FMR Fitting Manual

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- **Contents:**

Part I. Single Peak Fitting

MATLAB files for Lorentzian Fitting:

main	Single_Lorentz_main.m
fit-function	Single_Lorentz.m
model function with single peak Lorentzian	Single_Lorentz_fun.m
name sorting in natural order	sort_nat.m

Check latest version at Github: https://github.com/YCHEN-NYU/SingleLorentz.git

Input data format

- Input data name format:
  *_(frequency)MHz.dat (e. g. para_10000MHz.dat)
- Data Format

Column#	**1**	**2**	**3**	**4**	**5**	**6**	**7**
	Index	$H(T)$	s_{11}^{real}	s_{11}^{imag}	s_{11}^{A}	s_{11}^{phase}	s_{12}^{real}
Column#	8	9	10	11	12	13	14
	s_{12}^{imag}	s_{12}^{A}	s_{12}^{phase}	s_{22}^{real}	s_{22}^{imag}	s_{22}^{A}	s_{22}^{phase}

Output format

- Output file format (*.txt):

Column#	1	2	3	4	5
	f(GHz)	$H^{res}(Oe)$	$\Delta H \ \ (Oe)$	$\Delta H^{lb}(Oe)$	$\Delta H^{ub}(Oe)$

- Output figure format
  *.png with the input data file names (e. g. para_1000MHz.png)

Fitting Procedures

1. Open Single_Lorentz_main.m
   Set destination folder, outputname (fitting parameters storage), & indices of input data

   e. g. Set indexH = 2, indexS12real =7, indexS12imag = 8

```
%% ========================================================================
% Give destination folder, outputfile
cd '/Users/yiyi/Desktop/FMR_dataanalysis/f-H/#15/15_P2N1';
outputname='fit_parameters.txt';
% Give indices of field(T), S12_real, S12_imag
indexH = 2;
indexS12real = 7;
indexS12imag = 8;
```

2. Read all data files formatting as *MHz.dat & sort them in **natural order**

```
%%% read files in the current folder
folder = pwd;
% read all data file ended with *MHz.dat in the current folder
files=dir('*MHz.dat');
% sort out the files in natural order
[filenames, index] = sort_nat({files.name});
```

   e. g. sort data files in natural order

```
InPlane_3000MHz.dat
InPlane_3000sim.dat
InPlane_4000MHz.dat
InPlane_4000sim.dat
InPlane_5000MHz.dat
InPlane_5000sim.dat
InPlane_6000MHz.dat
InPlane_6000sim.dat
InPlane_7000MHz.dat
```

3. Set starting and ending indices of data files for the fitting loop

```
%% ========================================================================
% starting and ending indices of data files
i=1;
i_end = length(filenames);
```

4. Get microwave frequency from filenames

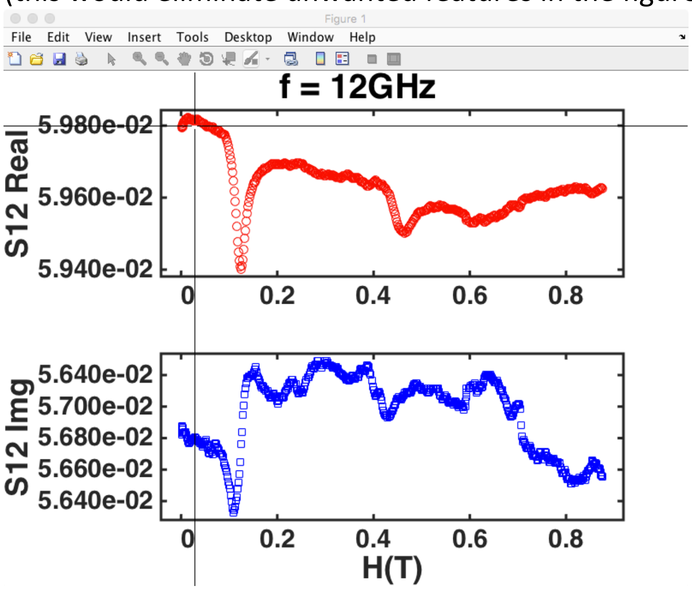
```
% Get frequency(GHz) from file names (read out number between _ and MHz)
str_splitted = strsplit(char(filenames{i}),'_');
strend = str_splitted(end);% Take '*MHz.dat' from data files 'XXX_*MHz.dat'
final_str = strsplit(char(strend),'MHz'); % Get '*' by splitting '*MHz.dat'
frequency = str2double(char(final_str(1)))/1000;% convert MHz to GHz
```

