Optimization of CSRR based RF Sensor for detecting ethanol in petrol

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Abstract

We have reported the solvent based optimization of radio frequency (RF) sensors for detecting ethanol mixtures in petrol using complementary split ring resonators (CSRR) using binary particle swarm optimization (BPSO). It is observed that the RF sensors designed using BPSO enabled faster convergence and provided efficient designs offering enhanced sensitivity

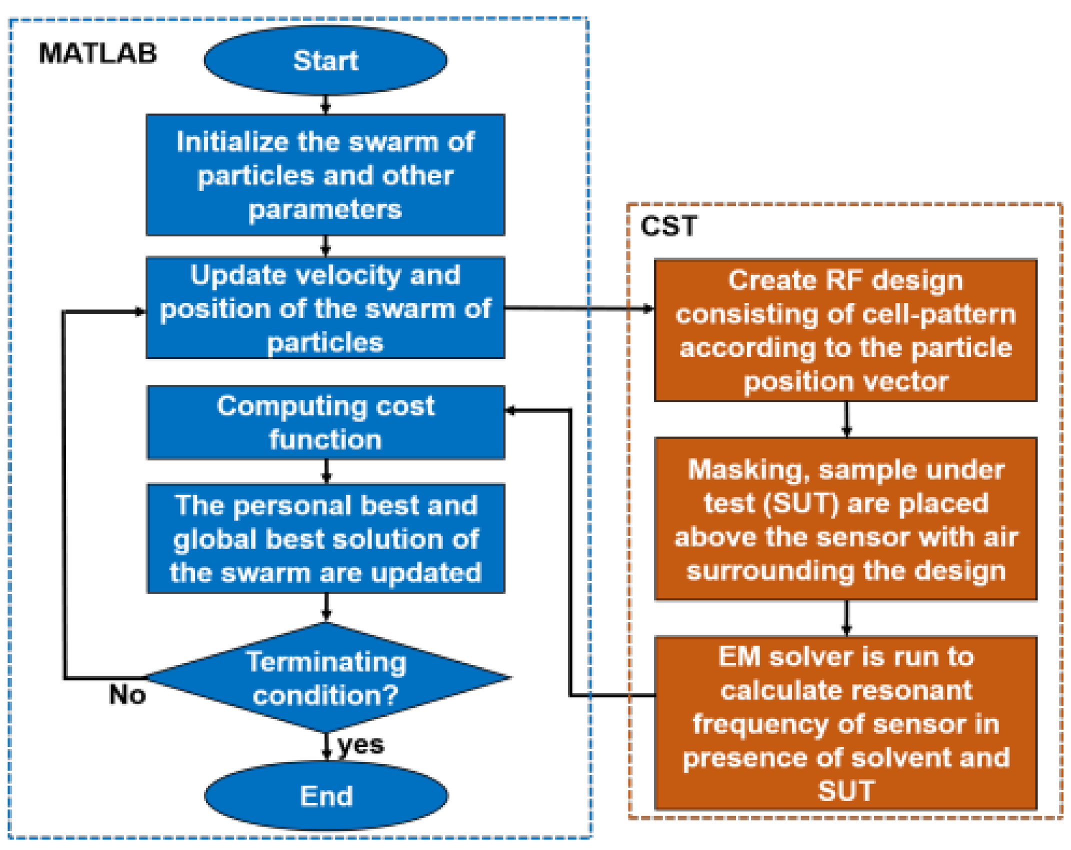
Methodology

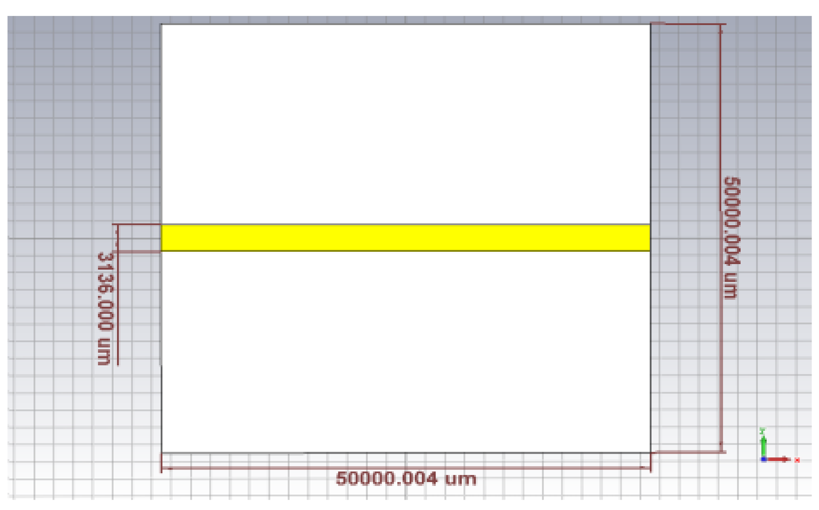
The normalized frequency (NF) is defined as $NF = \frac{\Delta f}{f_{petrol}}$

Where, f_{petrol} denotes the resonant frequency of the sensor when in pure petrol and Δf is given by $\Delta f = f_{ethanol-petrol} - f_{petrol}$ .Where, $f_{ethanol-petrol}$ is the resonant frequency of the sensor when in ethanol petrol blend. The algorithm is defined as a minima problem called cost function (CF) which is reciprocal of NF. The main goal in this work is to achieve high sensitivity, hence reducing the CF in order to reach the minima corresponding to the convergence of the algorithm for providing desirable final design for optimization. The equation for CF is given by,

$$CF = \frac{1}{NF} = \frac{f_{petrol}}{\Delta f}$$

The entire optimization procedure is concisely depicted in the flow chart as follows and the back view consisting of microstrip line in conventional CSRR, updated CSRR, air-based cell patterned designs and solvent based cell patterned designs.





