Dielectric Constant Experiments Summary

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Task list

6.5.1 NaCl, NH_4NO_3, KNO_3, $NaNO_3$,$KClO_3$ varying humidity from 0-10%

6.5.2 Mixing two powders of varying humidity from 0-10%

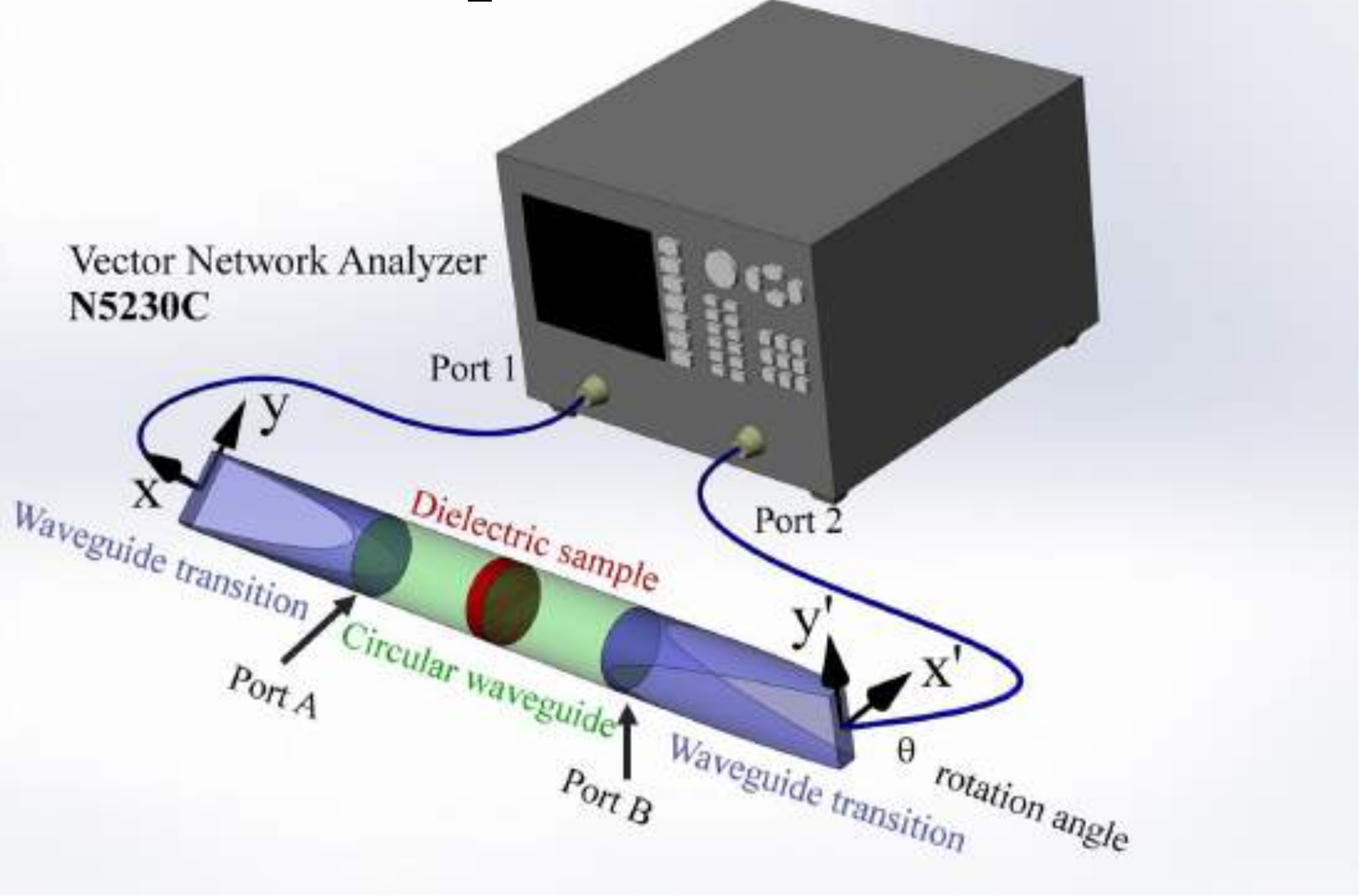
6.5.3 Aluminum powder

6.5.4 Water

6.5.5 Icing sugar (powder) humidity from 0-10%

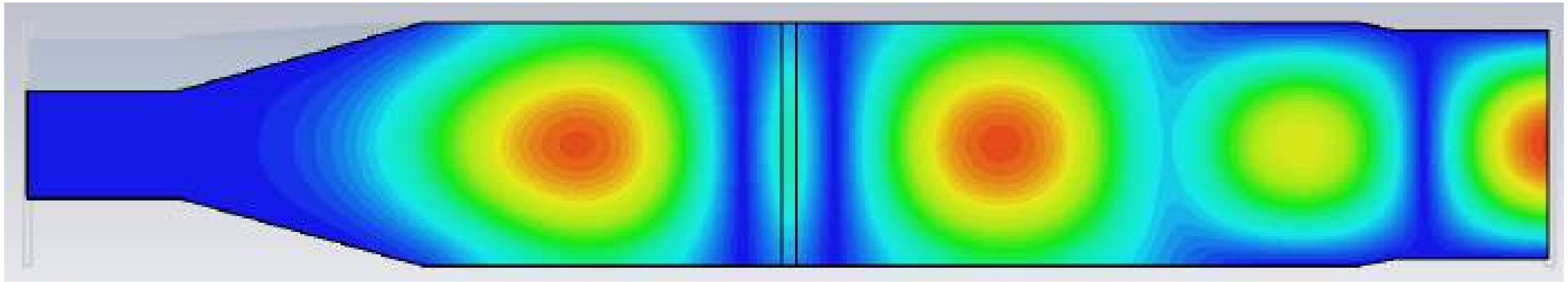
6.5.6 Fuel oil (car gasoline and diesel)

Experiment setup

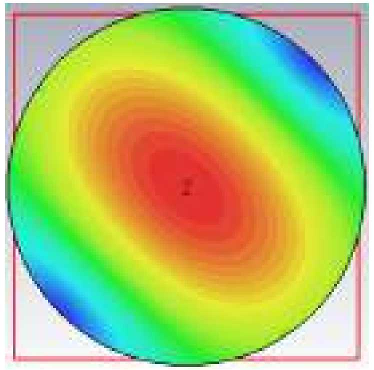


Simulations (E field, $\theta = 45^o$)

