Configuration of the Laboratory Setup for Scalar R/T Measurements in the Extended W-Band (70-115 GHz).

J.D. Gallego, I. Malo, I. López, C. Diez González

IT-CDT 2015-4

Observatorio de Yebes
Apdo. 148 19080 Guadalajara
SPAIN
Phone: +34 949 29 03 11
Fax: +34 949 29 00 63

Change Record

Revision	Date	Affected Paragraphs(s)	Reason/Initiation/Remarks
A	2015-03-30	All	First Issue

TABLE OF CONTENTS

1. Introduction 4
2. System Components........ 4
   HP8757A Scalar Network Analyzer 4
   Analog Signal Generator E8275D (250 KHz-50 GHz)........ 5
   HP HP83558A W band Multiplier Module (75-110 GHz). 5
   3×HP85025C Detector Adapter........ 6
   3×885025C K71 WR10 Waveguide Detector (75-110 GHz) 6
   2×W365A Waveguide Isolators (75-110 GHz) 7
   2xW752C Waveguide 10 dB Directional Coupler (75-110 GHz) 7
3. System Connection 8
4. Signal Generator Start-up Sequence and Configuration 9
5. SNA Configuration 10
6. Detector calibration........ 10
7. Data Acquisition and Plot 10
8. Known problems........ 11
9. Examples of measurements 11

1. Introduction

Scalar Network Analyzers (SNAs) for microwave measurements are seldom used these days since are almost completely displaced by modern Vector Network Analyzers (VNAs) which provide improved accuracy and extended dynamic However, W-band VNAs are complex and expensive and require very bulky external multipliers difficult to handle in some situations. This report describes the setup and the configuration used to perform scalar transmission and reflection measurements in our laboratory using the available equipment. The key instrument used is the SNA HP8757A which is still in good working conditions although is obsolete and non serviceable by the manufacturer (circa 1988!). The signal generator is a modern analog E8275D from Agilent driving an old ×6 multiplier model HP83558A. No power amplifier is needed. The waveguide components are Isolators, 10 dB directional couplers and diode detectors. The attainable dynamic range is ~50 dB and the directivity ~30 dB.

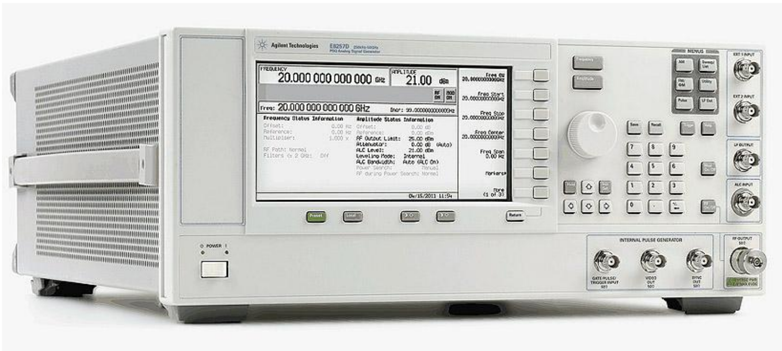
2. System Components

HP8757A Scalar Network Analyzer

It is a very old piece of equipment with a monochrome vacuum CRT and 3 inputs for detectors. It has two HPIB ports, one of which (SIB) is reserved for direct communication with the signal generator. Unfortunately the modern generators do not work well with the old protocol implemented in this unit. In the present case is necessary to LEAVE THE SIB PORT DISCONNECTED; otherwise the system will hang up. The main effect of not using SIB is that there will be no frequency readout of start/stop/marker frequency in the screen. Other than that the system works correctly. The communication with the signal generator is performed using 3 analog signals (sweep ramp, stop sweep and Z blanking) connected to the BNCs in the back panel. The detectors can be used in DC (CW signal) or AC (square wave modulation at 27.778 Kz). The AC mode is normally preferred since is not sensitive to the drift of the DC voltage offsets in the detectors and the dynamic range achieved is higher. However, AC mode requires modulation of the signal source.

