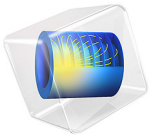


S-Parameter of a Thin-Film BAW Resonator

Introduction

This model shows how to compute the S-parameter for a piezoelectric MEMS device by extending the tutorial Thin-Film BAW Composite Resonator. The measurement of S-parameter is commonly used to characterize such devices for RF applications. The terminal feature in the Electrostatics physics interface provides straightforward access to the computed S-parameters for frequency domain study types.

See the PDF documentation for the tutorial Thin-Film BAW Composite Resonator (thin_film_baw_resonator.mph) for a general discussion on BAW resonators and for the specific device structure that the model is based on.

Model Definition

A new Terminal boundary condition and a new Frequency Domain study are added to the original model to use the built-in functionality of the software to compute the S-parameter.

Results and Discussion

Figure 1 and Figure 2 shows the real and imaginary parts of the computed S-parameter and the S-parameter in dB scale, respectively. Figure 1 also shows the S-parameter computed from the admittance, which matches exactly as the values computed by the new Terminal boundary condition, as one would expect.

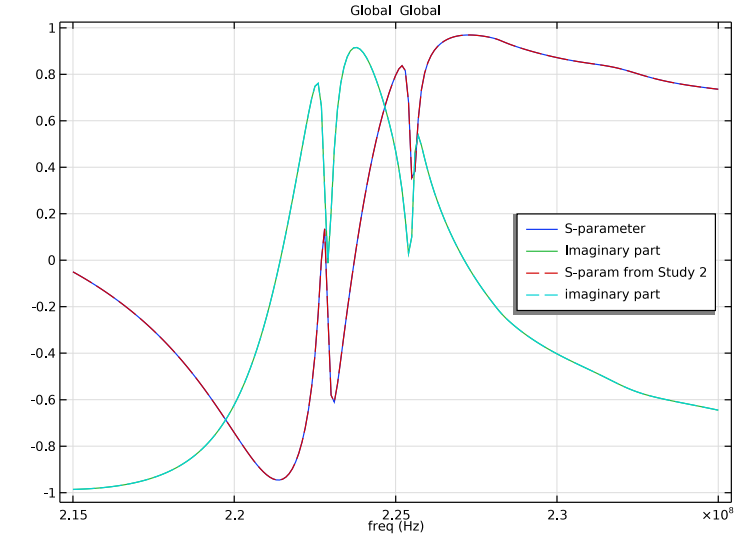


Figure 1: The real and imaginary parts of the S-parameter.

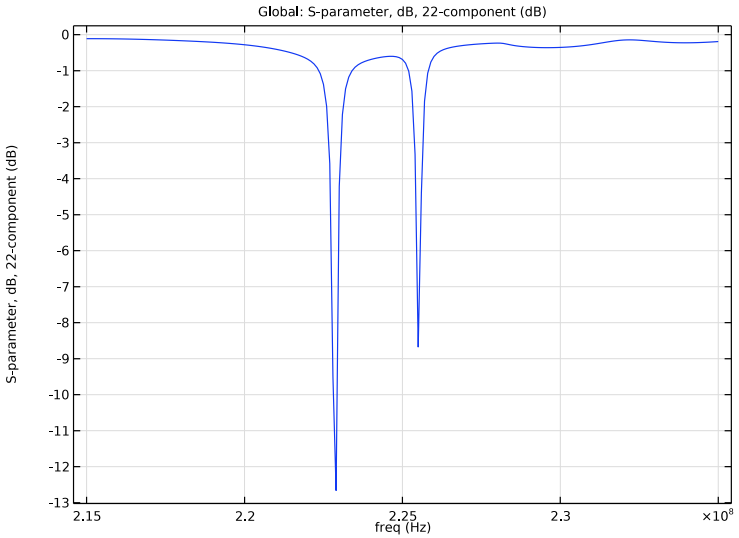


Figure 2: The S-parameter in dB scale.

References

1. See the PDF documentation for the original tutorial under MEMS_Module/Piezoelectric_Devices/thin_film_baw_resonator.

Application Library path: `MEMS_Module/Piezoelectric_Devices/thin_film_baw_resonator_s_parameter`

Modeling Instructions

ROOT

Open the tutorial model Thin-Film BAW Composite Resonator (filename: thin_film_baw_resonator.mph).

APPLICATION LIBRARIES

1. From the **File** menu, choose **Application Libraries**.
2. In the **Application Libraries** window, select **MEMS Module>Piezoelectric Devices>thin_film_baw_resonator** in the tree.
3. Click **Open**.

Duplicate the existing **Terminal** boundary condition and change the type to **Terminated** for the software to compute the S-parameter automatically. Note that the terminal number automatically increments from 1 to 2. The terminal number will be used later when accessing built-in global variables for the terminal. Set the power to a reasonable number.

COMPONENT 1 (COMP1)

In the **Model Builder** window, expand the **Component 1 (comp1)** node.

ELECTROSTATICS (ES)

Terminal 2

1. In the **Model Builder** window, expand the **Component 1 (comp1)>Electrostatics (es)** node.
2. Right-click **Component 1 (comp1)>Electrostatics (es)>Terminal 1** and choose **Duplicate**.
3. In the **Settings** window for **Terminal**, locate the **Terminal** section.
4. From the **Terminal type** list, choose **Terminated**.
5. In the P_0 text field, type `0.1`.

Disable the new boundary condition in the previous studies to preserve their original setup, so that if a previous study is computed again the result will not be affected.

STUDY 1

Step 1: Eigenfrequency

1 In the **Model Builder** window, expand the **Study 1** node, then click **Step 1: Eigenfrequency**.

2 In the **Settings** window for **Eigenfrequency**, locate the **Physics and Variables Selection** section.

3 Select the **Modify model configuration for study step** check box.

4 In the tree, select **Component 1 (comp1)>Electrostatics (es)>Terminal 2**.

5 Click **Disable**.

STUDY 2

Step 1: Frequency Domain

1 In the **Model Builder** window, expand the **Study 2** node, then click **Step 1: Frequency Domain**.

2 In the **Settings** window for **Frequency Domain**, locate the **Physics and Variables Selection** section.

3 Select the **Modify model configuration for study step** check box.

4 In the tree, select **Component 1 (comp1)>Electrostatics (es)>Terminal 2**.

5 Click **Disable**.

Now create a new study to use the new terminal boundary condition for S-parameter calculation. Start with an empty study and then copy and paste the Frequency Domain study step from Study 2. Clear the **Modify model configuration for study step** check box before clicking **Compute**.

ADD STUDY

1 In the **Home** toolbar, click **Add Study** to open the **Add Study** window.

2 Go to the **Add Study** window.

3 Find the **Studies** subsection. In the **Select Study** tree, select **Empty Study**.

4 Click **Add Study** in the window toolbar.

5 In the **Home** toolbar, click **Add Study** to close the **Add Study** window.

STUDY 2

Step 1: Frequency Domain

Right-click **Step 1: Frequency Domain** and choose **Copy**.

STUDY 3

In the **Model Builder** window, right-click **Study 3** and choose **Paste Frequency Domain**.

Step 1: Frequency Domain

1 In the **Settings** window for **Frequency Domain**, locate the **Physics and Variables Selection** section.

2 Clear the **Modify model configuration for study step** check box.

3 In the **Home** toolbar, click **Compute**.

RESULTS

Stress (solid)

Create a 1D plot group to plot the S-parameter as a function of the frequency. By default the real part of the expression is plotted. To plot the imaginary part, use the `imag()` function.

S-parameter

1 In the **Home** toolbar, click **Add Plot Group** and choose **1D Plot Group**.

2 In the **Settings** window for **1D Plot Group**, type `S-parameter` in the **Label** text field.

3 Locate the **Data** section. From the **Dataset** list, choose **Study 3/Solution 3 (sol3)**.

Global 1

1 Right-click **S-parameter** and choose **Global**.

2 In the **Settings** window for **Global**, locate the **y-Axis Data** section.

3 In the table, enter the following settings:

Expression	Unit	Description
`es.S22`	1	`S-parameter`
`imag(es.S22)`	1	`Imaginary part`

The S-parameter can also be calculated using the admittance from Study 2. By default the reference impedance is 50 Ohm, which can be customized under the section **Manual Terminal Sweep Settings** in the Settings window for the **Electrostatics** main physics node. Here we have left it as the default value, so we will use the formula `(1-es.Y11*50[ohm])/`

`(1+es.Y11*50[ohm])` to define the S-parameter. Use **Update Solution** to make the variable definition available to the solution of Study 2 without solving it again.

DEFINITIONS

Variables 1

1 In the **Model Builder** window, under **Component 1 (comp1)** right-click **Definitions** and choose **Variables**.

2 In the **Settings** window for **Variables**, locate the **Variables** section.

3 In the table, enter the following settings:

Name	Expression	Unit	Description
S11	`(1-es.Y11*50[ohm])/ (1+es.Y11*50[ohm])`		S-param from Study 2

STUDY 2

In the **Study** toolbar, click **Update Solution**.

RESULTS

Global 2

1 In the **Model Builder** window, right-click **S-parameter** and choose **Global**.

2 In the **Settings** window for **Global**, locate the **Data** section.

3 From the **Dataset** list, choose **Study 2/Solution 2 (sol2)**.

4 Locate the **y-Axis Data** section. In the table, enter the following settings:

Expression	Unit	Description
S11	1	S-param from Study 2
imag(S11)	1	imaginary part

5 Click to expand the **Coloring and Style** section. Find the **Line style** subsection. From the **Line** list, choose **Dashed**.

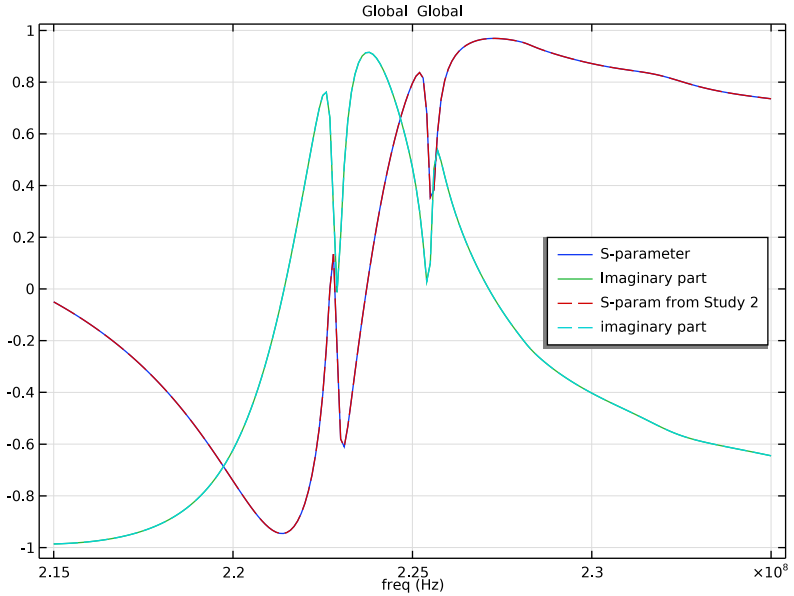
S-parameter

1 In the **Model Builder** window, click **S-parameter**.

2 In the **Settings** window for **1D Plot Group**, locate the **Legend** section.

3 From the **Position** list, choose **Middle right**.

4 In the **S-parameter** toolbar, click **Plot**.



Both the real and the imaginary part of the S-parameter matches exactly between the two studies, as one would expect. The S-parameter in dB scale is also available to be visualized, as shown below.

S-parameter, dB scale

1 In the **Home** toolbar, click **Add Plot Group** and choose **1D Plot Group**.

2 In the **Settings** window for **1D Plot Group**, type `S-parameter, dB scale` in the **Label** text field.

3 Locate the **Data** section. From the **Dataset** list, choose **Study 3/Solution 3 (sol3)**.

4 Locate the **Legend** section. Clear the **Show legends** check box.

Global 1

1 Right-click **S-parameter, dB scale** and choose **Global**.

2 In the **Settings** window for **Global**, locate the **y-Axis Data** section.

3 In the table, enter the following settings:

Expression	Unit	Description
`es.S22dB`	`dB`	`S-parameter, dB, 22-component`

4 In the **S-parameter, dB scale** toolbar, click **Plot**.