Chapter 2. Specifications

INTRODUCTION

This chapter provides information on the stand-alone specifications and characteristics of the analyzer, and on the specified and typical performance of the analyzer system. The analyzer system consists of the analyzer plus the test cable supplied with (and matched to) the analyzer.

ANALYZER SPECIFICATIONS AND CHARACTERISTICS

Table 2-1 lists specifications and typical characteristics of the stand-alone analyzer (without its matched cable). Specifications are the performance standards or limits against which the instrument can be tested. They are field verifiable using performance tests documented in the service manual.

Typical characteristics are not specifications but are non-warranted performance characteristics provided for use in applying the instrument. Typical characteristics are representative of most instruments, though not necessarily factory-tested in each unit. They are not field tested.

Table 2-2 lists supplemental characteristics of the instrument. These are general descriptive information provided for use in applying the instrument.

SYSTEM SPECIFICATIONS AND SYSTEM PERFORMANCE

Table 2-3 lists measurement port specifications for the system (analyzer and matched cable). These specifications are the residual system uncertainties with and without error correction.

The last part of this chapter explains system performance and residual measurement errors. It provides a description of error sources, graphs of typical measurement uncertainty, and information on determining expected performance for a particular system.

Table 2-1. Instrument Specifications (1 of 2)

Specifications describe the instrument's warranted performance over the temperature range of 0° to 55°C (except where noted). Figures denoted as typical are not specifications but are non-warranted performance parameters provided for use in applying the instrument.

SOURCE[1]

Frequency

Range: standard 300 kHz to 1.3 GHz
option 003 300 kHz to 3 GHz
Resolution: 1 Hz
Stability: typically ±7.5 ppm 0 to 55°C
typically ±3 ppm/year
Accuracy: 10 ppm at 25°C ±5°C

Output Power

Test port power range: −20 to +5 dBm
Resolution: 0.1 dB
Flatness[2]: 2 dB Peak to Peak
Level accuracy[2]: ±0.5 dB at 50 MHz
Level linearity[2]: ±0.5 dB from −20 to −15 dBm
±0.2 dB from −15 to 0 dBm
±0.5 dB from 0 to +5 dBm

RECEIVER[1]

Input

Frequency range: Standard 300 kHz to 1.3 GHz
Option 003 300 kHz to 3 GHz
Dynamic range[3]: 100 dB

Noise level:		
3 kHz BW	Reflection	−75 dBm (typical)
10 Hz BW	Reflection	−85 dBm (typical)
3 kHz BW	Transmission	−90 dBm
10 Hz BW	Transmission	−100 dBm (typically −110 dBm)

Maximum input level: 0 dBm at Transmission Port
10 dBm at Reflection Port
Damage Level: 20 dBm or >25 VDC at Transmission Port
30 dBm or >25 VDC at Reflection Port
Crosstalk: (Reflection Port to Transmission Port)
300 kHz to 1.3 GHz: 100 dB
1.3 to 3 GHz: 90 dB

Magnitude

Dynamic accuracy: Refer to Figure 2-1a.
Display resolution: 0.01 dB/div.
Marker resolution[3]: 0.001 dB
Trace noise: (0 dBm, 3 kHz BW; reflection): <0.006 dB rms
(0 dBm, 3 kHz BW; transmission): <0.006 dB rms
Reference level: range: ±500 dB
resolution: 0.001 dB
Stability: 0.02 dB/°C typically

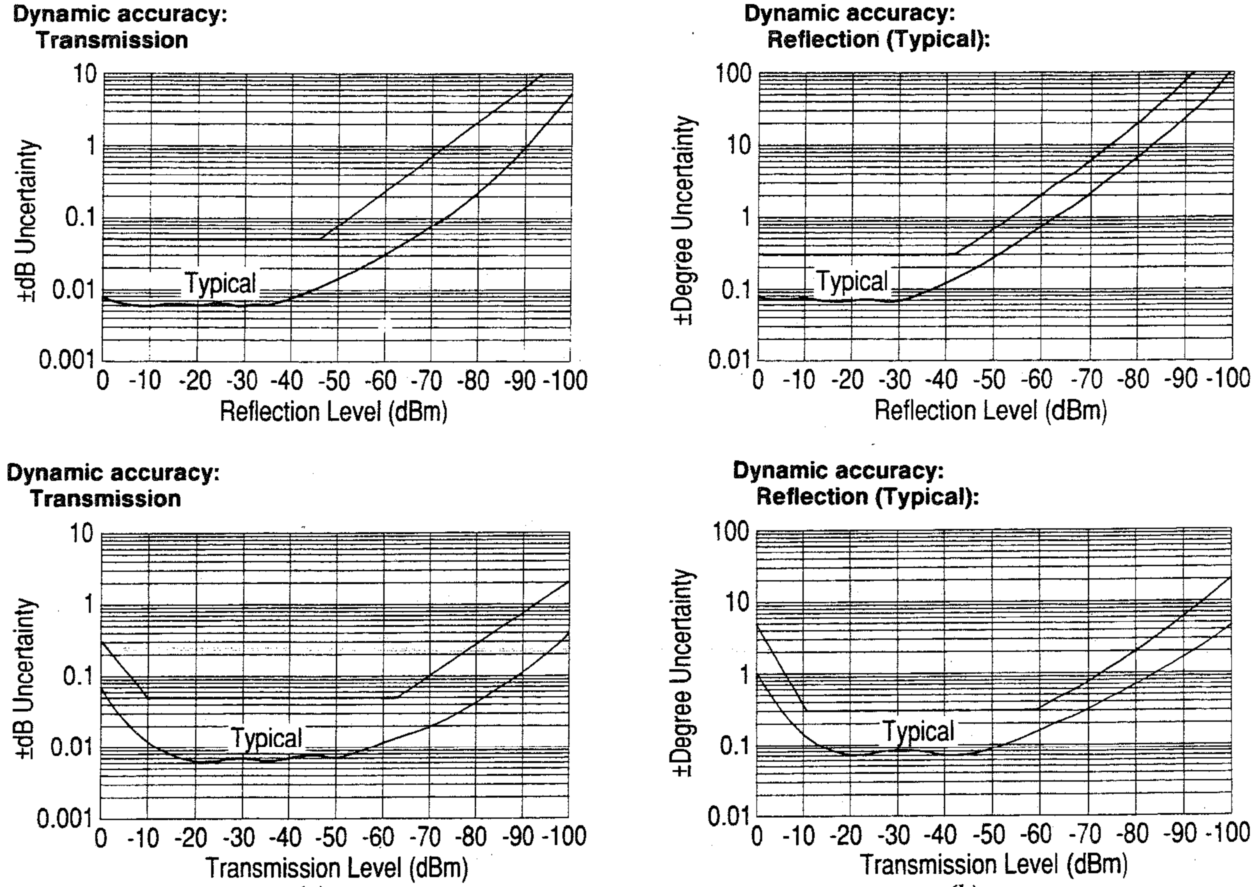
Phase

Dynamic accuracy: Refer to Figure 2-1b.
Range: ±180 degrees
Frequency response (deviation from linear, −10 dBm, 25°±5°C): ±3°
Display resolution: 0.01°/div.
Marker resolution[3]: 0.01°
Trace noise: (0 dBm, 3 kHz BW; reflection): <0.035° rms
(0 dBm, 3 kHz BW; transmission): <0.035° rms
Reference level: range: ±500 degrees
resolution: 0.01 degrees
Stability: 0.1°/°C typically