Analog Signal Generator E8275D (250 KHz-50 GHz)

Options installed: 007, 1EH, 1EU, 550, UNT, UNU.
This generator is used because of its spectral purity, high output power and analog sweep capability. The spectral purity is important since the sub harmonics of the desired output frequency could be amplified by the external ×6 multiplier used and may appear at the W band output as additional undesired spurious. The high output power (opt. 1EU) is needed to avoid the use of an external power amplifier. An 18 dBm leveled output can be easily obtained with this unit in the 11.6-19.2 GHz range, which is sufficient to drive the multiplier adequately. The option 007 ads the analog sweep capability and there are BNC connectors in the back to send the analog signals to the SNA. Pulse modulation option (opt UNU) allows to set an internally generated pulse modulation with selectable frequency. This option is better than the default “scalar” pulse option since it responds more adequately to unleveled output conditions. The pulse should be set to square wave and to 27.778 KHz modulation frequency. Note that no external pulse input is needed.



The generator has a connector in the back for the HP millimeter wave module. The module SHOULD BE PLUGGED WITH THE UNIT OFF. When there is an HP MM wave module plugged and the unit is switched on, the module is detected and the settings of the generator are changed according to the band of the module. Usually the PRESET condition is not adequate for our purpose and it HAS TO BE CHANGED MANUALLY. We found no way to store the adequate condition into generator memory or to program it with an external computer and this step is UNAVOIDABLE. The settings will be detailed in section 4.

HP HP83558A W band Multiplier Module (75-110 GHz).

This is an old multiplier which was intended to be used with a power amplifier at the input and with a leveling loop for controlling the output power in the standard W band (75-110 GHz). The leveling loop was found to introduce additional problems and some hysteresis, and it was found preferable to use it in the saturated condition without any feedback control of the input power.

As the leveling feature is not used, the output directional coupler, detector and connecting cable which appear in the photo were removed and the output was taken directly from the waveguide of the module.

3×HP85025C Detector Adapter

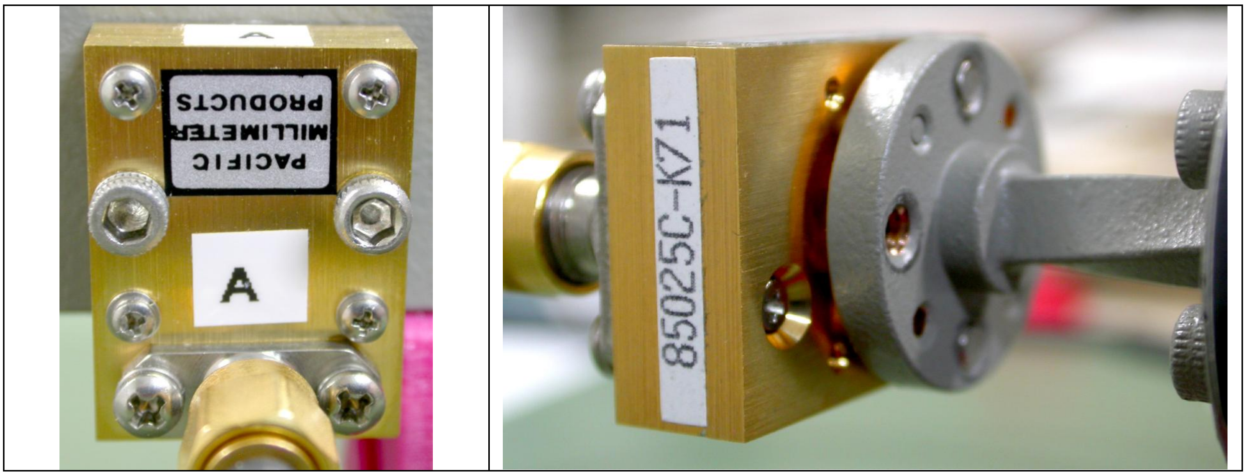
These adapters are for interfacing the output of the waveguide detectors to the input of the SNA HP8757A. The input is either a very small DC voltage or the 27.778 KHz video signal from the detector. The manufacturer recommends using direct connection to the detector output or a very short cable. In our case a ~10 cm length of RG174 coaxial cable is used to add positioning flexibility and to avoid excessive stress on the detector output conectors.

These adapters have a coarse offset adjustment (not needed in AC measurements) which has to be adjusted with the detectors and cables connected. The offset may drift noticeably in relatively short times and it is very sensitive to temperature variations.

