While publishing the resuts of your simulations based on this code please reference M. Kostylev, *J. Appl. Phys.* **106**, 043903 (2009).

S21 and S11 parameters and a number of characteristics of a stripline loaded by a ferromagnetic film are calculated.

The code assumes that the external static magnetic field is applied in the film plane. The film is an exchange-coupled bilayer. The FMR traces are calculated applied-field resolved for a given microwave frequency. Both layers need to have conductivities of a metal ($\sigma > 10^5$ $(\Omega*m)^{-1}$ in order for the code to work properly). Please contact me if you need a code for an arbitrary value of conductivity (as already implemented in the out-of-plane magnetisation code). Also a code for a tri-layer film is availble on a request.
If you need to simulate a single layer film you may set identical magnetic parameters for both layers and L1=L2=0.5L, where L is the thickness of the single-layer film you want tio simulate. You will also need to set the value of the inter-layer exchange constant A12 to A12=n*A1/(L1+L2) .

Enter the number of the mesh steps across the sample thickness:

$n := 80$

Enter the thicknesses *L1 and L2* of the layers. The ferromagentic layer is closer to the striplein transucer.

$L1 := 10 \cdot 10^{-7}$ $\qquad$ $L2 := 70 \cdot 10^{-7}$

Enter Gilbert α (unitless) and frequency-independent part of magnetic losses ΔH_0 (in Oe):

$\alpha H1 := 0.032$ $\qquad$ $\alpha H2 := 0.008$

$\Delta H1_0 := 0$ $\qquad$ $\Delta H2_0 := 0$

Enter M=$4\pi M_s$ in G, and the gyromagnetic coefficient γ in Hz/Oe (γ is the same for both layers):

$\gamma := 2 \cdot \pi \cdot 2.94 \cdot 10^6$

$M1 := 16000 = 1.6 \times 10^4$ $\qquad$ $M2 := 10500 = 1.05 \times 10^4$

Enter exchange constant A in erg/cm:

$A1 := 1 \times 10^{-6}$ $\qquad$ $A2 := .41 \times 10^{-6}$

Interlayer exchange coupling constant (in erg/cm^2)

$A12 := 20$

Enter the conductivity of the metal in $(\Omega*m)^{-1}$

$\sigma 1 := 18 \cdot 10^6$ $\qquad$ $\sigma 2 := 4.5 \cdot 10^6$

Enter microwave frequency in rad/s

$\omega_0 := 2 \cdot \pi \cdot 18 \cdot 10^9 = 1.131 \times 10^{11}$

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Enter the dielectric constant for the microstrip/coplanar line ε_{sl}.

$\varepsilon_{sl} := 5.04$

It determines the phase velocity of the electromagnetic wave in the stripline (m/s):

$$V_f := \frac{3.0 \cdot 10^8}{\sqrt{\frac{\varepsilon_{sl} + 1}{2}}} = 1.726 \times 10^8$$

Enter the length of the sample along the microstrip in cm:

$ls := 0.45$

Enter the width of the microstrip (or the width of the signal line of the CPW) in cm

$w_{mpl} := 0.035$

Surface A (facing the microstrip): Surface B (facing away from the microstrip):

unitless pinning constant (0: surface spins are fully unpinned, 1: the spins are fully pinned. Any value between 0 nad 1 is allowed.)

$zsa := 0$ $zsb := 0$

Note that for the in-plane magentised films only the **in-plane** component of dynamic magnetisation can be pinned by the surface normal uniaxial anisotropy (see the paper by Soohoo)

conversion in the conventional pinning constant *d* in cm^{-1}:

$$dda := \frac{-\ln(1 - zsa)}{2 \cdot \Delta} \qquad ddb := \frac{-\ln(1 - zsb)}{2 \cdot \Delta}$$

Coresponding surface easy-axis normal uniaxial anisotropy in erg/cm^2 (which is the same as mJ/m^2):

