Analysis for Miniaturization of a Spiral Antenna using Inductive and Resistive Loading

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***Abstract*—This letter discusses a miniature ultrawideband (UWB) square double spiral antenna. With the antenna operating at 300 MHz∼3 GHz, we used the inductive and resistive loading method. Using full-wave simulations with 3D FEM tools, it is demonstrated that operation bandwidth is extended to the lower frequency and antenna gain is increased. This means that traditional planar antennas can be made smaller with the same performance.**

I. Introduction

There is great interest in small, broadband antennas for both commercial and military applications. Recently, miniaturization of antennas that cross the VHF and UHF bands has been continuously studied. In this paper, rectangular spiral antenna is studied especially. Antennas operating from 300 MHz can be worked at lower frequencies using two methods, while achieving higher gain.

The miniaturization methods are roughly divided into two types: physical and electrical size reduction. The way to reduce the physical size is to change the shape and arrangement of the antenna, which is usually made of a meander structure [1]. Methods of reducing the electrical size include lumped element and dielectric loading, which have the effect of increasing the electrical length [2]. The inductive loading method used in this study has both these effects [3]. The resistive loading method reduces the reflection on the termination and improves the performance in the outermost part [4]. The simulation results using full wave 3D FEM solver are analyzed in this study.

II. condition of analysis

A. Structure of antenna

The spiral antenna has two types of antennas, the equiangular and Archimedean shape. In this study, the spiral antenna is designed as Archimedean type, because the thickness increases in active region as the spiral arm gets longer. The lower operating frequency(f_{low}) and upper operating frequency(f_{high}) of the antenna which is determined by the inner(r_i) and outer(r_o) radii of the antenna satisfy the formulas $2\pi r_i \leq \lambda_{high}$ and $2\pi r_o \leq \lambda_{low}$ [5]. If a square antenna is used instead of a circle, The outermost length is changed to 8r instead of 2πr

B. Parameter design and loading conditions

With the principle in Section II-A, a square double spiral antenna with dimensions of r_i = 12.5 mm and r_o = 125 mm was designed. A 2 mm thick copper wire was wound on a FR-4 board of 2 mm thickness with a 2 mm pitch and 14 times wounding. Also, a reversed phase current of 180 degrees with an input impedance of 140 Ω was fed to the spiral arm of the center part. For the inductive loading, a copper wire is arranged in a zig-zag shape through a via as shown in Fig. 1, instead of a straight-line arrangement in the outermost part. In this case, the inductive loading operates like a coil, which helps to increase the physical length as well as the electrical length [3]. The comparisons of S11 and Gain value are concentrated in the low frequency band of 200 MHz ∼ 400 MHz according to whether there is loading or not.

For spiral antennas that emit circularly polarized waves, not only size but also reflected waves must be reduced. In order to reduce the reflected wave and miniaturize, chip resistors were used in the outer spiral arms. The current dissipation in the resistor reduces the reflected wave, so that the impedance matches at low frequency [4]. The number of chip resistors are limited to 4 per arm because of increasing of the current dissipation. For minimal reflection, the resistance increased as tapered form by 50, 70, 100, and 140 ohms.

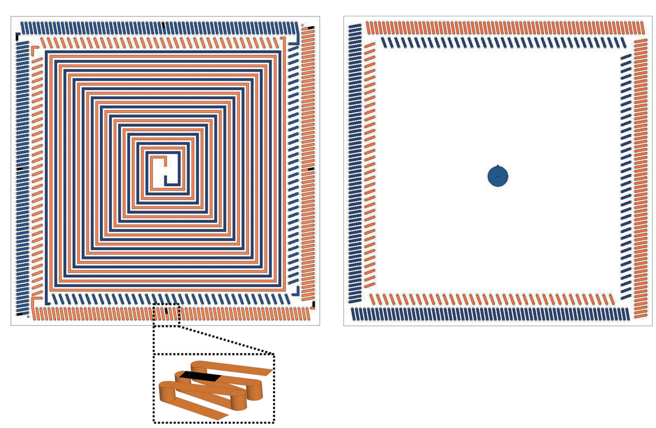

Fig. 1. The front and back structure of antenna.