3×885025C K71 WR10 Waveguide Detector (75-110 GHz)

Made by Pacific Millimeter, sold by HP.

CAUTION: This detector is EXTREMELY SENSITIVE TO ESD DAMAGE !!!
Wear always an ANTISTATIC WRIST STRAP when connecting or disconnecting the SMA port of this device. Use an ANTISTATIC MAT over the bench. DO NOT CONNECT OR DISCONNECT from detector adapter unless strictly necessary.



These detectors should be handled with extreme care since are very delicate. They have only two 4-40 tapped holes and only two screws can be used for attaching the input flange. The electrical contact is not perfect and any force applied to the body of the unit can slightly change the power reading. Be careful to avoid over tighten the screws.

Sensitivity:	250 mV/mW (min)
Flatness:	±2 dB (max)
Reflection loss:	7 dB (min)

2×W365A Waveguide Isolators (75-110 GHz)

Made by HP.

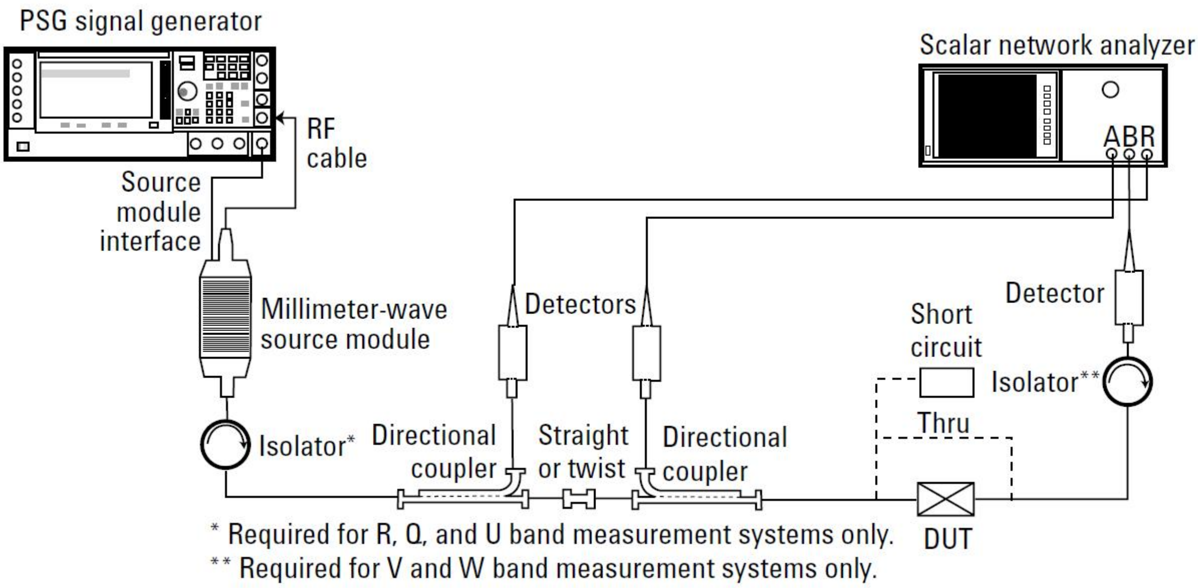
This is a reliable wideband Faraday rotation isolator which is sensitive to magnetic field. The perturbation of a ferromagnetic tool (i.e. screwdriver) close to the built in magnet can alter the insertion loss of the device.