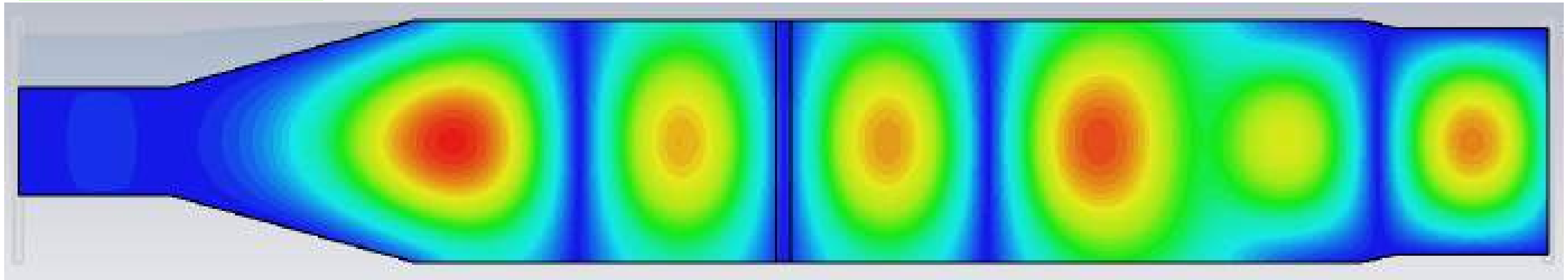
E-mode

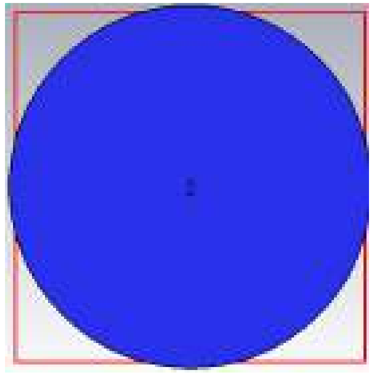


Z = 0 plane

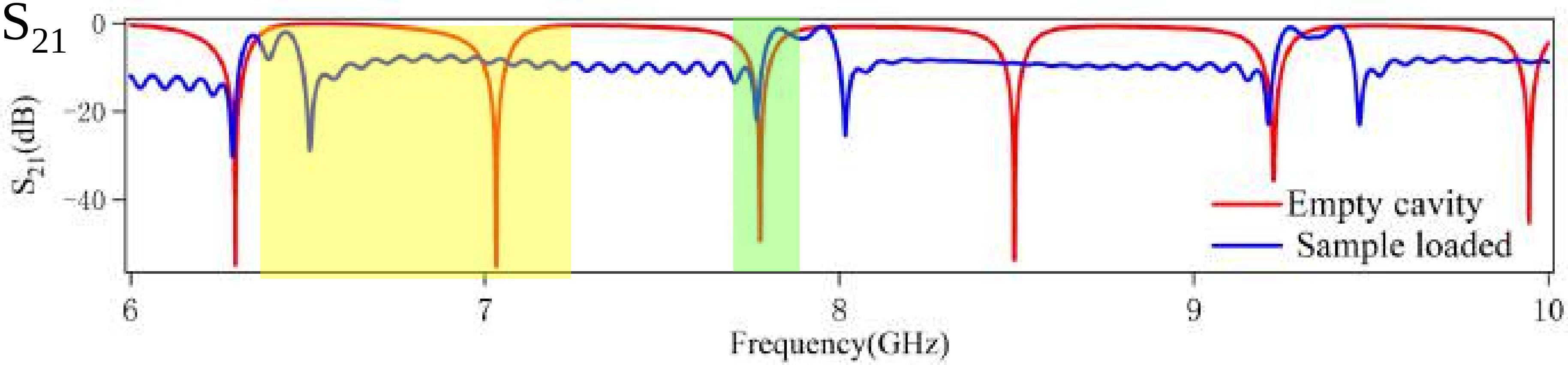


H-mode





S_{21}



Resonant method

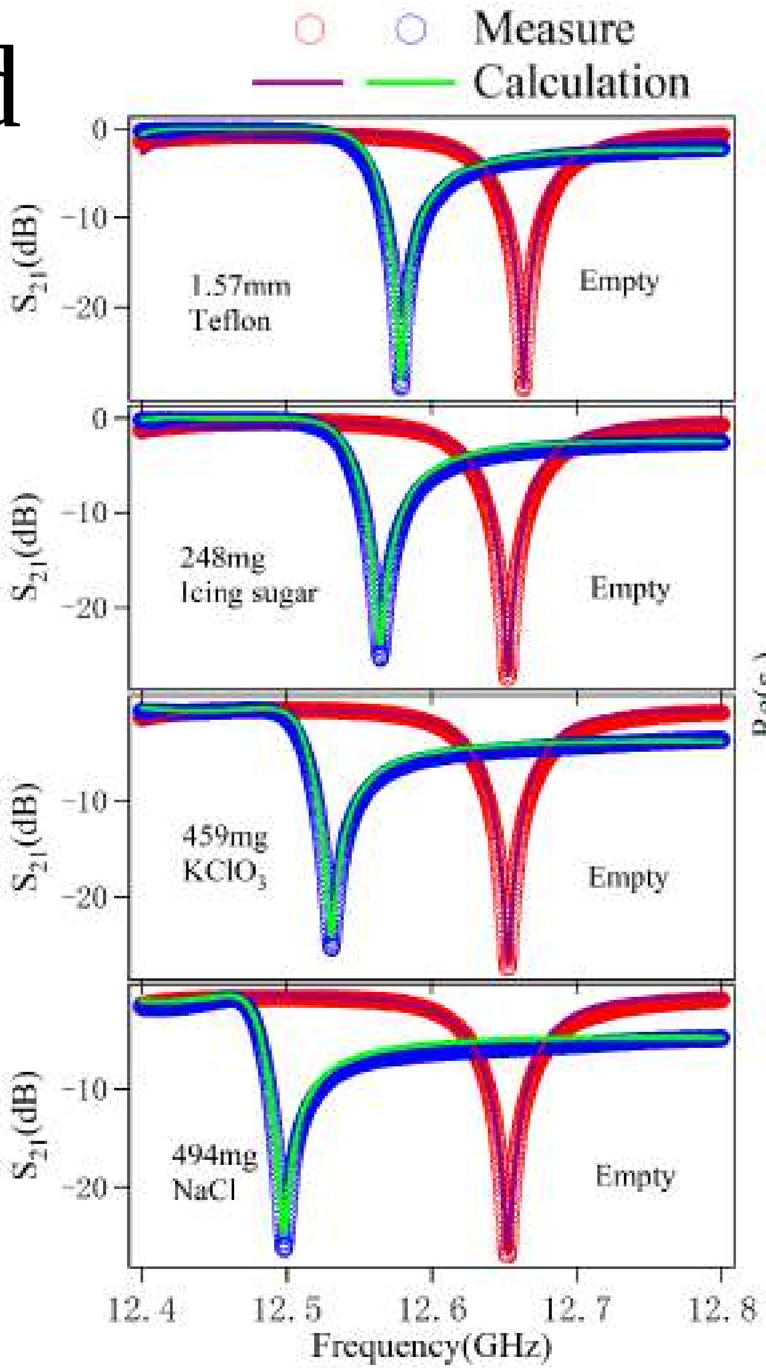
Sample	ϵ_r
NaCl	4.71
NH_4NO_3	5.37
KNO_3	3.91
$KClO_3$	4.36
Sugar	1.90
$NaNO_3$	4.60
Teflon	2.11

