Data analysis
&
Empirical Model
of dielectric constant measurements

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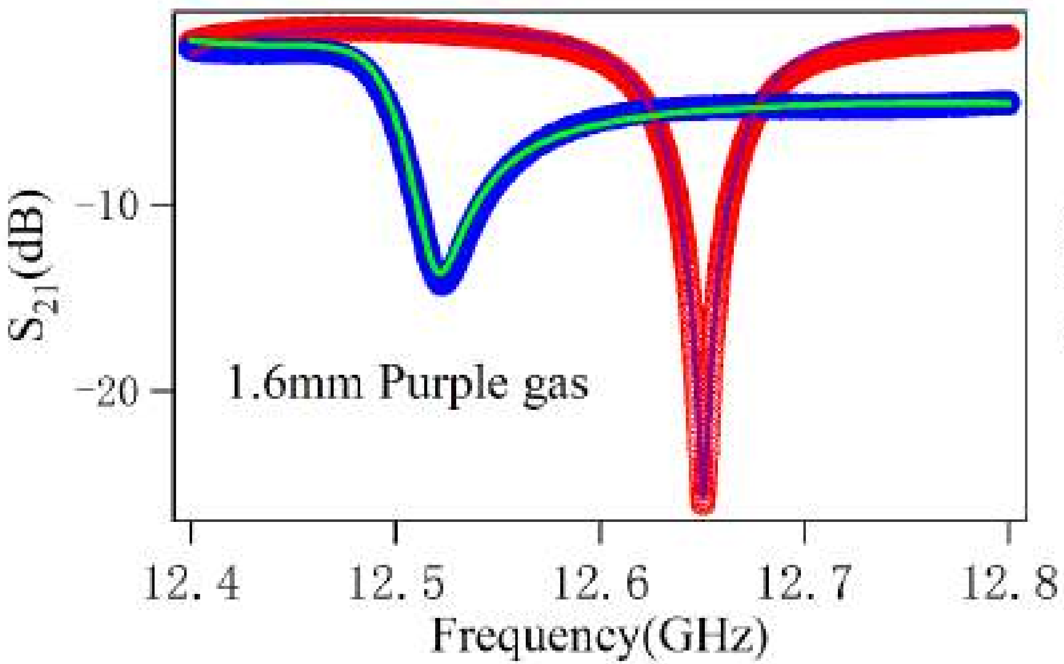
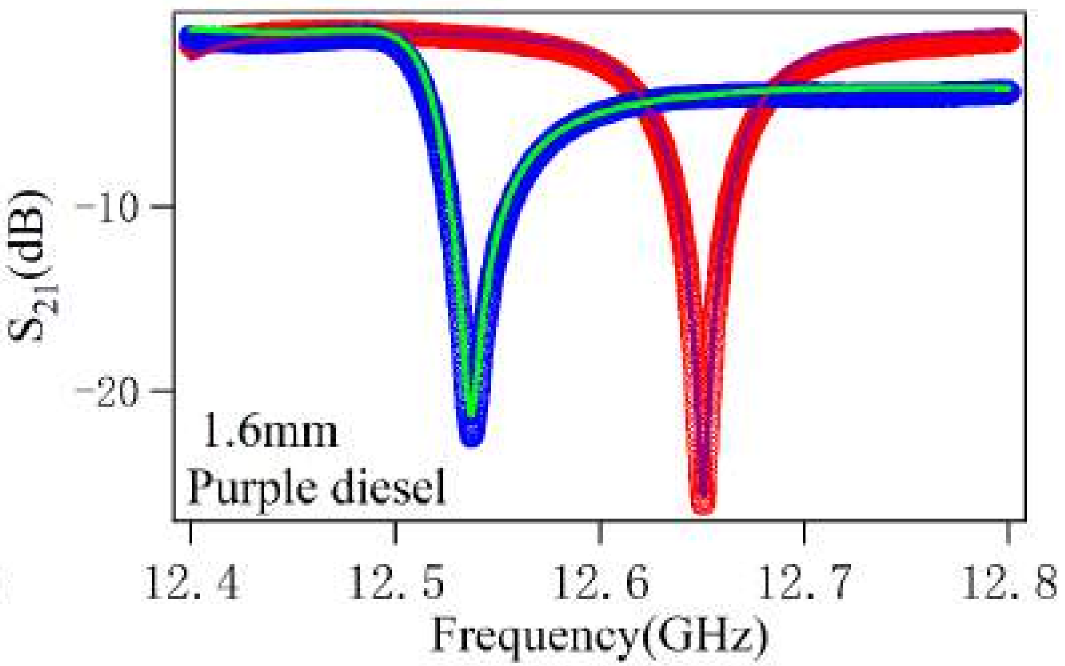
Determined gasoline and diesel