1. HP 8752B option 003 specifications above 2 GHz are typical due to 75 ohm measurement standards having an upper frequency limit of 2 GHz
2. At 25°C±5°C relative to −5 dBm test port power.
3. This specification applies to transmission measurements in the 300 kHz to 1.3 GHz frequency range at 10 Hz IF bandwidth with response and isolation correction. Dynamic range is limited by maximum receiver input level and system noise floor.
4. Marker resolution is dependent upon the value measured; resolution is limited to five digits.

Table 2-1. Instrument Specifications (2 of 2)

DYNAMIC ACCURACY



(a) *(b)*

Figure 2-1. Receiver Dynamic Accuracy

Dynamic accuracy for both reflection (typical) and transmission (specified) is determined from the plots in Figure 2-1. The power along the x-axis is expressed in dBm and is equivalent to the power at the transmission port for transmission measurements. For reflection measurements it is the power re-entering the reflection port after reflecting off the DUT.

Once the x-axis value is determined, read the corresponding dynamic accuracy from the plot.

Example: Reflection Dynamic Accuracy

(Refer to Figure 2-1b.)

Test port power: −10 dBm
DUT return loss: 20 dB
Reflected power = (test port power) − (DUT return loss)
= (−10 dBm) − (20 dB)
= −30 dBm

Reflection Dynamic Accuracy at −30 dBm: ±0.06 dB

Example: Transmission Dynamic Accuracy

(Refer to Figure 2-1a.)

Test port power: −10 dBm
DUT insertion loss: 10 dB
Transmitted power = (test port power) − (DUT insertion loss)
= (−10 dBm) − (10 dB)
= −20 dBm

Transmission Dynamic Accuracy at −20 dBm: ±0.05 dB

Table 2-2. Supplemental Characteristics (1 of 4)

These are not specifications, but general descriptive information provided for use in applying the instrument.

MEASUREMENT THROUGHPUT SUMMARY

The following shows typical measurement times in milliseconds.

Typical time for completion (msec)

	Number of Points			
	51	**201**	**401**	**1601**
Measurement				
Uncorrected or 1-port cal[1]	120	190	290	890
2-port cal	540	1030	1680	5610
Time domain conversion[2]	125	540	1150	2840
HP-IB data transfer[3]				
Internal	30	50	75	660
ASCII	500	1900	3800	15000
IEEE 754 floating point format:				
32 bit, 32 bit MS-DOS®	40	85	140	500
64 bit	60	125	210	700

REMOTE PROGRAMMING

Interface

HP-IB interface operates according to IEEE 488-1978 and IEC 625 standards and IEEE 728-1982 recommended practices.

Transfer Formats

Binary (internal 48-bit floating point complex format)

CITIFile ASCII

32/64 bit IEEE 754 Floating Point Format

Interface Function Codes

SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C1, C2, C3, C10, E2

1 Reflection 1-Port calibration with a 3 kHz IF BW. Includes system retrace time but does not include bandswitch time. Time domain gating is assumed off.

2. Option 010 only, gating off.

3 Measured with HP 9000 Series 300 computer

MS-DOS® is a U.S. registered trademark of Microsoft Corporation.

GROUP DELAY CHARACTERISTICS

Group delay is computed by measuring the phase change within a specified frequency step (determined by the frequency span, and the number of points per sweep).

Aperture: Selectable
Maximum aperture: 20% of frequency span
Minimum aperture: (frequency span)/(number of points −1)

Range:
The maximum delay is limited to measuring no more than 180° of phase change within the minimum aperture.

Range = 1/(2 x minimum aperture)

Accuracy:
The following graph shows group delay accuracy at 1.3 GHz with an uncorrected measurement. IF BW is 10 Hz. Insertion loss is assumed to be small and device electrical length is 10 meters.

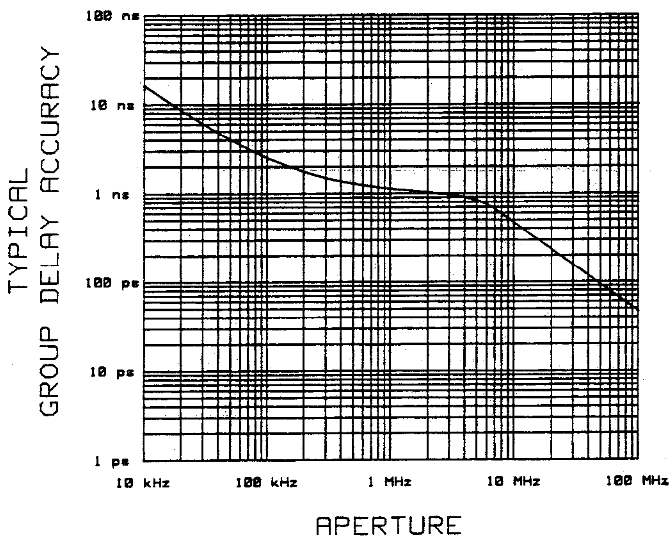


Figure 2-2. Group Delay Accuracy at 1.3 GHz

In general, the following formula can be used to determine the accuracy, in seconds, of a specific group delay measurement.

±(0.003 x Phase accuracy(deg)) / Aperture(Hz)

Depending on the aperture and device length, the phase accuracy used is either incremental phase accuracy or worst case phase accuracy. The above graph shows this transition.

Table 2-2. Supplemental Characteristics (3 of 4)

FRONT PANEL CONNECTORS

	HP 8752A	HP 8752B
Connector Type	type-N (female)	type-N (female)
Impedance	50 ohms (nominal)	75 ohms (nominal)
Connector Pin Protrusion	0.204 to 0.207 in	0.204 to 0.207 in

REAR PANEL CONNECTORS

External Reference Frequency Input (EXT REF INPUT)

Frequency	1, 2, 5, and 10 MHz (±200 Hz @ 10 MHz)
Level	−10 dBm to +20 dBm, typical
Impedance	50 ohms

External Auxiliary Input (AUX INPUT)

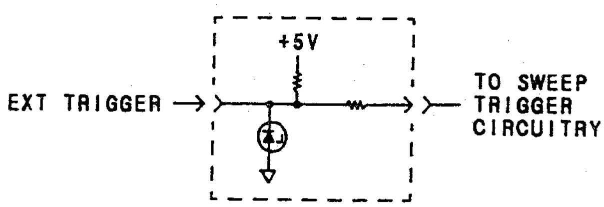
Input Voltage Limits −10V to +10V

External AM Input (EXT AM)

±1 volt into a 5k ohm resistor, 1 kHz maximum, resulting in 8 dB/volt amplitude modulation.