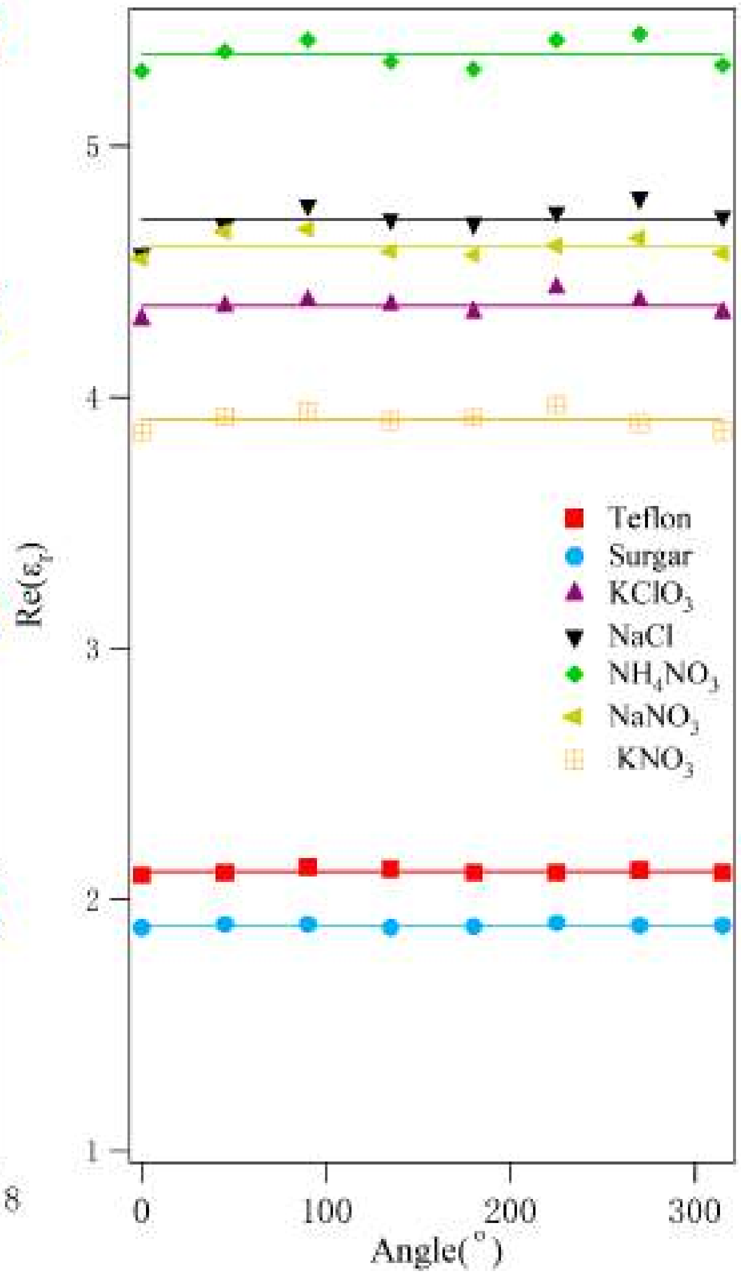
1.57mm Teflon

248mg icing sugar

459mg $KClO_3$

494mg NaCl





Error bar

1.09%

1.43%

0.97%

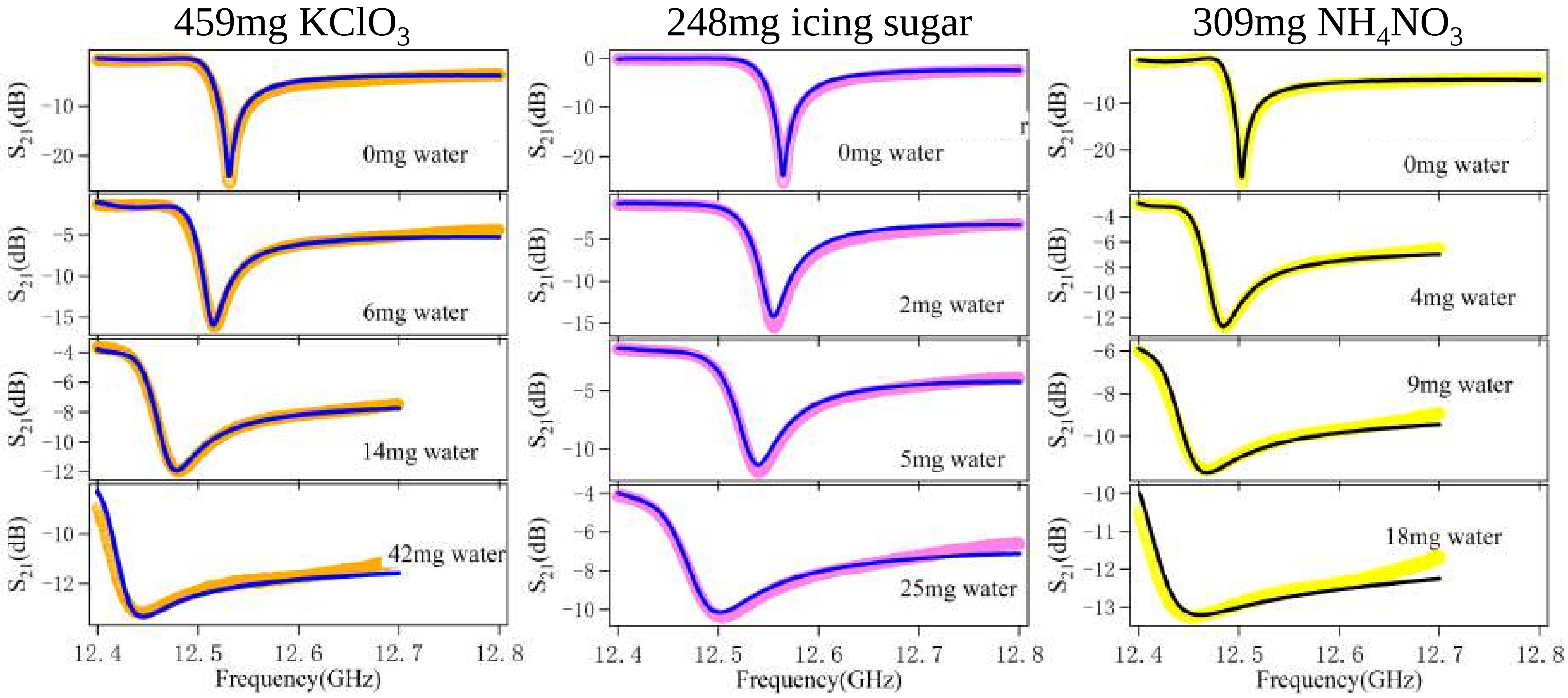
0.89%

0.96%

0.51%

0.38%

Spectra vs. humidity



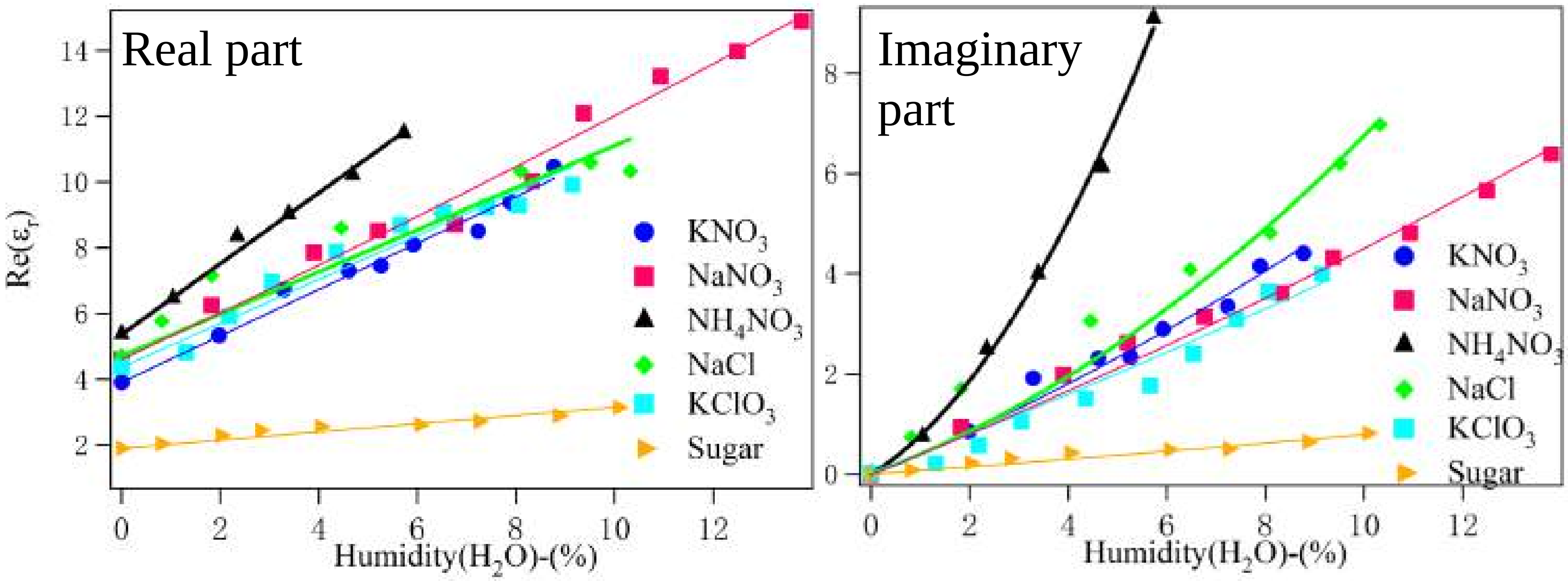
Empirical model for water content

$$\epsilon = \epsilon_s + a\epsilon_w w_c + b\epsilon_w w_c^2 + i \cdot \alpha w_c^2$$

- ϵ_s -- dielectric constant at dry material
- ϵ_w -- dielectric constant of water (57.95 + 32.72i) [Barthel et al];
- a, b -- empirical parameter
- α -- conductivity loss parameter
- w_c -- water content in mass(%)

