高靈敏度主動開口環共振腔量測液體介電常數

High Sensitive Active Split-Ring Resonators for Measuring Permittivity of Liquid

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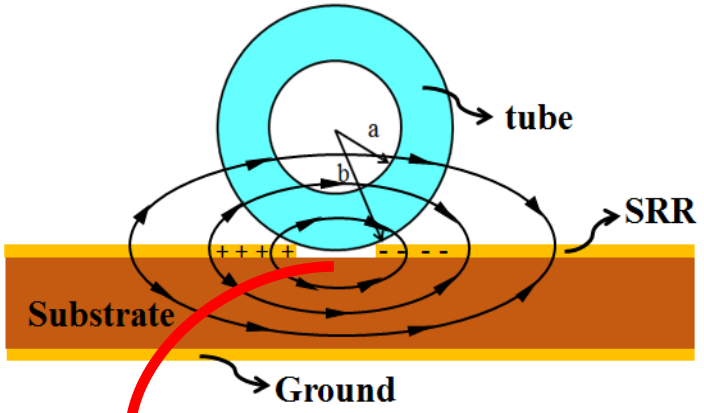
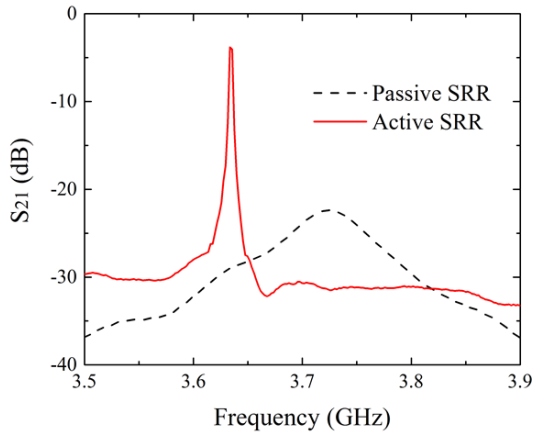
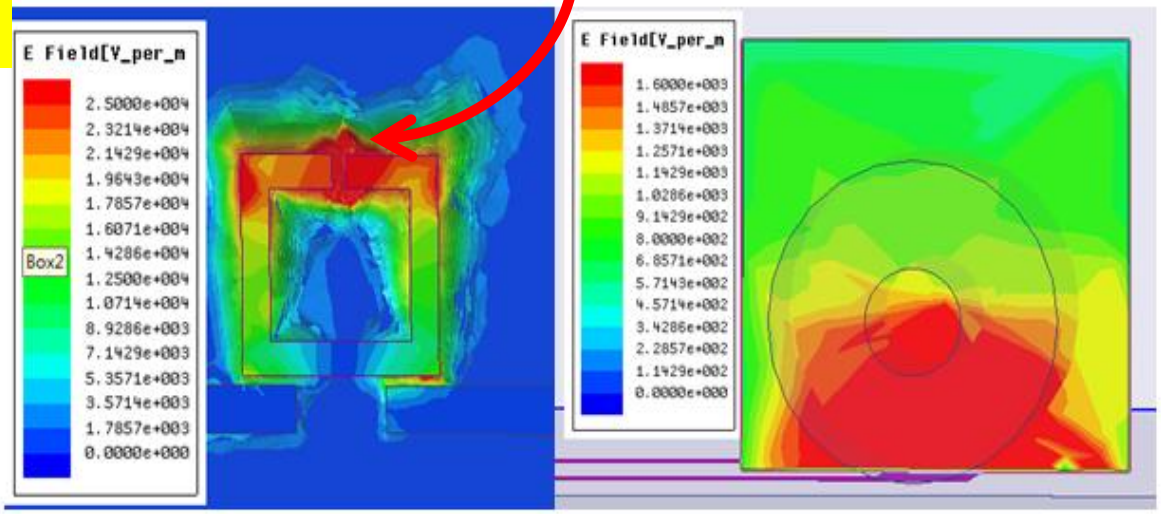
DA-SRR Theory Analysis

- $f_r = \frac{1}{2\pi\sqrt{LC_{total}}}$ ， $C_{total} = C_0 + \varepsilon_{MUT} C_{MUT}$
- High sensitivity theory analysis :
- High Q property
- $U = \frac{1}{2}\varepsilon_0 \int E^2 \, dV = \frac{1}{2}\varepsilon_0 E_0^{\,2} V_m$ ， $V_m \cong \int \frac{E^2}{E_0^{\,2}} dV$
- V_m is the volume of the penetration of the E field