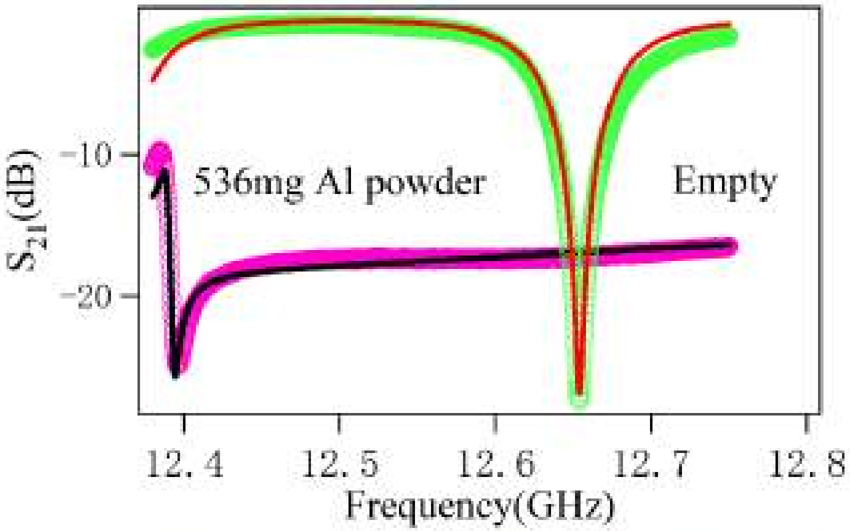


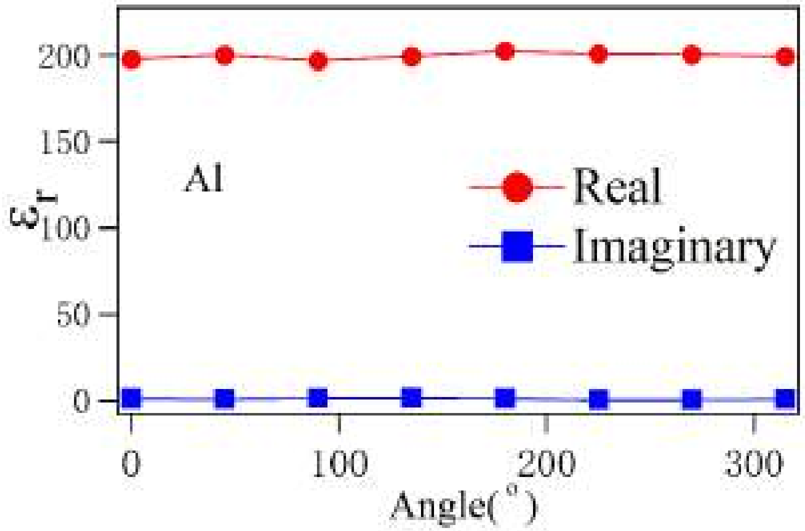
ϵ_r=3.016+0.196i

ϵ_r= 2.666 + 0.028i

Gasoline absorb microwave at dry!