External Trigger (EXT TRIGGER)

Triggers on a negative TTL transition or contact closure to ground.



External Trigger Circuit

LINE POWER

47 to 66 Hz
115V nominal +10% −25% or 230V +10% −15%. 220 VA max.

PROBE POWER

+15V ±2%, 400 mA
−12.6V ±5.5%, 300 mA

ENVIRONMENTAL REQUIREMENTS

Operating Conditions

Temperature	0 to 55°C
Humidity	Operate in a non-condensing environment
Altitude	0 to 4500 meters (15,000 feet)

Non-Operating Storage Conditions

Temperature	−40°C to +70°C
Humidity	Store in a non-condensing environment
Altitude	0 to 15,240 metres (50,000 feet)

WEIGHT

Net	25.4 kg (56 lb)
Shipping	28.4 kg (63 lb)

CABINET DIMENSIONS

178 H x 425 W x 497.8 mm D
(7.0 x 16.75 x 19.0 in)

(These dimensions exclude front and rear panel protrusions. Add 24 mm (1 in) to depth to include the front panel connectors.)

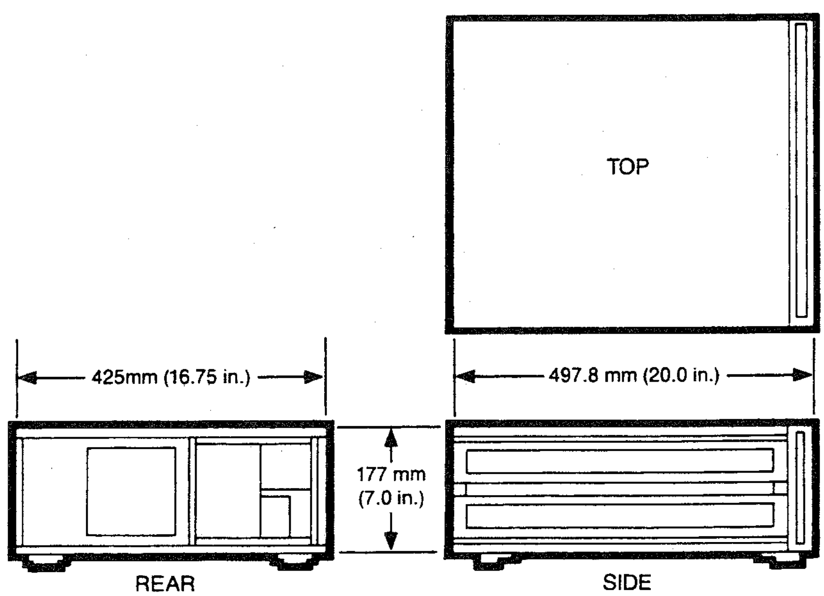


Table 2-3. System Specifications

MEASUREMENT PORTUNCERTAINTIES

The following specifications show the residual system uncertainties with and without error correction. The system is defined as the analyzer plus its matched cable. When two values are given for one specification (for example: 40/35), the number on the left applies up to 1.3 GHz, the number on the right applies from 1.3 to 3 GHz.

NOTE: All HP 8752B option 003 specifications above 2 GHz are typical due to 75 ohm measurement standards having an upper frequency limit of 2 GHz.

Error Term	Uncorrected[1]		3.5 mm[2,3]		Type-N[3]	
	dB	Linear	dB	Linear	dB	Linear
Directvity	−40/−35[4]	0.01/0.0178	−40	0.01	−44	0.0063
Reflection Tracking	±0.2/±0.3	0.0233/ 0.0351	±0.06	0.0069	±0.06	0.0069
Transmission Tracking	±0.2/±0.3	0.0233/ 0.351	±0.05/ ±0.1	0.0058/ 0.0116	±0.05/ ±0.1	0.0058/ 0.0116
Source Match (reflection)	−30/−25	0.0316/ 0.0562	−36	0.0158	−35	0.0178
Source Match (transmission)	−23/−20	0.0708/0.1	−23/−20	0.0708/0.1	−23/−20	0.0708/0.1
Load Match	−23/−20	0.0708/0.1	−23/−20	0.0708/0.1	−23/−20	0.0708/0.1
Crosstalk	−100/−90	0.00001/ 0.00003	−100/−90	0.00001/ 0.00003	−100/−90	0.00001/ 0.00003
Connector Repeatability (typical)	−65	0.0006	−70	0.0003	−65	0.0006

Error Term	dB	Linear
Noise Floor[5], Transmission: (included in dynamic accuracy)	−100 (10 Hz BW)	0.00001
Trace Noise	0.006 dB rms	0.0007
Cable Reflection Magnitude Stability (typical)	−60 dB	0.001

Error Term	Degrees
Cable Transmission Phase Stability (typical):	0.05 x Frequency (in GHz) degrees

1. These uncertainties apply in an environmental temperature of 23° +10/−5°C with an IF bandwidth of 10 Hz
2. HP 8752A only.
3. These uncertainties apply in an environmental temperature of 23° ± 3°C, with less than 1° deviation from the temperature at measurement calibration. IF BW is 10 HZ.
4. −30 dB from 300 kHz to 10 MHz.
5. Noise floor is already included in dynamic accuracy performance data.

SYSTEM PERFORMANCE

INTRODUCTION

System performance depends not only on the performance of the analyzer and the cables, but also on operating conditions and on measurement errors inherent in network analysis.

The following pages provide a brief description of the sources of measurement errors, graphs of typical measurement uncertainty for the HP 8752A and 8752B, and information to use in determining the expected performance of a particular system.

Also provided are tips on increasing dynamic range by reducing associated measurement errors.

INCREASING DYNAMIC RANGE

Dynamic range is limited by the maximum receiver input level (the high end of the range), and by either of these two factors on the minimum end of the range:

- System noise floor
- Crosstalk

Noise Floor

System noise floor can be reduced using a narrow IF bandwidth or with averaging, or with a combination of both. These measures can reduce noise floor below the crosstalk error level, making crosstalk error the limiting factor in dynamic range. A response and isolation calibration can then reduce the crosstalk errors. *The noise floor must be less than the crosstalk error or a response and isolation calibration will not reduce crosstalk errors.* The "Calibration" chapter explains how to determine which is greater: noise floor or crosstalk

Crosstalk

Crosstalk is a factor only in measurements requiring wide dynamic range. When crosstalk is greater than the noise floor, a response and isolation calibration can reduce its effects, thereby increasing dynamic range. However, if the noise floor is greater than crosstalk, the response and isolation cal will have no effect on dynamic range. The "Calibration" chapter explains this in detail.