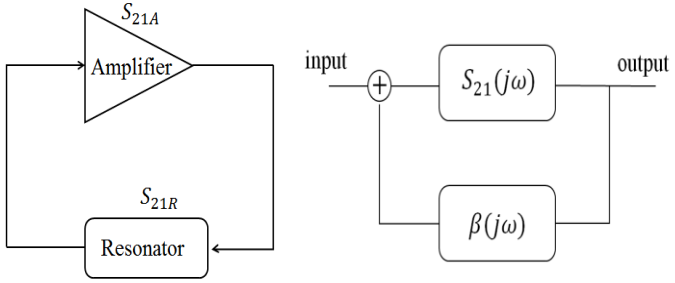
The Q factor is enhanced by 22 times

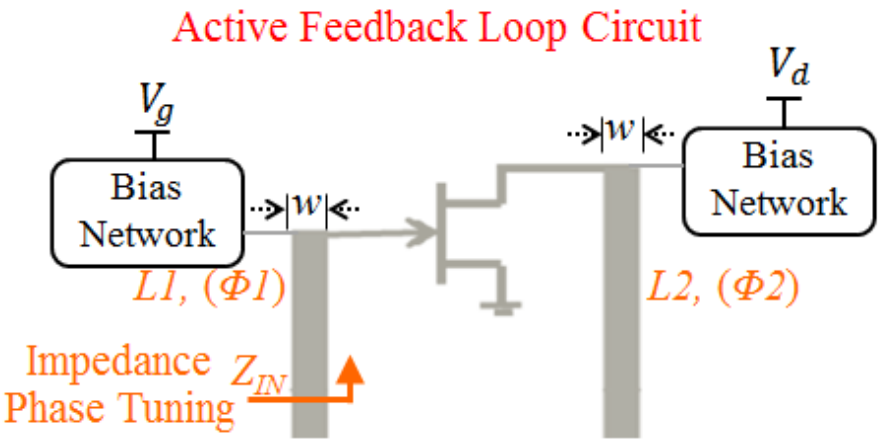




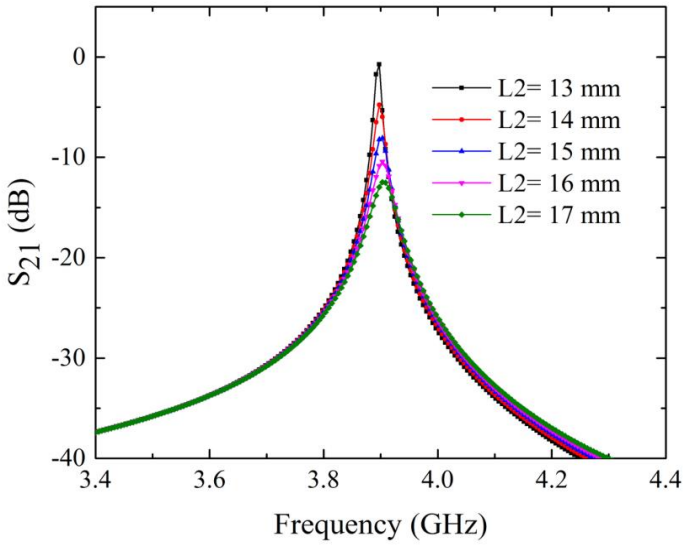
DA-SRR Design

- Active feedback loop method
- $H(j\omega)=\frac{S_{21}(j\omega)}{1-S_{21}(j\omega)*\beta(j\omega)}$
- Simulation optimal Q = 1265