$Ksa := dda \cdot A1$ $Ksb := ddb \cdot A1$

$Ksa = 0$ $Ksb = 0$

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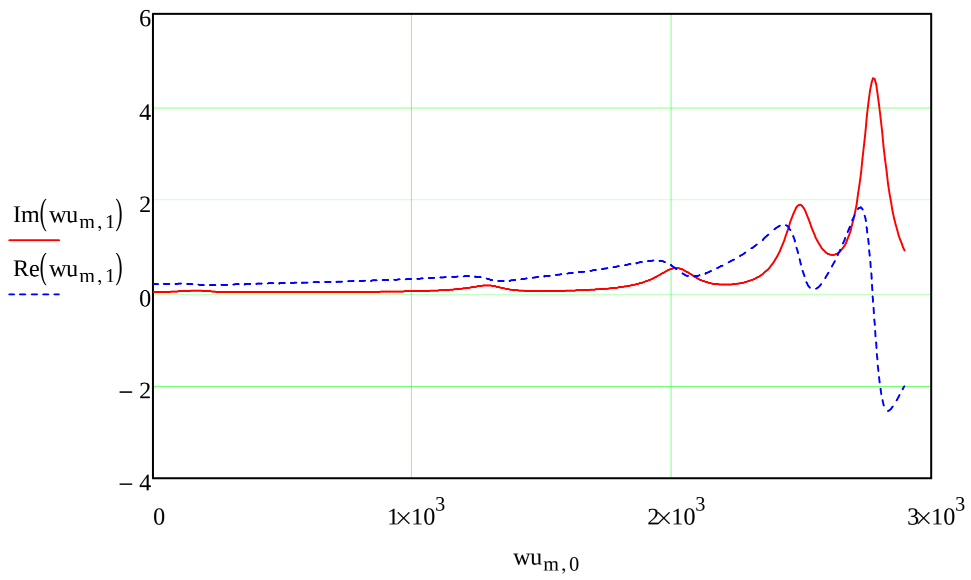
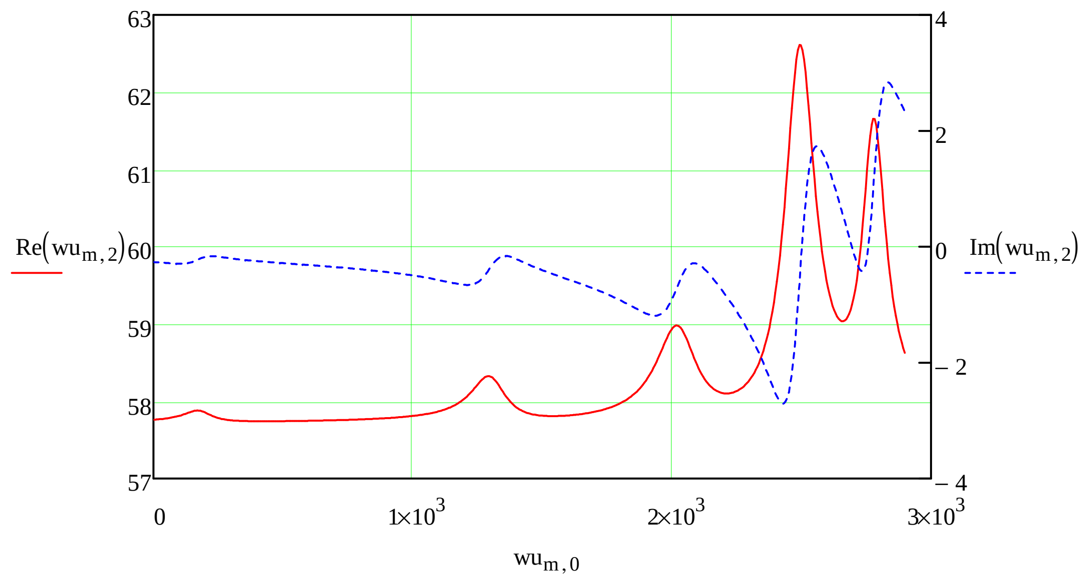
mean value of dynamic magnetisation across the film thickness (arb. unit) vs applied field (Oe):