SOURCES OF MEASUREMENT ERRORS

Network analysis measurement errors can be separated into the following types of errors:

- Systematic errors.
- Random errors.
- Drift errors.

Systematic Error Sources

The model for systematic errors is shown below. Refer to the end of the chapter for reflection uncertainty and transmission uncertainty equations derived from the system error model. Systematic errors result from imperfections in the calibration standards, connector standards, connector interface, interconnecting cables, and the instrumentation. All measurements are affected by dynamic accuracy.

Errors in Reflection Measurements. Directivity, source match, and reflection tracking are the errors that affect reflection measurements.

Errors in Transmission Measurements. Crosstalk, source match, load match, transmission tracking, and cable stability are the errors that affect transmission measurements.

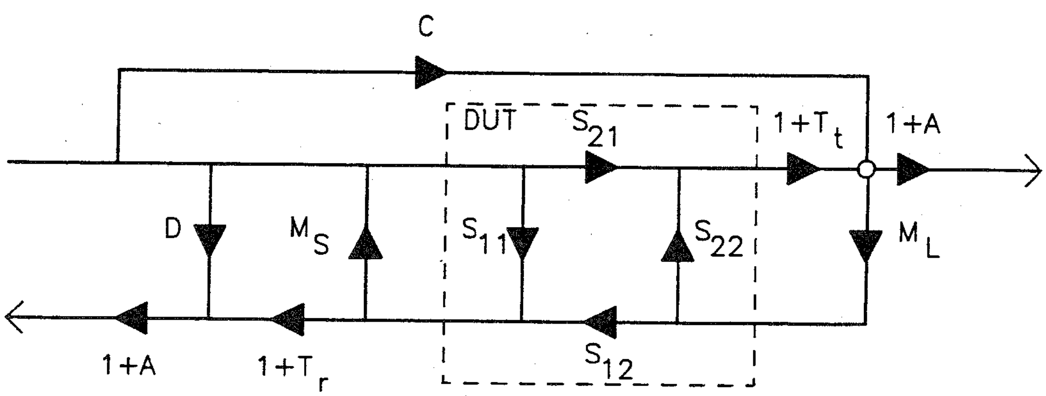
Refer to the "Measurement Calibration" chapter for an explanation of each of these individual errors.

Random Error Sources

Non-repeatable errors are trace noise, noise floor (included in dynamic accuracy), and connector repeatability. These errors affect both transmission and reflection measurements.

Drift Errors

The effects of temperature drift are included in the system specifications data.



A = Dynamic Accuracy
C = Crosstalk
D = Directivity

M_S = Source Match
M_L = Load Match

T_t = Transmission Tracking
T_r = Reflection Tracking

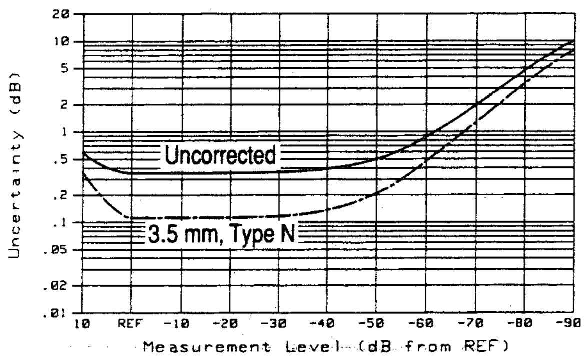
Figure 2-3. System Error Model

TYPICAL MEASUREMENT UNCERTAINTY FOR HP 8752A

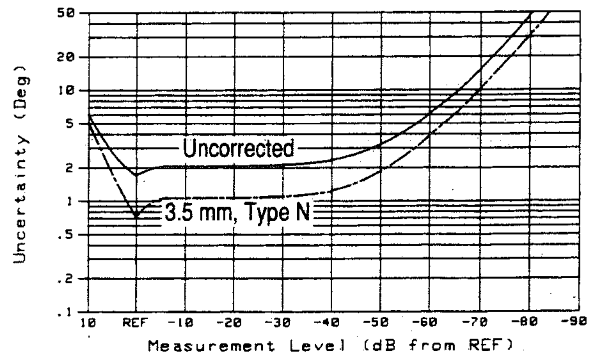
The graphs[1] below show the typical measurement uncertainty for the analyzer using type-N or 3.5 mm connectors, with and without error correction. Two graphs are provided for transmission measurements (a magnitude graph and a phase graph), and two for reflection measurements. The graphs on the next page apply to the HP 8752A option 003.

Corrected performance in the transmission measurement graphs shows the improvement obtained from a response and isolation calibration. Corrected performance in the reflection measurement graphs shows the improvement obtained from a reflection 1-port calibration.

Transmission measurements[2]

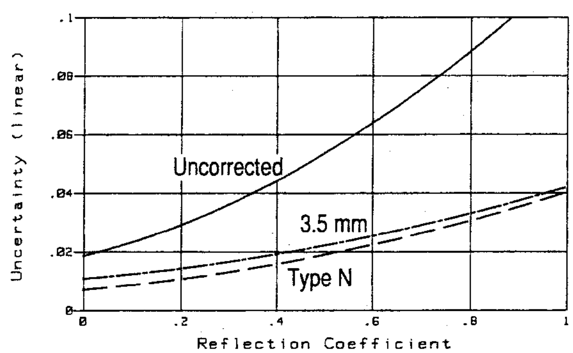


Magnitude

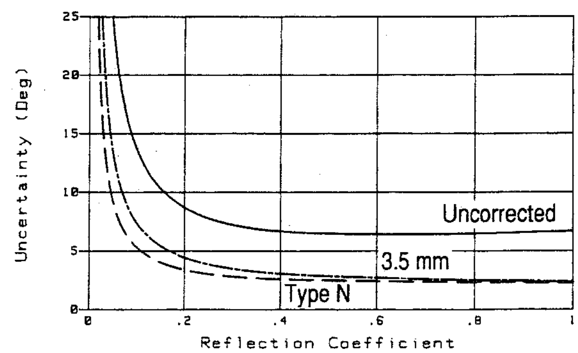


Phase

Reflection measurements[3]



