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A compact wireless sensor for material characterization based on spoof localized surface plasmons

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In recent years, resonant sensors based on metamaterials have attracted wide attention due to their strong electromagnetic (EM) responses, designable EM properties and small sizes. Among them, spoof localized surface plasmons (LSPs) with high Q-factor have been adopted for material characterization due to their properties of strong confinement and enhancement of EM fields[1]. It has been proved that the LSP sensors are effective in the characterization of solid, liquid, microfluid, etc, and are especially suitable for the characterization of small and thin objects.

Here we propose a wireless sensor for remote and contactless characterization of dielectric materials. The proposed sensor is a metallic array of LSP units, as shown in Fig. 1(a), which is printed on the dielectric material sample to be characterized (the blue part). The corrugated metallic strip (yellow part) can be uniquely described by R1, R2, and R3 with a duty cycle of 0.5, and the resonance frequency is determined by these geometric parameters together with the permittivity and thickness of the material sample. The scattering (S-) parameters and the electric field (E-field) distributions have been simulated in the commercial software CST and shown in Fig. 1(a)-(b). Here, the LSP unit has a size of 4 mm and the sensor works at dipole mode in the X band and Ku band. The permittivity of the sample can be easily distinguished according to the resonance frequency with high accuracy because of the high Q-factor and strong sensitivity of LSP.

In experimental demonstration, an 8-18 GHz spot-focusing lens antenna was used as the microwave source (Fig. 1(c)). Several material samples to be tested are made 40mm×40mm-sized and 0.254mm-thick, and 10×10 LSP units are printed on them respectively. In measurement, the samples are placed 300 mm away from the lens antenna. When time window function of the vector network analyzer (VNA) connected to the antenna is set between 6.75ns and 7.33ns, the S11 parameters are recorded and calibrated, as plotted in Fig. 1(d). Obviously, one is able to identify the permittivities of different samples through comparing and calibrating the measured resonance frequencies with the simulated ones. Moreover, the wireless sensor proposed in this work provides the ability to remotely detect the change of permittivity of the materials without touching them, and therefore has great potential in non-contact high temperature sensing [2].

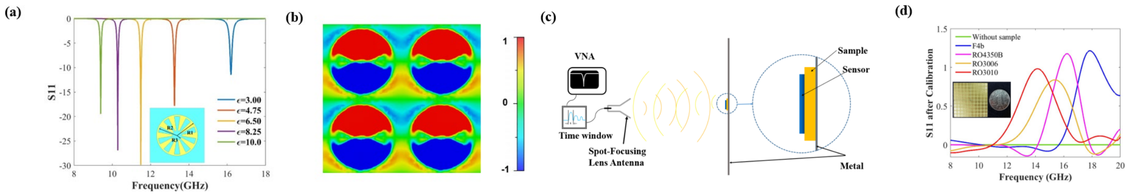

Figure 1. (a) Simulated S11 parameters of the designed LSP (R1=1.5mm, R2=1.4mm and R3=0.35mm) with samples of different permittivities. (b) Normalized E-field amplitude in the Z direction. (c) Schematic diagram of the experimental system. (d) Measured results of calibrated S11 parameters with 10×10 array.

References

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