Design Type	f_{petrol}	Δf	NF
Conventional CSRR	1.47 GHz	0.015 GHz	0.0102
Updated CSRR (before optimization)	1.485 GHz	0.015 GHz	0.0101
Air specific cell patterned Design (after air based optimization)	2.45 GHz	0.04 GHz	0.01632
Petrol specific cell patterned Design1 (after petrol based optimization)	3.855 GHz	0.07 GHz	0.01815
Petrol specific cell patterned Design2 (after petrol based optimization)	4.944 GHz	0.132 GHz	0.02669

Fig 1: Flow chart of optimization procedure (left); Back view of all sensors (Conventional, updated and cell patterned CSRR) (right-top); Comparison table for all designs (right-bottom)

Results

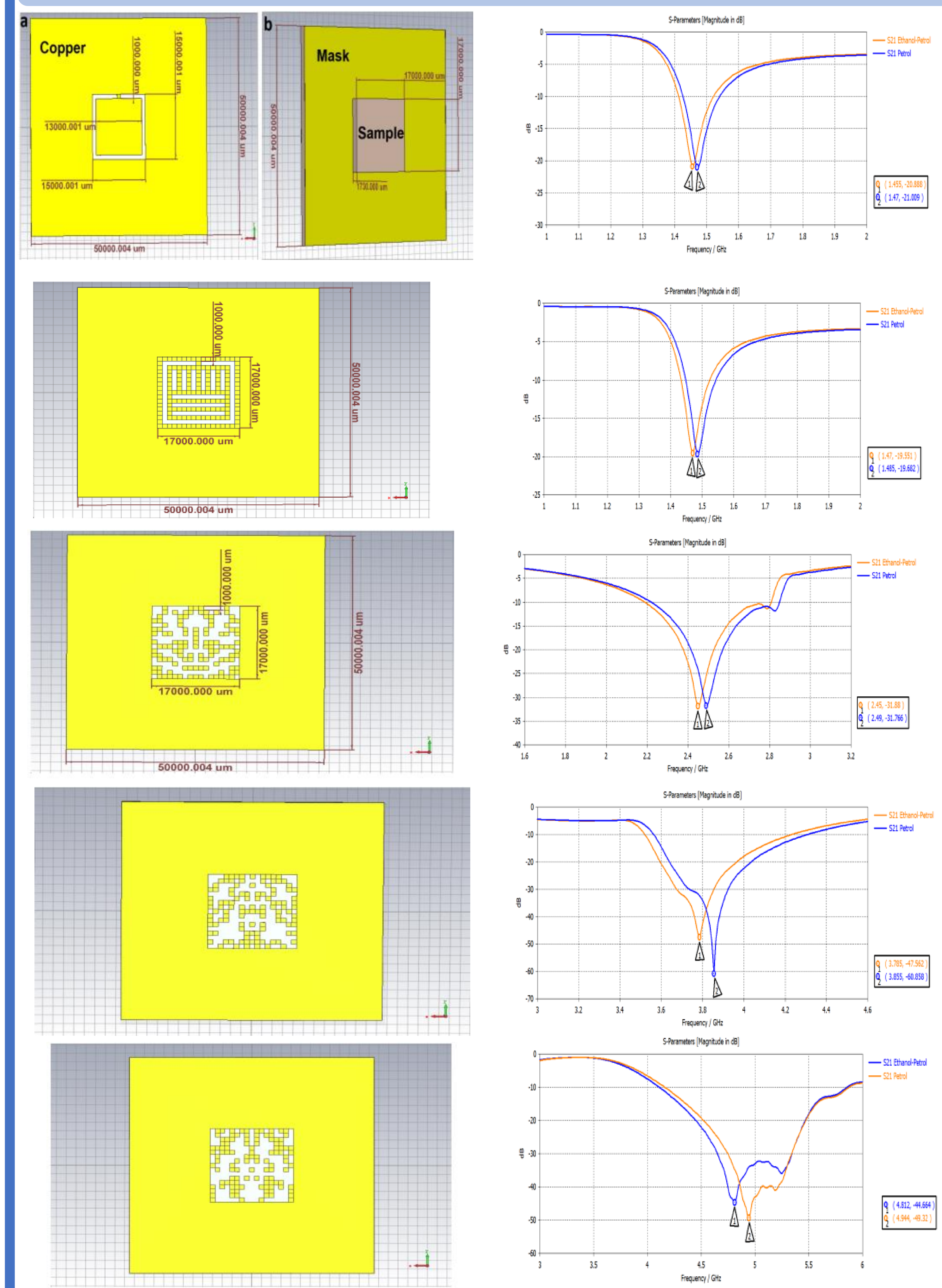


Fig 2: Top to bottom - Front view (left) and Mag S21 versus freq plot (right) of Conventional CSRR, Updated CSRR, Air-based cell patterned CSRR, Solvent based cell patterned Design1 and Design2 CSRR

Conclusions

This work presents the importance of solvent-based optimization for RF sensors with maximized sensitivity and efficiency using BPSO for detecting ethanol in ethanol-petrol mixtures using cell-patterned CSRR designs. This technique can also be applicable for detection of any SUT in solvent.

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