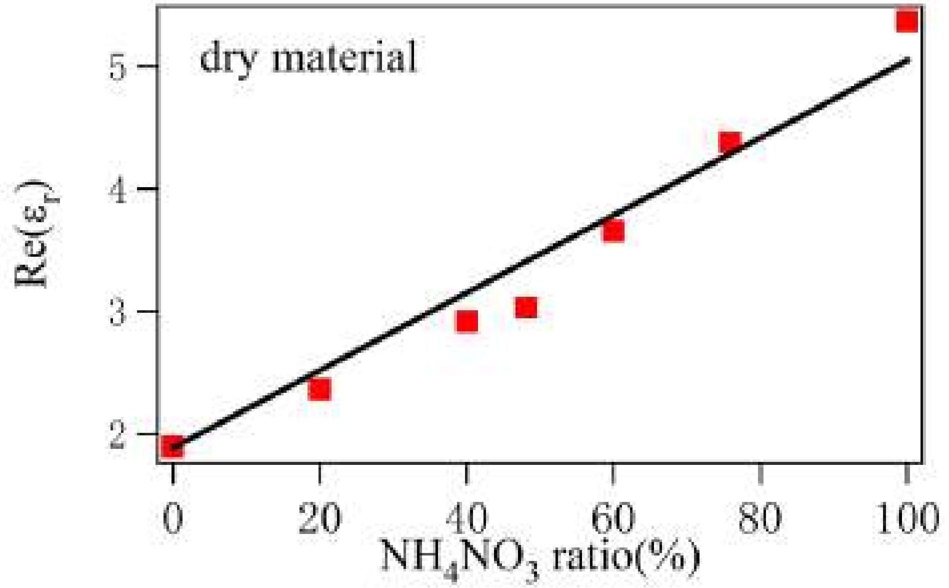
Pure chemicals at humidity from 0-10%

Solid lines: calculation results

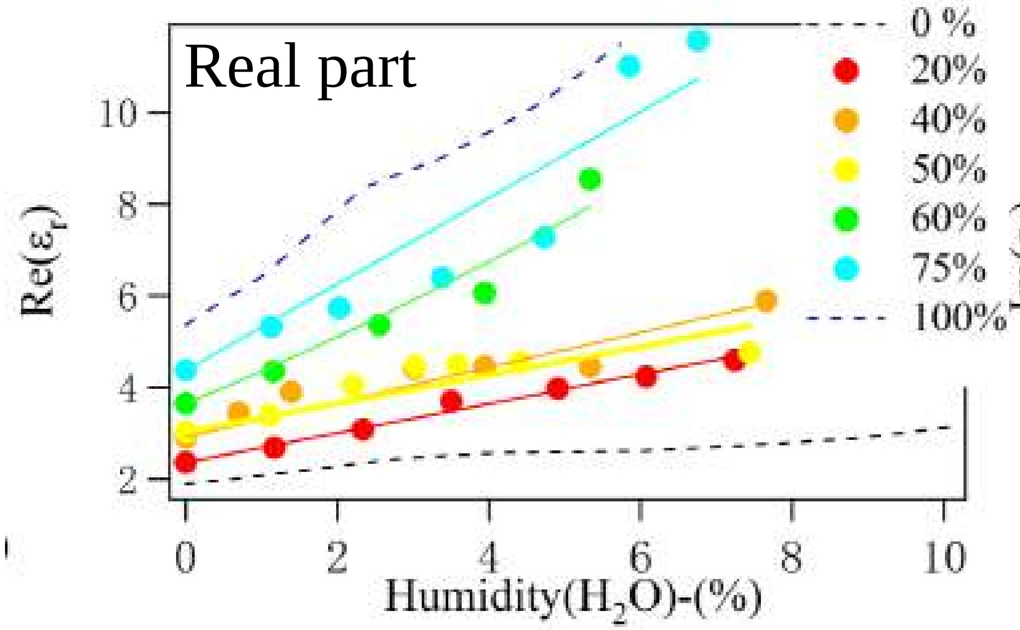


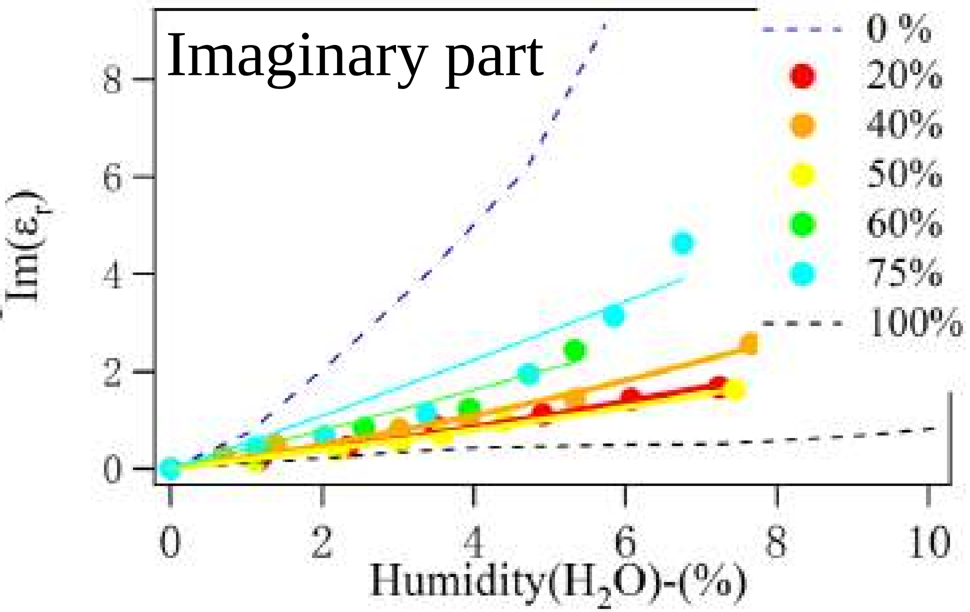
	$\boldsymbol{\epsilon_w = 57.95 + 37.22i}$ [Barthel et al]						
Sample	a	b	Alpha	**Sample**	a	b	Alpha
KNO_3	1.216	0.01	133.0	NaCl	1.104	0	315.5
$NaNO_3$	1.208	0.7	28.5	$KClO_3$	1.152	0	40.7
NH_4NO_3	1.856	0	1650.5	sugar	0.216	0	8.4

Mixture: NH_4NO_3 in sugar



Percent(%)	a	b	Alpha
0	0.216	0	8.4
20	0.522	0	80.5
40	0.656	0	109.5
50	0.536	0	57.5
60	1.176	0.4	84.5
75.87	1.624	0.4	144
100	1.856	0	1650.5