Magnitude

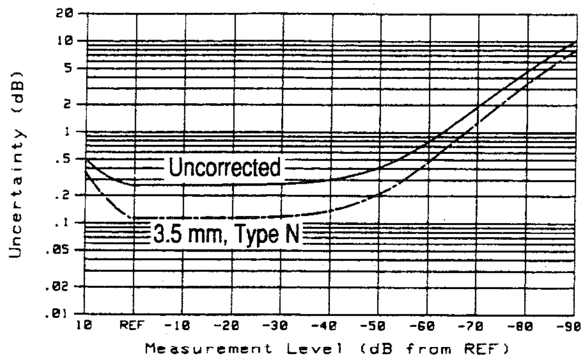


Phase

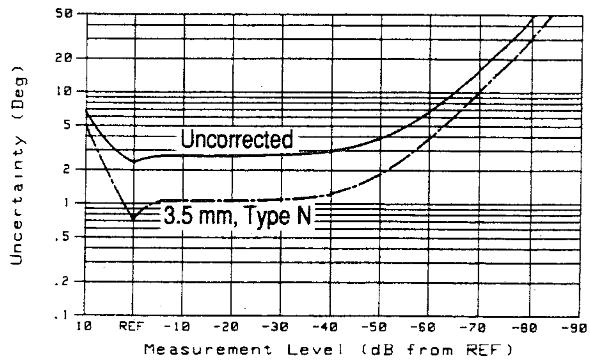
Figure 2-4. Typical Measurement Uncertainty for Standard HP 8752A (300 kHz to 1.3 GHz)

1. These measurement uncertainty curves utilize an RSS model for the contributions of random errors such as noise, and typical connector repeatabilities; and a worst-case model for the contributions of dynamic accuracy and residual systematic errors.
2. The graphs shown for transmission measurements assume a well-matched device ($S_{11} = S_{22} = 0$).
3. The graphs for reflection measurement uncertainty apply to either a one-port device or a two-port device with more than 6 dB of insertion loss.

Transmission measurements[1]

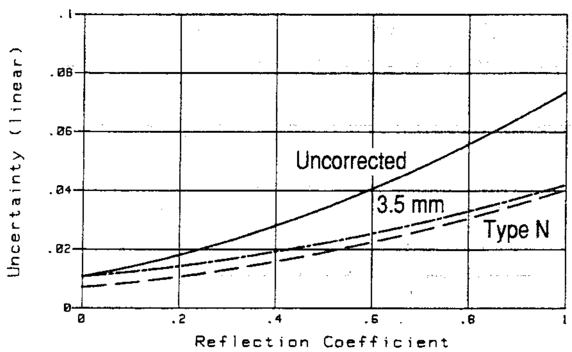


Magnitude

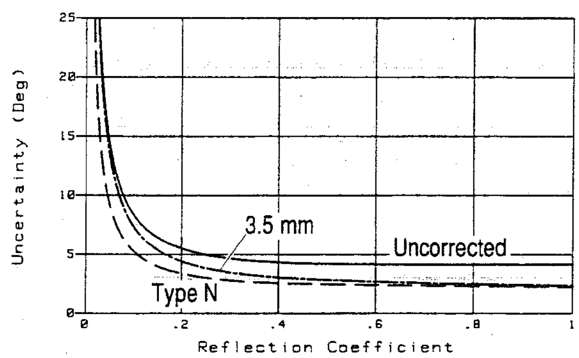


Phase

Reflection measurements[2]



Magnitude



Phase

Figure 2–5. Typical Measurement Uncertainty for HP 8752A Option 003 (300 kHz to 3 GHz)

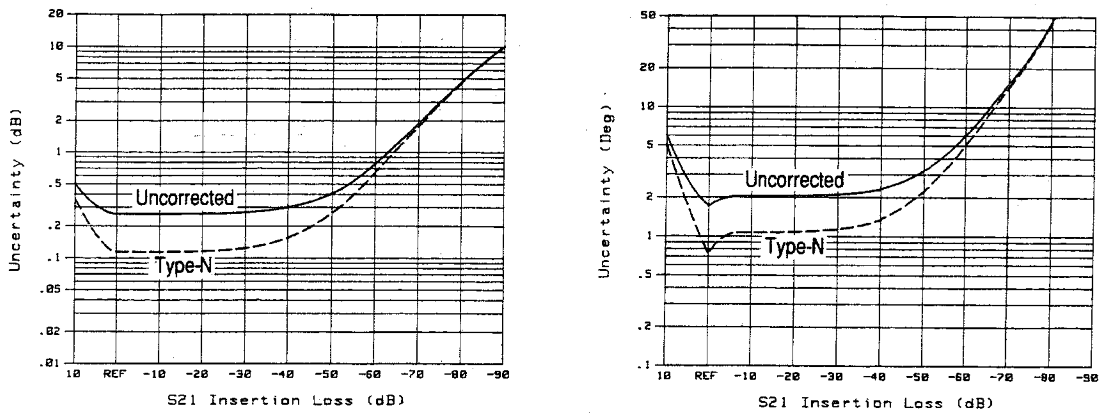
1. The graphs shown for transmission measurements assume a well-matched device ($S_{11} = S_{22} = 0$).
2. The graphs for reflection measurement uncertainty apply to either a one-port device or a two-port device with more than 6 dB of insertion loss.

TYPICAL MEASUREMENT UNCERTAINTY FOR HP 8752B

The graphs[1] below show the typical measurement uncertainty for the analyzer using type-N connectors, with and without error correction. Two graphs are provided for transmission measurements (a magnitude graph and a phase graph), and two for reflection measurements. The graphs on the next page apply to the HP 8752B option 003.

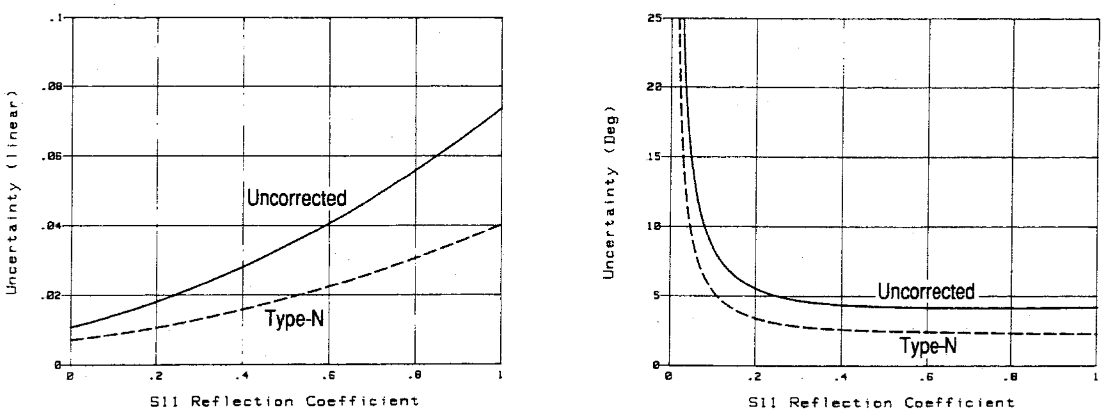
Corrected performance in the transmission measurement graphs shows the improvement obtained from a response and isolation calibration. Corrected performance in the reflection measurement graphs shows the improvement obtained from a reflection 1-port calibration.

