
Mismatch Uncertainty Calculator: A Microwave Freeware Software Tool

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Uncertainties abound when evaluating microwave measurement parameters and one must be reasonably certain that measurement results incorporate all applicable uncertainties in order to establish a unit's true performance. A software tool developed at Compaq Computer may provide some assistance in calculations for mismatch uncertainty.

Microwave measurement parameters required to verify the operational performance of modern microwave test and measurement equipment spans from simple to complex. Typically these parameters deal with signal integrity and signal spectral purity. Signal integrity measurements can range from amplitude accuracy to modulation index. Spectral purity measurements may be evaluated in terms of waveform harmonic content, phase noise, etc. Uncertainties abound when evaluating microwave measurement parameters and one must be reasonably certain that measurement results incorporate all applicable uncertainties in order to establish a unit's true performance.

One such measurement scenario is in the verification of RF power and attenuation. Mismatches and reflections are uncertainty components that must be considered in order to determine uncertainties on the actual RF power and attenuation measurements. It was during a National Voluntary Laboratory Accreditation Program (NVLAP) proficiency test for initial accreditation in the electromagnetic RF/ microwave discipline that the author developed the Mismatch Uncertainty Calculator. This program, written for Windows™95, proved very beneficial in performing mismatch uncertainty calculations used in determining test artifacts values.

The author's laboratory NVLAP proficiency test was based on the measurement of microwave scattering parameters (s-parameters) for three coaxial, N-type RF attenuators of 10 dB, 20 dB and 50 dB. The s-parameters of interest were S11 (input reflection coefficient), S22 (output reflection coefficient) and S21 (forward transmission coefficient).

The attenuators were evaluated at discrete frequencies from 100 MHz through 18 GHz. The S21 parameters were established using a synthesized microwave generator and RF measurement receiver equipped with an N-Type RF

power sensor. The S11 and S22 parameters were established using a scalar network analyzer. The S11 parameters were also obtained using the scalar network analyzer for the RF power sensor and the microwave source for the frequencies of interest. This information was entered into the Mismatch Uncertainty Calculator to derive mismatch uncertainties.

Measurement Options

The Mismatch Uncertainty Calculator allows four measurement scenarios:

1. Single Port
2. Load Power / Available Power
3. Load Power / Z0 Power
where: Z0 = characteristic impedance
4. Source to DUT to Load
where: DUT = device under test

Each measurement scenario requires port information in terms of either return loss, reflection coefficient (ρ) or standing wave ratio (SWR). Selecting a known port parameter is done using the MUC's top right "Option" button (Fig. 1). Selecting a measurement scenario is done using the "Measurement Option" dropdown listing. Selecting a measurement option will display the appropriate data entry boxes as well as associated results boxes.

All data entries must be in terms of the selected known port parameter (use of the "Single Port" measurement option allows conversion of data to the same parameter). The resolution used for computing and displaying results is selected using the "Resolution" dropdown listing. The MUC uses scientific notation for all displayed results, even though entries may be in general numeric format. Entries

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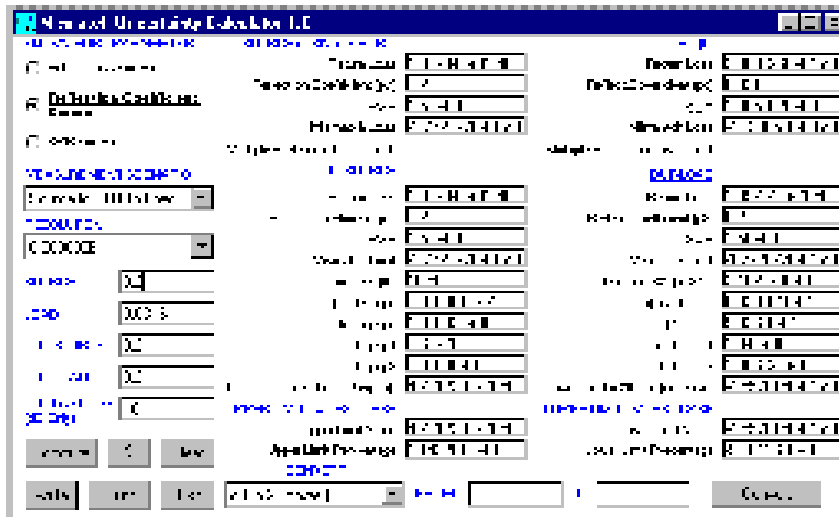


