Resonances in Receiving Two-Arm Spiral Antennas

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***Abstract*— A planar array of symmetrical square spiral antennas over a ground plane have resonances when scanning off-broadside. This paper demonstrates that resonances also appear in a single symmetrical receiving spiral antenna without a ground plane, provided that the incident wave is off-broadside. Transmission line analysis predicts the resonances.**

Keywords—planar array, spiral antennas, resonances, transmission line model.

I. Introduction

At certain frequencies, a planar array of symmetrical square spiral antennas over a ground plane is not effective for scanning off-broadside [1]. These frequencies are termed as resonances and the current distribution on the arms of the spirals forms a strong standing wave pattern. A spiral antenna becomes resonant at a frequency when the lengths of its arms are multiples of half the resonant wavelength. It has been observed that mutual coupling between the array elements contributes to these resonances [1]. The idea of a "spoiled" spiral (arms with a slight asymmetry in terms of length) was suggested in [1] for suppressing resonances. A lossless transmission line model was then proposed in [2] to explain the resonances in a spiral antenna in an array with a ground plane. The model was also used to verify that a perfect standing wave may not be set up on a spoiled spiral.

We show here that even a single symmetrical spiral antenna without a ground plane, in the receiving mode, may become resonant when the lengths of its arms are multiples of half the corresponding wavelength. Therefore, there does not seem to be a fundamental requirement for the presence of a ground plane or for a spiral to be in an array configuration. In fact, resonances have also been observed in spirals of various shapes. There is a standing wave current distribution setup on resonant spiral antennas, with the incident wave off-broadside, impeding the receiving capability of the antennas.

II. Resonances on a Single Spiral Antenna without Ground Plane

Fig. 1 shows a single two-arm symmetrical square spiral antenna in the receiving mode. The spiral is terminated in a load ZL at the center. If a linearly polarized plane wave illuminates the antenna along the plane of the spiral a current distribution is induced along the arms of the antenna. The spiral shown in the configuration in Fig. 1 becomes resonant when the incident fields satisfy any of the criteria in (1) or (2).

$$\mathbf{E_1}\neq 0 \ \&\ \mathbf{E_2}=0 \quad (1)$$

$$\mathbf{E_1}=0 \ \&\ \mathbf{E_2}\neq 0 \quad (2)$$

$\mathbf{E_1}$ and $\mathbf{k_1}$ ($\mathbf{E_2}$ and $\mathbf{k_2}$) correspond to electric-field and propagation vectors of an incident plane wave.

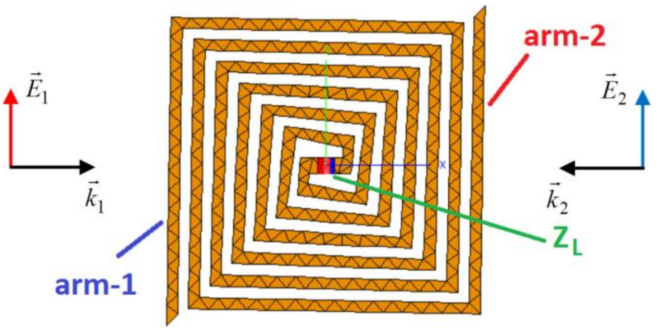
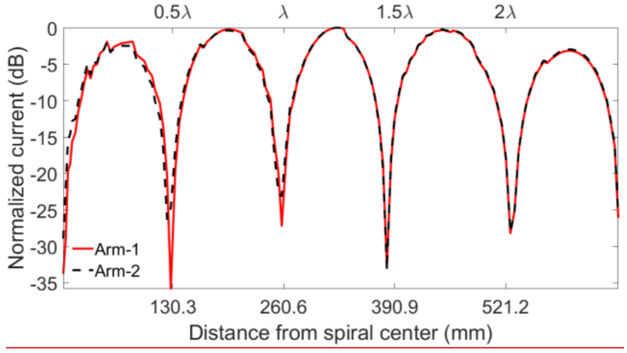
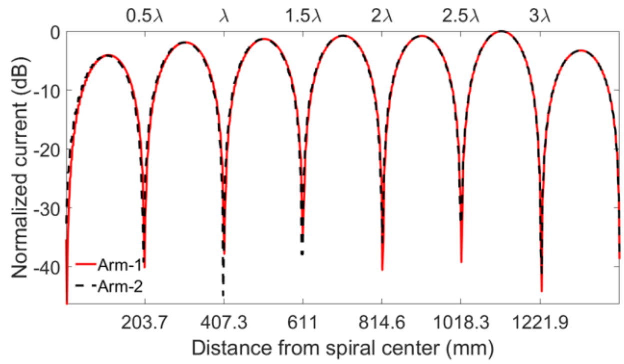


