# 频变材料的添加

Djordjevic-Sarkar Model Parameter Calculation The model parameters can be calculated if the following information about the material is known:

DC conductivity, sDC (optional; default value is 0)
DC permittivity, eDC (optional; you have to choose the default. See below)
A triplet of real numbers, consisting of
the measurement frequency w1 the real permittivity e1 at this frequency the loss tangent tan d1 at this frequency

From the model equation, observe that

$$\begin{aligned}\varepsilon(\omega_1) &= \varepsilon_\infty + \frac{\Delta\varepsilon}{\ln(\omega_B/\omega_A)}\ln\left(\frac{\omega_B + j\omega_1}{\omega_A + j\omega_1}\right) + \frac{\sigma_{DC}}{j\omega_1\varepsilon_0} \\ &\cong \varepsilon_\infty + \frac{\Delta\varepsilon}{\ln(\omega_B/\omega_A)}\ln\left(\frac{\omega_B + j\omega_1}{j\omega_1}\right) + \frac{\sigma_{DC}}{j\omega_1\varepsilon_0} \\ &= \varepsilon_\infty + \frac{\Delta\varepsilon}{\ln(\omega_B/\omega_A)}\ln\left(\frac{\sqrt{\omega_B^2+\omega_1^2}}{\omega_1}\right) - j\left[\frac{\Delta\varepsilon}{\ln(\omega_B/\omega_A)}\cdot\tan^{-1}\left(\frac{\omega_B}{\omega_1}\right) + \frac{\sigma_{DC}}{\omega_1\varepsilon_0}\right]\end{aligned} \tag{3}$$

Relative Permittivity:

$$\varepsilon(f) = \varepsilon_\infty + \frac{K}{2}\ln\left(\frac{f_B^2 + f^2}{f_A^2 + f^2}\right) \tag{9}$$

Conductivity:

$$\sigma(f) = \sigma_{DC} + 2\pi f\varepsilon_0 K\cdot\left[\tan^{-1}\left(\frac{f}{f_A}\right) - \tan^{-1}\left(\frac{f}{f_B}\right)\right] \tag{10}$$

$$f_B = 10^{12}/2\pi \tag{11}$$

$$K = \frac{\varepsilon_1\tan\delta_1 - \dfrac{\sigma_{DC}}{\omega_1\varepsilon_0}}{\tan^{-1}\left(\dfrac{\omega_B}{\omega_1}\right)} \tag{12}$$

$$\varepsilon_\infty = \varepsilon_1 - \frac{1}{2}K\ln\left[\left(\frac{\omega_B}{\omega_1}\right)^2 + 1\right] \tag{13}$$

$$f_A = \frac{f_B}{\exp\left(\dfrac{\Delta\varepsilon}{K}\right)} \tag{14}$$

$\Delta\varepsilon = \varepsilon_\infty - \varepsilon_{DC}$ if the DC permittivity is known; else $\Delta\varepsilon = 10 \cdot \tan\delta_1 \cdot \varepsilon_\infty$

In [ ]:
```
import sys
sys.path.append(r"C:\work\Study\Script\Ansys\quickAnalyze\FastSim") #添加pyaedt的
import pyLayout
pyLayout.log.setLogLevel("INFO")

from pyLayout import Layout
# layout = Layout()
layout = Layout() #least version
# layout.openAedt(r"C:\work\Project\AE\Script\test_pcb\galileo.aedt")
layout.initDesign()
```

```
2024/02/01 16:30:31 - INFO: pyLayout Version: V0.6 20231225
2024/02/01 16:30:31 - INFO: Intial aedt desktop Ansoft.ElectronicsDesktop.2024.1
2024/02/01 16:30:31 - INFO: init design: Project75 : EMDesign1
2024/02/01 16:30:31 - INFO: Simulation log recorded in: C:/Users/yguo/OneDrive - ANSYS, Inc/Documents/Ansoft/Project75_EMDesign1.log
```