Problems of Al and water





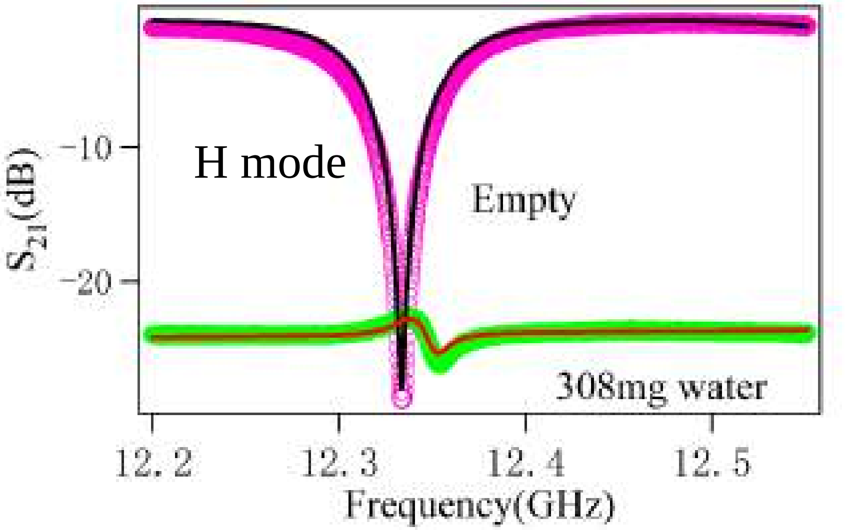
Our result

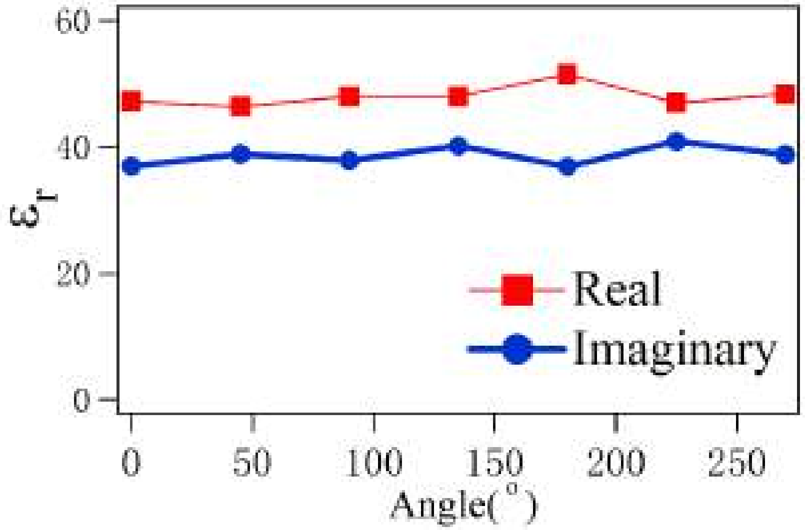
ϵ_r = 199.65 + 0.957i

Similar result:

ceramic-powder polymer

[Bai, Y., et al(2000)]





Our result

ϵ_r =48.06 + 38.63i

Other paper

ϵ_r =57.95 + 32.72i

[Barthel et al]

Wang, J. R., & Schmugge, T. J. (1980).
IEEE Transactions on Geoscience and Remote Sensing,
(4), 288-295.

Empirical Model for Soils

- w_t : Wilting points (plants concept)
- P : Porosity of dry soil $\mathrm{P} = \frac{V_{air}}{V_{total}}$
- $\epsilon_a\ \epsilon_w\ \epsilon_r\ \epsilon_i$ Dielectric constant for air, water, rock and ice
- γ : Fitting parameter

$$\epsilon = w_c \epsilon_x + (P - w_c)\epsilon_a - (1 - P)\epsilon_r$$

with $\epsilon_x = \epsilon_i + (\epsilon_w - \epsilon_i)\frac{w_c}{w_t} \cdot \gamma$