5. Load data into x(nx1 real) and y (nx1 complex). Then Call Single_Lorentz function to fit data

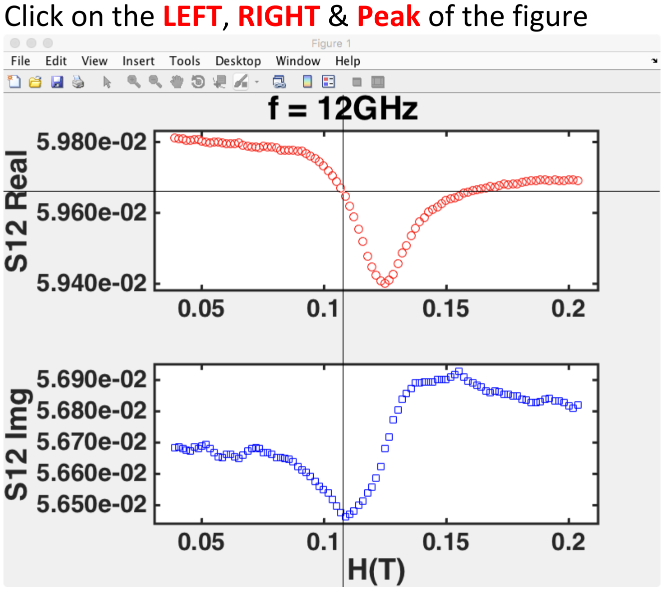
```
%% ======================================================================
% field in Tesla
x = data(:,indexH);
% Construct complex data y with S12_real and S12_imag
y = complex(data(:,indexS12real),data(:,indexS12imag));

% Call Fitting function to fit x-y with specific frequency
[fitpara, fitconfint, fig] = Single_Lorentz(x,y,frequency);
```

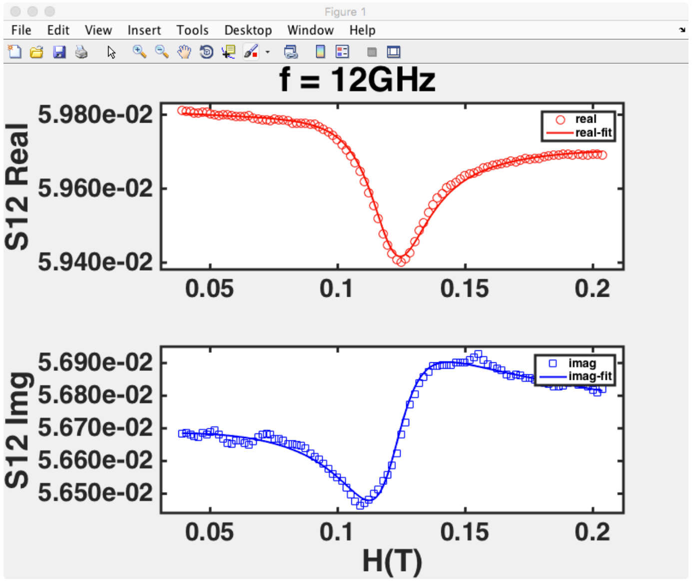
6. Click on the **LEFT** and **RIGHT** of the fitting area inside the top image or bottom image. (this would eliminate unwanted features in the figure)[no need to worry about y-axis]