# 方式1：按照HFSS UI设定方式生成 DK+Conductivity

In [ ]:
```
layout.materials.addHFSSDSModle("test1",dk=4.0,df=0.02)
```

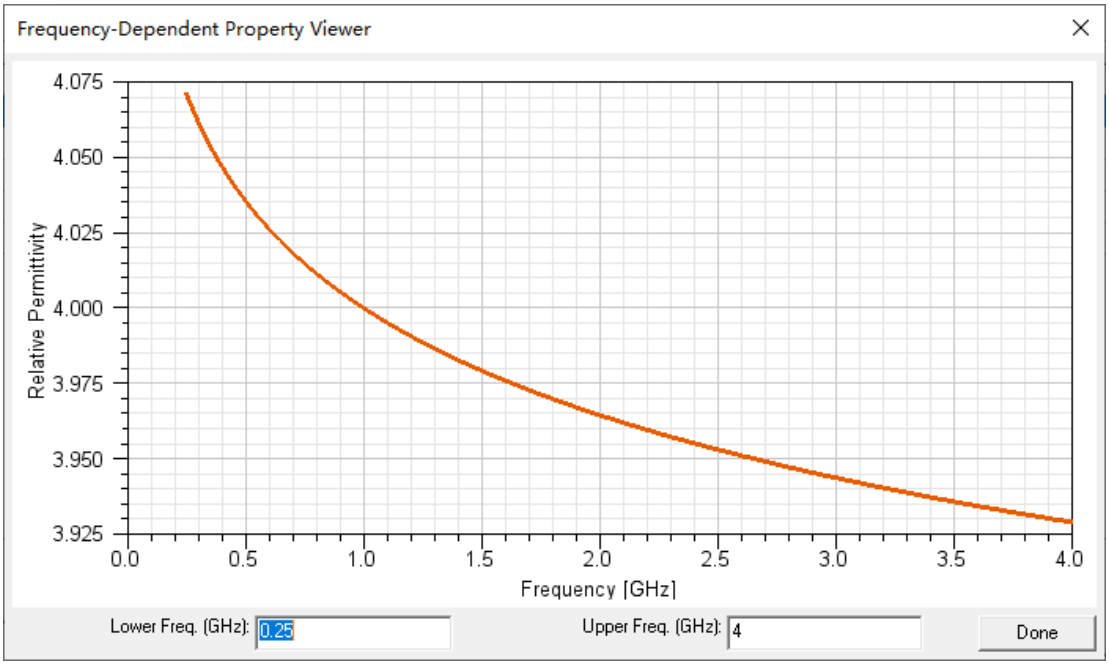
```
2024/02/01 16:30:31 - INFO: Djordjevic-Sarkar Model Parameter:
e_infi:3.740755252333763 ,e_delta:0.7481510504667526 ,fA:70403.0168767359 ,fB:159154943091.89536
2024/02/01 16:30:31 - INFO: Djordjevic-Sarkar Model Parameter:
DK:3.740755252333763+0.05113411554862952/2*ln((159154943091.89536**2+freq**2)/(70403.0168767359**2+freq**2))
,Conductivity:1e-12+2*pi*freq*e0*0.05113411554862952*(atan(freq/70403.0168767359)-atan(freq/159154943091.89536))
```