Fig. 1. Symmetrical square spiral illuminated by two plane waves.



(a) Resonant square spiral at 1.15 GHz



(b) Resonant Archimedean spiral at 0.73 GHz

Fig. 2. Symmetrical square spiral illuminated by two plane waves.

Taking the center of a spiral as a reference, the plots in Fig. 2 show the amplitude of surface current along the length of an arm on two different resonant two-arm symmetrical spiral antennas. Fig. 2a corresponds to the square spiral antenna in Fig. 1 resonating at 1.15 GHz. It was simulated using a full-wave solver, FEKO, and constructed from a perfect electrically conducting surface. Note that Fig. 2a remains the same irrespective of which criteria are used among (1) or (2). Similar resonances are observed in other kinds of individual spiral antennas, such as Archimedean spirals, as shown in Fig. 2b.

Simulations show that the spiral becomes resonant when the impinging plane wave is off-broadside and when the lengths of the arms are multiples of half the corresponding wavelength associated with the incident frequency. Moreover, the resonances are strongest when the wave's propagation and electric-field vectors are parallel to the plane of the spiral.

Table I shows geometrical dimensions and resonant frequencies considering two types of resonant two-arm symmetrical spiral antennas without a ground plane, where *f* is a resonant frequency in GHz, *l* is the length of each spiral arm in mm, l_λ is the spiral arm length in multiples of the free-space wavelength (λ) corresponding to the resonant frequency and *w* is the width of each spiral arm in mm.

TABLE I. GEOMETRICAL DIMENSIONS AND RESONANT FREQUENCIES CONSIDERED FOR VARIOUS SYMMETRICAL SPIRAL ANTENNAS

Spiral	**Square**	**Archimedean**
f (GHz)	1.15	0.73
l (mm)	653.2	1426.6
l_λ	2.5	3.5
w (mm)	3.4	2.7

The load impedance at the feed-terminals of the spirals is 220Ω. Note that the resonance phenomenon in Fig. 2, for a single spiral antenna without a ground plane, is very similar to the ones reported in [1] and [2] for planar arrays of symmetrical square spiral antennas over a ground plane.

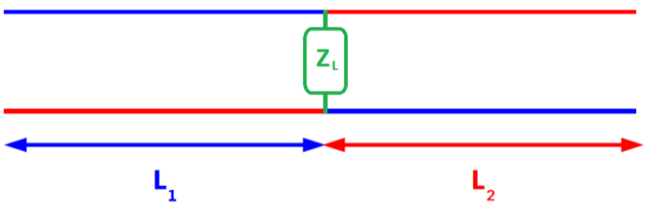


Fig. 3. Double transmission line model of spiral antenna of Fig. 1. Blue and red colors correspond to arm 1 and 2, respectively. L represents the arm lengths of the spiral.

To model the resonances, we have considered a double transmission line model, which has the same geometry as in [2]. If the arms of the spiral of Fig. 1 are unwrapped, considering the proximity between the arms, we obtain a double transmission line model without the need of an actual ground plane (see Fig. 3). Blue and red colors represent the arms 1 and 2 and the load ZL at the center is in green. However, the transmission lines in our model are considered to be lossy. Even after using the lossy transmission line model, we have obtained the same criteria required for the spiral to become resonant.

III. Conclusions

Our analysis is helpful in explaining the resonances that appear in receiving spiral antennas even without a ground plane, when the incident field is off-broadside. Resonances are observed in two kinds of individual spirals and are a fundamental characteristic of the element itself. Our analysis is also consistent with previous works, which show that a spoiled spiral is helpful in suppressing strong resonant behavior.

References

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