If $w_c \leq w_t$

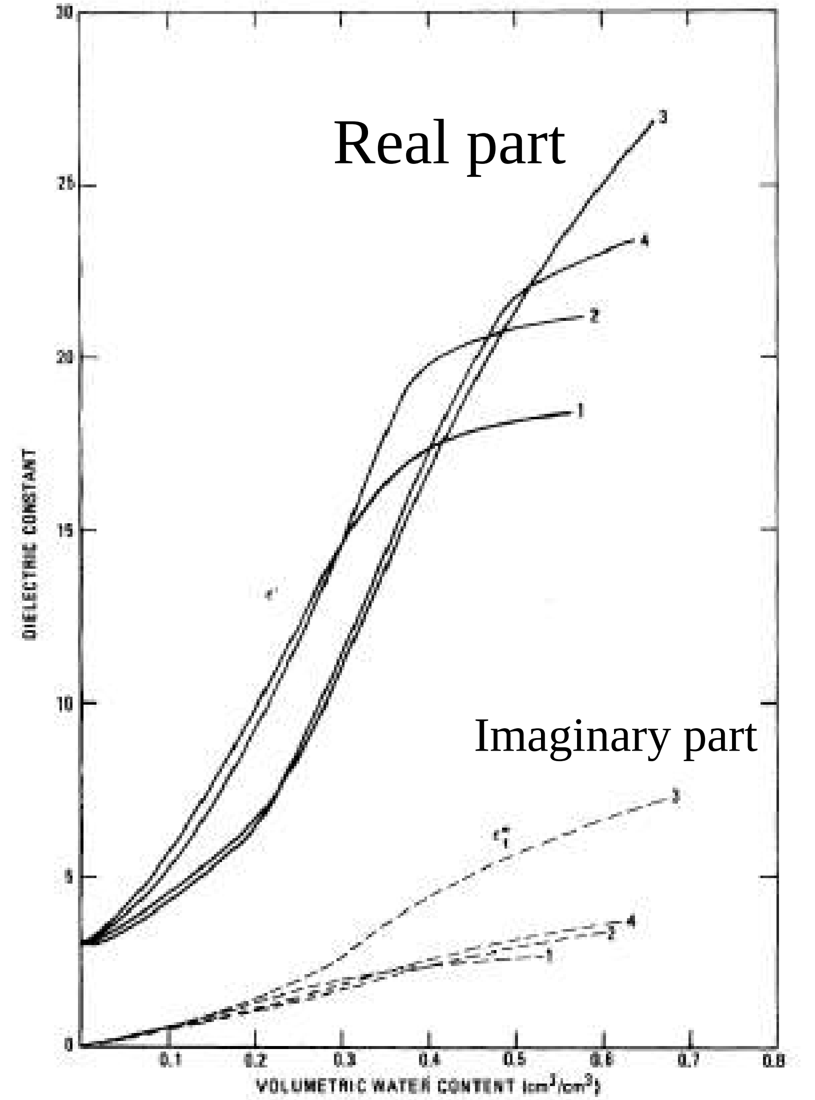


Fig. 1. The dielectric constants versus volumetric water content for four soils measured at 5 GHz. Soil types are identified by the numbers assigned to the curves in accordance with Table I.

