Rotation Sensor based on Near Field Perturbations of Metamaterial Split Ring Resonator

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Abstract – **This paper uses the field distribution properties of metamaterial Split Ring Resonators (SRRs) for the implementation of a rotation sensor. The proposed sensor structure includes a stator, which is a SRR and a rotor, a thin dielectric strip in the near field region of the resonator attached to the rotating axis of a stepper motor arrangement. The sensing principle is based on the shift in resonance frequency due to the change in effective capacitance of the SRR because of the perturbations in the field owing to the presence of the dielectric rotor. This novel and simple metamaterial inspired rotation sensor shows a linear response up to 45^0 with flexibility of changing the sensitivity of the proposed sensor. The possible non-linear issues involved for rotation up to 180^0 is also presented.**

I. Introduction

Metamaterial resonator structures like Split Ring Resonators (SRRs) have gained major attention in recent years due to its applications in the field of sensing and imaging. The attractive features of these microwave sensors include high sensitivity, high quality factor and high tunability[1]. The resonance frequency dependence of these artificially engineered materials is effectively utilized for the realisation of various sensors. Though different types of metamaterial structure related sensors have been introduced by some researchers, the field related analysis for the working of these sensors is seldom seen in literature. A few works already reported portraits the realization of the rotation sensor by the rotation of the SRR structure which changes the symmetry of the resonator [2]–[3].

In this paper, we introduce a novel rotation sensor in which the SRR probe is kept stationary where by the undesired movement effects are eliminated. The analysis is carried out by using the perturbation effects in the near field of the resonator caused by the non-contact rotation scanning of a dielectric strip whose dimensions along with the dielectric constant can be varied for enhancing the sensitivity.

II. Experimental Methods and Results

The experimental arrangement includes a SRR fabricated on a thin poly ethylene film [4] of thickness 18 μm and it is arranged precisely between the transmitting and receiving probes connected to a Vector Network Analyzer (VNA). SRR used for the sensing purpose is having an inner radius 2.43 mm, width of the metal rings 0.945 mm, spacing between the rings 0.245 mm and split width 1.36 mm. Dielectric strip of selected permittivity is fixed on a rotating axial made of low loss dielectric material and it is attached to a stepper motor arrangement so that the rotation can be electronically controlled. The entire experimental set up is shown in Fig. 1.

The resonant frequency of the SRR probe is determined by the intrinsic values of its capacitance and inductance. The presence of a dielectric in the near field [5] region of the SRR will enhance the effective capacitance which in turn will reduce the resonant frequency. Care should be taken to precisely set the dielectric sensing strip near the SRR within its fringing field.Closer the position of the sensor strip to the SRR, greater will be the sensitivity owing to the enhanced capacitive contribution to the resonance shift. Capacitive contribution at different regions of SRR is revealed by allowing the dielectric thin strip to gradually rotate through the near field of resonator with the axis of rotation passing through the centre of the ring structure. Fig. 2 shows the resonant frequency variation for 180^0 rotation with a dielectric strip of thickness t = 1.27 mm, width w = 2.98 mm and dielectric constant ε = 3.7. In the

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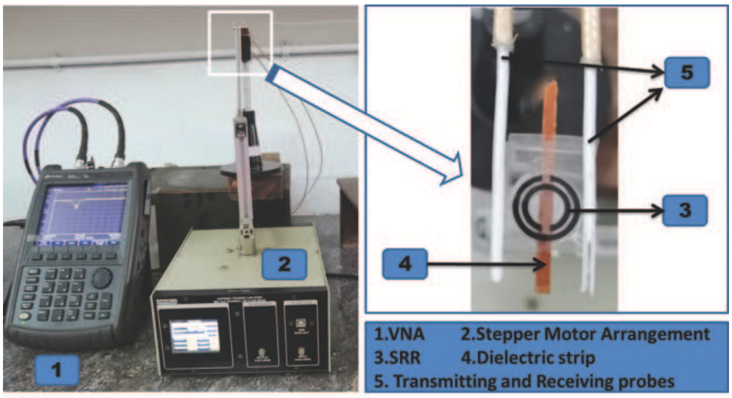

Fig. 1: The photograph of the experimental set up used for the rotation sensor along with the magnified view of the sensing probe.

above figure, points with minimum resonance frequency ($0^0$and 180^0) occur when the position of dielectric strip is in line with the slit direction (position marked as a). When dielectric strip rotates to position b (45^0 and 135^0), we observe maximum resonance showing a minimum capacitive contribution. As the rotor turns to 90^0(position c), another capacitive contribution which is due to mutual coupling between the rings is observed resulting in a lowering of the resonant frequency. We can utilize the linear region between a and b for precisely sensing rotation up to a dynamic range of 45^0.