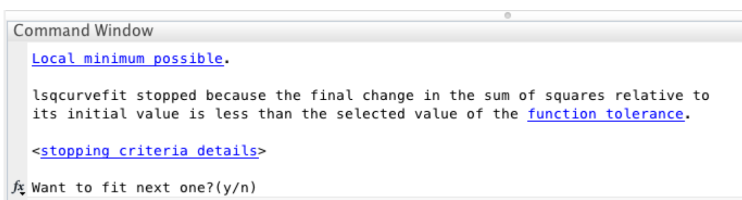
7. Click on the **LEFT**, **RIGHT** & **Peak** of the figure



8. After that we would have correct fitting as shown below.



9. **Return to the command window**, *type 'y' or 'Y' to fit the next data file*. Otherwise if the fitting doesn't work properly, *type any character other than 'y' or 'Y' to re-fit current data file*. *(click on the LEFT, RIGHT and Peak would give the program a set of starting parameters, correctly set the starting parameters are important for least-square fitting of multiple parameters.)*



10. Continue to fit all data until the ending message was sent inside the command windows.

11. Check output files and figures for reliability. Remove bad data points if necessary.

Part II: Double Peak Fitting

MATLAB codes for Lorentzian Fitting:

main	Double_Lorentz_main.m
fit-function	Double_Lorentz.m
model function with single peak Lorentzian	Double_Lorentz_fun.m
name sorting in natural order	sort_nat.m

Check latest version at Github: https://github.com/YCHEN-NYU/DoubleLorentz.git

Input data format

- Input data name format:
  *_(frequency)MHz.dat (e. g. para_10000MHz.dat)
- Data Format

Column#	1	2	3	4	5	6	7
	Index	$H(T)$	S_{11}^{real}	S_{11}^{imag}	S_{11}^{A}	S_{11}^{phase}	S_{12}^{real}
Column#	8	9	10	11	12	13	14
	S_{12}^{imag}	S_{12}^{A}	S_{12}^{phase}	S_{22}^{real}	S_{22}^{imag}	S_{22}^{A}	S_{22}^{phase}

Output format

- Output file format (*.txt):

Column	1	2	3	4	5	6	7	8	9
Data	f(GHz)	$H_1^{res}(Oe)$	$\Delta H_1(Oe)$	$\Delta H_1^{lb}(Oe)$	$\Delta H_1^{ub}(Oe)$	$H_2^{res}(Oe)$	$\Delta H_2(Oe)$	$\Delta H_2^{lb}(Oe)$	$\Delta H_2^{lb}(Oe)$

Output figure format (*.png) with the input data file names (e. g. para_1000MHz.png)

Fitting Steps

1. Open Double_Lorentz_main.m
   Set destination folder, outputname (fitting parameters storage), & indices of input data

   e. g. Set indexH = 2, indexS12real =7, indexS12imag = 8

```
%% =====================================================================
% Give destination folder, outputfile
cd '/Users/yiyi/Desktop/FMR_dataanalysis/f-H/#15/15_P2N1';
outputname='fit_parameters.txt';
% Give indices of field(T), S12_real, S12_imag
indexH = 2;
indexS12real = 7;
indexS12imag = 8;
```

2. Read all data files formatting as *MHz.dat & sort them in **natural order**

```
%%% read files in the current folder
folder = pwd;
% read all data file ended with *MHz.dat in the current folder
files=dir('*MHz.dat');
% sort out the files in natural order
[filenames, index] = sort_nat({files.name});
```

e. g. sort data files in natural order

InPlane_3000MHz.dat
InPlane_3000sim.dat
InPlane_4000MHz.dat
InPlane_4000sim.dat
InPlane_5000MHz.dat
InPlane_5000sim.dat
InPlane_6000MHz.dat
InPlane_6000sim.dat
InPlane_7000MHz.dat

