APPLICATION NOTE 2866

Converting S-Parameters from 50Ω to 75Ω Impedance

Abstract: Cable television integrated circuits are usually designed to interface with 75Ω input and output impedance, while most RF test equipment is 50Ω impedance. In most cases, minimum loss pads are used to convert the input and output impedance from 75Ω to 50Ω, and visa versa, for testing purposes. Although convenient, minimum loss pads should be avoided when measuring S-parameters. One easy way to perform such measurement is by treating the input and output impedance of the cable device as 50Ω, perform the test, and use the equations and Excel spreadsheet presented in this application note to convert the 50Ω-referenced S-parameters back to 75Ω.

Introduction

Cable television integrated circuits are usually designed to interface with 75Ω inputs and outputs, while most RF test equipment use 50Ω impedance. In most cases, minimum-loss pads are used to convert the input and output impedances from 75Ω to 50Ω, and vice-versa. Although convenient, minimum-loss pads should be avoided when measuring S-parameters.

This application note presents an easy way to perform S-parameter measurements by treating the input and output impedance of the cable device as 50Ω, performing the test, and making a mathematical conversion. We provide the equations and a handy Excel spreadsheet to convert 50Ω-referenced S-parameters back to 75Ω.

S-Parameter to Impedance

The conversion of a 50Ω-referenced S-parameter to 75Ω begins with equation 1. Both the S-parameter and input impedance are complex numbers ($R + jX$), where R represents the real component, and the X represents the imaginary component. Z_O is usually a real impedance. For the sake of simplicity, input return loss (S_{11}) will be considered throughout this application note.

$$S_{11} = \frac{Z_{IN} - Z_0}{Z_{IN} + Z_0} \qquad \text{Eq.01}$$

Rearrange Eq. 1 to obtain an input impedance (Z_{IN}) expression Eq. 2,

$$Z_{IN} = Z_0 \left(\frac{1 + S_{11}}{1 - S_{11}} \right) \qquad \text{Eq. 02}$$

Replace the S_{11} with $R + jX$,

$$Z_{IN} = Z_0 \left(\frac{1 + R + jX}{1 - R - jX} \right) \qquad \text{Eq. 03}$$

Multiply the denominator of Eq. 3 with its complex conjugate to separate the real and imaginary components,

$$Z_{IN} = Z_0 \left(\frac{1+R+jX}{1-R-jX} \right) \left(\frac{1-R+jX}{1-R+jX} \right)$$

Eq. 04

$$Z_{IN} = Z_0 \left(\frac{1-R^2 - X^2 + j2X}{(1-R)^2 + X^2} \right)$$

Eq. 05

Eq. 6 is the real component of the input impedance,

$$Z_{IN} \text{ (REAL)} = Z_0 \left(\frac{1-R^2 - X^2}{(1-R)^2 + X^2} \right)$$

Eq. 06

Eq. 7 is the imaginary component of the input impedance,

$$Z_{IN} \text{ (IMAGINARY)} = Z_0 \left(\frac{j2X}{(1-R)^2 + X^2} \right)$$

Eq. 07

Impedance to S-Parameter

Once the complex input impedance is obtained, Eq. 1 is used once again to convert the impedance back to a 75Ω-referenced S-parameter.

Eq. 8 is the same expression as Eq. 1, except Z_{IN} is replaced with R + jX,

$$S_{11} = \frac{R+jX - Z_0}{R+jX + Z_0}$$

Eq. 08

Multiply the denominator of Eq. 8 with its complex conjugate to separate the real and imaginary components,

$$S_{11} = \left(\frac{R - Z_0 + jX}{R + Z_0 + jX} \right) \left(\frac{R + Z_0 - jX}{R + Z_0 - jX} \right)$$