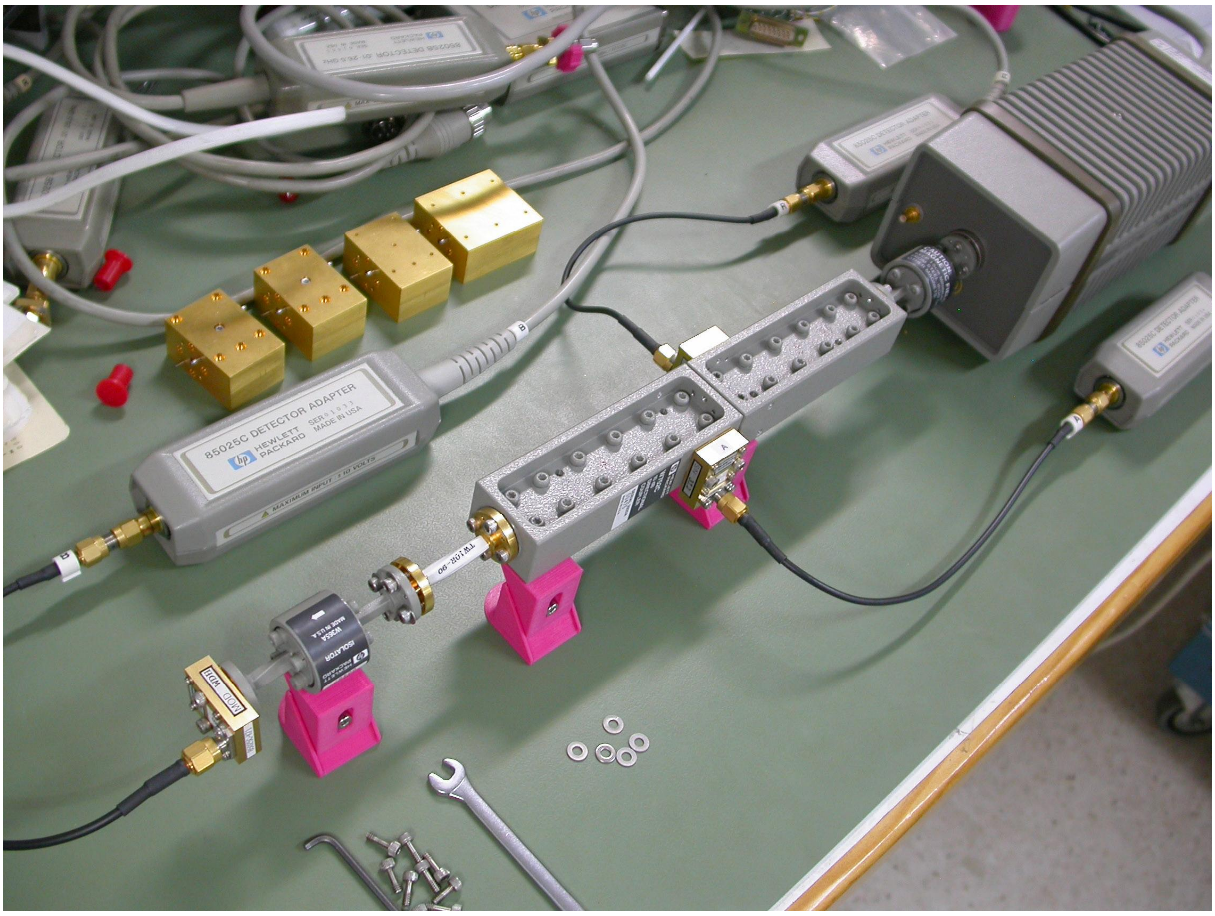
Insertion loss:	2.5 dB (max)
Reflection loss:	14 dB (min)
Isolation:	25 dB (min)

2xW752C Waveguide 10 dB Directional Coupler (75-110 GHz)

Coupling:	10 dB
Coupling variation:	±0.7 dB (max)
Coupling accuracy:	±0.7 dB (max)
Directivity (typical):	38 dB
Return Loss (main line):	28 dB (min)
Return Loss (aux. port):	28 dB (min)

3. System Connection



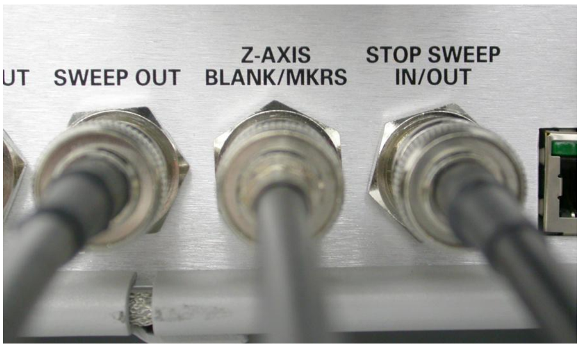


The photo shows the system in the configuration of THRU calibration. Note that a short waveguide section is included at the output of the directional coupler to make possible the measurement of DUTs without flanges.