Task list

6.5.1 NaCl, NH_4NO_3, KNO_3, $NaNO_3$,$KClO_3$ varying humidity from 0-10% ✓

6.5.2 Mixing two powders of varying humidity from 0-10% ✓

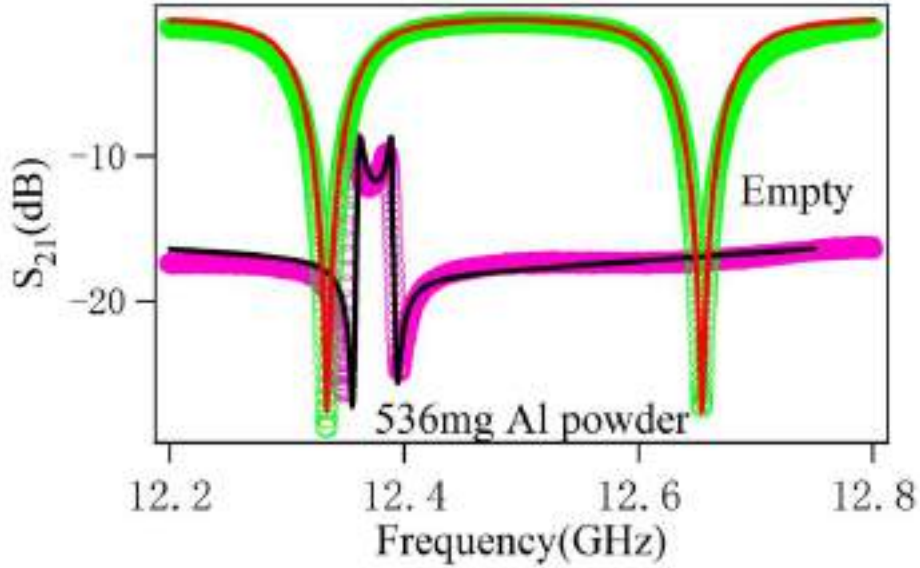
6.5.3 Aluminum powder

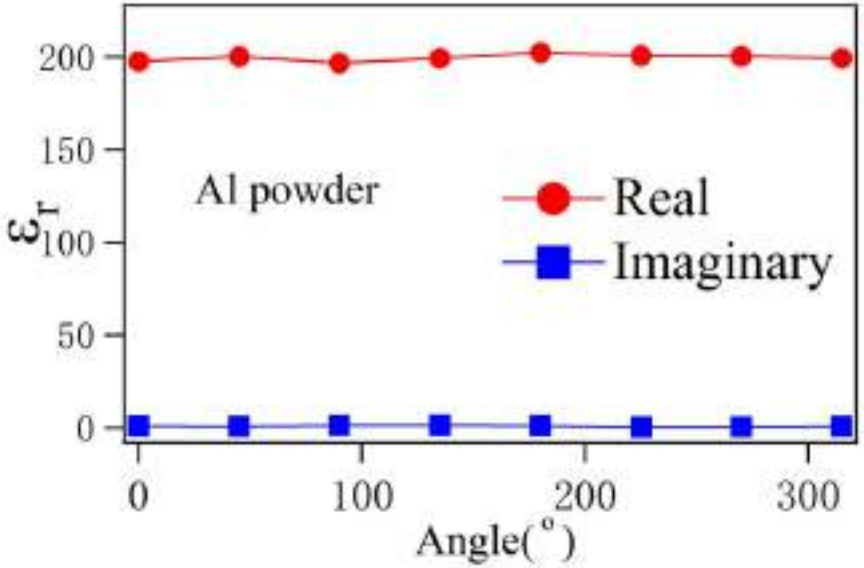
6.5.4 Water

6.5.5 Icing sugar (powder) humidity from 0-10% ✓

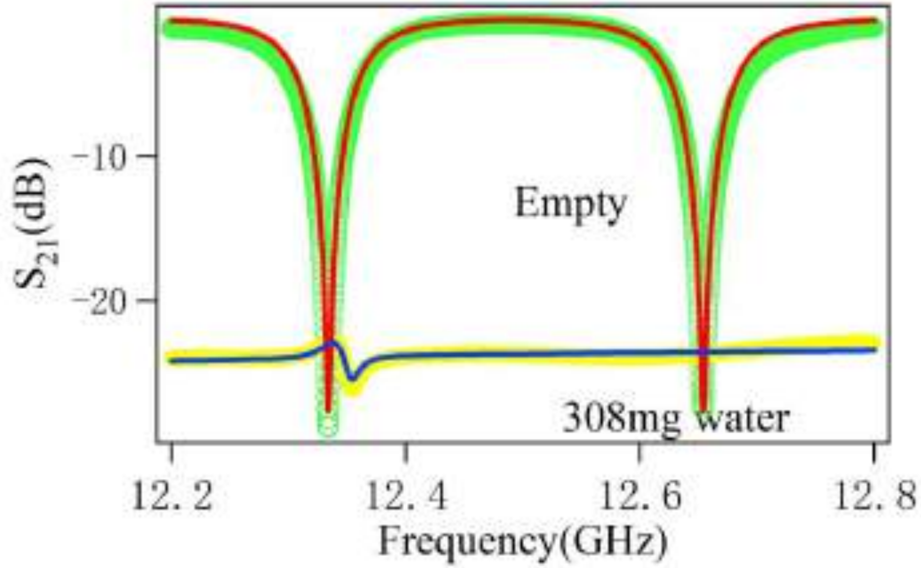
6.5.6 Fuel oil (car gasoline and diesel)

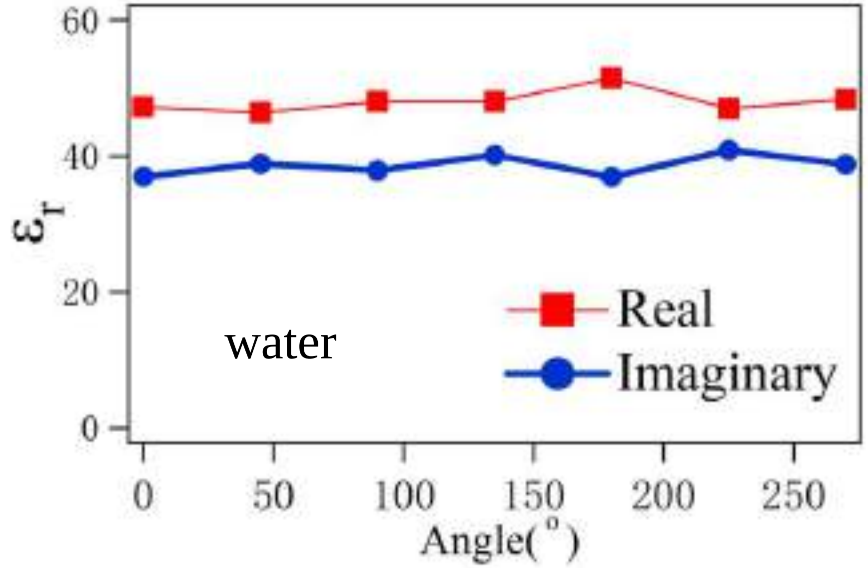
Problem: water and Al powder





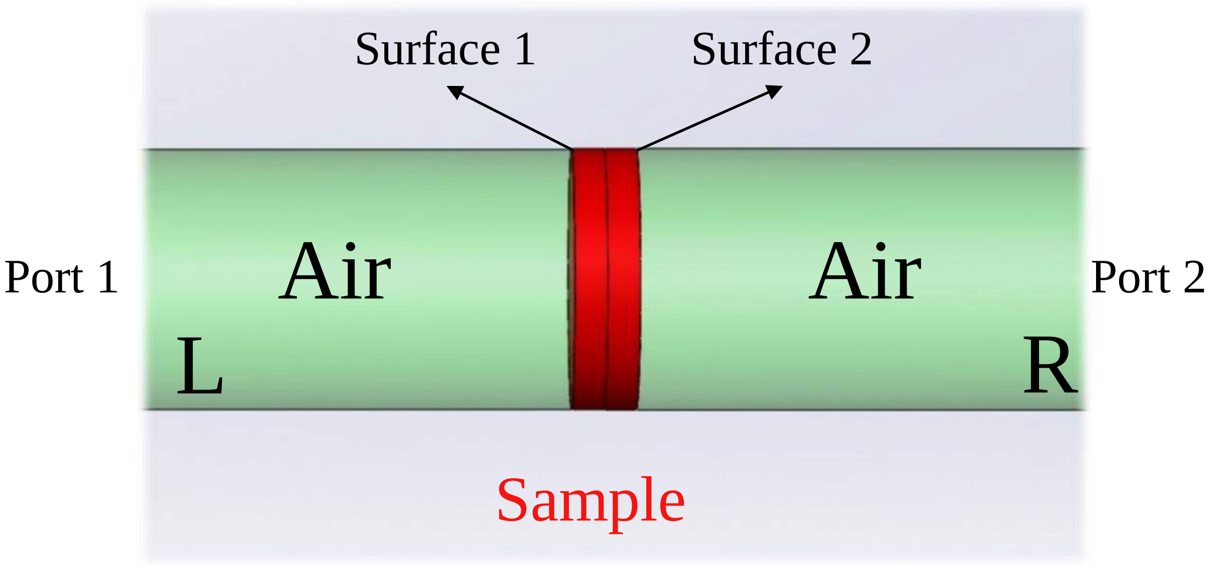
$\epsilon_r = 199.65$
$+0.96i$
$\Delta\epsilon_r = 3.7\%$