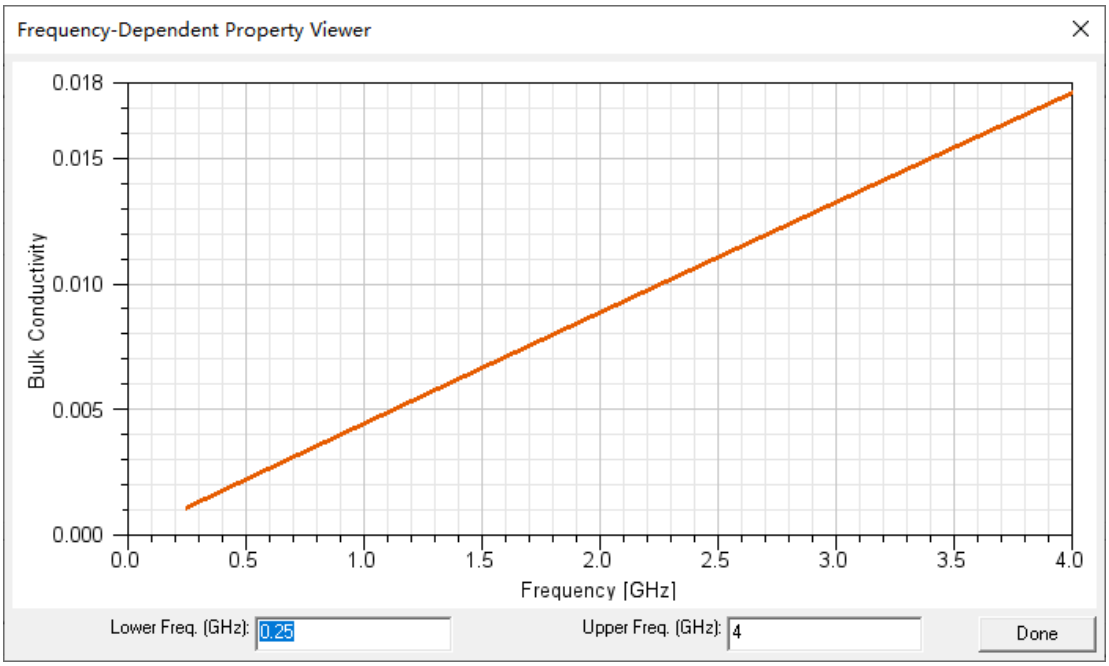
对比HFSS生成的材料参数和脚本生成的材料参数，两者完全一致：

Set in HFSS UI:

DK:3.74076+0.0255671*ln((2.53303e+22+Freq*Freq)/(4.95658e+09+Freq*Freq))*

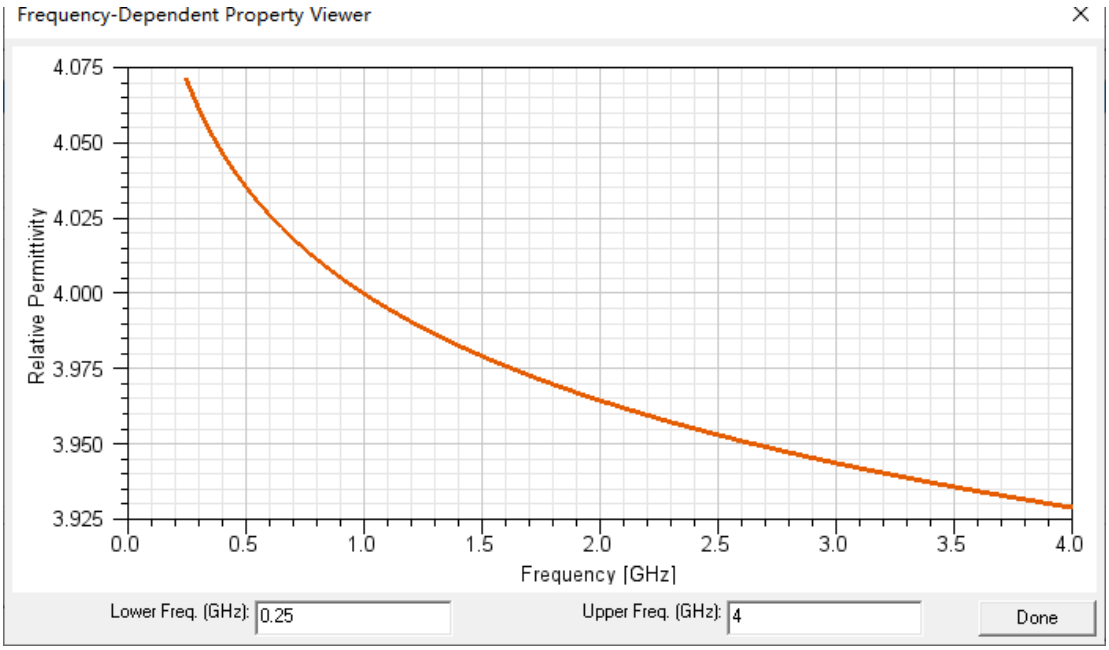
*Cond:1e-12+2.84472e-12*Freq*(atan(Freq/70403)-atan(Freq/1.59155e+11))