3. Set starting and ending indices of data files for the fitting loop

```
%% ====================================================================
% starting and ending indices of data files
i=1;
i_end = length(filenames);
```

4. Get microwave frequency from filenames

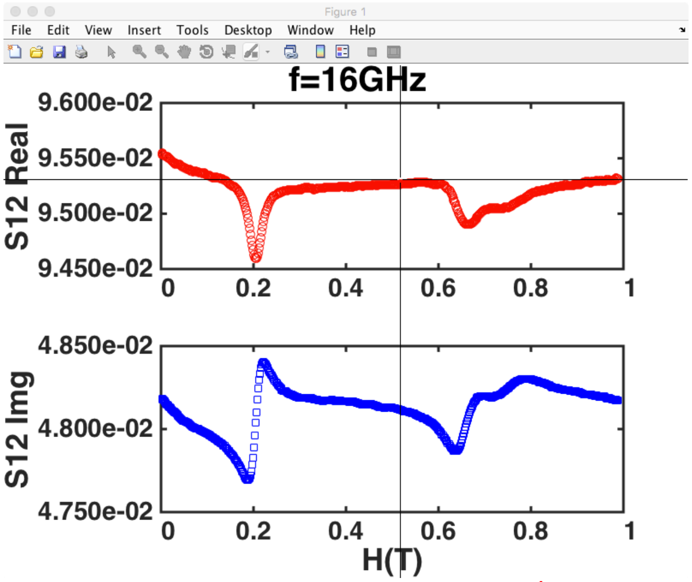
```
% Get frequency(GHz) from file names (read out number between _ and MHz)
str_splitted = strsplit(char(filenames{i}),'_');
strend = str_splitted(end);% Take '*MHz.dat' from data files 'XXX_*MHz.dat'
final_str = strsplit(char(strend),'MHz'); % Get '*' by splitting '*MHz.dat'
frequency = str2double(char(final_str(1)))/1000;% convert MHz to GHz
```

5. Load data into x(nx1 real) and y (nx1 complex). Then Call Double_Lorentz function to fit data

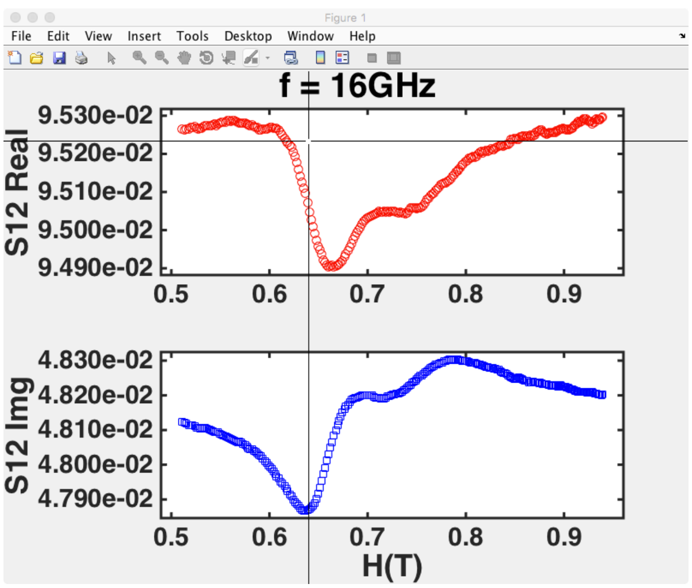
```
x = data(:,2); % field in Tesla
y = complex(data(:,7),data(:,8)); % S12_real and S12_imag

[fitpara, fitconfint, S12_plot] = Double_Lorentz(x,y,frequency);
```