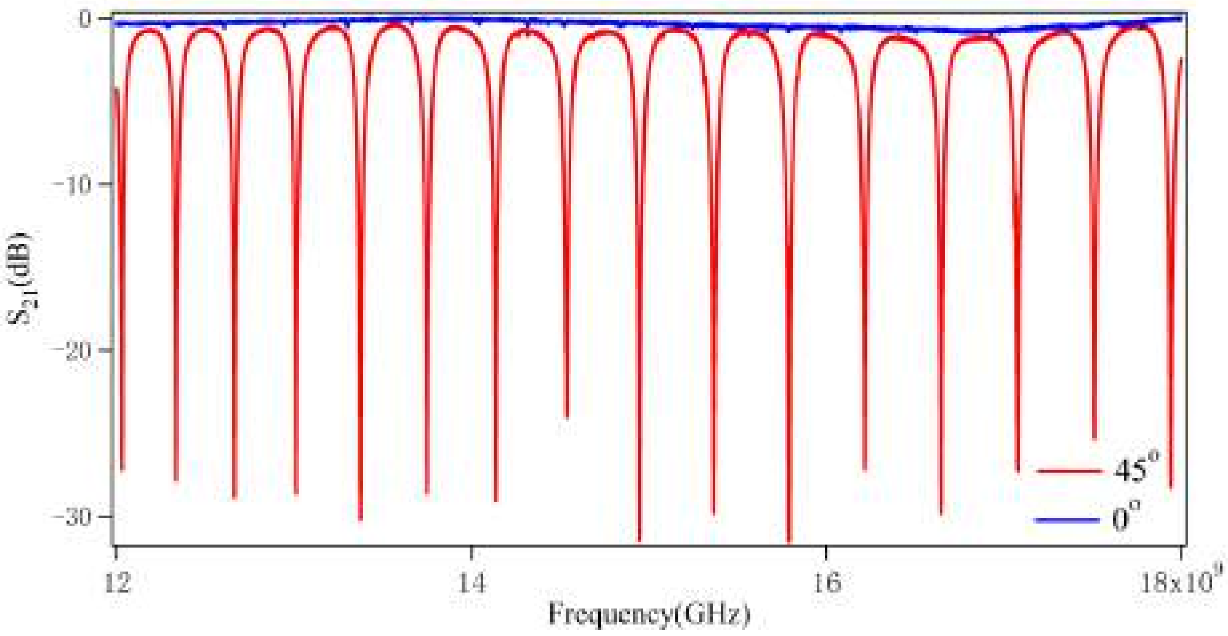




$\epsilon_r = 45.12$
$+38.00i$
$\Delta\epsilon_r = 7.9\%$

Non-resonant measurement (theta = 0°)



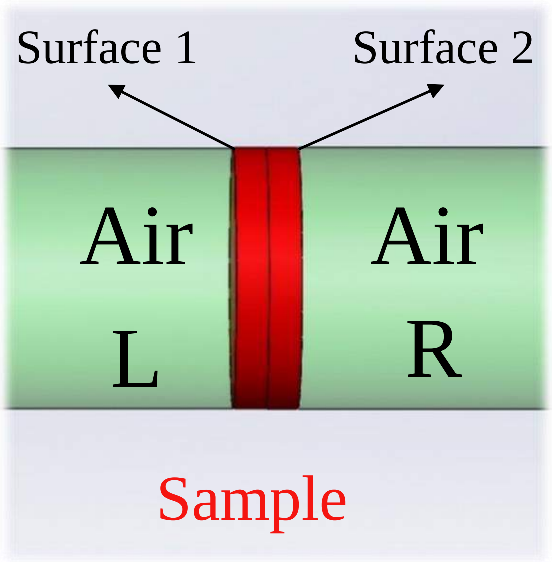


$$M_i = L \cdot T_{refi} T_i T_{refi}^{-1} \cdot R$$

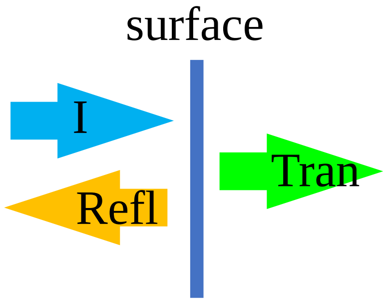
$$M_i = \begin{pmatrix} S_{12}^i - \frac{S_{11}^i S_{22}^i}{S_{21}^i} & \frac{S_{11}^i}{S_{21}^i} \\ -\frac{S_{22}^i}{S_{21}^i} & \frac{1}{S_{21}^i} \end{pmatrix}$$

➔ Measure 4 S parameters
➔ Define transfer matrix
➔ Fit result

Definition of transfer matrix



$$T_i = \begin{pmatrix} e^{-\gamma_i d} & 0 \\ 0 & e^{\gamma_i d} \end{pmatrix} \qquad \gamma_i = \gamma_i(\epsilon_i^*)$$



$$T_{refi} = \begin{pmatrix} \frac{1}{1-\Gamma_i} & \frac{\Gamma_i}{1-\Gamma_i} \\ \frac{\Gamma_i}{1-\Gamma_i} & \frac{1}{1-\Gamma_i} \end{pmatrix} \qquad \Gamma_i = \Gamma_i(\epsilon_i^*)$$