Transmission measurements[2]



Magnitude　　　Phase

Reflection measurements[3]

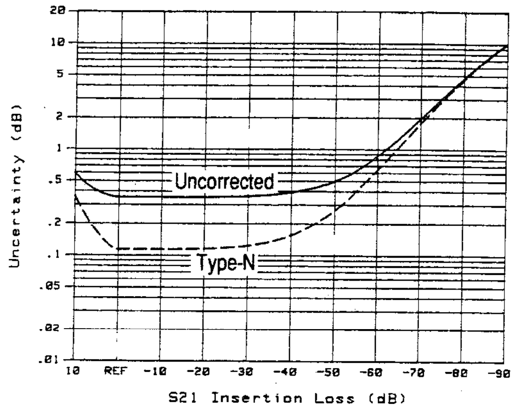


Magnitude　　　Phase

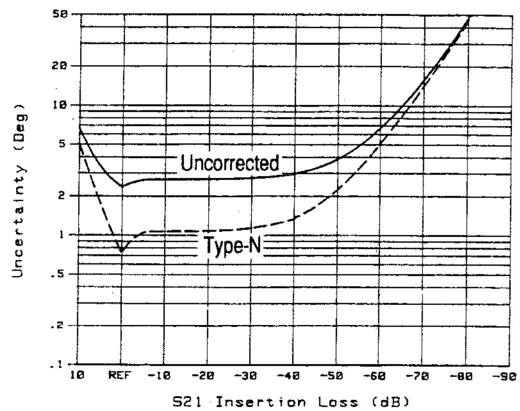
Figure 2-6. Typical Measurement Uncertainty for Standard HP 8752B (300 kHz to 1.3 GHz)

1. These measurement uncertainty curves utilize an RSS model for the contributions of random errors such as noise, and typical connector repeatabilities; and a worst-case model for the contributions of dynamic accuracy and residual systematic errors.
2. The graphs shown for transmission measurements assume a well-matched device ($S_{11} = S_{22} = 0$).
3. The graphs for reflection measurement uncertainty apply to either a one-port device or a two-port device with more than 6 dB of insertion loss

Transmission measurements[1]

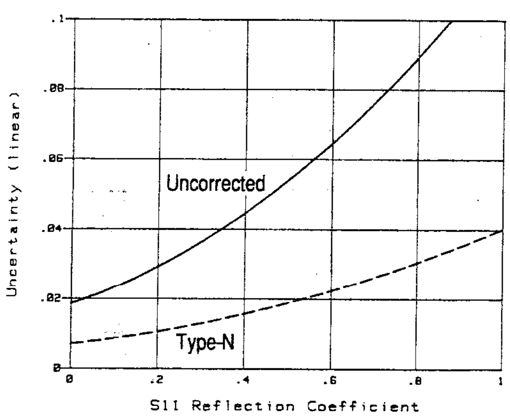


Magnitude

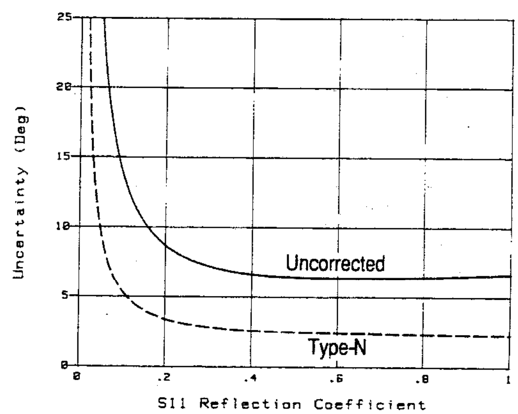


Phase

Reflection measurements[2]



Magnitude



Phase

Figure 2–14. Typical Measurement Uncertainty for HP 8752B Option 003 (300 kHz to 3 GHz)

1. The graphs shown for transmission measurements assume a well-matched device ($S_{11} = S_{22} = 0$).
2. The graphs for reflection measurement uncertainty apply to either a one-port device or a two-port device with more than 6 dB of insertion loss.

DETERMINING EXPECTED SYSTEM PERFORMANCE

The uncertainty equations and tables of system specifications provided in this chapter can be used to calculate the expected system performance of the analyzer. The following pages explain how to determine the residual errors of a particular system and combine them to obtain total error-corrected residual uncertainty values, using worksheets (Tables 2-4 and 2-5).

Separate tables are used to determine residual magnitude and phase uncertainties in the following measurement types:

- Table 2-4: Reflection measurements
- Table 2-5: Transmission measurements
- Completed examples of the residual uncertainty tables are provided after Table 2-5.

NOTE: A spreadsheet program can automate the uncertainty worksheets and eliminate mathematical errors.

Determining Crosstalk

The crosstalk error value is required in the transmission uncertainty worksheet. You can use the value in Table 2-3 or measure it as explained below:

Connect impedance-matched loads to the reflection and transmission ports. Set IF bandwidth to 10 Hz by pressing **[AVG]** ***[IF BW]*** **[10]** **[x1]**. Turn on an averaging factor of 5 by pressing ***[AVERAGING FACTOR]*** **[5]** **[x1]** ***[AVERAGING ON]***. Averaging reduces the analyzer's noise floor as explained earlier in this section.

Select a transmission measurement, turn on the marker statistics function (see "Using Markers"), and measure the mean value of the trace. Use the mean value plus one standard deviation as the residual crosstalk value of your system.

Table 2-4. Reflection Measurement Uncertainty Worksheet

PART A — Analyzer Performance **Frequency:** ________

In the columns below, enter the values for each term. Values are obtained from Table 2-3 and Figure 2-1.

Error Term	Symbol	dB Value	Linear Value
Directivity	D		________
Reflection tracking	T_r		________
Source match (reflection)	M_s		________
Load match	M_l		________
Dynamic accuracy			
Magnitude[1]	A_m	+ ________	________
Phase	A_p		________
Trace noise	N_h		________
Connector repeatability	R_c		________

PART B — DUT Performance

In the columns below, enter the calculated or measured performance of the DUT.

Performance Parameter	dB Value	Linear Value ($10^{\text{dB Value}/20}$)
S11	________	________
S21	________	________
S12	________	________

PART C — Total Magnitude Errors (Systematic and Random)

Systematic Errors

In the spaces provided, enter the required linear values from Parts A and B. Then combine these errors to obtain the total sum of systematic errors.