Figure 1. Mismatch Uncertainty Calculator allows port parameter selection using the Option Button.

and calculated results may be printed using the “Print” command or transferred to the Windows Write™ program for printing and archiving using the “Write” command (see Fig. 2 for DUT example). The “Clear” command erases all entries and sets the MUC to default conditions.

Clicking any calculated result will copy that result to the Windows Clipboard where it may be pasted in another program or document. The “?” command provides a quick summary of the calculations used as well as provides information for registering a copy of the Mismatch Uncertainty Calculator and contacting the author with questions and suggestions.

The single port measurement option provides a convenient means for converting between return loss, reflection coefficient, and SWR. The core calculations used for the single port and other measurement scenarios are as follows:

Return Loss (RL)	-20 Log (p)
SWR	(1+p)/(1-p)
Reflection Coefficient (p)	(SWR-1)/(SWR+1) or 10^(return loss/-20)
Mismatch Loss	-10 Log (1-p^2)

Load Power/Available Power Measurement

The load power/available power measurement option is for a two port, source-to-load configuration. This option is used to calculate power at the load relative to the available power at the source. This measurement scenario is commonly employed in amplifier design work. Load

power/available power calculations take into consideration double reflections, which are computed as follows:

$$\text{Double Reflections} = 20 \text{ Log } (1 \pm ps * pd)$$

where:

ps = source port reflection coefficient
 pd = Load port reflection coefficient

The upper and lower limits for load power/available power is as follows:

$$\text{Upper Limit} = 10 \text{ log } [(1-ps^2)*(1-pd^2)/((1-ps * pd)^2)]$$

$$\text{Lower Limit} = 10 \text{ log } [(1-ps^2)*(1-pd^2)/((1+ ps * pd)^2)]$$

The load power/available power worst case upper and lower limits are calculated and given in dB units as are their equivalent percentages.

Load Power/Z0 Power Measurement

The Load Power/Z0 Power Measurement option is also for a two-port, source-to-load configuration. This measurement scenario describes the following typical situation: If the load is a calibrated power meter which reads in W dBm, then the source will deliver W±dBm to a Z0 load. The upper and lower limits in the W dbm reading being attributable to mismatch errors. Load power/Z0 power limit calculations are as follows:

$$\text{Upper Limit} = 10 \text{ log } [(1-pd^2)/((1-pd*ps)^2)]$$

$$\text{Lower Limit} = 10 \text{ log } [(1-pd^2)/((1+ pd*ps)^2)]$$

The load power/Z0 power measurement option is a convenient means for calculating power for either a perfect load or perfect source. Entering either the source

data as zero or the load data as zero (but not both) will provide this calculation.

Source-to-DUT-to-Load Measurement

The source to DUT to load measurement option is for a two-port, source to load configuration with a DUT inserted between the ports. It is assumed that the DUT is a bilateral two-port device identical forward transmission coefficient (S21) and reverse transmission coefficient (S12). Examples of such devices are transmission lines, tuners, directional couplers, attenuators, connectors and filters. (Amplifiers, ferrite isolators and mixers are example of devices that are unilateral.) Source to DUT to load calculations requires the DUT's insertion loss be entered in dBs. Source to DUT to load calculations are as follows:

$$\text{Source to DUT to Load} = 20 \log [a / (bc \pm d)]$$

For: $a = 1 \pm ps * pd$
 $b = 1 -/+ ps * p1$
 $c = 1 -/+ pd * p2$
 $d = ps * Tf * Tr * pd$

Where: p1 is DUT reflection coefficient port at source
 p2 is DUT reflection coefficient port at load

Note: For a bilateral 2 port device, Tf=Tr= 10[^](-Insertion Loss/20)

The Source to DUT to Load measurement option was the option used in determining test artifact values for the author's NVLAP proficiency tests (MUC Source to DUT to Load printouts were submitted as part of the summary

test results).

