ARMY RESEARCH LABORATORY

Microsoft Excel Based S-parameter Device Analysis Software

by Brianna Murphy, Ali Darwish, and Thomas Farmer

ARL-TR-5339 **September 2010**

NOTICES

Disclaimers

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of manufacturer's or trade names does not constitute an official endorsement or approval of the use thereof.

Destroy this report when it is no longer needed. Do not return it to the originator.

Army Research Laboratory
Adelphi, MD 20783-1197

ARL-TR-5339 **September 2010**

Microsoft Excel Based S-parameter Device Analysis Software

Brianna Murphy, Ali Darwish, and Thomas Farmer
Sensors and Electron Devices Directorate, ARL

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED (From - To)
September 2010	Final	

4. TITLE AND SUBTITLE
Microsoft Excel Based S-parameter Device Analysis Software

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Brianna Murphy, Ali Darwish, and Thomas Farmer

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Research Laboratory
ATTN: RDRL-SER-E
2800 Powder Mill Road
Adelphi, MD 20783-1197

8. PERFORMING ORGANIZATION REPORT NUMBER
ARL-TR-5339

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
When collecting S-parameter data from a 2-port measurement device, such as a vector network analyzer (VNA), it is typically necessary to view this data on a computer other than the VNA for use in design or analysis of the measured device. To graphically view S-parameter data on a standard Microsoft Windows-based computer requires proprietary software, which typically requires licensing or installation. In an effort to eliminate the need for such proprietary software, a Microsoft Excel spreadsheet with built in macro software has been developed at the U.S. Army Research Laboratory (ARL) to read in and plot S-parameter data collected from a VNA. This technical report discusses the use, the design, and provides a listing of this macro-based software.

15. SUBJECT TERMS
Amplifier, MEMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Thomas Farmer
Unclassified	Unclassified	Unclassified	UU	16	19b. TELEPHONE NUMBER (*Include area code*) (301) 394-0487

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

Contents

List of Figures

1. Introduction

When using a network analyzer to analyze a 2-port device, S-parameter data is collected, typically in an ASCII file known as an S2P file. Several formats for this file exist. In the context of this report, we require the S2P file to be in the touchstone format, which was developed by EEsof in 1984. In order to analyze this data, it is necessary to import it into a software program to both plot and analyze the data. Typically the data plotted in linear representation as magnitude versus frequency or in a Smith chart representation. Typical analysis of S-parameters for transistor devices is the determination of f_T, f_{MAX}, and g_m. These plots and analysis are easily performed on some network analyzers and several proprietary or purchased licensed only software.

The purpose of this work was to create a Microsoft (MS) Excel program using the MS Excel macro scripting language to both plot and analyze S-parameter data from S2P files generated by network analyzers. The advantage of using MS Excel is that it allows engineers universal access to the plotting and analysis of S-parameters using any standard image computer equipped with MS Excel within the U.S. Army Research Laboratory, and possibly in a Department of Defense (DoD)-wide environment, to avoid the installation of proprietary or costly S-parameter analysis software.

2. User Manual

The following are the steps for using the program:

1. Open the S-parameter analyzer MS Excel Macro Workbook:
    - Filename: SParameter_Analyzer_v1.xslm
    - At the time of this report was written, this file was located on the common RDRL-SER-E server share drive:
        – L:\Sparameter_Analysis_Software\Brianna_Murphys_Sparameter_Plotting_Tool\ SParameter_Analyzer_v1.xlsm
    - A complete listing of the source code for this MS Excel Macro Workbook is in appendix A, so that the reader may create their own instance of this software in their own copy of MS Excel if L:\ drive access is not possible or the location listed above has expired.
2. The user is then prompted to select an .S2P file to be analyzed.

- Note: If the user chooses a file that is not an .S2P file, the program will not work.