The DUT is inserted between the isolator and the waveguide section (down-left in the photo).

BNC connections

Generator E8275D



SNA HP 8757 A

4. Signal Generator Start-up Sequence and Configuration

1. Connect the multiplier module to the signal generator (if not already done) with the POWER OFF.
2. Switch ON the generator
3. Push *Utility > Error Info > Clear Error Queue*
4. Push the *Preset* key
5. Push *Recall > Select Reg 03 (SWEEP W BAND) > RECALL Seq [0] Reg [03]*
6. Push *Frequency > More > More > Source Module > On*
7. Push *Frequency > More > More > Source Module > Off*
8. Push *Amplitude > 18 dBm*
9. Push *Recall > Select Reg 03 (SWEEP W BAND) > RECALL Seq [0] Reg [03]*

This sequence “cheats” the generator and leaves the power supply of the multiplier on even when it is supposed to be turned off. It is very important to perform steps 6 and 7 (turn the module ON and OFF or, if needed, OFF-ON-OFF).

The main parameters stored in the saved state are:

– Modulation ON with internal square pulse of 27.778 KHz
– Output power set to 18 dBm (internal ALC)
– Ramp (analog) sweep type, continuous trigger
– Sweep time 200 ms
– Frequency multiplier ×6
– Start frequency 70 GHz; Stop frequency 115 GHz
– Markers at 75 and 110 GHz, status = ON

5. SNA Configuration

Extended W band SNA configurations can be stored on registers 8 and 9. Reg 8 is for reflection/transmission measurements relative to the reference and Reg 9 is for reading the absolute power levels in the 3 detectors.

REG 8:

- CH1 to detector A
- CH2 to detector B
- CH3 to detector R
- AVG OFF
- SMOOTH OFF
- MODE AC
- 401 points
- CURSOR ON

REG 9:

- CH1 to detector A/R
- CH2 to detector B/R
- DISPLAY MEAS-MEM in CH1 and CH2 (for calibrated measurements)
- AVG OFF
- SMOOTH OFF
- MODE AC
- 401 points
- CURSOR ON

6. Detector calibration

Detectors must be calibrated with known power levels to adjust the parameters of the standard diode curve stored in the SNA. The detailed procedure can be found in the *HP85025C Detector Adapter manual*. In the present case they were calibrated at 100 GHz and with two known power levels (~ +3.74 & -25.3 dBm as measured with a power meter) following the standard procedure. If for some reason the calibration is lost it can be easily recovered just by introducing the CAL VALUE of each detector in the EXT DET CAL menu of the SNA.

	Det S/N	**Adapt S/N**	**CAL VALUE**
A	312	01034	567 071
B	317	01033	590 068
R	313	01031	595 073

7. Data Acquisition and Plot

For computer data acquisition is necessary to connect the SNA and the Signal Generator to the HPIB bus. Remember that the generator should NOT be connected to the SIB of the SNA.

The computer program for the acquisition is ***SNA_DUMP_W_band.bas***. The frequency, CH1 & CH2 data is stored into an ASCII file.

There is a PLOT command implemented in the SNA originally conceived to send the data to a pen plotter connected to the SIB. As pen plotters are long obsolete, we developed a computer program to "listen" to the HPGL plotter commands on the SIB. This is done by using a PROLOGIC module (HPIB-USB) connected to the SIB and mapped to a serial port (COM3) in the computer. The graphics in the SNA screen can be dumped into bitmap computer files in two steps. First the program ***Read SNA Plot USB.bas*** is left running in the computer waiting for calls to the plotter on the SIB. Once the plot is complete this program writes an ASCII file (PLOT_nnn.HGL) with all the HPGL commands sent. Later, the *.HGL file can be read with another program (***PrintCapture***) and translated into a bitmap (*.BMP) which can be finally visualized or imported into other windows programs. The examples shown in this report have been obtained using this procedure.