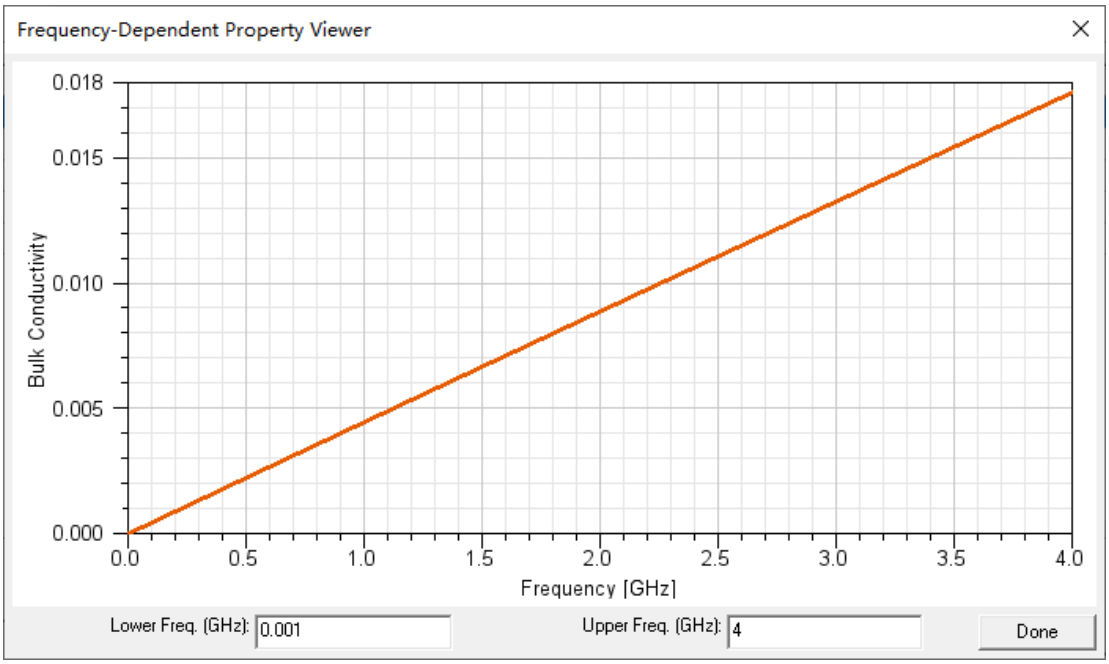



Set by Script:

DK:3.740755252333763+0.05113411554862952/2*ln((159154943091.89536**2+freq**2)/(70403.0*DF:1e-12+2*pi*freq*e0*0.05113411554862952*(atan(freq/70403.0168767359)-atan(freq/159154943091.89536))



