Dimensional Parametric Study of the Spiral Resonator as a Metamaterial Planar-Antenna

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Abstract – In this paper, the square spiral resonator (SR) as a metamaterial planar-antenna with electromagnetically coupled (EMC) feed is proposed. The proposed antenna will be operated at the frequency range of 2.4 – 2.5 GHz. To define the dimensional parametrics of the proposed antenna such as the spiral turn number (*N*), strip width (*w*), and gap width (*s*), it is simulated. The highest gain obtained is –0.5 dB at the frequency of 2.43 GHz by using dimensional parametrics of *N*=3; *w*=3.1mm; and *s*=0.5mm.

Keyword – Metamaterial planar-antenna, spiral resonator, antenna gain

I. Introduction

The modern communication tend to use the compact and small size antennas. To achieve this requirement, the substrate with high permitivity is usually applied. However, the antenna characteristic will encounter degradation. Therefore, many research of miniaturizing antennas have been conducted by using the miu negative (MNG) metamaterial [1] – [4].

The MNG metamaterial has two shapes such as split ring resonator (SRR) and spiral resonator (SR). Bilotti F. *et al* [1], [2] discussed the resonance frequency changing to the ring number of MSRR or spiral turn number of SR which can be obtained by using equivalent circuit, respectively. According to the equivalent circuit, the values of resistance, inductance, capacitance, effective impedance, and effective permeability of the MSRR and SR can be obtained. By using these values, MNG property is obtained at frequency range of 0.2 GHz – 0.225 GHz for *N*=12, *w*=0.1mm, *s*=0.1mm, and *l*=8mm. MSRR and SR structures can reduce the dimension linearly upto $\lambda_0/30$–$\lambda_0/40$ dan $\lambda_0/65$–$\lambda_0/250$, respectively. However, the antenna parameters such as return loss, bandwidth, gain, and radiation pattern have not been discussed yet. Moreover, Ref. [3] and [4] is engineered magnetic material by using spiral structure as a substrate for applying small patch antenna. This can provide adjustable reduction factor. Spiral structure had been used to create the substrate, while the radiator element used conventional patch. Measurement result shows that the reduction factor can be obtained about 40% – 70% with efficiency of 20% – 30% [3].

SR structure is used frequently to compose magnetic material as substrate, however it has not been found yet to be used as a planar antenna. Therefore, this paper will discuss the novelty of the SR structure as a planar antenna.

II. Spiral Resonator as a Metamaterial Planar-Antenna

The SR structure as metamaterial planar-antenna with the EMC feeding is shown in Fig. 1.

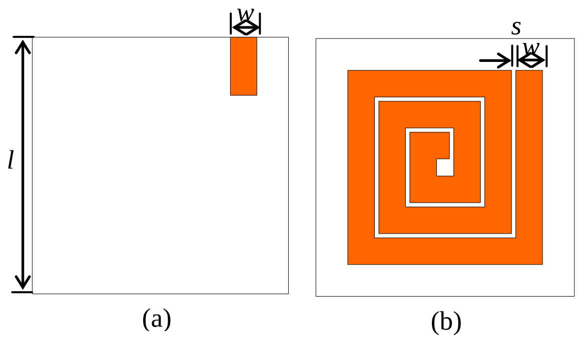
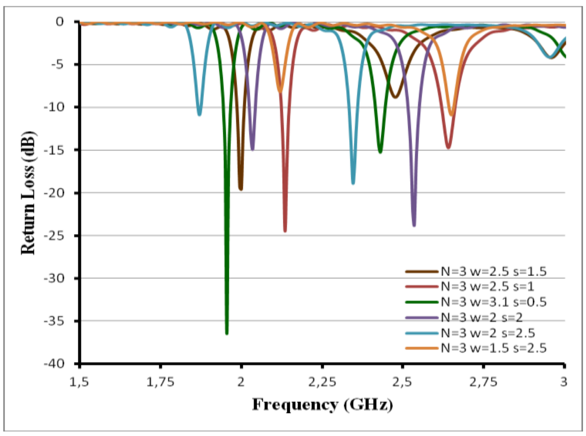
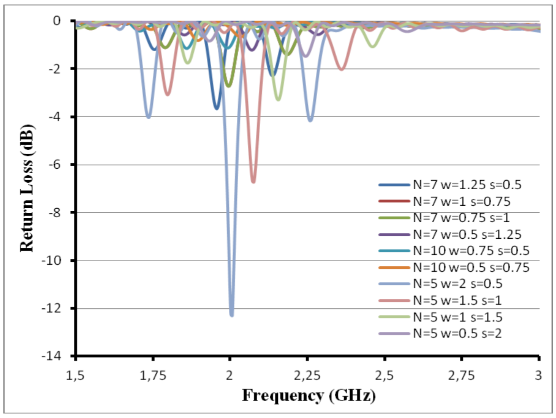


