Analitical results:
Coaxial setup with differents materials

Introduction

In order to analyze the variation of the permittivity of a coaxial cell culture inside when applied to a microwave beam must first determine if our network analyzer have sufficient sensitivity. To obtain the sensitivity to be measured, the S parameters of the coaxial have been analyzed when the interior has different medium. The mediums that will be analyzed are the following:

- Vacuum
- Distilled water
- Sea water
- Cultivation water
- Cell culture (P = 0.1)

Experiment

//Cal definir els parametres de matlab

Expressions

Expressions only valid for $\boldsymbol{\varepsilon_r'' \ll \varepsilon_r'}$

$$\boldsymbol{\varepsilon_r'' = \frac{\sigma}{\omega \varepsilon_0}}$$

$$\boldsymbol{\alpha = 60\pi \frac{\sigma}{\sqrt{\varepsilon_r'}}}$$

$$\boldsymbol{\beta = \frac{2\pi\sqrt{\varepsilon_r'}}{\lambda_0}}$$

$$\boldsymbol{|S_{21}| = e^{-j\alpha\Delta z}}$$

$$\boldsymbol{\emptyset_{S_{21}} = -\beta\Delta z}$$

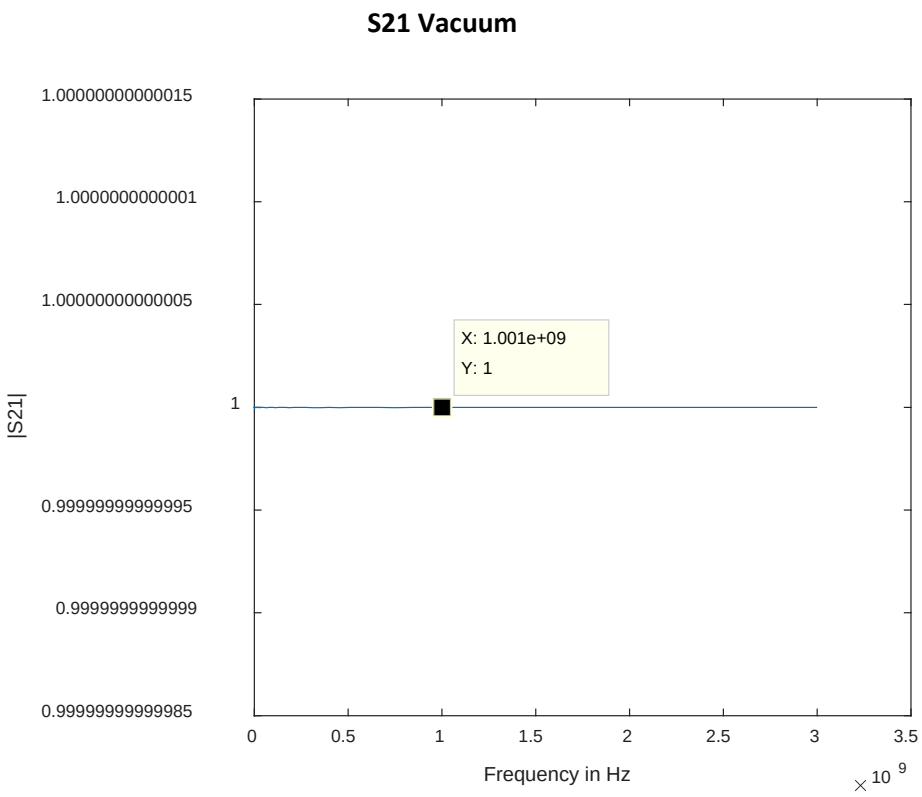
$$\boldsymbol{\varepsilon_0 = 8.854 \cdot 10^{-12}}$$

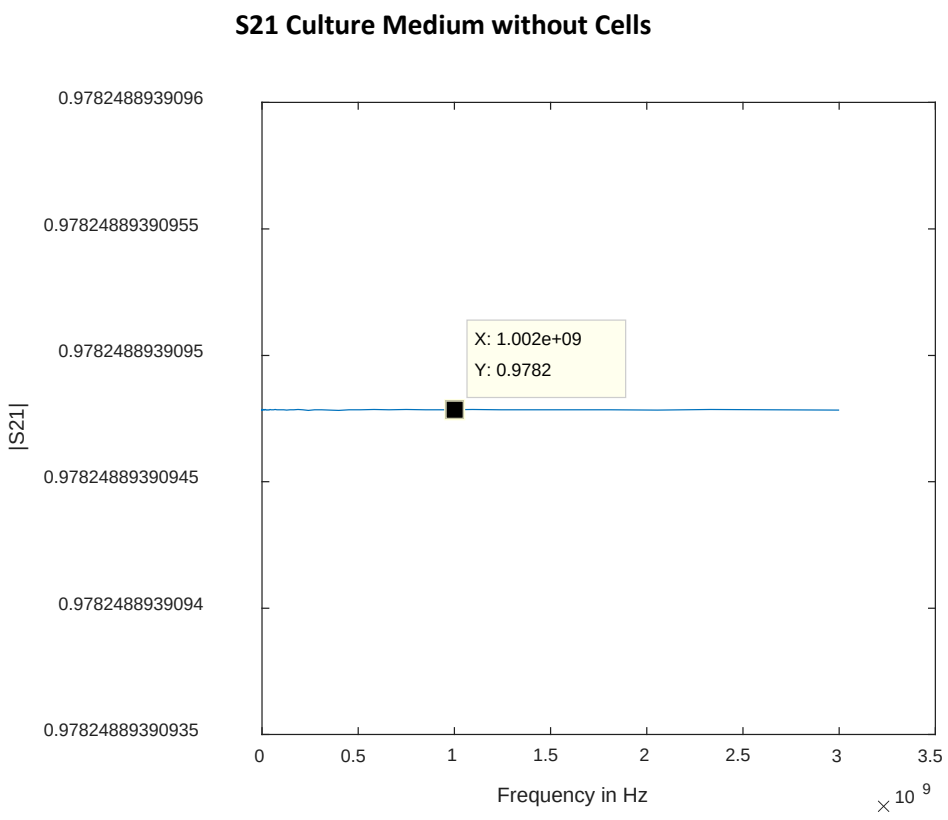
In general

$$\alpha = \frac{2\pi}{\lambda_0}\left[\frac{1}{2}\varepsilon'\left(\sqrt{1+\left(\frac{\varepsilon''}{\varepsilon'}\right)^2}-1\right)\right]^{1/2}$$