3. Once the appropriate .S2P file is chosen, the program will process the S2P data
   - The original .S2P data file is not be manipulated or changed in any way.
4. Once the MS Excel macro has completed, there will be multiple sheets/tabs in a newly create MS Excel workbook:
   - The first sheet is a listing of the original .S2P data.
   - The second sheet is named Sparams_dB and includes the data with each column labeled. This sheet also has four extra columns that show the numerical data for 20*log(Magnitude) of the S11, S21, S21, and S22 magnitudes.
   - The third sheet has four S-parameter plots. Each of the two-port S-parameters has the logarithmic form of the magnitude plotted against frequency:
     – The plots are on top of one another, so the user must drag them apart to see all four S-parameters.

3. Structure of the MS Excel Macro Program

The MS Excel macro is split into several functions. The function at the top of the macro hierarchy is called **run_all_macros()** and is listed in figure 1. The functions or sub-routines called by this top function define the structure of this macro.

```
Sub run_all_macros()

   import_data_file

   analyze_data_dB

   add_sheet

   plot_S11

   plot_S21

   plot_S12

   plot_S22

End Sub
```

Figure 1. The **run_all_macros()** function.

As listed previously, the main macro function calls seven sub-routines to perform the tasks specified by their names. The following is a brief list of the functionality encapsulated by each sub-routine:

- import_data_file

  This sub-routine prompts the user for the .S2P file to import. Once the file is located, it creates a new MS Excel spreadsheet, then imports the ASCII-based data into that MS Excel spreadsheet

- analyze_data_dB

  This sub-routine converts the magnitude of each S-parameter into dB, using the following MS Excel formula: 20*LOG10(B3). A new tab is created in the current MS Excel spreadsheet and the logarithmic form of the magnitude of each S-parameter is placed in this tab

- add_sheet

  A new tab is created in the current MS Excel spreadsheet to hold the S-parameter plots.

- plot_S11

  An MS Excel XY-scatter plot of the logarithmic form of S11 versus the frequencies defined by the imported data is created and plotted in the new tab of the MS Excel spreadsheet.

- plot_S21

  An MS Excel XY-scatter plot of the logarithmic form of S21 versus the frequencies defined by the imported data is created and plotted in the new tab of the MS Excel spreadsheet.

- plot_S12

  An MS Excel XY-scatter plot of the logarithmic form of S12 versus the frequencies defined by the imported data is created and plotted in the new tab of the MS Excel spreadsheet.

- plot_S22

  An MS Excel XY-scatter plot of the logarithmic form of S22 versus the frequencies defined by the imported data is created and plotted in the new tab of the MS Excel spreadsheet.

A complete listing of each of these functions is given in the appendix. This section serves merely as an explanation of the programs hierarchy and flow.

4. Conclusions and Future Work

This program will allow all users to easily convert S-parameter data into graphs using MS Excel as opposed to using proprietary or costly S-parameter analysis software. Future work includes expanding this software into a more robust tool that will allow engineers future insight into the devices they are measuring.

Future improvements to this software include the following:

1. Auto-separating the four S-parameter plots.
2. Plotting the Smith chart representations of the imported S-parameter data.
3. Calculating H21 from the imported S-parameter data to plot f_T for a single transistor.
4. Calculating the U-parameter from the imported S-parameter data to plot f_{MAX} parameter for a single transistor.
5. Calculating the gm from the imported S-parameter data.

Appendix. Source Code Listing of the S-parameter Analysis Software

This is the complete source code listing of the S-parameter Analysis Software created in the Visual Basic Macro Scripting Language for MS Excel, version 2007.

This code can be copied and pasted into the macro section of an MS Excel spreadsheet and then saved as an .XLSM (macro-enabled workbook) file.