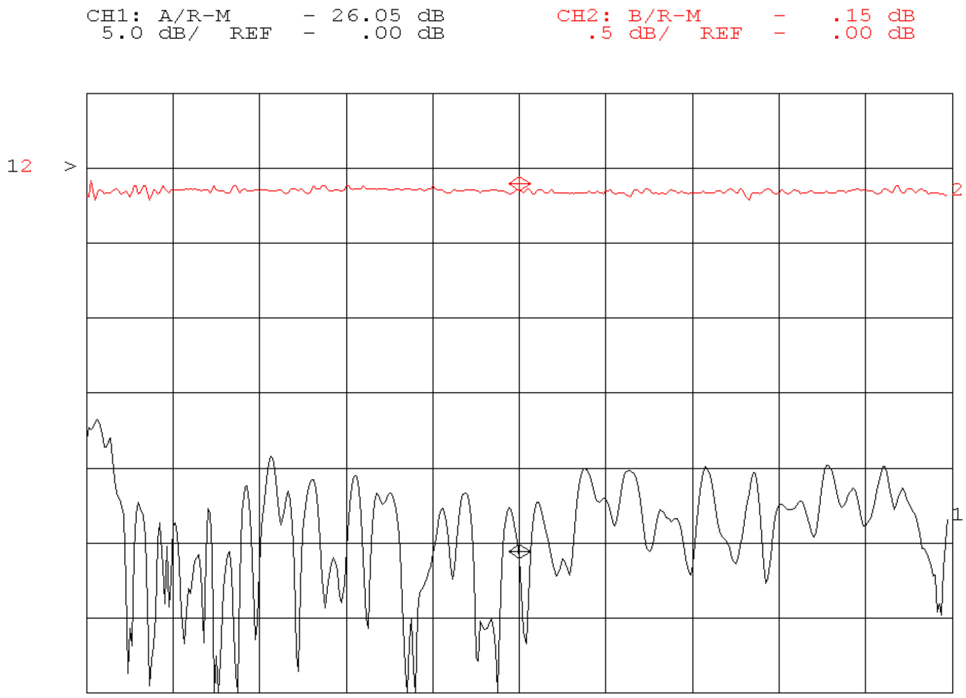
8. Known problems

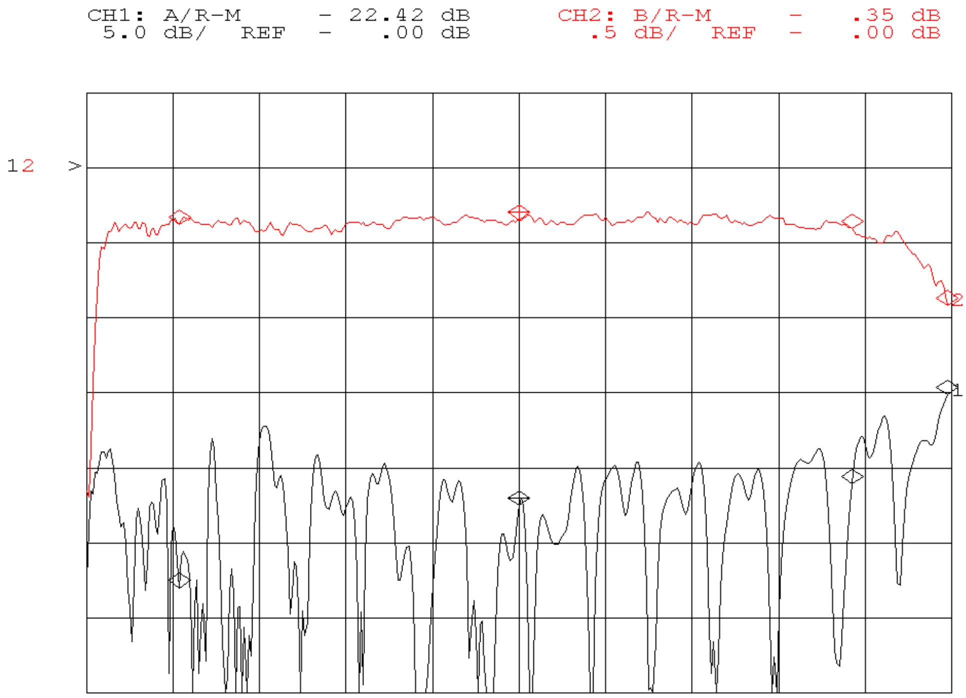
- Frequency markers: The markers selected in the generator do not always work as expected. Some combinations of number of points and sweep time in the generator produce erratic results in the screen of the SNA. In addition, it appears that only 4 markers can be shown simultaneously, probably due to the memory limitations of the SNA.
- Sweep time: It appears that changing the sweep time slightly affects to the calibration. For best results the sweep time should not be changed between calibration and measurement. 200 ms is a good starting value.
- DC mode: DC (no modulation) mode is quite problematic since the offset drifts considerably and it appears that a sweep dependant DC current circulates by the cables between detectors and adapters causing additional errors. The usable dynamic range is reduced considerably. Do not use this mode unless it is strictly needed.
- Multiplier Module: The multiplier was designed for the strict 75-110 GHz frequency range. When it is connected it sets a special mode in the generator which does not allow going beyond these limits. That is the reason why the system needs to be "cheated" to use it as non-HP multiplier with arbitrary frequency limits, but keeping the module power supply connected.
- Detector flanges: The waveguide detectors are designed in such a way that only two screws can be used to attach them to other components. This make the electrical contact erratic an prone to variations with small changes of the torque of the screws or to the force applied to the body of the detector.