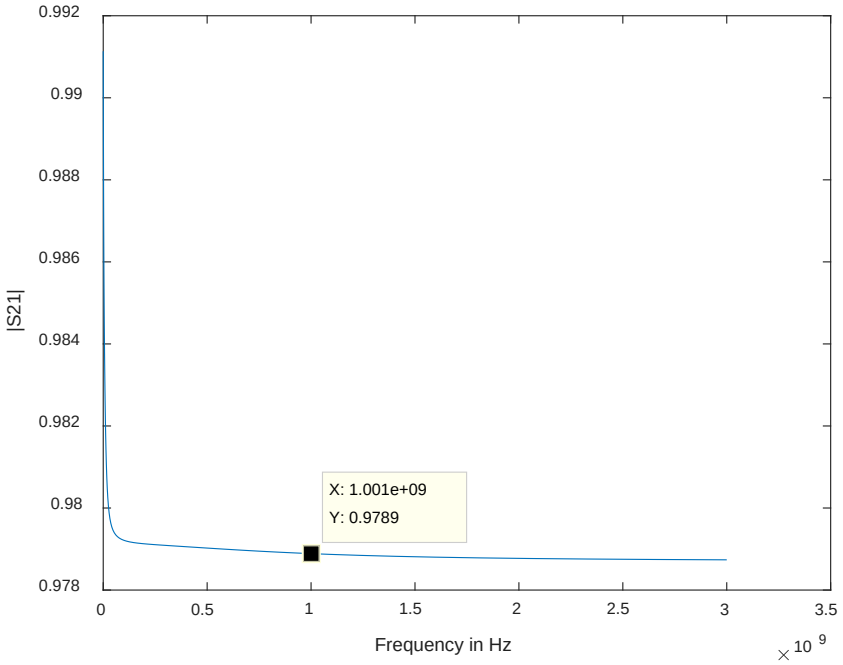
Results

Scattering parameters for differents mediums

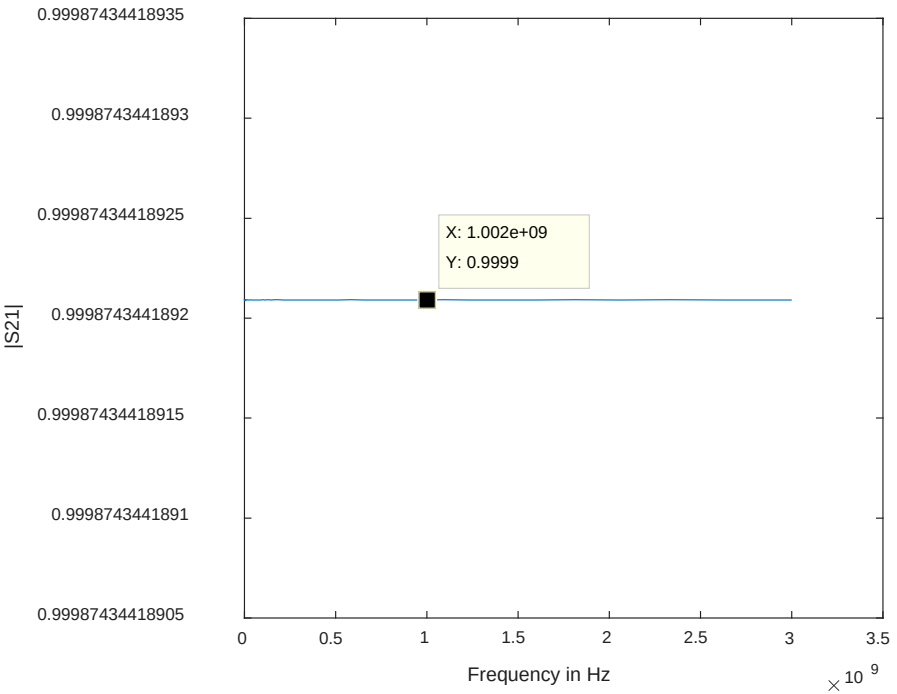




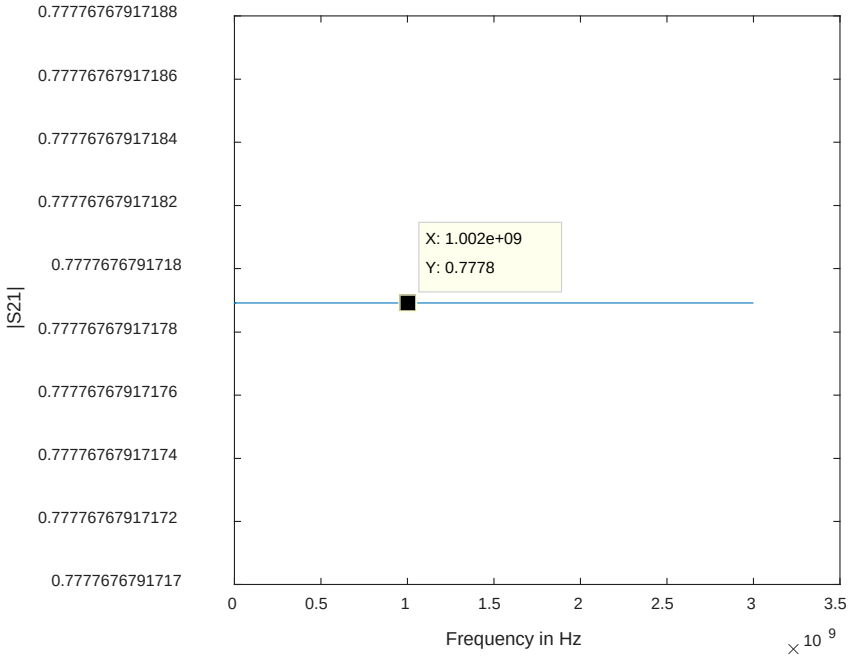
S21 Culture Medium with 0.1% Cells



S21 Distilled Water



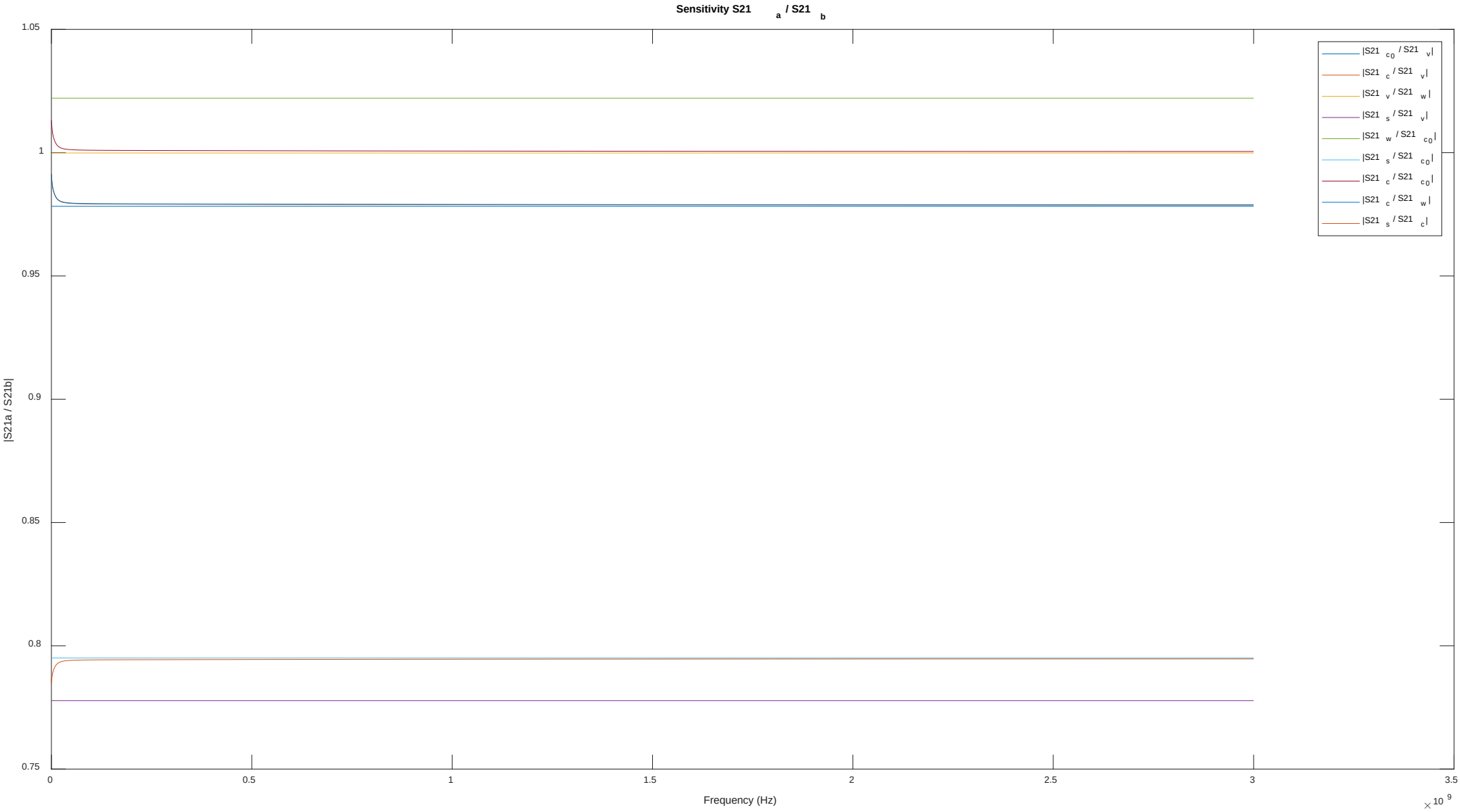
S21 Sea Water

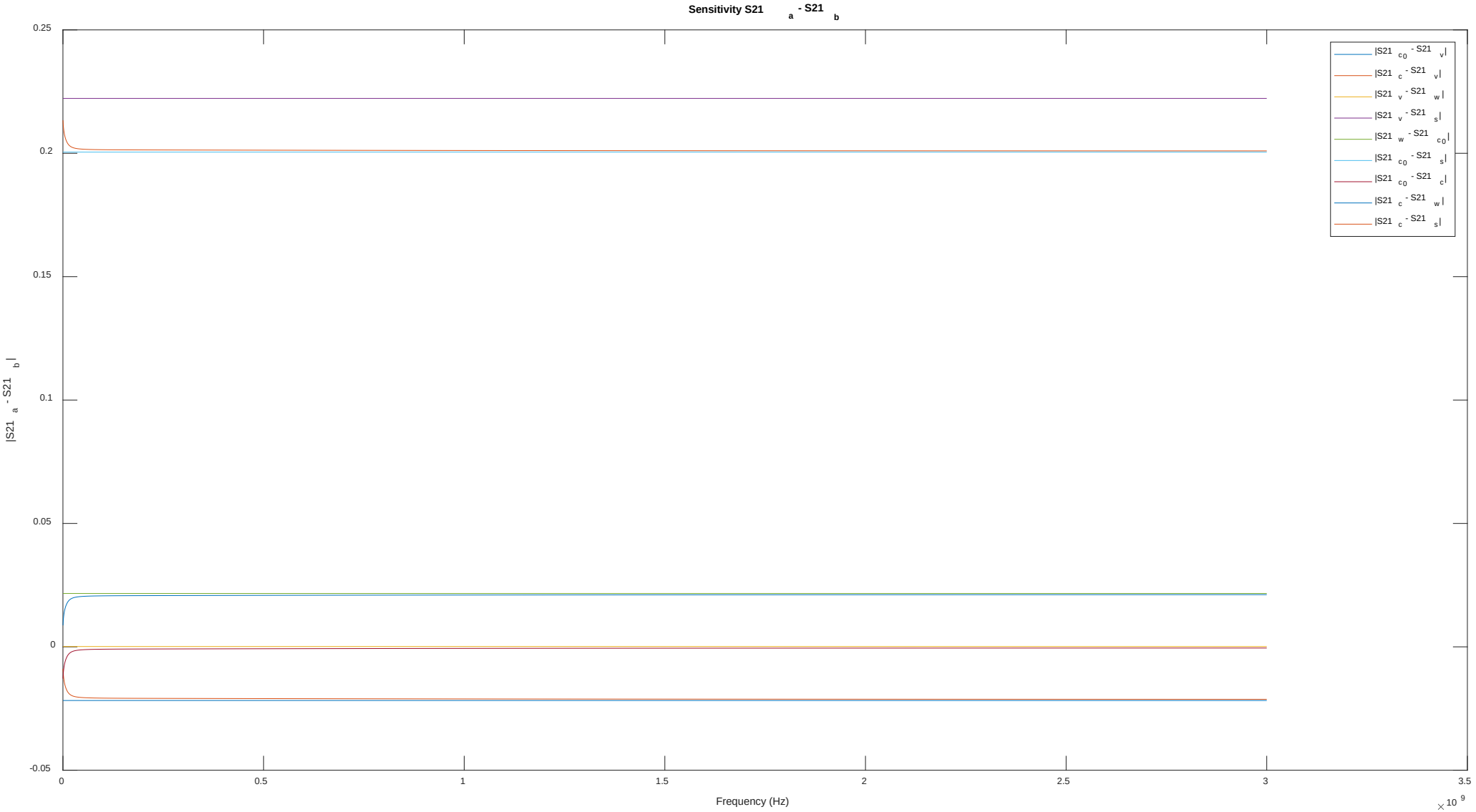


Para poder definir el medio de cultivo (para distintas concentraciones de células) en HFSS utilizaremos el modelo de Debye:

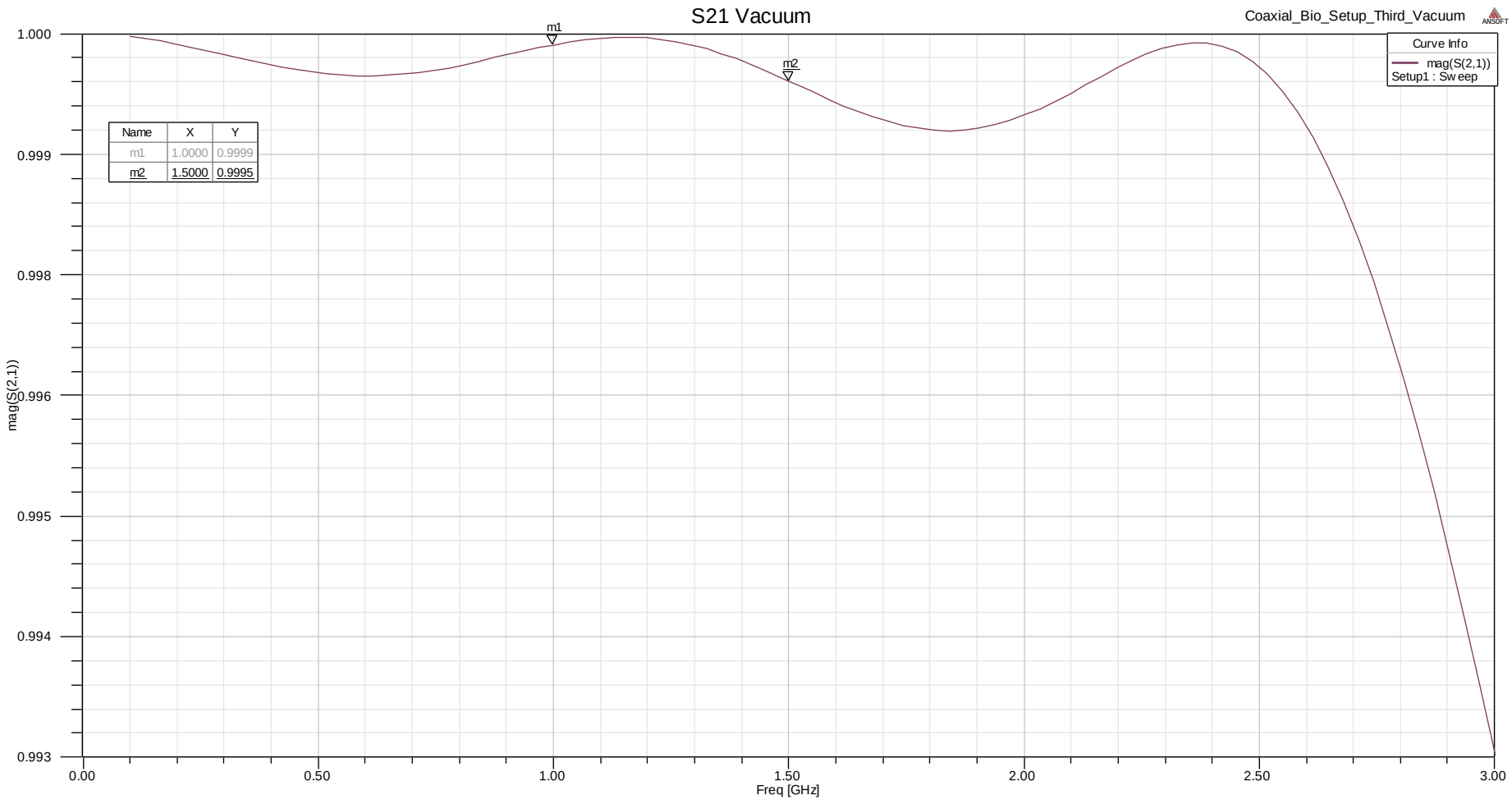
P	**Frequency**		**Relative Permittivity (Real)**		**Loss tangent**		**Conductivity (at DC)**	$\|S_{21}\|$ **(f= 1GHx)**	$\|S_{21}\|$ **(f= 1.5GHx)**
	L	**U**	**L**	**U**	**L**	**U**			
0.1	**1x10^4**	**3x10^9**	**335.2686**	**80.5064**	**1.5018e3**	**0.0254**	**0.2968**	**0.975612 - 0.107228dB**	**0.961974**
0.05	**1x10^4**	**3x10^9**	**225.5160**	**80.7530**	**2.5724e3**	**0.0256**	**0.3227**	**0.975185 - 0.109129dB**	**0.961555**
0.025	**1x10^4**	**3x10^9**	**115.2145**	**80.8764**	**3.8933e3**	**0.0258**	**0.3362**	**0.975811 - 0.106342dB**	**0.962153**
0.0125	**1x10^4**	**3x10^9**	**118.6111**	**80.9382**	**5.1988e3**	**0.0258**	**0.3430**	**0.975817 - 0.106316dB**	**0.962158**

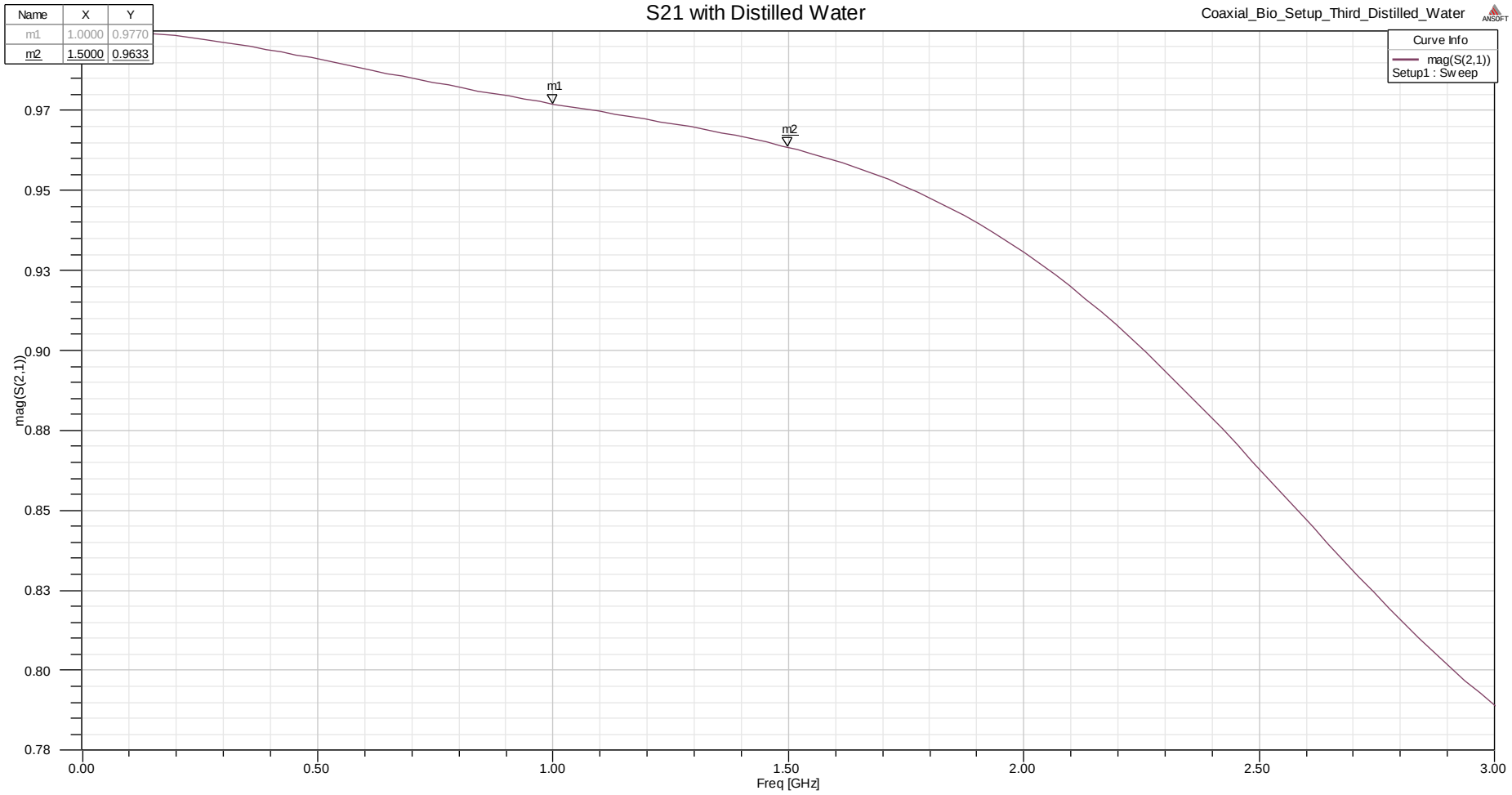
Material **(1GHz, Δz=3 mm)**	ε_r'	σ	ε_r''	α	β	$\|S_{21}\|$	$\emptyset_{S_{21}}$	$tg\partial = \frac{\varepsilon_r''}{\varepsilon_r'}$
Distilled Water	81	0.0002	0.023	0.0042	188.5	**0.99998740** - 0.00011 dB	-32.401°	2.8395x10^{-4}
Fresh Water	81	0.0325	3.671	0.6807	188.5	**0.99795998** -0.0177	-32.401°	0.0453209
Sea Water	81	4.0	451.77	83.78 (287.9218 exact)	188.5	**0.77775789** -2.1831 dB -7.5025 dB	-32.401°	5.577407407
Culture Liquid	81	0.35	39.53	7.33	188.5	**0.97825002** -0.1910 dB	-32.401°	0.4880246