Afterwards, this .XLSM file can be opened and it will prompt to user for an .S2P file to analyze.

```
Sub run_all_macros()
'
' This Macro will call all the subsequent macros (consider in like main() in C)
'

   ' Import Data
   import_data_file

   ' Analyze Data - Convert to dB
   analyze_data_dB

   add_sheet

   plot_S11

   plot_S21

   plot_S12

   plot_S22

End Sub
```

```
Sub import_data_file()
'
' This macro will import the S2P file and save it as an .XLSX file
'

    ' Prompt user for filename

    Dim vFile As Variant

    ' Showing Excel Open Dialog Form
    vFile = Application.GetOpenFilename("S2P files (*.S2P*)," & _
    "*.S2P*", 1, "Select S2P File", "Open", False)

    ' Open S2P file and create new file
    Workbooks.OpenText Filename:= _
        vFile, _
        Origin:=437, StartRow:=1, DataType:=xlDelimited, TextQualifier:= _
        xlDoubleQuote, ConsecutiveDelimiter:=True, Tab:=False, Semicolon:=False, _
        Comma:=False, Space:=True, Other:=False, FieldInfo:=Array(Array(1, 1), _
        Array(2, 1), Array(3, 1), Array(4, 1), Array(5, 1), Array(6, 1), Array(7, 1),
Array(8, 1), _
        Array(9, 1), Array(10, 1)), TrailingMinusNumbers:=True
```

```
    ' Save in .XLSX format
    ActiveWorkbook.SaveAs vFile + ".xlsx", FileFormat:=51

    Set dataWorkBook = ActiveWorkbook

End Sub
```

```
Sub analyze_data_dB()
'
' This macro will copy the imported S2P data into a separate tab, convert it to dB,
and plot it
'

    ' Copy data from one tab to a new tab
    Sheets.Copy After:=dataWorkBook.ActiveSheet

    ' rename new tab
    ActiveSheet.Name = "Sparams_dB"

    ' organize columns and rows

    Rows("1:3").Select
    Selection.Delete Shift:=xlUp
    Columns("A:A").Select
    Selection.Delete Shift:=xlToLeft
    Range("A1").Select
    ActiveCell.FormulaR1C1 = "Frequency"
    Range("B1").Select
    ActiveCell.FormulaR1C1 = "S11 Magnitude"
    Range("C1").Select
    ActiveCell.FormulaR1C1 = "S11 Phase"
    Range("D1").Select
    ActiveCell.FormulaR1C1 = "S21 Magnitude"
    Range("E1").Select
    ActiveCell.FormulaR1C1 = "S21 Phase"
    Range("F1").Select
    ActiveCell.FormulaR1C1 = "S12 Magnitude"
    Range("G1").Select
    ActiveCell.FormulaR1C1 = "S12 Phase"
    Range("H1").Select
    ActiveCell.FormulaR1C1 = "S22 Magnitude"
    Range("I1").Select
    ActiveCell.FormulaR1C1 = "S22 Phase"
    Range("A2").Select

    Columns("C:C").Select
    Selection.Insert Shift:=xlToRight, CopyOrigin:=xlFormatFromLeftOrAbove
    Columns("F:F").Select
    Selection.Insert Shift:=xlToRight, CopyOrigin:=xlFormatFromLeftOrAbove
    Columns("I:I").Select
    Selection.Insert Shift:=xlToRight, CopyOrigin:=xlFormatFromLeftOrAbove
    Columns("L:L").Select
    Selection.Insert Shift:=xlToRight, CopyOrigin:=xlFormatFromLeftOrAbove
    Range("C1").Select
    ActiveCell.FormulaR1C1 = "20log(S11)"
    Range("C2").Select
    ActiveCell.FormulaR1C1 = "=IF(ISBLANK(RC[-1])=TRUE,"" "",20*LOG10(RC[-1]))"
    Range("C2").Select
    Selection.AutoFill Destination:=Range("C2:C402")
    Range("C2:C402").Select
    Range("F1").Select
```

```
    ActiveCell.FormulaR1C1 = "20log(S21)"
    Range("F2").Select
    ActiveCell.FormulaR1C1 = "=IF(ISBLANK(RC[-1])=TRUE,"" "",20*LOG10(RC[-1]))"
    Range("F2").Select
    Selection.AutoFill Destination:=Range("F2:F402")
    Range("F2:F402").Select
    Range("I1").Select
    ActiveCell.FormulaR1C1 = "20log(S12)"
    Range("I2").Select
    ActiveCell.FormulaR1C1 = "=IF(ISBLANK(RC[-1])=TRUE,"" "",20*LOG10(RC[-1]))"
    Range("I2").Select
    Selection.AutoFill Destination:=Range("I2:I402")