D = ________ [k]

T_r x S11 ________ ________ = ________ [l]

M_s x S11 x S11 ________ x ________ x ________ = ________ [m]

M_l x S21 x S12 ________ x ________ x ________ = ________ [n]

A_m x S11 ________ ________ = ________ [o]

Total Systematic Errors: k +l +m +n +o = ________ [S]

Random Errors

Enter the required linear values from Parts A and B. Combine these errors in a root sum of the squares (RSS) fashion to obtain a total sum of random errors.

3 x N_h x S11 3x________ x ________ = ________ [x]

R_c x (1 + 2 S11 + $S11^2$) ________x (1 + 2 x ________ + ________^{2}) = ________ [y]

R_c x S21 x S12 ________ x ________ x ________ = ________ [z]

Total Random Errors

$\sqrt{x^2 + y^2 + z^2}$ $\sqrt{\_\_\_\_ + \_\_\_\_ + \_\_\_\_}$ = ________ [R]

TOTAL MAGNITUDE ERRORS:

E_{rm}(linear) = S + R ________ + ________ = ________ [E_{rm}]

E_{rm}(log) = 20 Log (1 + E_{rm}/S11) 20 Log (1 + ________ / ________) = + ________ dB

20 Log (1 − E_{rm}/S11) 20 Log (1 − ________ / ________) = − ________ dB

PART D — Total Phase Errors

E_{rp} = Arcsin[(E_{rm} − (A_m x S11))/S11] + A_p

Arcsin[(________ − (______ x ______)) / ______] + ______ = ± ______ °

1. Enter the value from Figure 2-1 as a positive dB value. Convert to linear using the formula: Linear Value = $10^{\text{dB value}/20} - 1$.

Table 2-5. Transmission Measurement Uncertainty Worksheet

PART A — Analyzer Performance:

In the columns below, enter the values for each term. Values are obtained from Table 2-3 and Figure 2-1.

Error Term	Symbol	dB Value	Linear Value
Crosstalk[1]	C		________
Transmission tracking	T_t		________
Source match (transmission)	M_s		________
Load match	M_l		________
Dynamic accuracy			
Magnitude[2]	A_m	+ ________	________
Phase	A_p		________
Trace noise	N_h		________
Connector repeatability	R_c		________
Cable Reflection Magnitude			
Stability	S_r		________
Cable Transmission Phase			
Stability (Degrees)	S_t		________

PART B — DUT Performance

In the columns below, enter the calculated or measured performance of the DUT.

Performance Parameter	dB Value	Linear Value ($10^{\text{dB Value}/20}$)
S11	________	________
S21	________	________
S12	________	________
S22	________	________

PART C — Total Magnitude Errors (Systematic and Random)

Systematic Errors

In the spaces provided, enter the required linear values from Parts A and B. Then combine these errors to obtain the total sum of systematic errors.

C = ________ [k]

T_t x S21 ________ x ________ = ________ [l]

M_s x S11 x S21 ________ x ________ x ________ = ________ [m]

(S_r + M_l) x S21 x S22 (________ + ________) x ________ x ________ = ________ [n]

A_m x S21 ________ x ________ = ________ [o]

Total Systematic Errors: k +l +m +n +o = ________ [S]

Random Errors

Enter the required linear values from Parts A and B. Combine these errors in a root sum of the squares (RSS) fashion to obtain a total sum of random errors.

3 x N_h x S21 3x________ x ________ = ________ [x]

R_c x S21 x (1 + S11) ________ x ________ x (1 + ________) = ________ [y]

R_c x S21 x (1 + S22) ________ x ________ x (1 + ________) = ________ [z]

Total Random Errors

$\sqrt{x^2 + y^2 + z^2}$ $\sqrt{\_\_\_\_ + \_\_\_\_ + \_\_\_\_}$ = ________[R]

TOTAL MAGNITUDE ERRORS:

E_{tm}(linear) = S + R ________ + ________ = ________ E_{tm}

E_{tm}(log) = 20 Log (1 + E_{tm}/S21) 20 Log (1 + ________ /________) = + ________ dB

20 Log (1 − E_{tm}/S21) 20 Log (1 − ________ /________) = − ________ dB

PART D — Total Phase Errors

E_{tp} = Arcsin[(E_{tm} − (A_m x S21))/S21] S_t + A_p

Arcsin[(________ − (______ x ______)) / ______] + ______ + ______ = ± ______ °

1. Use the value listed in Table 2-3 or measure (using the instructions provided in "Determining Crosstalk," earlier in this chapter).
1. Enter the value from Figure 2-1 as a positive dB value. Convert to linear using the formula: Linear Value = $10^{\text{dB value}/20} - 1$.

EXAMPLE

Table 2–4. Reflection Measurement Uncertainty Worksheet

PART A — Analyzer Performance **Frequency:** 1.0GHz

In the columns below, enter the values for each term. Values are obtained from Table 2-3 and Figure 2-1.

Error Term	Symbol	dB Value	Linear Value
Directivity	D		.01
Reflection tracking	T_r		.0233
Source match (reflection)	M_s		.0316
Load match	M_l		.0718
Dynamic accuracy			
Magnitude[1]	A_m	+ .05	.0058
Phase	A_p		.3
Trace noise	N_h		.0007
Connector repeatability	R_c		.0006

PART B — DUT Performance

In the columns below, enter the calculated or measured performance of the DUT.

Performance Parameter	dB Value	Linear Value ($10^{\text{dB Value}/20}$)
S11	-22	.08
S21	-20	.1
S12	-20	.1

PART C — Total Magnitude Errors (Systematic and Random)

Systematic Errors

In the spaces provided, enter the required linear values from Parts A and B. Then combine these errors to obtain the total sum of systematic errors.

D			= .01	[k]
T_r x S11		.0233 x .08	= .001864	[l]
M_s x S11 x S11	.0316	x .08 x .08	= .000202	[m]
M_l x S21 x S12	.0708	x .1 x .1	= .000708	[n]
A_m x S11		.0058 x .08	= .000464	[o]
Total Systematic Errors: k +l +m +n +o			= .013238	[S]

Random Errors

Enter the required linear values from Parts A and B. Combine these errors in a root sum of the squares (RSS) fashion to obtain a total sum of random errors.