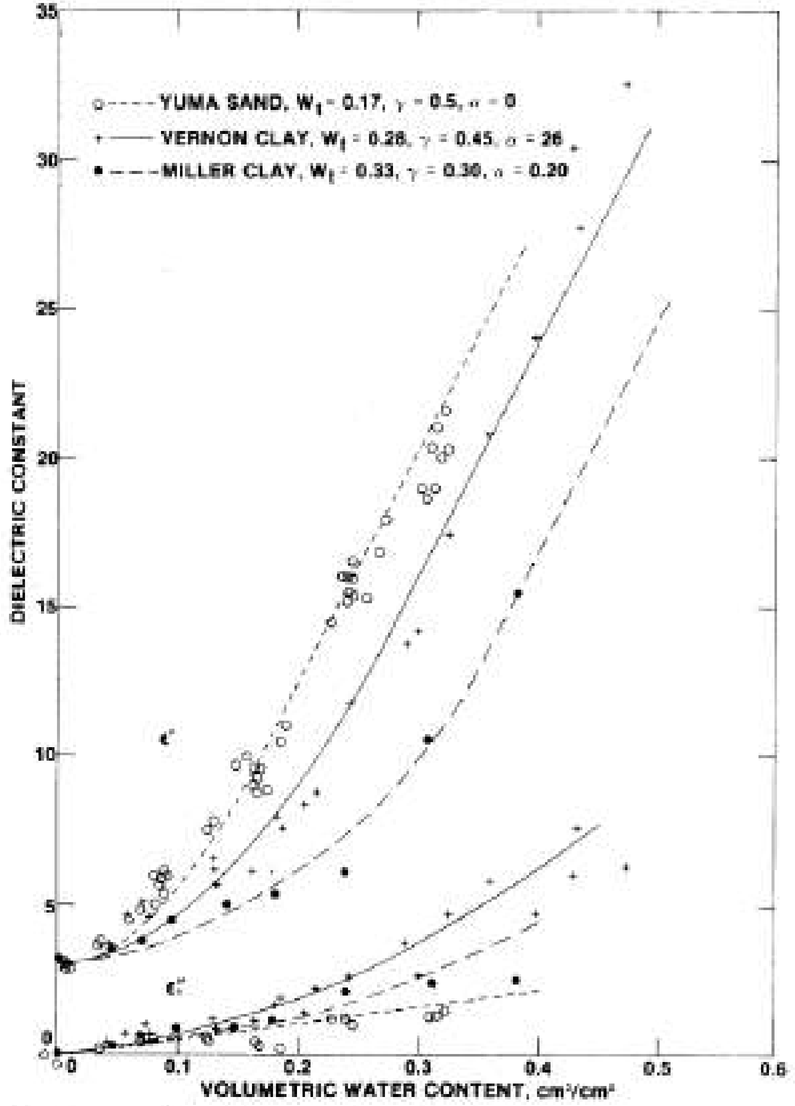


Fig. 6. A comparison between the calculated dielectric constants from the empirical model and the measured values at 5 GHz.

Different soil at 5 GHz

Data and model fit at 5 GHz

Simplified model

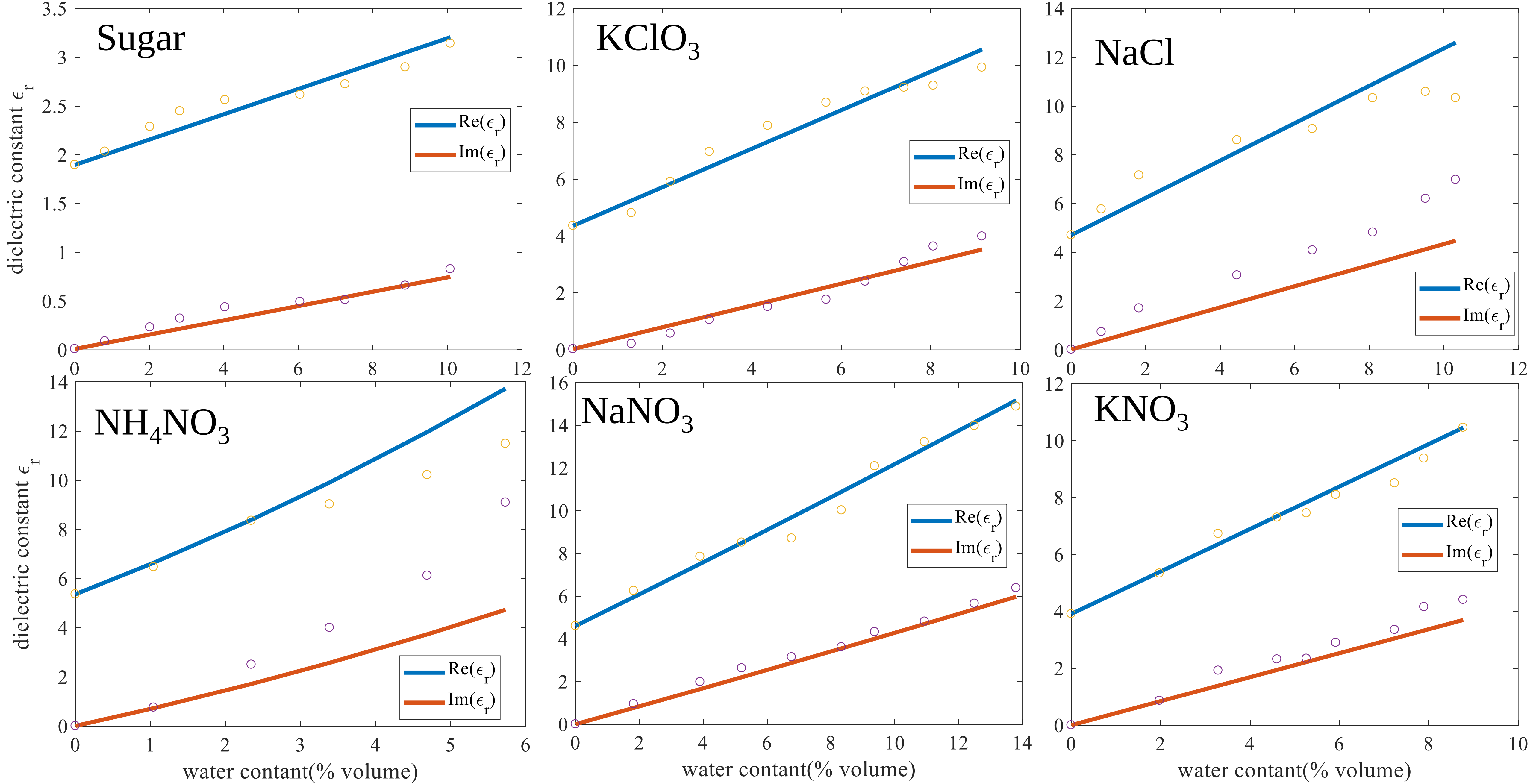
- No air , P = 0 and no ice involved
- Replace ϵ_r (rock) with ϵ_{sample}(dry)
- Consider conductivity loss $\epsilon_r{}'' = \epsilon'' + \alpha \cdot w_c^2$

