

Detection of Water Quality using Defected Ground Double Split Ring Resonator



Sushmita Bhushan, Sanjeev Kuamr

Abstract: Water is an essential thing for life. Now days due to population growth and pollution, the quality of water is degraded. In this paper, a single element double split ring resonator (DSRR) has been presented as a sensor to detect the quality of water. Here, two square shape metallic split rings are designed along with the microstrip line. On the back side of the substrate, defected ground structure (DGS) is introduced. The resonant frequency of the resonator is 11.12 GHz. Quality of water is detected by the shift in S21 resonant frequency with the variation in transmission coefficient. This sensor can be used in our daily life to detect the quality of water and it may be useful in medical field also.

Keywords: Detection, Defected ground structure, Split ring resonator, Water quality

I. INTRODUCTION

Detection of water quality is a great challenge for us and many research have been done to test the sea water, lake water, and well water. For this, various sensors had been used in past [1]-[2]. In recent years, metamaterial has been widely used for sensing application, microwaves and infrared, optics etc. Metamaterials are the artificially designed materials having the property which is not available in nature. Split ring resonator is a basic component of metamaterials which exhibit negative permeability and permittivity [3]. In the microwave regime, the great application of metamaterial is as a sensing device. There are many other ways to fabricate and design different types of sensors, but the sensors based on metamaterials are very easy to design and fabricate, more accurate, cost effective and portable. The main characteristic of SRR is its very small electrical size, due to this; they are widely used from microwave to terahertz frequency range. In the past, split ring resonators have been used for the sensing of glucose content in blood plasma [4], DNA sensing [5], detection of label free stress biomarkers [6] and for ethanol and petrol sensing [7]. In this work, we have used split ring resonator as sensor to detect the quality of water whether it is fresh water, distilled water or sea water. Here, we have designed a square shape double split ring resonator. The SRR is excited by a 50 Ω microstrip transmission line. In the design, a defected ground structure is also introduced to give a better result. The whole structure was designed and simulated on HFSS software and the results are reported here.

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II. THEORY FORMULATION

A. Split Ring Resonator

The split ring resonators (SRR) may have different shapes like circular, square or triangular. It consists of a metallic ring with a slit or gap on a dielectric substrate. The SRR basically work as an LC resonator. The SRR resonates at its magnetic resonance frequency, when it is excited by a time varying magnetic field [6], [8]. When the time varying magnetic field penetrates the SRR, currents are induced in the rings and flow in the same direction [9]. We can express the resonant frequency of SRR as [10]

$$f = \frac{1}{2\pi\sqrt{LC}} ; C = C_g + C_s; \quad (1)$$

Here the inductance (L) and capacitance (C) depend on the shape of the SRR. The overall capacitance of the SRR is the combination of the gap capacitance (Cg) and surface capacitance (Cs). The expression for the gap capacitance and surface capacitance can be stated as follows [10]

$$C_g = \epsilon_{eff} \frac{hw}{g} + \epsilon_{eff} (h + g + w) \quad (2)$$

$$C_s = 2\epsilon_{eff} \frac{(h+w)}{\pi} \ln\left(\frac{4r}{g}\right) \quad (3)$$

Here r, h, w and g represent radius, height, width slit gap of square split ring resonator.

In this work, we have used the resonant frequency as an effective microwave parameter for the detection of water quality.

B. Defected Ground Structure

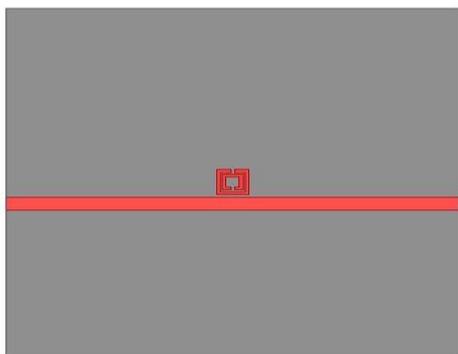
Any periodic or non-periodic slots or defects etched on the ground plane of a circuit are referred as defected ground structure. Due to these defects the current distribution in the ground plane is disturbed and thus the equivalent line parameters (resistance, inductance and capacitance) changed by adding slot resistance, inductance and capacitance [11]. Defected ground structure is used in the circuit to improve the performance. By using the effect of DGS, the operating frequency & gain are enhanced [12]. We can change the shape of the defects from simple to complex for the better performance [13].

III. DESIGN AND SIMULATION

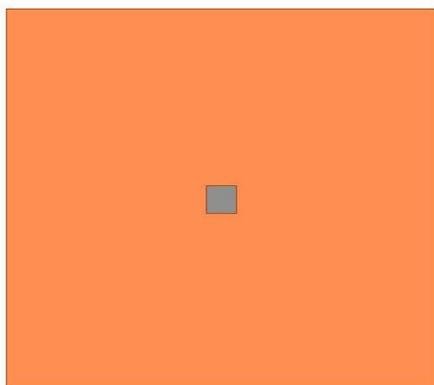
Here we have designed two square shape metallic rings having splits on opposite sides.