3 x N_h x S11	3x .007 x .08	= .00168	[x]
R_c x (1 + 2 S11 + S11²)	.0006 x (1 + 2 x .08 + .08²)	= .0007	[y]
R_c x S21 x S12	.0006 x .1 x .1	= .000006	[z]

Total Random Errors

$\sqrt{x^2 + y^2 + z^2}$ $\sqrt{2.822\times10^{-6} + 4.9\times10^{-7} + 3.6\times10^{-11}}$ = .00182 [R]

TOTAL MAGNITUDE ERRORS:

E_{rm}(linear) = S + R .01328 + .00182 = .01506 [E_{rm}]

E_{rm}(log) = 20 Log (1 + E_{rm}/S11) 20 Log (1 + .01506 / .08) = + 1.50 dB

20 Log (1 − E_{rm}/S11) 20 Log (1 − .01506 / .08) = − 1.81 dB

PART D — Total Phase Errors

E_{rp} = Arcsin[(E_{rm} − (A_m x S11))/S11] + A_p

Arcsin[(.01506 − (.0058 x .08)) / .08] + .3 = ± 10.8 °

1. Enter the value from Figure 2-1 as a positive dB value. Convert to linear using the formula: Linear Value = $10^{\text{dB value}/20} - 1$.

EXAMPLE

Table 2-5. Transmission Measurement Uncertainty Worksheet

PART A — Analyzer Performance: Frequency 1.0 GHz

In the columns below, enter the values for each term. Values are obtained from Table 2-3 and Figure 2-1.

Error Term	Symbol	dB Value	Linear Value
Crosstalk[1]	C		.00001
Transmission tracking	T_t		.0233
Source match (transmission)	M_s		.0708
Load match	M_l		.0708
Dynamic accuracy			
Magnitude[2]	A_m	+ .05	.0058
Phase	A_p		.3
Trace noise	N_h		.0007
Connector repeatability	R_c		.0006
Cable Reflection Magnitude			
Stability	S_r		.001
Cable Transmission Phase			
Stability (Degrees)	S_t		.05

PART B — DUT Performance

In the columns below, enter the calculated or measured performance of the DUT.

Performance Parameter	dB Value	Linear Value ($10^{dB\ Value/20}$)
S11	-22	.08
S21	-20	.1
S12	-20	.1
S22	-23	.071

PART C — Total Magnitude Errors (Systematic and Random)

Systematic Errors

In the spaces provided, enter the required linear values from Parts A and B. Then combine these errors to obtain the total sum of systematic errors.

C = .00001 [k]

T_t x S21: .0233 x .1 = .00233 [l]

M_s x S11 x S21: .0708 x .08 x .1 = .000566 [m]

(S_r + M_l) x S21 x S22: (.001 + .0708) x .1 x .071 = .00051 [n]

A_m x S21: .0058 x .1 = .00058 [o]

Total Systematic Errors: k + l + m + n + o = .004 [S]

Random Errors

Enter the required linear values from Parts A and B. Combine these errors in a root sum of the squares (RSS) fashion to obtain a total sum of random errors.

3 x N_h x S21: 3x .0007 x .1 = .00021 [x]

R_c x S21 x (1 + S11): .0006 x .1 x (1 + .08) = .0000065 [y]

R_c x S21 x (1 + S22): .0006 x .1 x (1 + .071) = .000064 [z]

Total Random Errors

$\sqrt{x^2 + y^2 + z^2}$: $\sqrt{4.41 \times 10^{-8} + 4.2 \times 10^{-9} + 4.129 \times 10^{-9}}$ = .000229 [R]

TOTAL MAGNITUDE ERRORS:

E_{tm}(linear) = S + R: .004 + .00029 = .004229 E_{tm}

E_{tm}(log) = 20 Log (1 + E_{tm}/S21): 20 Log (1 + .004229 / .1) = + .36 dB

20 Log (1 − E_{tm}/S21): 20 Log (1 − .004229 / .1) = − .38 dB

PART D — Total Phase Errors

E_{tp} = Arcsin[(E_{tm} − (A_m x S21))/S21] S_t + A_p

Arcsin[(.004229 − (.0058 x .1)) / .1] + .05 + .3 = ± 2.44°

1. Use the value listed in Table 2-3 or measure (using the instructions provided in "Determining Crosstalk," earlier in this chapter).

1. Enter the value from Figure 2-1 as a positive dB value. Convert to linear using the formula: Linear Value = $10^{dB\ value/20} - 1$.

REFLECTION UNCERTAINTY EQUATIONS

This page shows how E_{rm} is derived from analysis of the system error model shown in Figure 2-3.

Total Reflection Magnitude Uncertainty (E_{rm})

An analysis of the error model (Figure 2-3) yields an equation for the reflection magnitude uncertainty. The equation contains all of the first order terms and the significant second order terms. The three terms under the radical are random and are combined on a root sum of the squares (RSS) basis. The terms in the systematic error group are combined on a worst case basis. In all cases, the error terms and the S-parameters are treated as linear absolute magnitudes.

$E_{rm}(\log) = 20\log(1 \pm E_{rm}/S11)$

where

$E_{rm} = S_r + \sqrt{X_r^2 + Y_r^2 + Z_r^2}$

S_r = systematic error = $D + T_r \times S11 + M_s \times S11^2 + M_l \times S21 \times S12 + A_m \times S11$

X_r = random trace noise = $3 \times N_h \times S11$

Y_r = random port 1 repeatability = $R_c \times (1 + 2\,S11 + S11^2)$

Z_r = random port 2 repeatability = $R_c \times S21 \times S12$

Total Reflection Phase Uncertainty (E_{rp})

Reflection phase uncertainty is determined from a comparison of the magnitude uncertainty with the test signal magnitude. The worst case phase angle is computed. The result is combined with phase dynamic accuracy.

$E_{rp} = \arcsin((E_{rm} - A_m \times S11)/S11) + A_p$

TRANSMISSION UNCERTAINTY EQUATIONS

This page shows how E_{tm} is derived from analysis of the system error model shown in Figure 2–3.

Total Transmission Magnitude Uncertainty (E_{tm})

An analysis of the error model in Figure 2–3 yields an equation for the transmission magnitude uncertainty. The equation contains all of the first order terms and some of the significant second order terms. The three terms under the radical are random and are combined on an RSS basis. The terms in the systematic error group are combined on a worst case basis. In all cases, the error terms are treated as linear absolute magnitudes.

E_{tm} (log) = 20 log (1 ± E_{tm} / S21)

where

$$E_{tm} = S_t + \sqrt{Xt^2 + Yt^2 + Zt^2}$$

S_t = systematic error = C + T_t x S21 + M_s x S11 x S21 + (M_l + S_r) x S21 x S22 + A_m x S21

X_t = random high-level noise = 3 x N_h x S21

Y_t = random port 1 repeatability = R_c x S21 + R_c x S11 x S21

Z_t = random port 2 repeatability = R_c x S21 + R_c x S22 x S21

Total Transmission Phase Uncertainty (E_{tp})

Transmission phase uncertainty is calculated from a comparison of the magnitude uncertainty with the test signal magnitude. The worst case phase angle is computed. This result is combined with the error terms related to phase dynamic accuracy, cable phase stability, and thermal drift of the total system.

E_{tp} = arcsin ((E_{tm} − A_m x S21) / S21) + S_t + A_p