III. Results and Discussion

For quantitative analysis of the antenna, Comparisons of S11 values and realized Gain right hand-circularly polarized(RHCP) values are shown in Fig. 2 and Fig. 3 for the three types of treatments. Fig. 2 has a thin boxed display with improved operating frequency for each types based on -10dB in S11 parameter. Simulation results show that the lower operating frequency (f_{low}) is reduced to 250MHz when inductive loading is applied and reduced to 190MHz when inductive with resistive element loading. Also, when inductive loading was performed, gain of 0.5dBi $\sim$ 3dBi is obtained in the 180MHz $\sim$ 300MHz bands. Conversely, in the case of inductive with resistive loading, the gain of 0.5dBi $\sim$ 2dBi is reduced in the 210MHz $\sim$ 330MHz bands. This can be thought of as a result of some being dissipated by the current. At around 190MHz, the gain of the inductive with resistive loaded type is the highest, and the result depends on the resistance values.

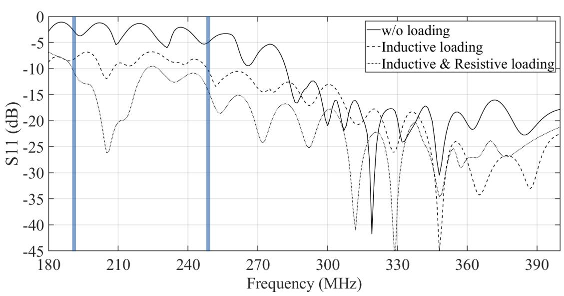

Fig. 2. Comparisons of S11 parameter for spiral antenna using 3 types of miniaturization treatments.

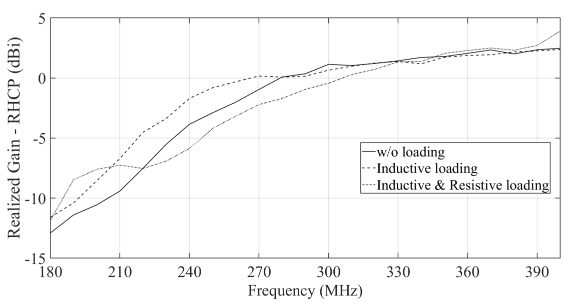

Fig. 3. Comparisons of Realized Gain(RHCP) for spiral antenna using 3 types of miniaturization treatments.

The bi-directional nature of a sprial antenna is important. A back cavity used for uni-directionality in many cases is not covered in this paper. Fig 4. shows the radiation pattern for each loading method. All three cases work well at 300 MHz with bi-directionality. However, at 200 MHz, the antennas with fundamental and inductive loading show a loss of bi-directionality. It is not perfect for both inductive and resistive loading methods that operating from 190 MHz, but it has bi-directionality as at 300 MHz. The radiation pattern is also slightly different depending on the resistance values of the chip resistors.

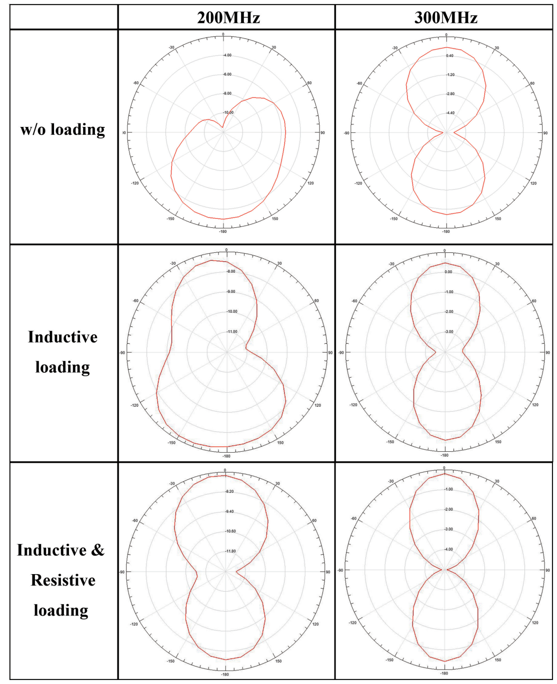

Fig. 4. Comparisons of Realized Gain(RHCP) for spiral antenna using 3 types of miniaturization treatments.

IV. Conclusion

In this paper, the inductive loading method and the method using both inductive and resistive loading are used to miniaturize the spiral antenna. By the full wave FEM simulation, it is confirmed that the spiral antenna is miniaturized up to 40 percent by the proposed method without degradation of antenna gain.

Acknowledgement

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