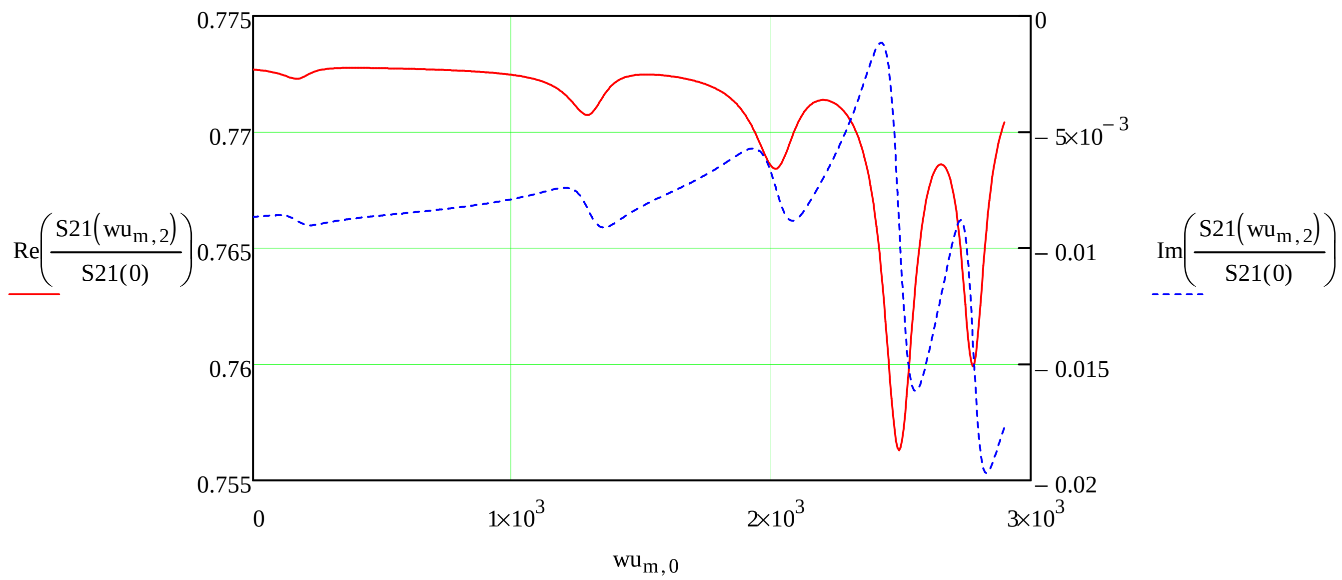
Charcteristic impedance of the stripline loaded by the film ("loaded stripline, "l.h. axis) and the respective propgation losses of the signal (r.h. axis)