9. Examples of measurements

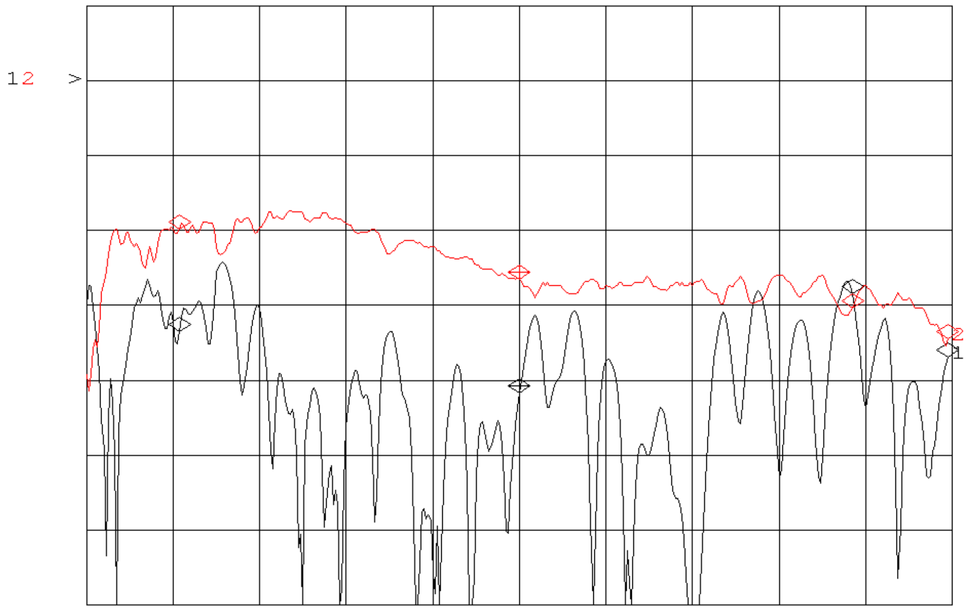
The next measurements were taken in the 70-115 GHz band used the setup described above. DUTs are

1. Gold plated (hard gold) 2 cm long WR10 waveguide (split block)
2. Gold plated (hard gold) 4 cm long WR10 waveguide (split block)
3. Back to back u-strip to WR10 transition, 5 mil Duroid (split block)
4. Repeatability check after previous measurements (THRU)


CH1: A/R-M - 26.05 dB
5.0 dB/ REF - .00 dB
CH2: B/R-M - .15 dB
.5 dB/ REF - .00 dB
12 >
2
1


CH1: A/R-M - 22.42 dB
5.0 dB/ REF - .00 dB
CH2: B/R-M - .35 dB
.5 dB/ REF - .00 dB
12 >
2
1

CH1: A/R−M − 20.82 dB   CH2: B/R−M − 1.33 dB
5.0 dB/ REF − .00 dB   .5 dB/ REF − .00 dB



CH1: A/R−M − 24.86 dB   CH2: B/R−M − .04 dB
5.0 dB/ REF − .00 dB   .5 dB/ REF − .00 dB