Fig. 1. SR Structure as Metamaterial Planar-Antenna : (a) EMC Feeder and (b) Radiator

The proposed antenna is composed of two layers substrate in which the first (top) layer is the radiator and the second (bottom) layer is the feeding system. The SR structure dimension is defined by variables of the spiral turn number *N*, strip width *w*, gap width *s*. The proposed antenna is assumed to have the constrain of constan *l*, so that the *w* and *s* values are adjusted to the *N* variations of 3, 5, 7, 10; and then it is simulated. The simulation result is shown in Fig. 2.



(a)



(b)

Fig. 2. Return Loss of the Proposed Antenna : (a) with *N*=3; (b) with *N*=5,7,10 and Variations of *w* and *s*

From Fig. 2(a) and Fig. 2(b), they can be observed that the frequency range at 2.4 GHz – 2.5 GHz occured at the dimensional parametric of *N*=3 with combinational variations of *w*=3.1mm, *s*=0.5mm and *w*=2.5mm, *s*=1.5mm, while the others are out of range and they are not observed.

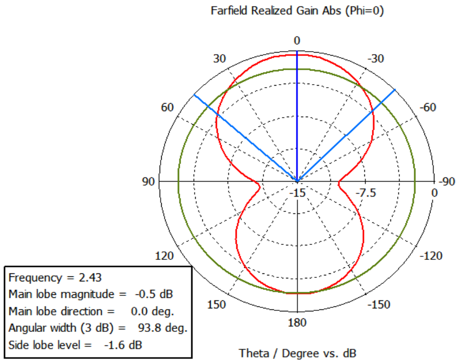


Fig. 3. Radiation Pattern of the Proposed Antenna with *N*=3, *w*=3.1mm, *s*=0.5mm

The radiation pattern of the proposed antenna is shown in Fig. 3. The performance of the proposed antenna at the frequency range of 2.4 GHz – 2.5 GHz is shown in Table I.

TABLE I
ANTENNA PARAMETERS VS DIMENSIONAL PARAMETERS

Parameter		Freq Range of 2.4 - 2.5 GHz	S_{11} (dB)	Gain (dB)
N=3	*w*=3.1 *s*=0.5	2.43	-15	-0.5
	w=2.5 *s*=1.5	2.47	-9	-0.6
	w=2.5 *s*=1	out of range	not observed	not observed
	w=2 *s*=2	out of range	not observed	not observed
	w=2 *s*=2.5	out of range	not observed	not observed
	w=1.5 *s*=2.5	out of range	not observed	not observed

The MNG property of the proposed antenna is obtained by using *N*=3, *w*=3.1mm, *s*=0.5mm, *l*=22.6mm at the frequency range of 0.75 GHz – 5 GHz, and its realized gain is –0.5 dB at the frequency of 2.43 GHz.

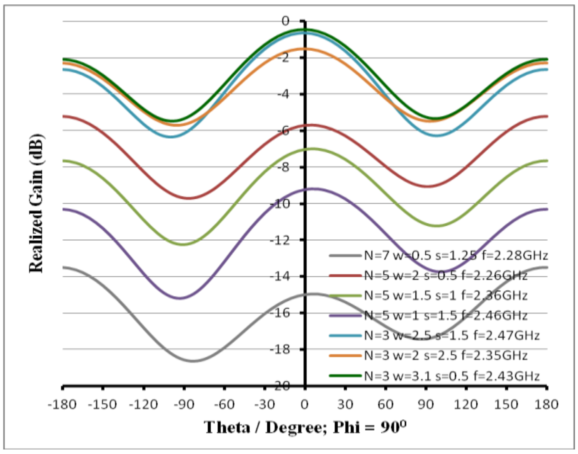


Fig. 4. Realized Gain of Proposed Antenna with Variation of *N*, *w*, *s* at the Frequency Range of 2.0 GHz – 2.5 GHz.

Moreover, the realized gain of the proposed antenna with the variation of *N*, *w*, *s* at the 2.0 GHz – 2.5 GHz frequency range is shown in Fig. 4. From Fig. 4, it can be observed that the proposed antenna with *N*=3, *w*=3.1mm, *s*=0.5mm at the frequency range of 2.0 GHz – 2.5 GHz has the highest gain than the others.

III. CONCLUSION

Dimensional parametric study of SR as metamaterial planar-antenna lead to the conclusion that the proposed antenna with *N*=3, *w*=3.1mm, *s*=0.5mm has the highest gain than the others. The proposed antenna gain is –0.5 dB at the frequency of 2.43 GHz.

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