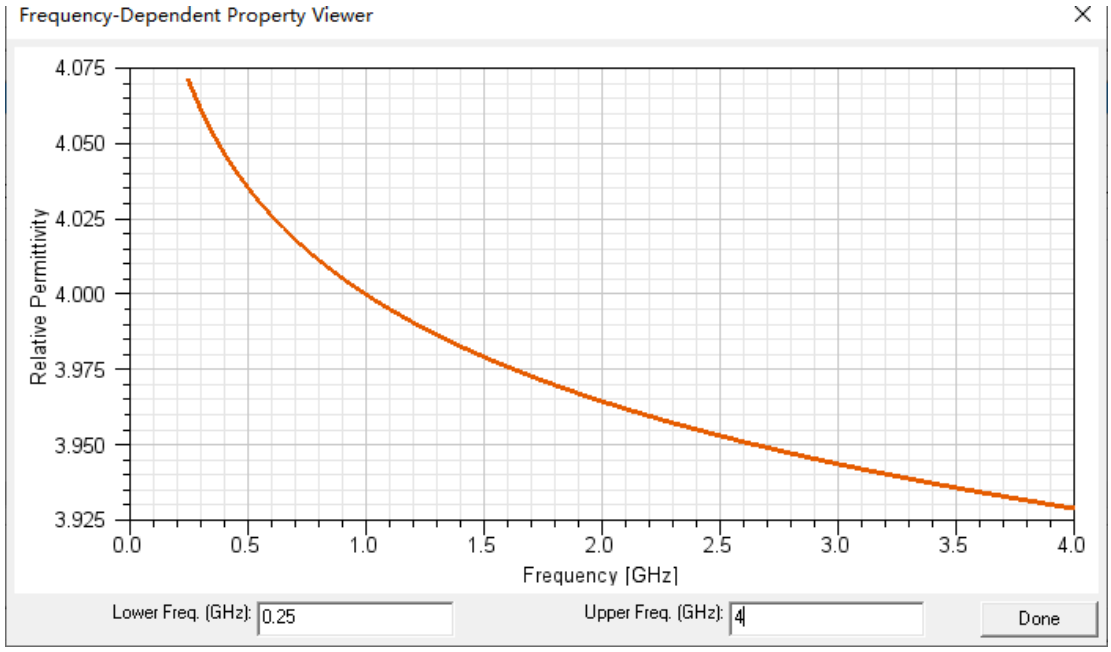

## 方式2 按照Djordjevic-Sarkar Model方式进行输入，频变DK+DF

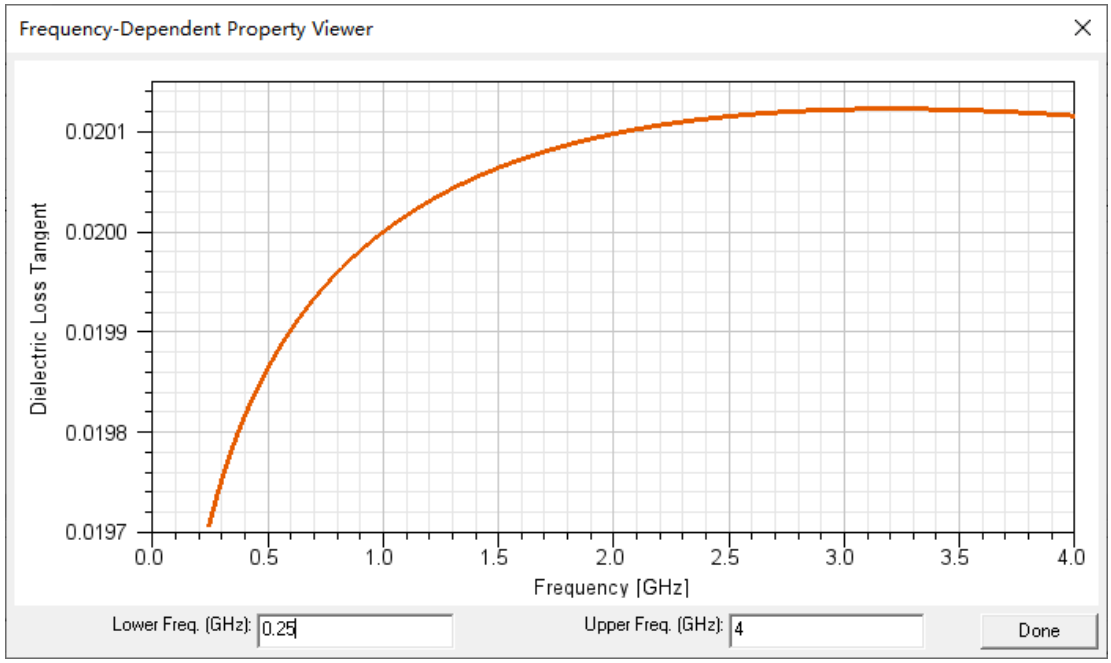
$$\varepsilon = \varepsilon_\infty + \Delta\varepsilon \cdot \frac{1}{m_2 - m_1} \cdot \log_{10}\left(\frac{10^{m_2} + i \cdot f}{10^{m_1} + i \cdot f}\right)$$
$$= \varepsilon_r \cdot (1 - i \cdot \tan\delta)$$