Generic Calculations

The Mismatch Uncertainty Calculator also performs the following generic calculations:

- dB to a percentage (power)
- a (power) percentage to a dB
- dbm to mW (1mW Ref.)
- mW to dbm (1mW Ref.)

Note: the dB to a percentage (power) option is used for computing percentage limits from dB limits as follows:

$$\text{Percentage (power)} = 100 * [(10^{(dB/10)}) - 1]$$

Mismatch Calculator Download Sites

The Mismatch Uncertainty Calculator is a FREEWARE software program and as such may be freely copied and distributed (without modification) with no cost. This program, and similar FREEWARE programs Tolerance Calculator 3.0 and Uncertainty Calculator 2.1 (new for 1998), may be downloaded (or soon to be added for downloading) from the following websites:

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| Cal Lab Magazine | www.callabmag.com |
| Fluke Corporation | www.fluke.com |
| Hewlett Packard (Metrology Forum) | www.uktm.external.hp.com |
| Measurements International | www.mintl.com |
| National Association for Proficiency Testing(NAPT) | www.proficiency.org |
| Norfox Software | www.norfox.com |

References

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2. Gray, David A., Handbook of Coaxial Microwave Measurements, Reprinted by Gilbert Engineering, Phoenix AZ. With permission of GenRad, Inc. 1968
3. Application Note 183, High Frequency Swept Measurements, Hewlett Packard 1978

The author wishes to express his sincere thanks to the companies and organizations providing the means for obtaining metrology related FREEWARE software via their websites. This is a public service, which testifies to their commitment to and support of the worldwide measurement community. The author also wishes to thank Robert D. Moyer of Sandia National Laboratory for his insight, technical observations and patience on this project. It is the author's hope that other metrology laboratories that have developed useful software tools will consider placing them in the freeware arena.

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SOURCE TO DUT TO LOAD:
SOURCE CALCULATIONS:
Return Loss      1.29794E+01 dB
Reflection Coefficient (ps)  0.2
SER              1.5E+00
Mismatch Loss    -1.732877E-03 dB
LOAD CALCULATIONS:
Return Loss      3.20043E+02 dB
Reflect.Coef. (pd)  0.0216
SER              1.04525E+00
Mismatch Loss    -4.338888E-03 dB
SOURCE TO DUT CALCULATIONS:
Return Loss      1.29794E+01 dB
Reflect.Coef. (p1)  0.2
SER              1.5E+00
Mismatch Loss    -1.732877E-03 dB
LOAD TO DUT CALCULATIONS:
Return Loss      1.29794E+01 dB
Reflect.Coef. (p2)  0.2
SER              1.5E+00
Mismatch Loss    -1.732877E-03 dB
DUT INSERTION LOSS CALCULATIONS:
Insertion Loss [IL]      20 dB
Tf = Tr = |S21| = |S12|  1.162270E-02
DUT COEFFICIENT CALCULATIONS:
a) ps Tf Tr pd      6.320001E-04
b) 1 + ps*pd        1.03632E+00
c) 1 - ps*pd        9.9288E-01
d) 1 + ps*p1        1.04E+00
e) 1 - ps*p1        9.9E-01
f) 1 + ps*p2        1.03632E+00
g) 1 - ps*p2        9.9288E-01
Upper Limit = 20 Log [b/(cg - a)]  4.702229E-02 dB
Lower Limit = 20 Log [c/(ce + a)] -4.557015E-02 dB
CALCULATED LIMITS:
Upper Limit Value      4.702229E-02 dB
Lower Limit Value      -4.557015E-02 dB
Upper Limit Percentage  1.142261E+02
Lower Limit Percentage  -9.981169E+01
    
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Figure 2. Sample printout of test results.