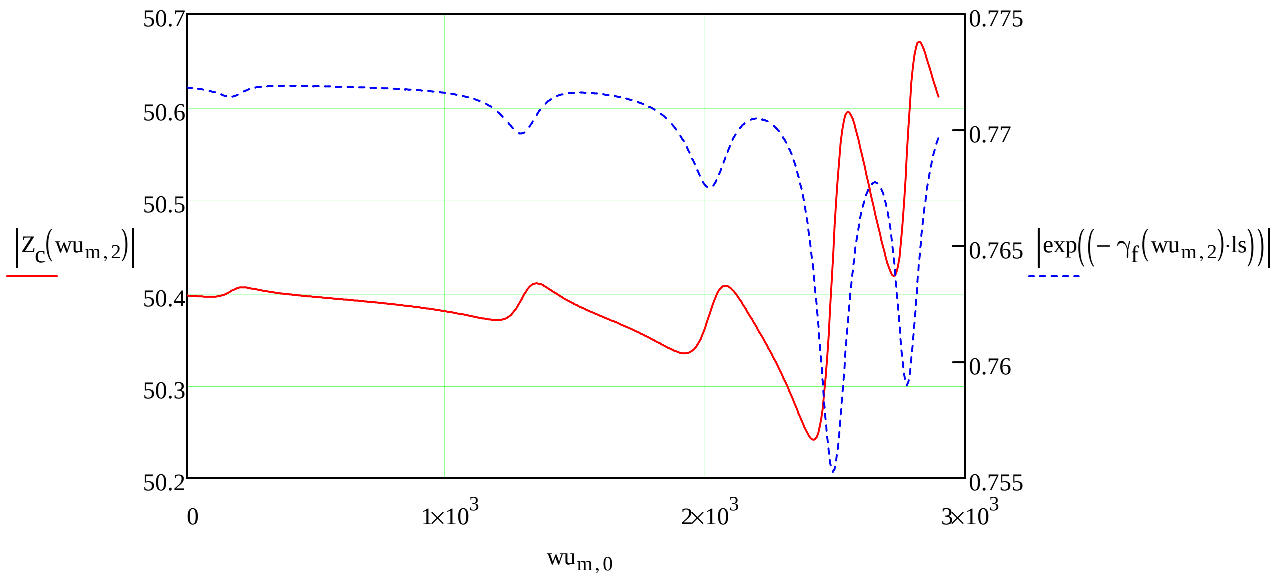


Complex impedance of the loaded stripline per unit length (Ω/cm)

