Asymmetric complementary split ring resonator for identification of materials

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Abstract. In this paper, a new microwave sensor for identification of materials is presented. The sensor is composed of an asymmetric complementary split ring resonator etched on the ground side of the microstrip line. The sensor is designed using low cost FR4 substrate. The S21 simulation result shows the unloaded resonator operates at 6.45 GHz. The overall size of the sensor is 100mm×50mm×0.8mm. When the sensor is loaded with sample material, the resonant frequency shift is noticed. This change in frequency shift is used to identify the material type and also the thickness of the material under test. The sensor is tested for different test samples placed on the ground and is correctly able to identify the material under test and its thickness by its resonant frequency variations.

1. Introduction

The substrate material is one of the key components used to design microwave devices like antenna, filters, phase shifters and other radio frequency devices. Selecting correct materials for the device design will lead to optimum results. However, when having multiple substrate material in a laboratory setup and using correct substrate thickness to design suitable microwave devices is always a key challenge.

The substrate materials are characterized by its dielectric constant and the change in dielectric constant also cause the electromagnetic property of the material to change. This property can be used to identify material under test. Also, when the thickness of the substrate is varied the characteristics of the substrate also changes. Hence, a low-cost sensor which can detect the material and its thickness is paramount important.

The microwave sensors are used by different researchers for various applications [1-6]. The sensors using various configurations like split ring resonator (SRR) [7-9], complementary split ring resonator (CSRR) [10-12], inter digital capacitor (IDC) [13-14], SIW [15-16] have been proposed.

In this paper, a novel planar microwave sensor using asymmetric complementary split ring resonator (ACSRR) is designed. The simulation results show the sensor resonates at 6.45GHz. The S21 shows when the sensor loaded with material under test, it can identify the correct material by resonant frequency shift. The resonant characteristics of the substrate is studied by varying the thickness of the substrate.
2. Asymmetric CSRR
The conventional complementary split resonator consists of two complementary rings. It can be either
circular or rectangular rings. The width of the ring is uniform and symmetric in arrangement. The
proposed asymmetric CSRR have the similar complementary rings but with asymmetric width. The
rings are of non-uniform width. Figure 1 shows the basic structure of asymmetric resonator. The
Figure 2 shows the ACSRR loaded on the ground plane of the microstrip line. The $S_{21}$ response shows
the sensor operate at 6.45 GHz. The $S_{21}$ of the ACSRR is presented in Figure 3. All dimensions of the
sensor are in mm. The overall size the resonator is $w\times w$. The stripline width is $s$. The optimum
dimensions of the sensor are given by Table 1. The overall dimension of the sensor is $GL\times GW\times tm$.

![Figure 1. Asymmetric Complementary Split Ring Resonator (ACSRR).](image1)

![Figure 2. ACSRR loaded on the ground plane of the microstrip line](image2)
Table 1. Overall dimensions of the sensor

| Parameters | Dimension (mm) | Parameters | Dimension (mm) |
|------------|----------------|------------|----------------|
| GL         | 100            | c          | 0.3            |
| GW         | 50             | d          | 0.3            |
| s          | 1.7            | tm         | 0.8            |
| a          | 0.6            | w          | 3.3            |
| b          | 0.3            |            |                |

3. Identification of Material Under Test
The material under test (MUT) is modelled with dimensions of 5mm×5mm×5mm. The MUT placed on the resonator which is at the ground plane. The MUT can be any sample material available. In this simulation study, three samples are selected, for which the identification has to be done. First, the sample material 1 is loaded on the sensor surface and the resonant frequency from the transmission coefficient is noted. The frequency shift is at 5.93 GHz as shown in Figure 4. When compared with unloaded sensor without any sample material loaded, the frequency is 6.45 GHz. The difference in shift is 0.52 GHz. The shift corresponds to sample material 1 which is Roger 5880.

Similarly, second and third material sample are loaded and corresponding frequency shift are recorded as 5.36 GHz and 4.8 GHz. This shows that each sample material when loaded have different frequency shift value. The frequency shift is mainly due to the dielectric constant of the samples. Thus when an unknown sample (one similar to any of the three MUT) from the laboratory is loaded on the sensor, the frequency shift will correspond to any of the one value in the Table 2.
Table 2. $S_{21}$ values of various MUTs (Samples)

| Samples                  | Frequency (GHz) | $S_{21}$ (dB) | Frequency Difference = unloaded frequency – MUT frequency (GHz) |
|--------------------------|-----------------|---------------|---------------------------------------------------------------|
| Unloaded (No sample)     | 6.45            | -19.68        | -                                                            |
| MUT1 (Roger 5880, $\varepsilon_r = 2.2$) | 5.93            | -18.34        | 0.52                                                          |
| MUT2 (Epoxy Resin, $\varepsilon_r = 4$)   | 5.36            | -15.85        | 1.09                                                          |
| MUT3 (Roger RO3006, $\varepsilon_r = 6.5$) | 4.8             | -14.85        | 1.65                                                          |

4. Identification of Sample Thickness

The proposed sensor can also be used to find the thickness of the MUT. The MUT1 with various thicknesses are placed on the sensor and transmission coefficients responses are plotted as in Figure 5. It is noted that when the thickness of the sample are varied, the frequency values also changes. For 0.8mm thickness sample, the frequency value is 5.93GHz. As the thickness is increased, the frequency value decreases, the frequency shifts to the lower values.
5. Conclusions
In this paper, asymmetric CSRR having asymmetric ring width is proposed and analysed numerically for identification of material under test. The sensing performances of the sensor are validated through simulation. The sensor is able to sense and identify the material samples placed on the ground side below the microstrip line. The sensitivity of the sensor is verified by varying the thickness of the material sample under test. The proposed sensor can be good candidate to characterize any dielectric materials which are used for designing antennas, filters and other microwave devices.

6. References

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