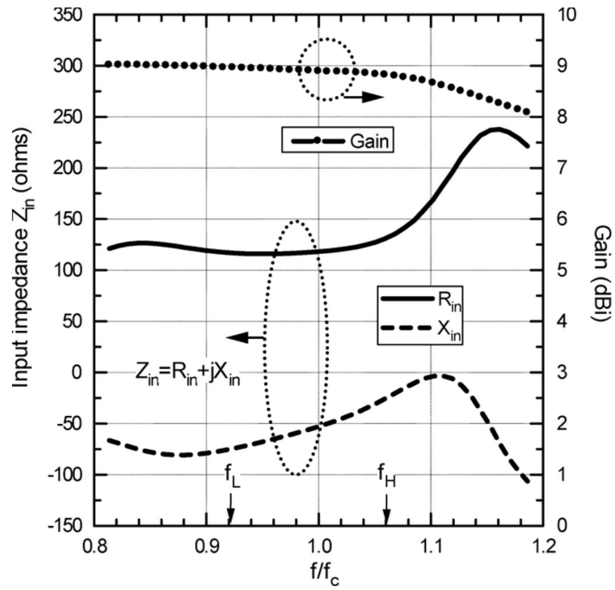

Fig. 12. Input impedance and gain of the circular-loop antenna with a parasitic element

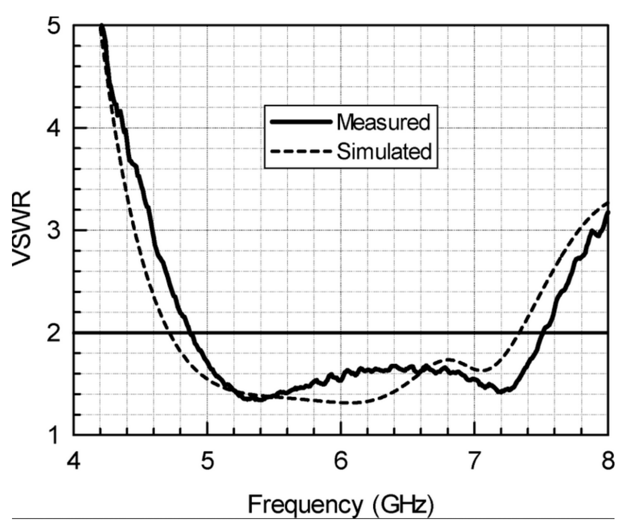

Fig. 13. VSWR of the printed broad-band series-fed dual rhombic-loop antenna with a broad-band balun

References

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