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Angular Displacement Sensor Based on Coplanar Waveguide (CPWs) Loaded with S-Shaped Golden Spiral-Tapered Split Ring Resonators (SGS-SRRs)

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Abstract

An angular displacement sensor based on coplanar waveguides (CPWs) loaded with s-shaped golden spiral-tapered split ring resonators (SGS-SRRs) is proposed in this paper. The proposed device is composed of a CPW and a SGS-SRR which was designed based on the golden ratio number and etching on double copper layer of PCB. The transmission coefficient (S_{21}), linearity and sensitivity of the sensor were simulated and analyzed using electromagnetic models. The results show that the sensor was able to sense the rotation angle. It has a wide dynamic range, high linearity, higher sensitivity and lower cost, which is particularly suitable for use as a sensor and transducer technology in the future.

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Keywords: Angular displacement sensor; Coplanar waveguide; Golden ratio; S-shaped; Golden spiral-tapered split ring resonators.

1. Introduction

1.1 Golden ratio

The golden ratio is an extra number that is approximately equal to 1.618. It is a mysterious number that appears in all forms of nature and science, such as flower petals, seed heads, tree branches, shells, spiral galaxies, hurricanes, animal bodies and DNA molecules [1-2]. When a and b are the length of a line segment, the ratio of a + b divided by a is equal to the ratio of a divided by b, as presented in Fig. 1(a) and eq. (1) [3].

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$$\frac{a+b}{a}=\frac{a}{b}=1.618...=\frac{1+\sqrt{5}}{2}=\Phi \quad (1)$$

1.2 Golden spiral

Golden spirals are often found in nature and science. They can be derived from a golden rectangle, and are presented in Fig. 1(a). Much of the arts and architecture are designed based on the golden ratio. Moreover, the golden ratio has been used for designing many technologies, such as multi-wave oscillator (MWO) antenna [4] and angle sensors [5].

1.3 Angular displacement sensors

Angular displacement sensors can be developed using many techniques, such as gyroscopes, and they work based on Newton's law of gravitation. They have been developed as a reel mounted on a contact that lies on the horizontal plane of a rotating ring. The ring can rotate freely [6]. Currently, they can be built in microelectromechanical systems (MEMS), but are still expensive. More recently, new angular displacement sensors based on CPWs loaded with a split ring resonator have been proposed [7-8]. The angles of rotation of the SRR are not symmetrical with the CPWs to give a transmittance (S_{21}) that functions with a range of angle rotations in the SRR, but the rotation of the SRR in this structure is not easy to deploy. From this issue, tapered horn-shaped [9], diamond shaped [10] and golden spiral–shaped tapered ring resonator [5] structures have been proposed. The third type of proposed structure works on a fixed frequency. However, they only have a response to a narrow angle: by approximately 6-12 degrees only. Naqui et al. proposed an Electric-LC (ELC) structure [11-12] and S-shaped split ring resonator (S-SRR) [13] that increased the dynamic range up to 90 degrees, but it still had low linearity. In this paper, a new structure of an s-shaped golden spiral-tapered split ring resonator is introduced. The advantages in the proposed design include a wider dynamic range, high linearity and lower fabrication cost.

2. CPWs loaded with SGS-SRRs structure

Fig. 1(b) shows a CPW loaded with a SGS-SRR structure. The angle and centre of rotation are marked with a red arrow and a red dot, respectively. The angle sensor design was produced using electromagnetic models and analysed using the finite difference time-domain method, for which the parameters of thickness with a relative permittivity (ε_r) and both sides having copper metallization, are the same as in ref. 5. The width (w) of the CPW's signal trace was 4.75 mm, the slot width was 0.3 mm, R_1 was 15 mm, R_2 was 14 mm and t was 1 mm. The size of the golden spiral–tapered structure is shown in Fig. 1(b).

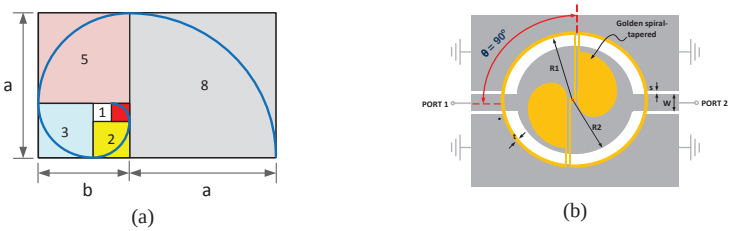

Fig. 1. (a) Golden spiral and (b) CPW loaded with SGS-SRRs.