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This SRR structure is excited by a microstrip line having a width of 0.78 mm and length of 22 mm. The SRR and microstrip line are separated by 0.2 mm. The rings are separated by 0.1 mm and the width of each ring is 0.18 mm. The average length of the SRR from the center is 0.64 mm. The substrate which we have used here is the RT/duriod 6010 having thickness of 0.76 mm and 35 μm thick copper layer on both side.



(a)



(b)

Figure 1 Schematic of DSRR (a) Top view (b) Bottom view

On the back side of the SRR a slot is etched from the ground plane to introduce the effect of defected ground structure. The equivalent circuit of defected ground structure consists of inductance and capacitance. Due to this, current distribution in the ground plane is perturbed. The DGS is used to reject the unwanted frequency.

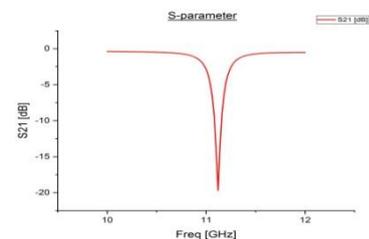
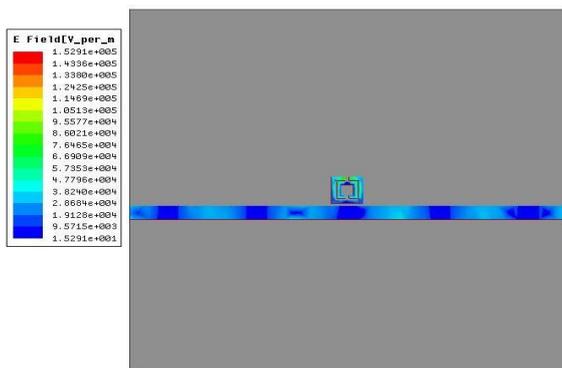


Figure 2 Simulated S_{21} spectra of the DSRR with resonant frequency 11.12 GHz

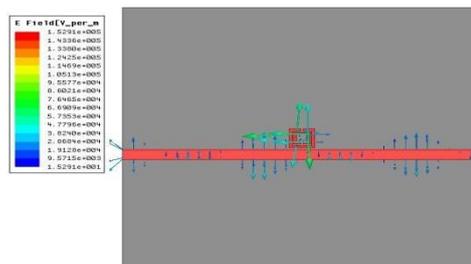


Figure 3 Simulated surface current density of the DSRR

The whole structure was designed and simulated by commercially available electromagnetic solver base software (Ansys HFSS 15.0). The SRR resonates at 11.12 GHz frequency having the transmission coefficient 19.70 dB. Simulated design and S_{21} response of the DSRR is shown in figure 1 and figure 2 respectively. Figure 3 shows the simulated surface current density for the DSRR structure.

IV. RESULT AND DISCUSSION

We have seen the simulated S_{21} response of DSRR structure in figure 2. When we have simulated the bare DSRR, it resonates at 11.12 GHz frequency. Now this structure was simulated by placing a water droplet of 2 μl volume. For testing three different samples of water, fresh water, distilled water and sea water are used. The result after loading of water droplet is shown in figure 4.

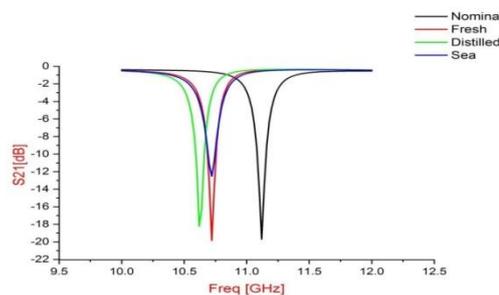


Figure 4 Simulated S_{21} response of DSRR for different types of water

It is observed in figure 4 that after loading of water droplet the resonant frequency and transmission coefficient of S_{21} are changed. The resonant frequency is shifted from 11.12 GHz to 10.72 GHz for the fresh water 10.62 GHz for the distilled water.

In case of distilled water and sea water the transmission coefficient is also changed from 19.70 dB to 18.21 dB and 12.20 dB respectively. Depending on the volume of the droplet, the result will vary. Here, all types of water were tested for the same volume of droplet.

V. CONCLUSION

In this work, we have presented a double split ring resonator for the detection of water quality whether the used water is fresh water, distilled water or sea water. These three types of water have been simulated on HFSS software. A very small volume of water droplet is required for the detection. When a water droplet is kept on the double split ring resonator, the resonant frequency and the transmission coefficient of the device vary.

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AUTHORS PROFILE



Sushmita Bhushan received AMIE (Bachelors) degree in electronics and communication engineering from The Institution of Engineers (India), in 2015, and the M.Tech degree in RF and microwave engineering from Ambedkar Institute of Advanced Communication Technologies & Research (GGSIU University), Delhi, India, in 2019. She is an Associate Member of The Institution of Engineers (India).



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