$$\boxed{\epsilon = \epsilon_s + a\epsilon_w + b\epsilon_w^2}$$

$$\epsilon^* = Re(\epsilon) + [Im(\epsilon) + \alpha \cdot w_c^2] * i$$

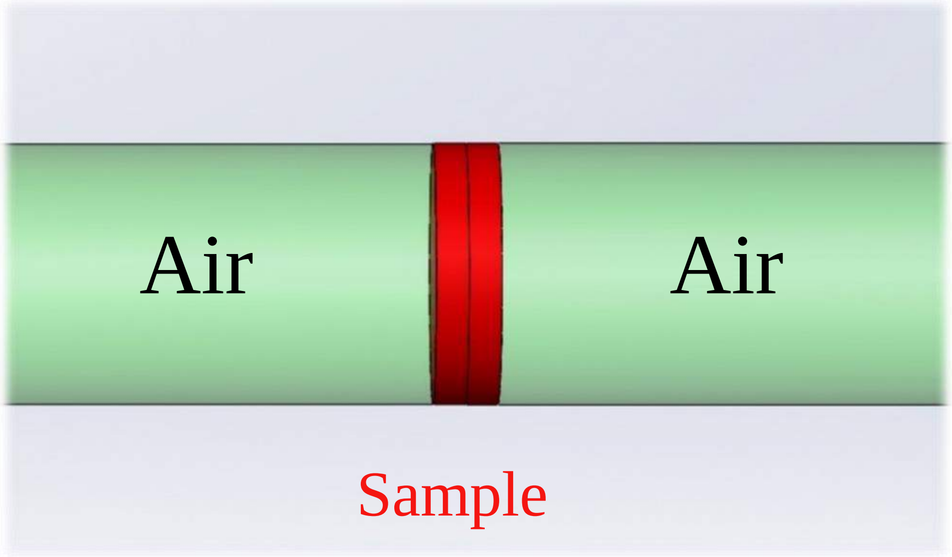
Next step fitting

Fitting results at $\alpha = 0$



Method for water & Al powder

- Transmission /Reflection(T/R) method



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

$$\gamma_i = \gamma_i(\epsilon_i, \mu_i)$$

$$M_i = x \cdot T_{refi} \cdot T_i \cdot T_{refi}^{-1} \cdot y$$

$$T_i = \begin{pmatrix} e^{-\gamma_i d} & 0 \\ 0 & e^{\gamma_i d} \end{pmatrix}$$

$$T_{refi} = \begin{pmatrix} \frac{1}{1-\Gamma_i} & \frac{\Gamma_i}{1-\Gamma_i} \\ \frac{\Gamma_i}{1-\Gamma_i} & \frac{1}{1-\Gamma_i} \end{pmatrix}$$

Eliminate systematic error x & y

Standard : $M_1 = x \cdot T_{ref1} \cdot T_1 \cdot T_{ref1}^{-1} \cdot y$

Sample : $M_2 = x \cdot T_{ref2} \cdot T_2 \cdot T_{ref2}^{-1} \cdot y$

$$M_1 M_2^{-1} = x \cdot (T_{ref1} \cdot T_1 \cdot T_{ref1}^{-1} \cdot T_{ref2} \cdot T_2 \cdot T_{ref2}^{-1}) \cdot x^{-1}$$

$$f(\epsilon_{r2}^*) = Tr(T_{ref1} \cdot T_1 \cdot T_{ref1}^{-1} \cdot T_{ref2} \cdot T_2 \cdot T_{ref2}^{-1})$$

- Many complex value of ϵ_{r2}^* can satisfy the function
- Need a good initial guess!
- Data collection completed

Next step

- Analysis data by setting $\alpha \neq 0$ in empirical model for water content.
- Build a Matlab code calculate the ϵ_r using T/R method.