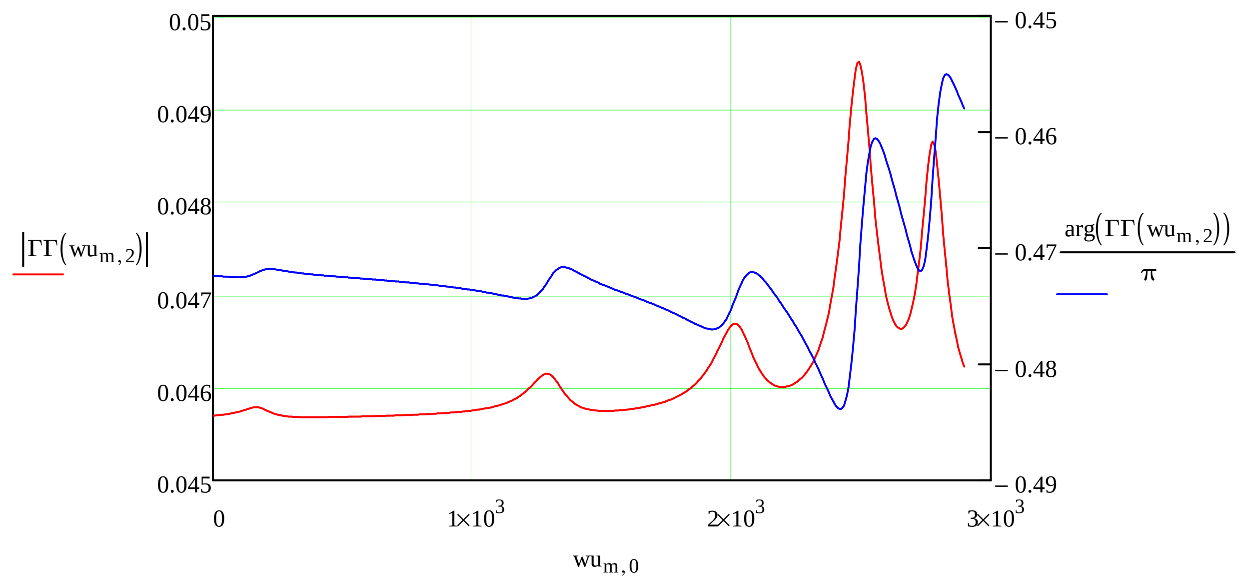


Complex processed S21

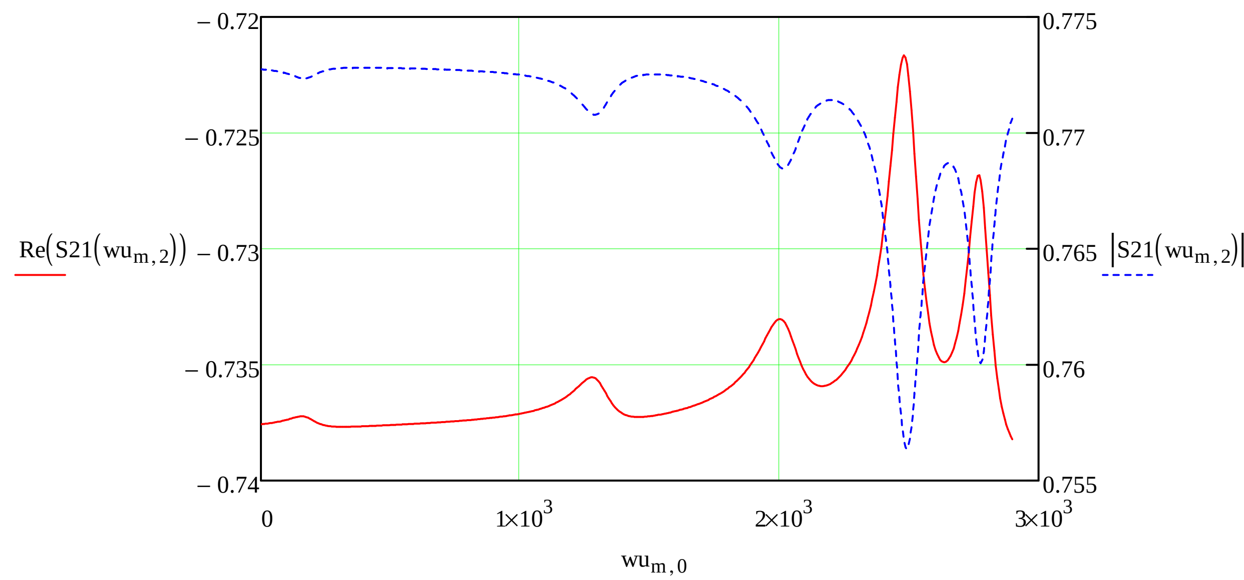




Reflecton coefficient from the front edge of the sample (essentially S11)



Complex unprocessed S21



Output data tables (for copy-pasting in your grahing software:)

$wu_{m,0} =$

0
5.807
11.614
17.421
23.228
29.035
34.842
40.649
46.456
52.263
58.07
63.878
69.685
75.492
81.299
...

$\mathrm{Re}\left(\frac{S21\left(wu_{m,2}\right)}{S21(0)}\right) =$

0.772705
0.7727
0.772694
0.772688
0.772681
0.772674
0.772666
0.772658
0.772649
0.772639
0.772629
0.772617
0.772605
0.772592
0.772577
...

$\mathrm{Im}\left(\frac{S21\left(wu_{m,2}\right)}{S21(0)}\right) =$

$-8.640777 \cdot 10^{-3}$
$-8.635416 \cdot 10^{-3}$
$-8.63 \cdot 10^{-3}$
$-8.624538 \cdot 10^{-3}$
$-8.619044 \cdot 10^{-3}$
$-8.613535 \cdot 10^{-3}$
$-8.608032 \cdot 10^{-3}$
$-8.602564 \cdot 10^{-3}$
$-8.597167 \cdot 10^{-3}$
$-8.591888 \cdot 10^{-3}$
$-8.586783 \cdot 10^{-3}$
$-8.581927 \cdot 10^{-3}$
$-8.577412 \cdot 10^{-3}$
$-8.573352 \cdot 10^{-3}$
$-8.569893 \cdot 10^{-3}$
...

Here, additionally, you may calculate thickness profiles for different physical quantities for a particular applied field Hp. (Enter Hp below)