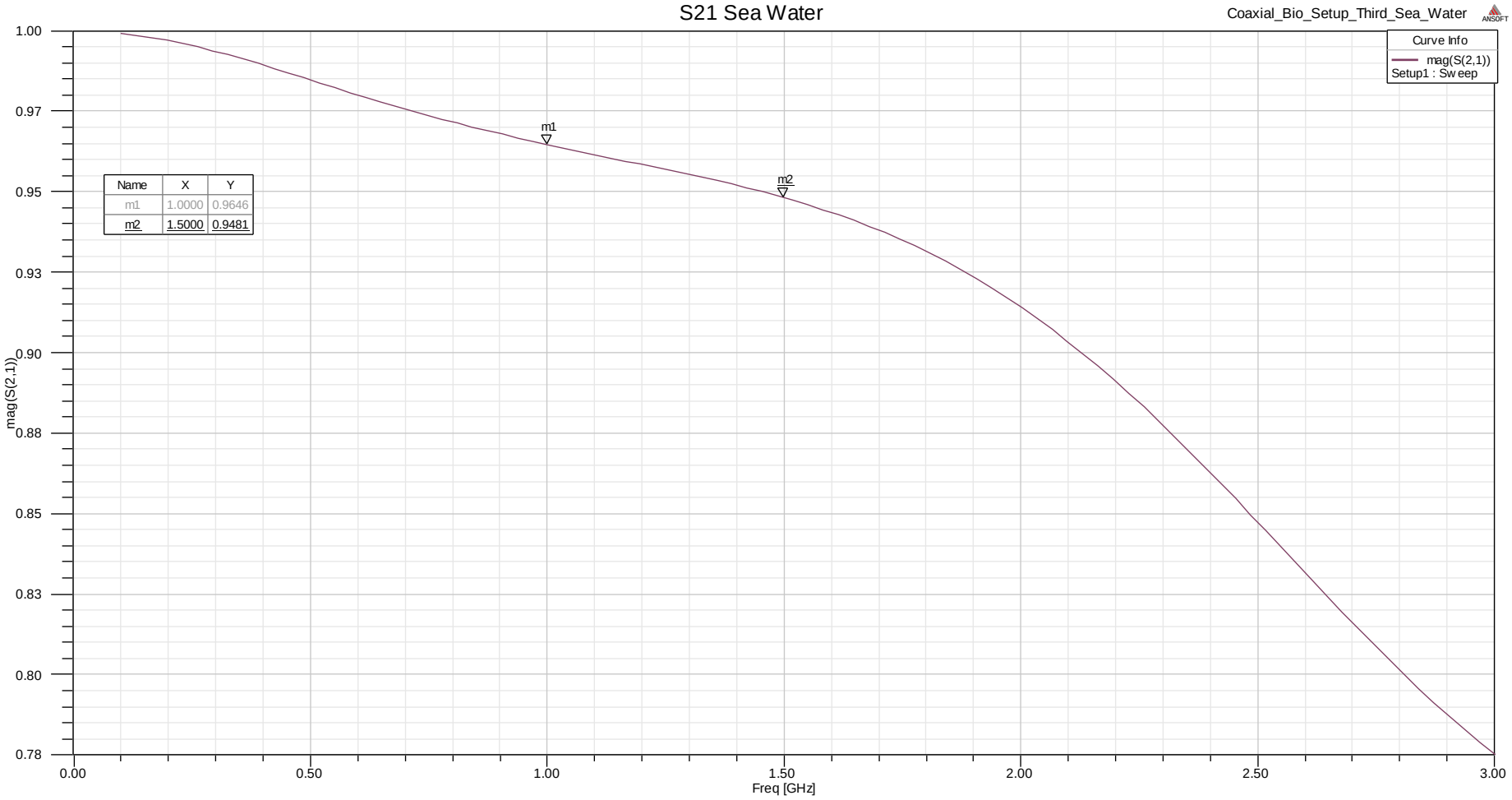

Sensitivity S21 a / S21 b
1.05
1
0.95
0.9
0.85
0.8
0.75
|S21a / S21b|
0
0.5
1
1.5
2
2.5
3
3.5
Frequency (Hz)
× 10 9
|S21 c0 / S21 v|
|S21 c / S21 v|
|S21 v / S21 w|
|S21 s / S21 v|
|S21 w / S21 c0|
|S21 s / S21 c0|
|S21 c / S21 c0|
|S21 c / S21 w|
|S21 s / S21 c|