or

$$\varepsilon(\omega_1) = \varepsilon_\infty + \frac{\Delta\varepsilon}{\ln(\omega_B/\omega_A)} \ln\left(\frac{\omega_B + j\omega_1}{\omega_A + j\omega_1}\right) + \frac{\sigma_{DC}}{j\omega_1\varepsilon_0}$$

可以获取跟HFSS UI设定一致的结果，使用DK/DF形式更加直观




In [ ]:
```
layout.materials.addHFSSDSModle2("test2",dk=4.0,df=0.02)
```

```
2024/02/01 16:30:31 - INFO: Causal material set fA as: 70403.0168767359
2024/02/01 16:30:31 - INFO: Djordjevic-Sarkar Model Parameter:
e_infi:3.740755252333763 ,e_delta:0.7481510504667526 ,fA:70403.0168767359 ,fB:159
154943091.89536
2024/02/01 16:30:31 - INFO: Djordjevic-Sarkar Model Parameter:
DK:re(3.740755252333763+0.7481510504667526/ln(1000000000000.0001/442355.201221023
45)*ln((1000000000000.0001+1j*2*pi*freq)/(442355.20122102345+1j*2*pi*freq))+1e-1
2/(1j*2*pi*freq*e0))
,DF:-im(3.740755252333763+0.7481510504667526/ln(1000000000000.0001/442355.2012210
2345)*ln((1000000000000.0001+1j*2*pi*freq)/(442355.20122102345+1j*2*pi*freq))+1e-
12/(1j*2*pi*freq*e0))/re(3.740755252333763+0.7481510504667526/ln(1000000000000.00
01/442355.20122102345)*ln((1000000000000.0001+1j*2*pi*freq)/(442355.20122102345+1
j*2*pi*freq))+1e-12/(1j*2*pi*freq*e0))
```

# 方式三，使用Djordjevic-Sarkar Model 的标准形式，

直接输入e_infi,e_delta,fA,fB,cond_dc=1e-12

In [ ]:
```
layout.materials.addStdDSModel("test3",e_infi=3.740755252333763,e_delta=0.748151
```

```
2024/02/01 16:31:06 - INFO: Djordjevic-Sarkar Model Parameter:
e_infi:3.740755252333763 ,e_delta:0.7481510504667526 ,fA:70403.016876735 ,fB:1591
54943091.89536
2024/02/01 16:31:06 - INFO: Djordjevic-Sarkar Model Parameter:
DK:re(3.740755252333763+0.7481510504667526/ln(1000000000000.0001/442355.201221017
75)*ln((1000000000000.0001+1j*2*pi*freq)/(442355.20122101775+1j*2*pi*freq))+1e-1
2/(1j*2*pi*freq*e0))
,DF:-im(3.740755252333763+0.7481510504667526/ln(1000000000000.0001/442355.2012210
1775)*ln((1000000000000.0001+1j*2*pi*freq)/(442355.20122101775+1j*2*pi*freq))+1e-
12/(1j*2*pi*freq*e0))/re(3.740755252333763+0.7481510504667526/ln(1000000000000.00
01/442355.20122101775)*ln((1000000000000.0001+1j*2*pi*freq)/(442355.20122101775+1
j*2*pi*freq))+1e-12/(1j*2*pi*freq*e0))
```