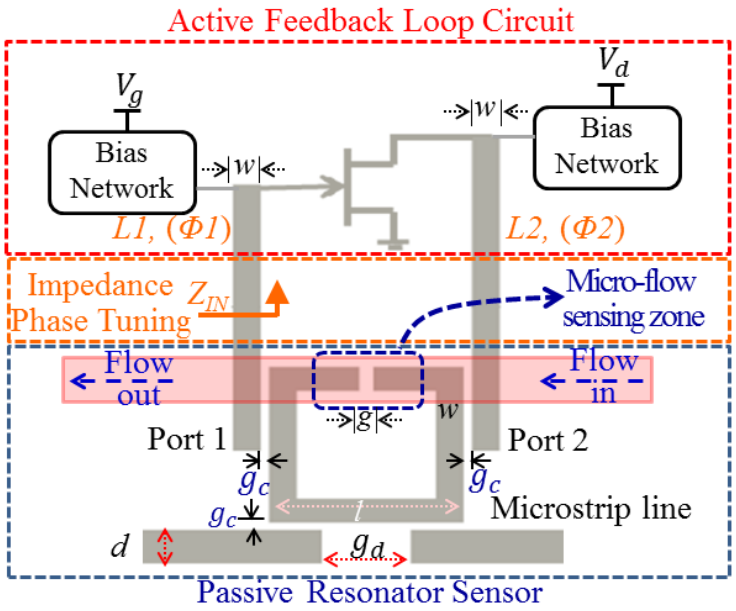


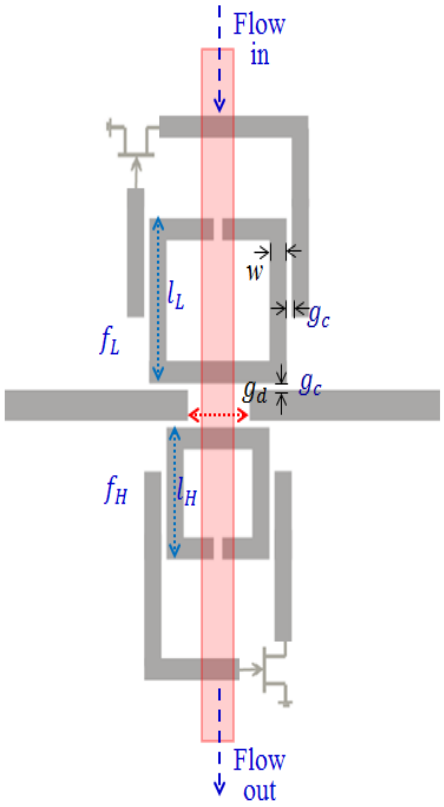
- DA-SRR calibration technique
- $\varepsilon_{eff} \propto {f_r}^{-2}$
- $\varepsilon_{eff} = 1+(\varepsilon_{rMUT}'-1)q_1 +(\varepsilon_{tube}'-1)q_2$
- ${f_{rL}}^{-2} = S_1(\varepsilon_{rMUT}'-1) + {f_{L0}}^{-2}+ E_{tube}* {f_{L0}}^{-2}$
- ${f_{rH}}^{-2} = S_2(\varepsilon_{rMUT}'-1) + {f_{H0}}^{-2}+ E_{tube}* {f_{H0}}^{-2}$