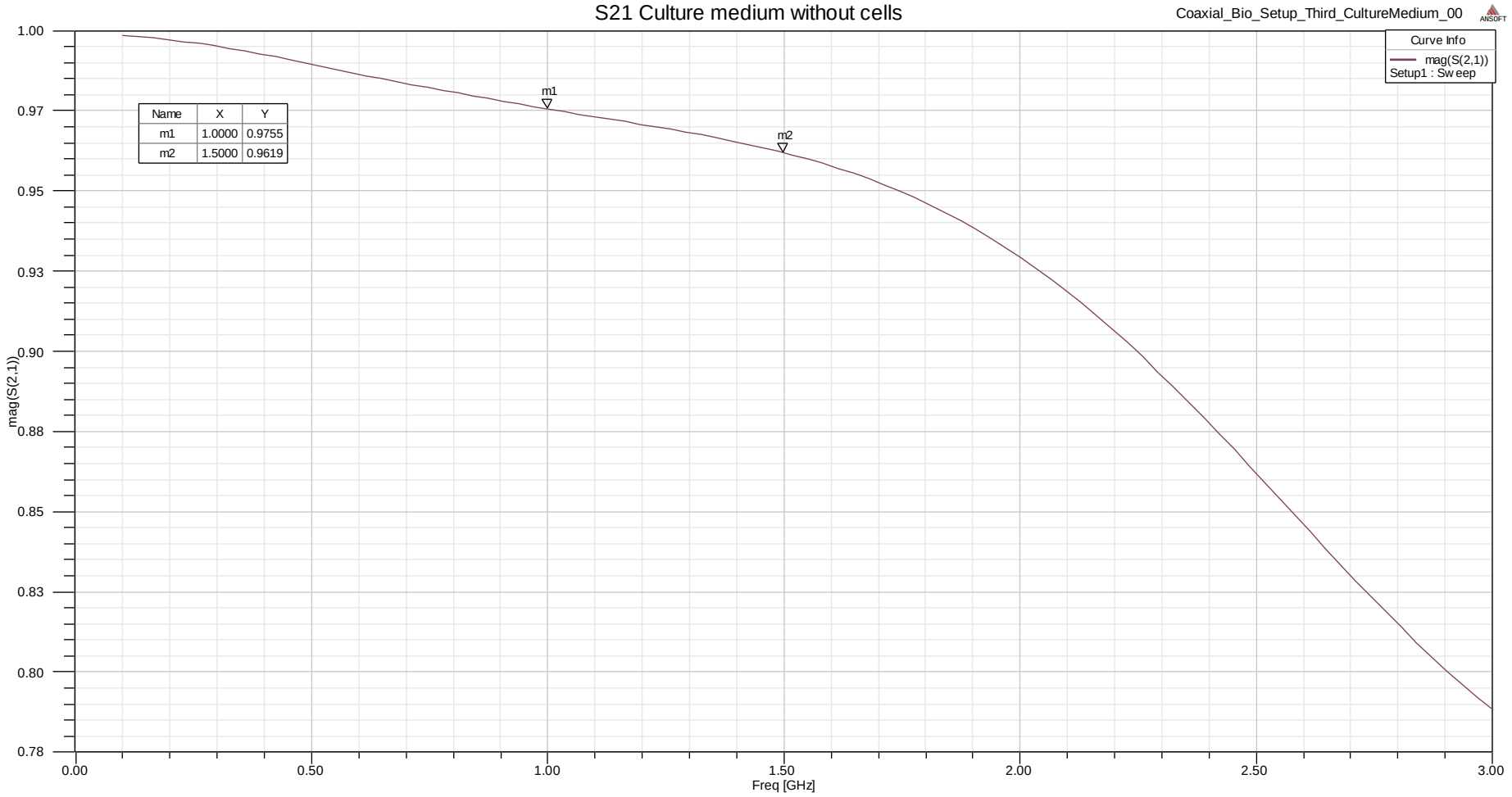

Sensitivity S21 a - S21 b
0.25
0.2
0.15
0.1
0.05
0
-0.05
|S21 a - S21 b|
0
0.5
1
1.5
2
2.5
3
3.5
Frequency (Hz)
× 10 9
|S21 c0 - S21 v|
|S21 c - S21 v|
|S21 v - S21 w|
|S21 v - S21 s|
|S21 w - S21 c0|
|S21 c0 - S21 s|
|S21 c0 - S21 c|
|S21 c - S21 w|
|S21 c - S21 s|