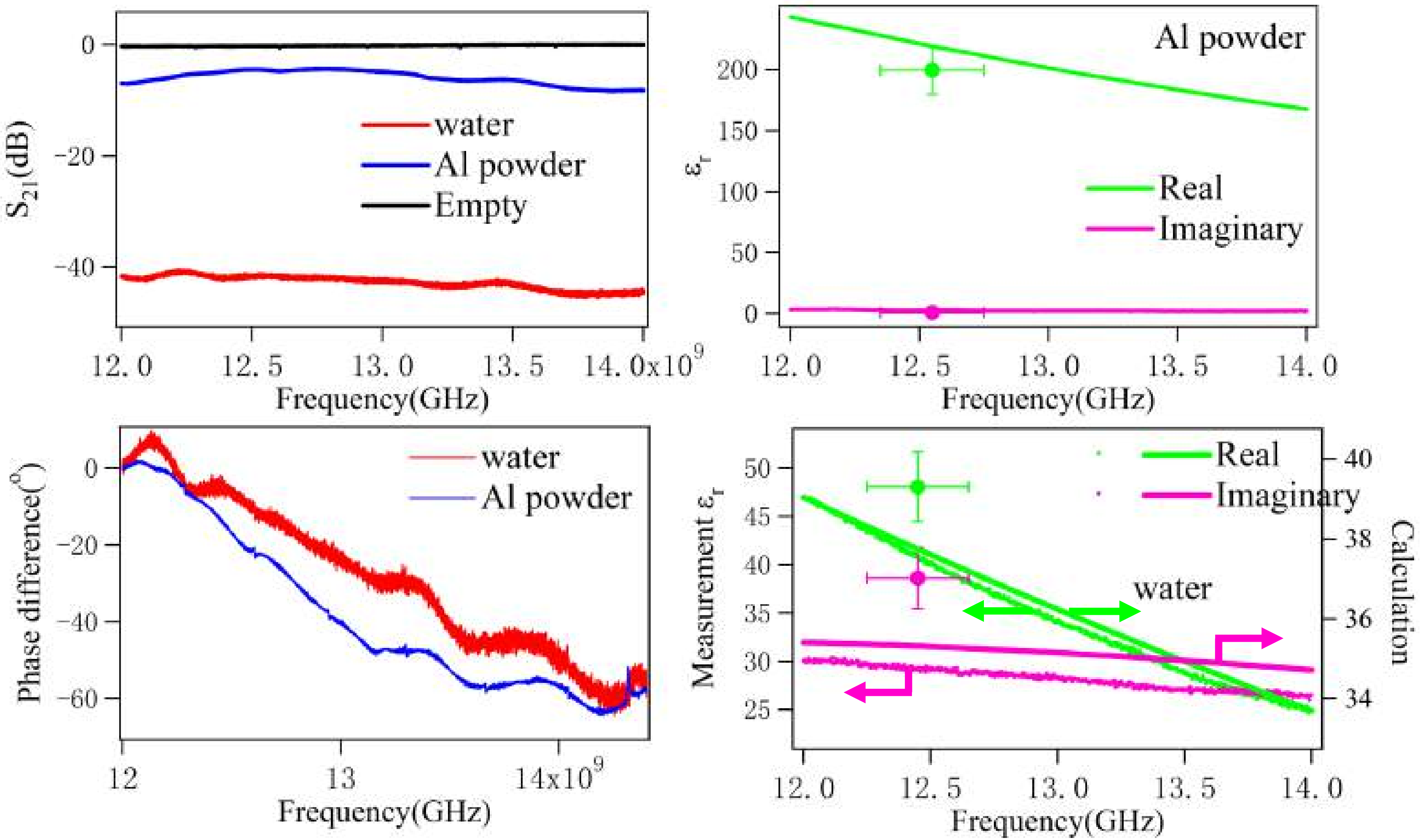
$$M_i = L \cdot T_{refi} T_i T_{refi}^{-1} \cdot R$$ Sample measure

$$M_0 = L \cdot T_{ref0} T_0 T_{ref0}^{-1} \cdot R$$ Standard measure

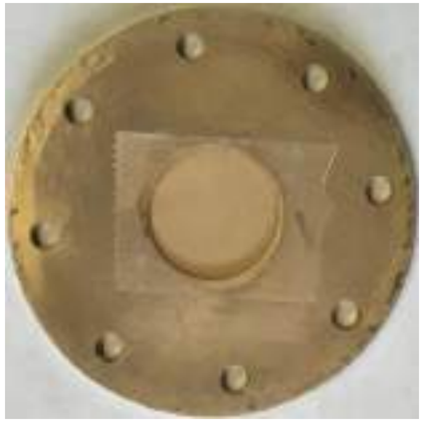
$$M_0^{-1} = R^{-1} \cdot T_{ref0} T_0^{-1} T_{ref0}^{-1} \cdot L^{-1}$$

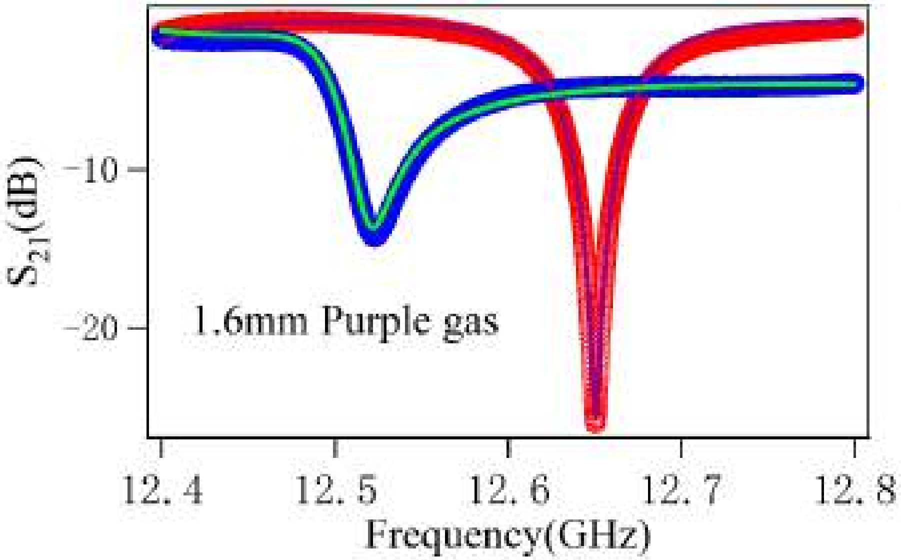
[illegible]

Raw data and fitting results

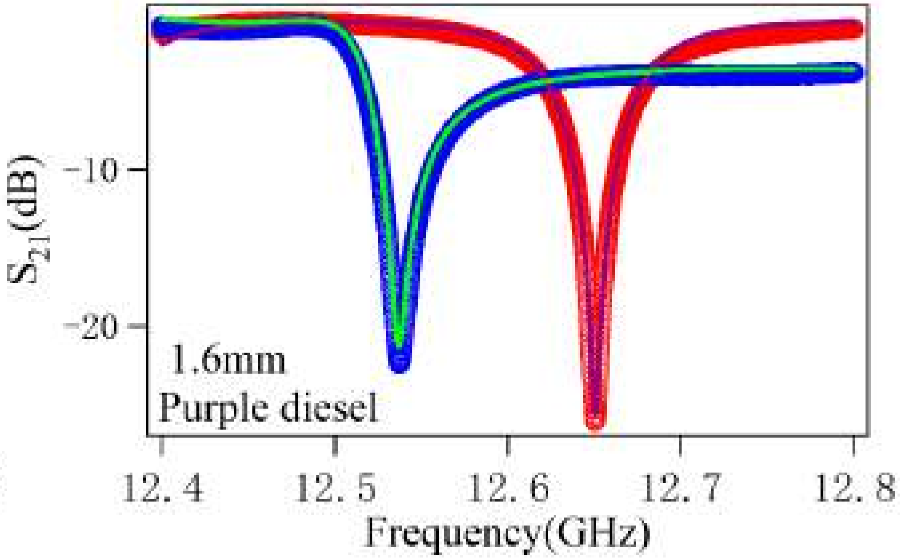


Car fuel Measurement





ϵ_r=3.016+0.196i



ϵ_r= 2.666 + 0.028i

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6.5.4 Water ?

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Next step

- Redo measurement of water.