    Range("I2:I402").Select
    Range("L1").Select
    ActiveCell.FormulaR1C1 = "20log(S22)"
    Range("L2").Select
    ActiveCell.FormulaR1C1 = "=IF(ISBLANK(RC[-1])=TRUE,"" "",20*LOG10(RC[-1]))"
    Range("L2").Select
    Selection.AutoFill Destination:=Range("L2:L402")
    Range("L2:L402").Select
    Range("Q2").Select

End Sub
```

```
Sub add_sheet()
'
' This macro will add a new sheet to put the plots on


    Sheets.Add After:=Sheets(Sheets.Count)
    ActiveSheet.Select
    ActiveSheet.Name = "Sparam_plots"

    Sheets("Sparams_dB").Select

   End Sub

   Sub plot_S11()
'
' plot_S11 Macro
' Will plot grap of freq vs. 20log(S11)
'

'
    Range("A:A,C:C").Select
    Range("C1").Activate
    Charts.Add
    ActiveChart.ChartType = xlXYScatterSmooth
    ActiveChart.SetSourceData Source:=Sheets("Sparams_dB").Range( _
        "A1:A405,C1:C405"), PlotBy:=xlColumns
    ActiveChart.Location Where:=xlLocationAsObject, Name:="Sparam_plots"
    With ActiveChart
        .HasTitle = True
        .ChartTitle.Characters.Text = "S11"
        .Axes(xlCategory, xlPrimary).HasTitle = True
        .Axes(xlCategory, xlPrimary).AxisTitle.Characters.Text = "Frequency"
        .Axes(xlValue, xlPrimary).HasTitle = True
        .Axes(xlValue, xlPrimary).AxisTitle.Characters.Text = "20log(S11)"
    End With
End Sub
```

```
Sub plot_S21()
'
' plot_S21 Macro
' Will plot grap of freq vs. 20log(S21)

'
    Range("A:A,F:F").Select
    Range("F1").Activate
    Charts.Add
    ActiveChart.ChartType = xlXYScatterSmooth
    ActiveChart.SetSourceData Source:=Sheets("Sparams_dB").Range( _
        "A1:A405,F1:F405"), PlotBy:=xlColumns
    ActiveChart.Location Where:=xlLocationAsObject, Name:="Sparam_plots"
    With ActiveChart
        .HasTitle = True
        .ChartTitle.Characters.Text = "S21"
        .Axes(xlCategory, xlPrimary).HasTitle = True
        .Axes(xlCategory, xlPrimary).AxisTitle.Characters.Text = "Frequency"
        .Axes(xlValue, xlPrimary).HasTitle = True
        .Axes(xlValue, xlPrimary).AxisTitle.Characters.Text = "20log(S21)"
    End With
End Sub
```

```
Sub plot_S12()
'
' plot_S12 Macro
' Will plot grap of freq vs. 20log(S12)
'

'
    Range("A:A,I:I").Select
    Range("I1").Activate
    Charts.Add
    ActiveChart.ChartType = xlXYScatterSmooth
    ActiveChart.SetSourceData Source:=Sheets("Sparams_dB").Range( _
        "A1:A405,I1:I405"), PlotBy:=xlColumns
    ActiveChart.Location Where:=xlLocationAsObject, Name:="Sparam_plots"
    With ActiveChart
        .HasTitle = True
        .ChartTitle.Characters.Text = "S12"
        .Axes(xlCategory, xlPrimary).HasTitle = True
        .Axes(xlCategory, xlPrimary).AxisTitle.Characters.Text = "Frequency"
        .Axes(xlValue, xlPrimary).HasTitle = True
        .Axes(xlValue, xlPrimary).AxisTitle.Characters.Text = "20log(S21)"
    End With
End Sub
```

```
   Sub plot_S22()
'
' plot_S22 Macro
' Will plot grap of freq vs. 20log(S22)
'

'
    Range("A:A,L:L").Select
    Range("L1").Activate
    Charts.Add
    ActiveChart.ChartType = xlXYScatterSmooth
    ActiveChart.SetSourceData Source:=Sheets("Sparams_dB").Range( _
        "A1:A405,L1:L405"), PlotBy:=xlColumns
    ActiveChart.Location Where:=xlLocationAsObject, Name:="Sparam_plots"
    With ActiveChart
```

```
        .HasTitle = True
        .ChartTitle.Characters.Text = "S22"
        .Axes(xlCategory, xlPrimary).HasTitle = True
        .Axes(xlCategory, xlPrimary).AxisTitle.Characters.Text = "Frequency"
        .Axes(xlValue, xlPrimary).HasTitle = True
        .Axes(xlValue, xlPrimary).AxisTitle.Characters.Text = "20log(S22)"
    End With
End Sub
```