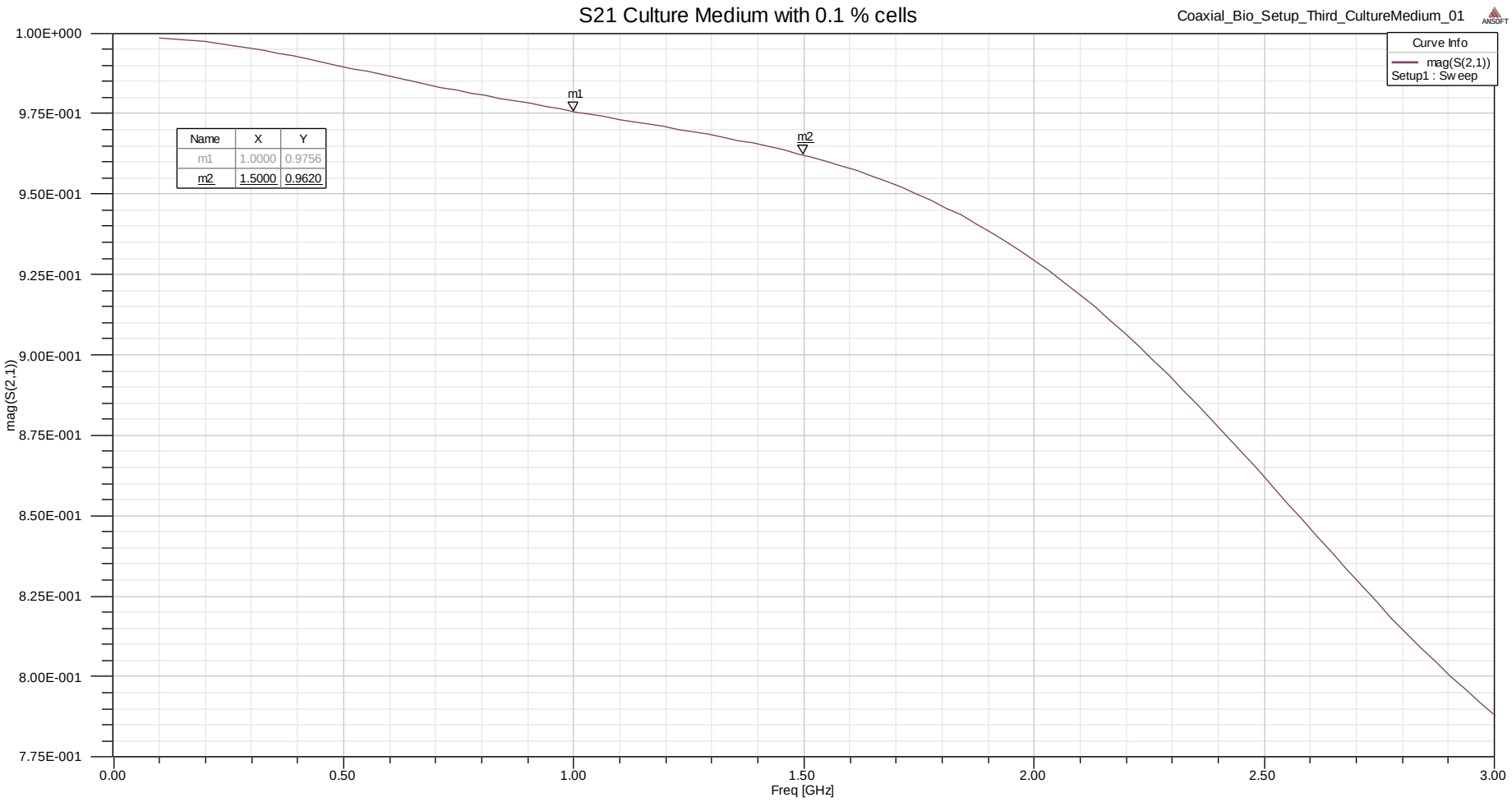
Simulation results in HFSS

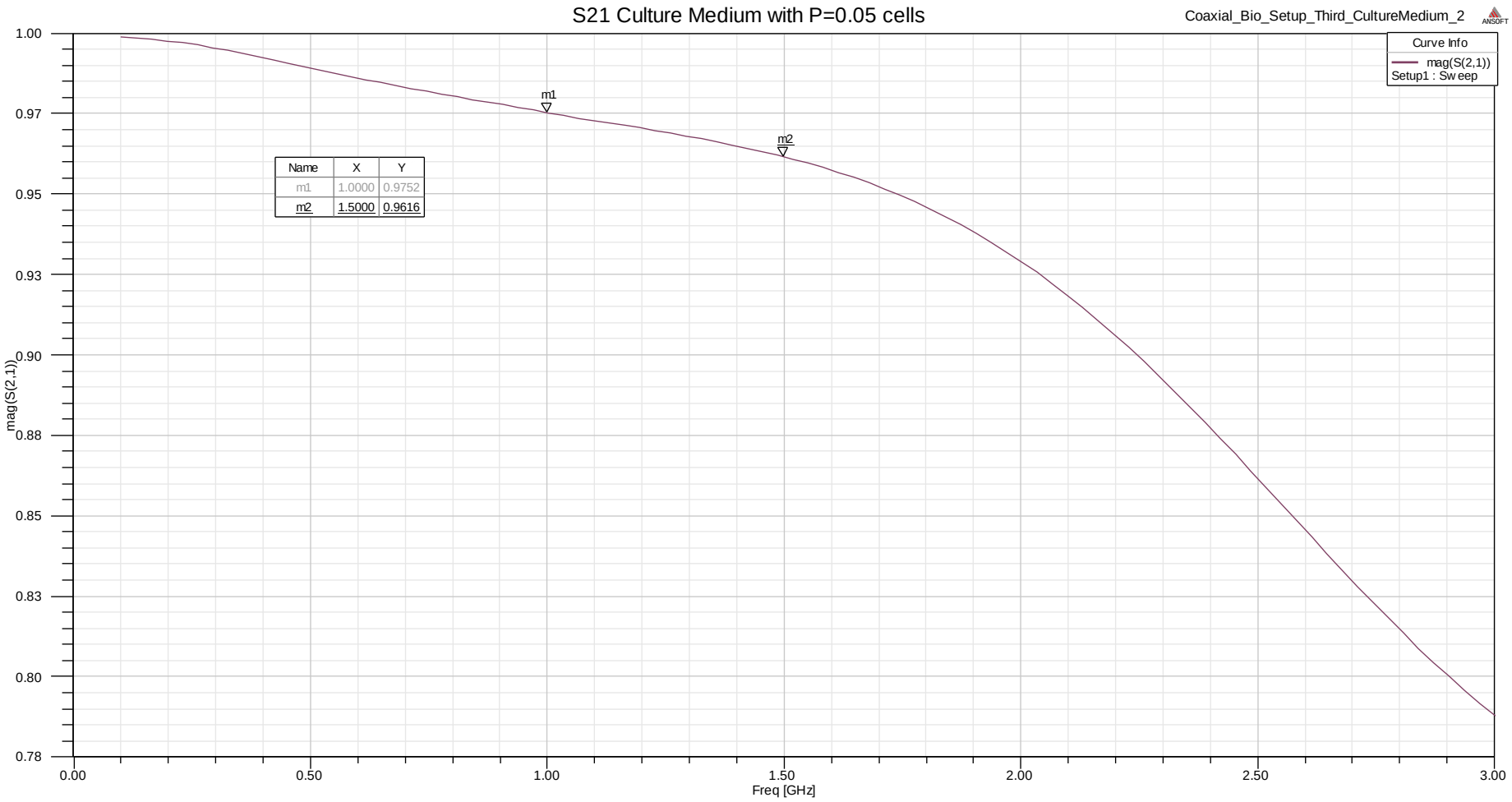


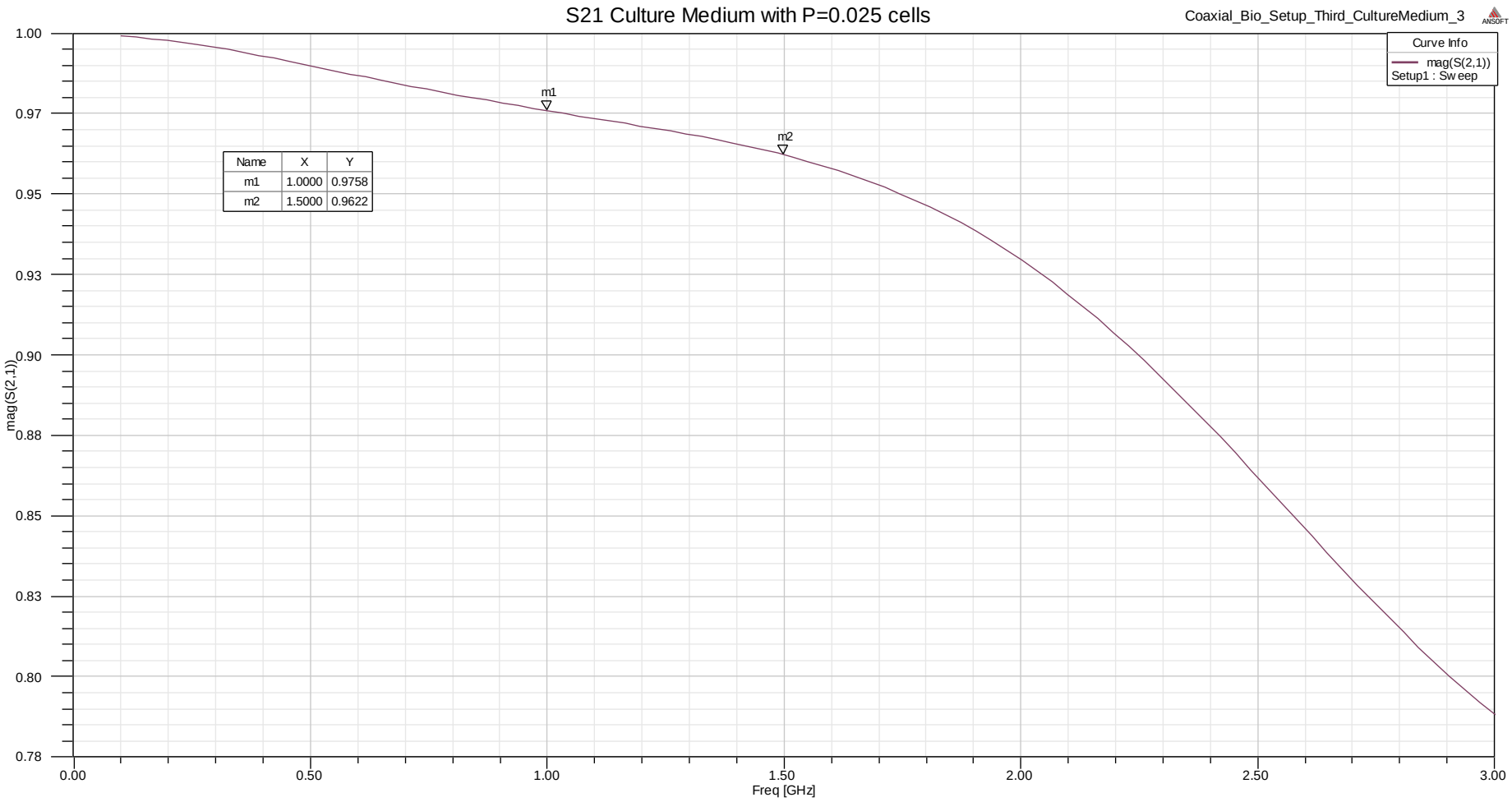

S21 with Distilled Water
Coaxial_Bio_Setup_Third_Distilled_Water
ANSOFT
Name | X | Y
m1 | 1.0000 | 0.9770
m2 | 1.5000 | 0.9633
Curve Info
mag(S(2,1))
Setup1 : Sweep
m1
m2
mag(S(2,1))
0.97
0.95
0.93
0.90
0.88
0.85
0.83
0.80
0.78
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Freq [GHz]