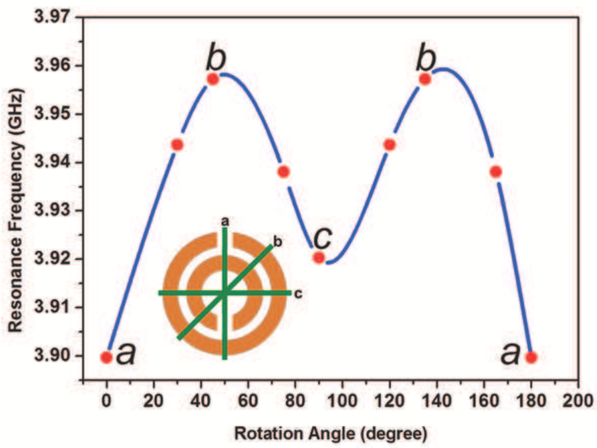

Fig. 2: The variation of the resonance frequency with rotation angle from 0^0 to 180^0 for a dielectric strip of ε = 3.7, w = 2.98 mm and t = 1.27 mm along with the three positions a, b and c of the dielectric strip.

Fig. 3 depicts the resonance frequency shift for a rotation of 45^0 for two different dielectric strips having permittivity values $\varepsilon_1 = 1.2$ and $\varepsilon_2 = 3.7$. It is obvious from this figure that as the dielectric constant of the strip increases, the resonant frequency shift also increases and by using a strip of dielectric constant 3.7, we achieve a sensitivity of 1.45 MHz/degree. By using strips having high dielectric constants we can enhance the sensitivity of the rotation sensor to higher desired values.

III. Conclusion

By utilizing the perturbation effects of the near field of a SRR using a suitable dielectric strip we have realized a novel rotation sensor with high dynamic range and sensitivity. Since the field generating resonator structure is

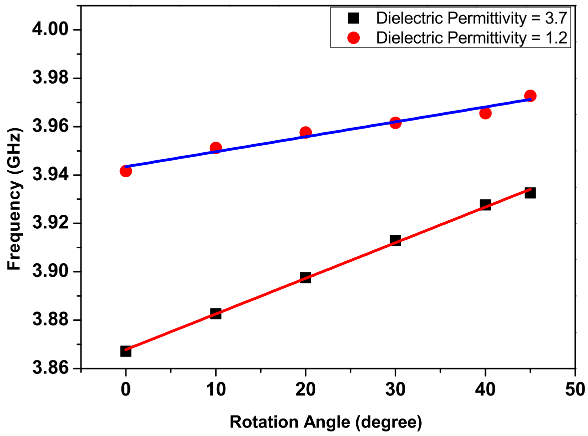

Fig. 3: Resonant frequency shift with rotation angle from 0^0 to 45^0 for two different dielectric strips.

kept stationary we are able to eliminate the unexpected noises originating due to the position shift of the resonator. This sensor may find application for precise determination of shear related movements in various engineering and instrumentation problems.

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References

[1] F. Rao, Z. Yu, X. Huang, S. Hu, Y. Jin, and H. Yang, “Metamaterial-inspired rotation sensor based on complementary single split-ring resonator (cssrr),”*Journal of Electromagnetic Waves and Applications,* vol. 32, p. 1664–1674, 2018.

[2] A. M. Gargari, B. Ozbey, H. V. Demir, A. Altintas, U. Albostan, O. Kurc, and V. B. Ertürk, “A wireless metamaterial-inspired passive rotation sensor with submilliradian resolution,” *IEEE Sensors Journal,* vol. 18, p. 4482–4490, 2018.

[3] A. K. Horestani, D. Abbott, and C. Fumeaux, “Rotation sensor based on horn-shaped split ring resonator,” *IEEE Sensors Journal,* vol. 13, p. 3014–3015, 2013.

[4] P. M. Ragi, K. Umadevi, P. Nees, J. Jose, M. Keerthy, and V. P. Joseph, “Flexible split-ring resonator metamaterial structure at microwave frequencies,” *Microwave and Optical Technology Letters,* vol. 54, p. 1415–1416, 2012.

[5] S. P. Chakyar, S. K. Simon, C. Bindu, J. Andrews, and V. Joseph, “Complex permittivity measurement using metamaterial split ring resonators,” *Journal of Applied Physics,* vol. 121, p. 054101, 2017.