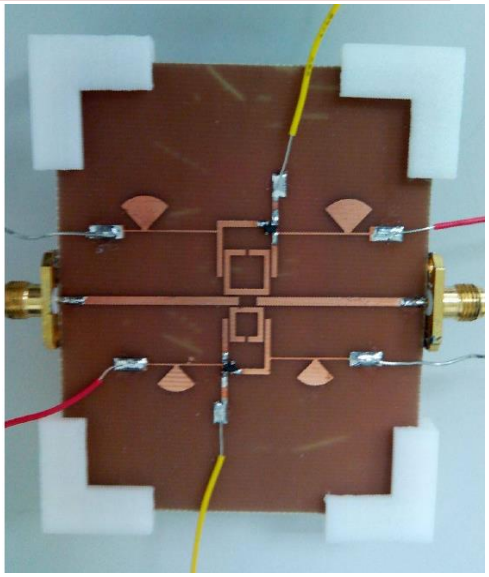


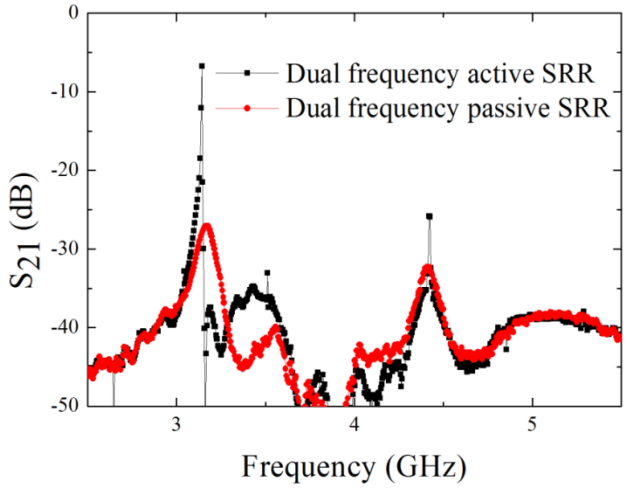
DA-SRR Structure

- DA-SRR circuit stricture
- l_L = 8 mm，g = 0.5 mm，w = 1 mm， g_d = 3.5 mm，l_H = 6 mm and g_c = 0.3 mm。f_{L0}= 3.1291 GHz，f_{H0} = 4.4745 GHz。
- Q_L = 1023 ，Q_H = 984









Experiment Results

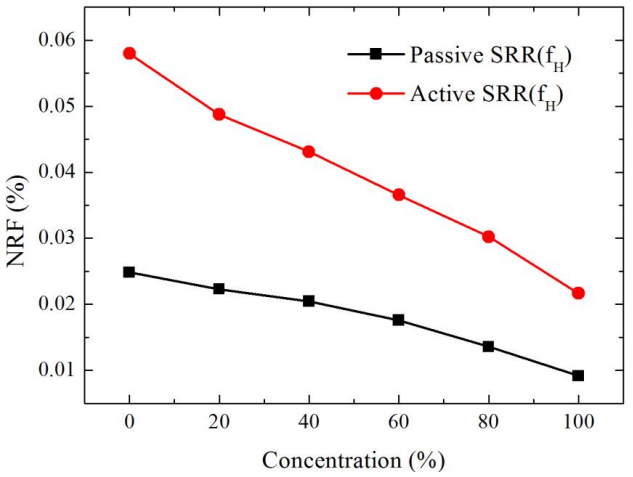
- The Q factor of sensor is enhanced by 22 times from (passive SRR) 49.7 to 1098.
- The sensitivity is improved by 2.3 to 3.7.
- Average error : 4.5 %

Passive SRR Sensor:

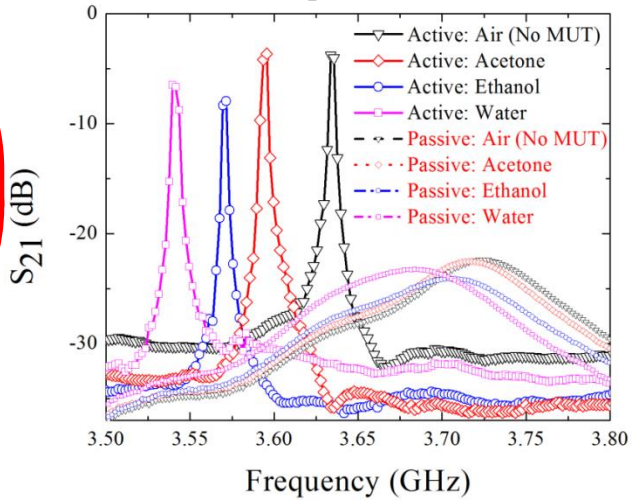
Parameter	f (GHz)	Q	S_{21} (dB)	$\Delta f/f_{air}$ (%)	$(\Delta f/f_{air})/\Delta\varepsilon_r$(%)
Air (no MUT)	3.7257	49.7	-22.4	---	---
Acetone	3.7157	35.7	-22.5	0.27	0.013
Ethanol	3.7078	49.0	-24.1	0.48	0.02
Water	3.6834	36.4	-23.3	1.10	0.014

Active SRR Sensors:

Parameter	f (GHz)	Q	S_{21} (dB)	$\Delta f/f_{air}$ (%)	$(\Delta f/f_{air})/\Delta\varepsilon_r$(%)
Air (no MUT)	3.6336	1098.4	-3.81	---	---
Acetone	3.5955	1016.4	-3.67	1.00	0.048
Ethanol	3.5836	1041.2	-4.89	1.37	0.057
Water	3.5412	728.0	-6.50	2.54	0.031



DA-SRR and Dual passive SRR sensors



The measured S_{21} performance of various solvents