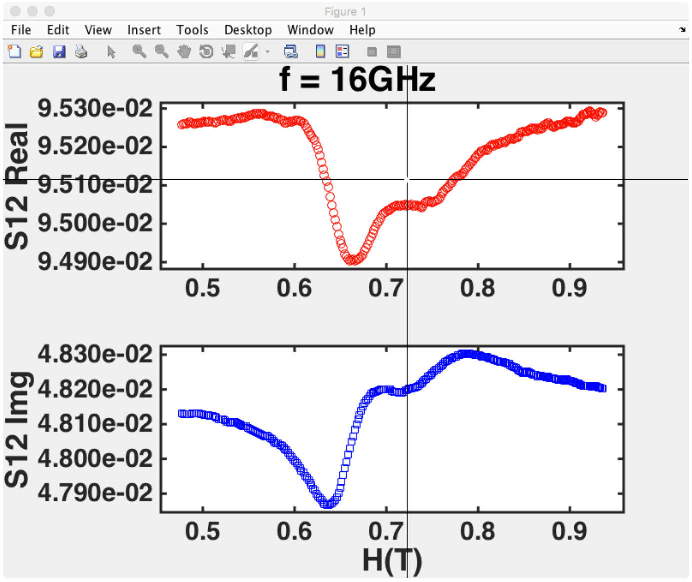
6. Click on the **LEFT** and **RIGHT** of the fitting area inside the top image or bottom image. (this would eliminate unwanted features of S12)[no need to worry about the y-axis]



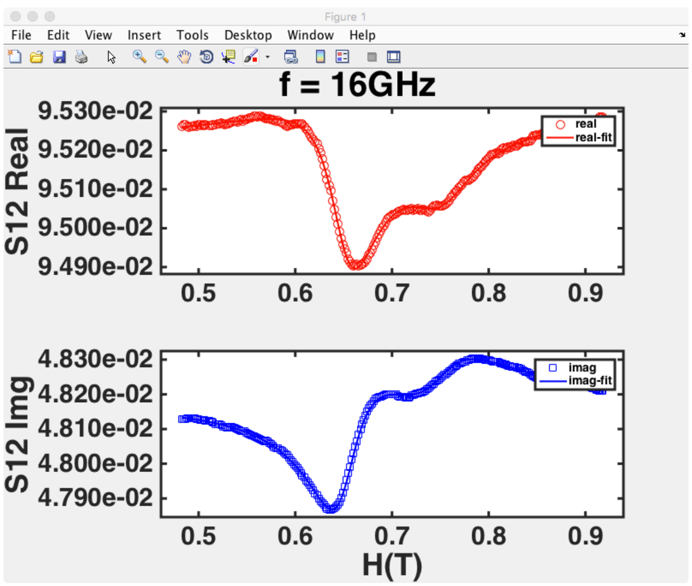
7. Click on the **LEFT**, **RIGHT** & **Peak** of **the 1st Peak**



8. Click on the **LEFT**, **RIGHT** & **Peak** of **the 2nd Peak**



9. After that we would have correct fitting as shown below.



10. Continue to fit all data until the ending message was sent inside the command windows.

11. Check output files and figures for reliability. Remove bad data points if necessary.

Part III. Fit Kittel and Gilbert Damping

(1) Extract H_{eff}, α and ΔH_0 with fixed g-factor
(2) Extract g-factor separately with 2 - parameters model

MATLAB codes for Lorentzian Fitting:

main	fit_Kittel_and_Gilbert.m
name sorting in natural order	sort_nat.m

Check latest version at Github: https://github.com/YCHEN-NYU/fit_Kittel_and_Gilbert.git

Input data format

- Input data name format: *.txt(e. g. 21_P2N1.txt)
- Data Format

Column#	1	2	3	4	5
	$f(GHz)$	$H_{res}(Oe)$	$\Delta H \quad (Oe)$	$\Delta H^{lb}(Oe)$	$\Delta H^{ub}(Oe)$

Output format

- Output file format (*.txt):

Column#	1	2	3	4	5	6	7	8
	$t(nm)$	g	Δg	$H_{eff}(T)$	$\Delta H_{eff}(T)$	α	$\Delta\alpha$	$\Delta H_0(Oe)$

Output figure format:
a. (*.png) with $\frac{f^2}{(\frac{\gamma}{2\pi})^2 H_{res}} - H_{res}$ and $\Delta H - f$ Plot (*e. g.* 21_P2N1.png)
b. (fH.png) with $f - H_{res}$ Plot

Fitting Steps

1. Set Destination Folder, g-factor, H interval, output file, Hmesh and thickness of layers (for legends)

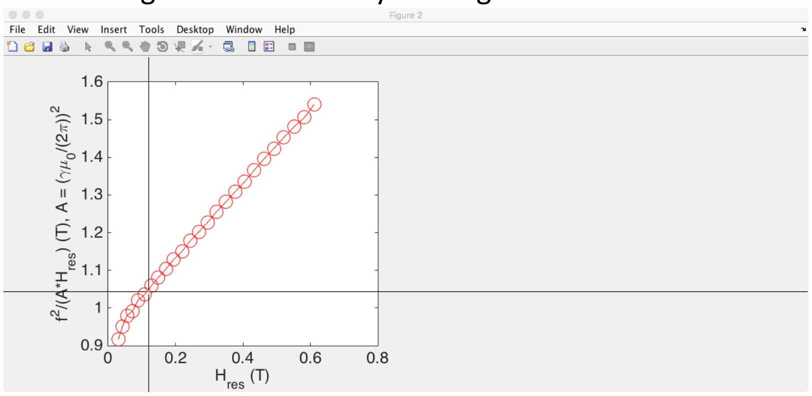
```
% =======================================
% Move to destination folder
cd '/Users/yiyi/Desktop/FMR_dataanalysis/f-H/#21/21_1stPeak_v3';
g = 2.135; % set a fixed g-factor
Hint = [0,150]; %set inhomogeneous broadening interval
fidout=fopen('fit_fH.txt','a+'); % Load output file
Hmesh = linspace(0,0.8,100); % set fit
thickness = [2.67,2.33, 2.19, 2.06, 1.96, 1.86, 1.78, 1.69]'; % thickness
```

2. Set Unit Conversion Constants and input data name format

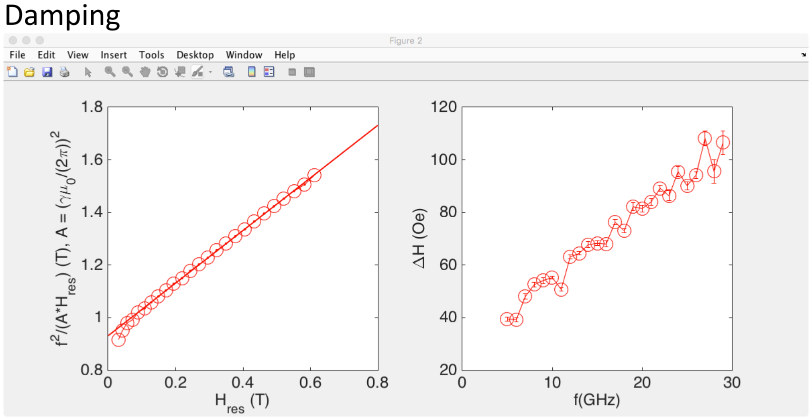
```
% constants for unit conversion
% Check "The NIST Reference on Constants, Units, and Uncertainty" for more details
em=1.758820*1e11;
A = g^2*em^2/(4*pi*1e9)^2;
gamma=2*pi*1e9*1e4/(1.758*1e11*0.5*g);% 1e9 from GHz, 1e4 from Oe
```

```
files=dir('*N1.txt');
```

3. Choose Region to be fitted by clicking on the LEFT and RIGHT of the plot



4. After Kittel Fitting on the left side, choose fitting region of the right plot to fit Gilbert Damping



5. Continue to finish all fittings & Check data & plots saved. Like those here.