No. of Copies	Organization
1 ELEC	ADMNSTR DEFNS TECHL INFO CTR ATTN DTIC OCP 8725 JOHN J KINGMAN RD STE 0944 FT BELVOIR VA 22060-6218
1 CD	OFC OF THE SECY OF DEFNS ATTN ODDRE (R&AT) THE PENTAGON WASHINGTON DC 20301-3080
1	US ARMY RSRCH DEV AND ENGRG CMND ARMAMENT RSRCH DEV & ENGRG CTR ARMAMENT ENGRG & TECHNLGY CTR ATTN AMSRD AAR AEF T J MATTS BLDG 305 ABERDEEN PROVING GROUND MD 21005-5001
1	PM TIMS, PROFILER (MMS-P) AN/TMQ-52 ATTN B GRIFFIES BUILDING 563 FT MONMOUTH NJ 07703
1	US ARMY INFO SYS ENGRG CMND ATTN AMSEL IE TD A RIVERA FT HUACHUCA AZ 85613-5300
1	COMMANDER US ARMY RDECOM ATTN AMSRD AMR W C MCCORKLE 5400 FOWLER RD REDSTONE ARSENAL AL 35898-5000
1	US GOVERNMENT PRINT OFF DEPOSITORY RECEIVING SECTION ATTN MAIL STOP IDAD J TATE 732 NORTH CAPITOL ST NW WASHINGTON DC 20402
1	US ARMY RSRCH LAB ATTN RDRL CIM G T LANDFRIED BLDG 4600 ABERDEEN PROVING GROUND MD 21005-5066
3	US ARMY RSRCH LAB ATTN IMNE ALC HRR MAIL & RECORDS MGMT ATTN RDRL CIM L TECHL LIB ATTN RDRL CIM P TECHL PUB ADELPHI MD 20783-1197
18	US ARMY RSRCH LAB ATTN RDRL SER E ROMEO DEL ROSARIO EDWARD VIVEIROS JOHN PENN KWOK TOM BENJAMIN HUEBSCHMAN ROBERT PROIE TONY IVANOV CAROLINE WAIYAKI KEN MCKNIGHT KHAMSOUK KINGKEO JAMES WILSON ROGER KAUL ALI DARWISH THOMAS FARMER (5 COPIES) ADELPHI MD 20783-1197
1	UNIVERSITY OF MARYLAND DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING STEVE NORTON 2425 AV WILLIAMS BUILDING COLLEGE PARK MD 20742
1	UNIVERSITY OF MARYLAND 1125 CUMBERLAND HALL BETSY MENDELSOHN COLLEGE PARK MD 20742
1	UNIVERSITY OF MARYLAND DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING MS. BRIANNA MURPHY C/O STEVE NORTON 2425 AV WILLIAMS BUILDING COLLEGE PARK MD 20742
TOTAL:	32 (1 ELEC, 1 CD, 30 HCS)