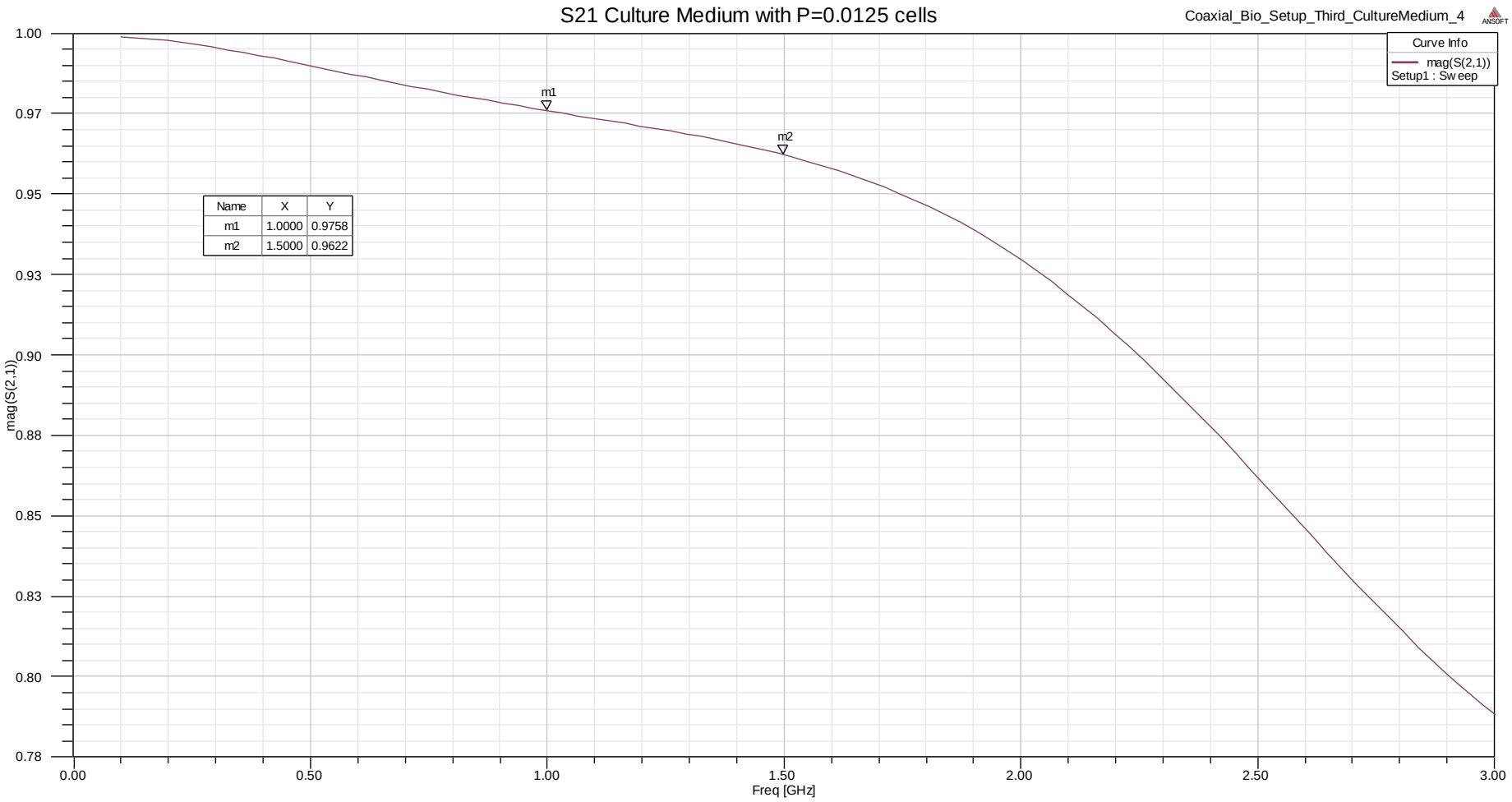

S21 Sea Water
Coaxial_Bio_Setup_Third_Sea_Water
ANSOFT
Curve Info
mag(S(2,1))
Setup1 : Sweep
Name X Y
m1 1.0000 0.9646
m2 1.5000 0.9481
m1
m2
mag(S(2,1))
1.00
0.97
0.95
0.93
0.90
0.88
0.85
0.83
0.80
0.78
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Freq [GHz]


S21 Culture medium without cells
Coaxial_Bio_Setup_Third_CultureMedium_00
Curve Info
mag(S(2,1))
Setup1 : Sweep
Name | X | Y
m1 | 1.0000 | 0.9755
m2 | 1.5000 | 0.9619
m1
m2
mag(S(2,1))
1.00
0.97
0.95
0.93
0.90
0.88
0.85
0.83
0.80
0.78
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Freq [GHz]


S21 Culture Medium with 0.1 % cells
Coaxial_Bio_Setup_Third_CultureMedium_01
Curve Info
mag(S(2,1))
Setup1 : Sweep
Name | X | Y
m1 | 1.0000 | 0.9756
m2 | 1.5000 | 0.9620
m1
m2
1.00E+000
9.75E-001
9.50E-001
9.25E-001
9.00E-001
8.75E-001
8.50E-001
8.25E-001
8.00E-001
7.75E-001
mag(S(2,1))
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Freq [GHz]


S21 Culture Medium with P=0.05 cells
Coaxial_Bio_Setup_Third_CultureMedium_2
ANSOFT
Curve Info
mag(S(2,1))
Setup1 : Sweep
m1
m2
Name | X | Y
m1 | 1.0000 | 0.9752
m2 | 1.5000 | 0.9616
mag(S(2,1))
1.00
0.97
0.95
0.93
0.90
0.88
0.85
0.83
0.80
0.78
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Freq [GHz]


S21 Culture Medium with P=0.025 cells
Coaxial_Bio_Setup_Third_CultureMedium_3
Curve Info
mag(S(2,1))
Setup1 : Sweep
m1
m2
Name X Y
m1 1.0000 0.9758
m2 1.5000 0.9622
mag(S(2,1))
1.00
0.97
0.95
0.93
0.90
0.88
0.85
0.83
0.80
0.78
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Freq [GHz]


S21 Culture Medium with P=0.0125 cells
Coaxial_Bio_Setup_Third_CultureMedium_4
ANSOFT
Curve Info
mag(S(2,1))
Setup1 : Sweep
m1
m2
Name X Y
m1 1.0000 0.9758
m2 1.5000 0.9622
mag(S(2,1))
1.00
0.97
0.95
0.93
0.90
0.88
0.85
0.83
0.80
0.78
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Freq [GHz]