Eq. 09

$$S_{11} = \frac{R^2 - Z_0^2 + X^2 + j2XZ_0}{(R + Z_0)^2 + X^2}$$

Eq. 10

Eq. 11 is the real component of the input return loss (S_{11}),

$$S_{11} \text{ (REAL)} = \frac{R^2 - Z_0^2 + X^2}{(R + Z_0)^2 + X^2}$$

Eq. 11

Eq. 12 is the imaginary component of the input return loss (S_{11}),

$$S_{11} \text{ (IMAGINARY)} = \frac{j2XZ_0}{(R + Z_0)^2 + X^2}$$

Eq. 12

Example

$S_{11} = 0.53 - j0.12$ (Return loss value taken from a network analyzer)

$$Z_{IN}\,(REAL) = Z_0\left(\frac{1-R^2-X^2}{(1-R)^2+X^2}\right) = 50\left(\frac{1-(0.53)^2-(-0.12)^2}{(1-0.53)^2+(-0.12)^2}\right)$$

$Z_{IN}\,(REAL) = 149.75\Omega$

$$Z_{IN}\,(IMAGINARY) = Z_0\left(\frac{j2X}{(1-R)^2+X^2}\right) = 50\left(\frac{j2(-0.12)}{(1-0.53)^2+(-0.12)^2}\right)$$

$Z_{IN}\,(IMAGINARY) = -j51\Omega$

$Z_{IN} = 149.75 - j51\Omega$

$$S_{11}\,(REAL) = \frac{R^2-Z_0^2+X^2}{(R+Z_0)^2+X^2} = \frac{(149.75)^2-(75)^2+(-51)^2}{(149.75+75)^2+(-51)^2}$$

$S_{11}\,(REAL) = 0.37$

$$S_{11}\,(IMAGINARY) = \frac{j2XZ_0}{(R+Z_0)^2+X^2} = \frac{j2(-51)(75)}{(149.75+75)^2+(-51)^2}$$

$S_{11}\,(IMAGINARY) = -0.14$

$S_{11} = 0.37 - j0.14$ (Return loss of the device with 75Ω characteristic impedance)

Excel Spreadsheet

Table 1 shows the Excel spreadsheet that allows fast conversion of 50Ω S-parameter data to 75Ω.

Network Analyzer Impedance:	50
MAX3550/3553 Input Impedance:	75

Frequency (MHz)	S11 (in 50Ω)		Impedance		S11 (in 75Ω)	
	Real	Image	Real	Image	Real	Image
1	0.53	-0.12	150.98	-50.17	0.37	-0.14
2	0.53	-0.12	148.11	-52.37	0.36	-0.15
3	0.53	-0.13	145.59	-55.14	0.36	-0.16
4	0.52	-0.14	142.66	-57.44	0.36	-0.17
5	0.52	-0.15	139.69	-59.71	0.35	-0.18
6	0.52	-0.16	136.83	-61.40	0.35	-0.19
7	0.51	-0.17	133.72	-63.43	0.34	-0.20
8	0.51	-0.18	130.63	-65.16	0.34	-0.21
9	0.51	-0.19	127.48	-66.63	0.33	-0.22
10	0.50	-0.19	124.44	-67.89	0.33	-0.23

Download Table as an Excel Spreadsheet (XLS, 16kB)

Application Note 2866: http://www.maxim-ic.com/an2866

More Information
For technical questions and support: http://www.maxim-ic.com/support
For samples: http://www.maxim-ic.com/samples
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Related Parts

MAX3507: QuickView -- Full (PDF) Data Sheet

MAX3509: QuickView -- Full (PDF) Data Sheet

MAX3510: QuickView -- Full (PDF) Data Sheet

MAX3514: QuickView -- Full (PDF) Data Sheet

MAX3516: QuickView -- Full (PDF) Data Sheet -- Free Samples

MAX3517: QuickView -- Full (PDF) Data Sheet

MAX3550: QuickView -- Full (PDF) Data Sheet

MAX3553: QuickView -- Full (PDF) Data Sheet

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