$Hp := 2770$

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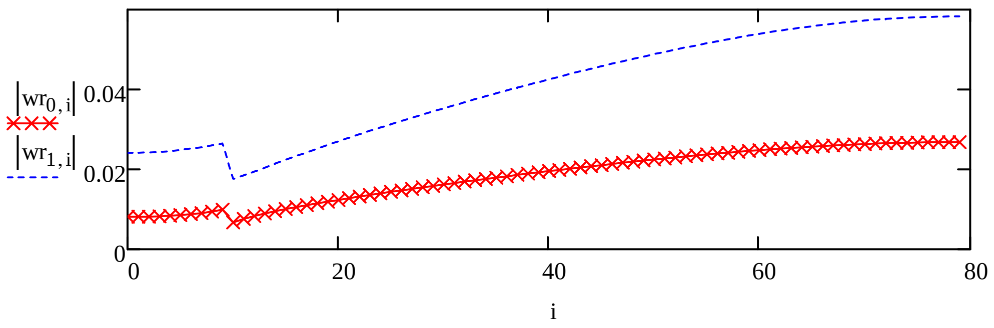
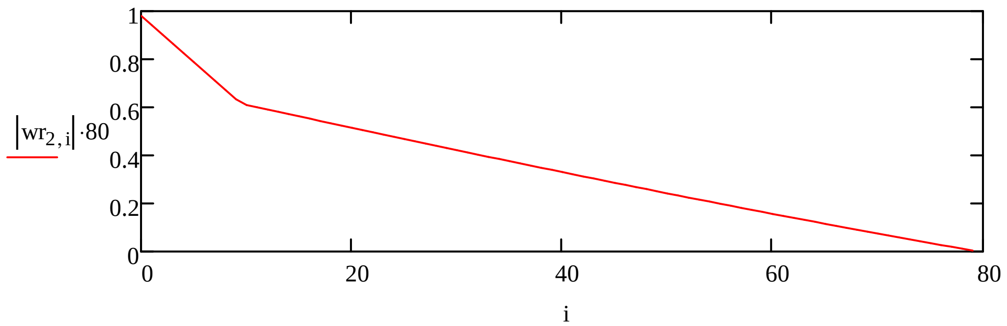
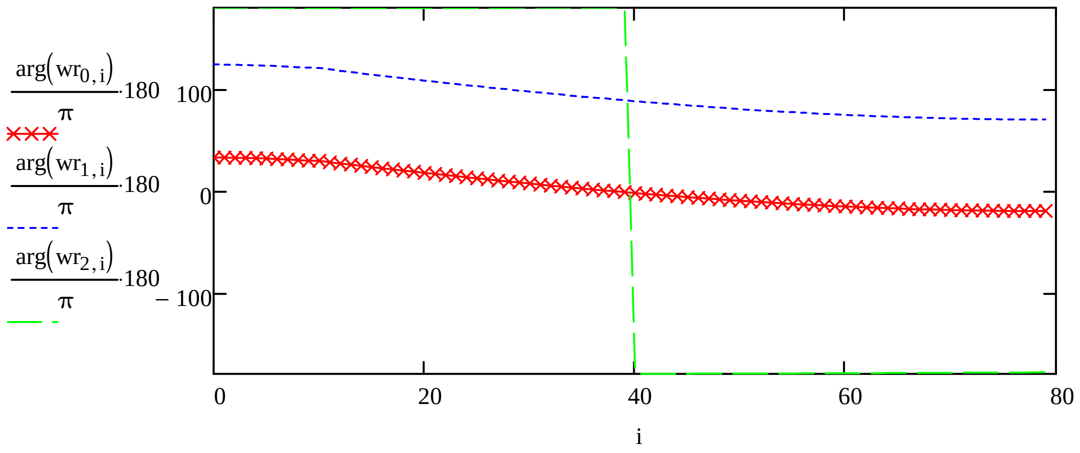
Amplitudes of both in-plane components of dynamic magnetisation vs. point number:



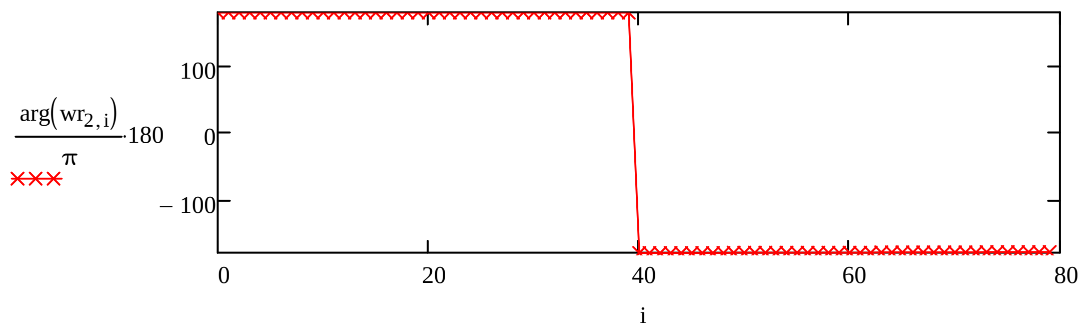
The microwave magnetic field



Their phases in angle degrees



Its phase in angle degrees



Microwave electric field: