E-Band Scalar Network Analyser

Instruction Manual

www.terahertz.co.uk

Version 1.0

Contents

Introduction

The E-Band Quasi-Optical Scalar Network Analyser (SNA) is a turn-key system designed to measure material properties – namely transmission, reflection and dissipation loss - of radar housings between 60 and 90 GHz.

The system, shown in Figure 1 & Figure 2 below, uses quasi-optics to transmit mm-wave Gaussian beams between the source, sample and transmission & reflection detectors. The beams are extremely well controlled with low sidelobes generated by corrugated feedhorns providing extremely low loss transmission from waveguide to waveguide. The system provides measurements relative to a calibration which is performed prior to sample measurements.

The SNA subsystem uses a microwave signal generator (Vaunix LAB BRICK) to generate a sweep between 10->15 GHz. The signal is then passed to a VDI (Virginia Diodes Inc.) 6x multiplier chain to generate the 60->90 GHz signal. The multiplier is run at saturation to provide stability (at a power of 15dBm). The radiation passes through the optics and sample to the VDI zero-bias detectors. The detector voltage is then digitised by an analogue to digital converter and passed to the control software (LabVIEW).

The optics is discussed in the next section.

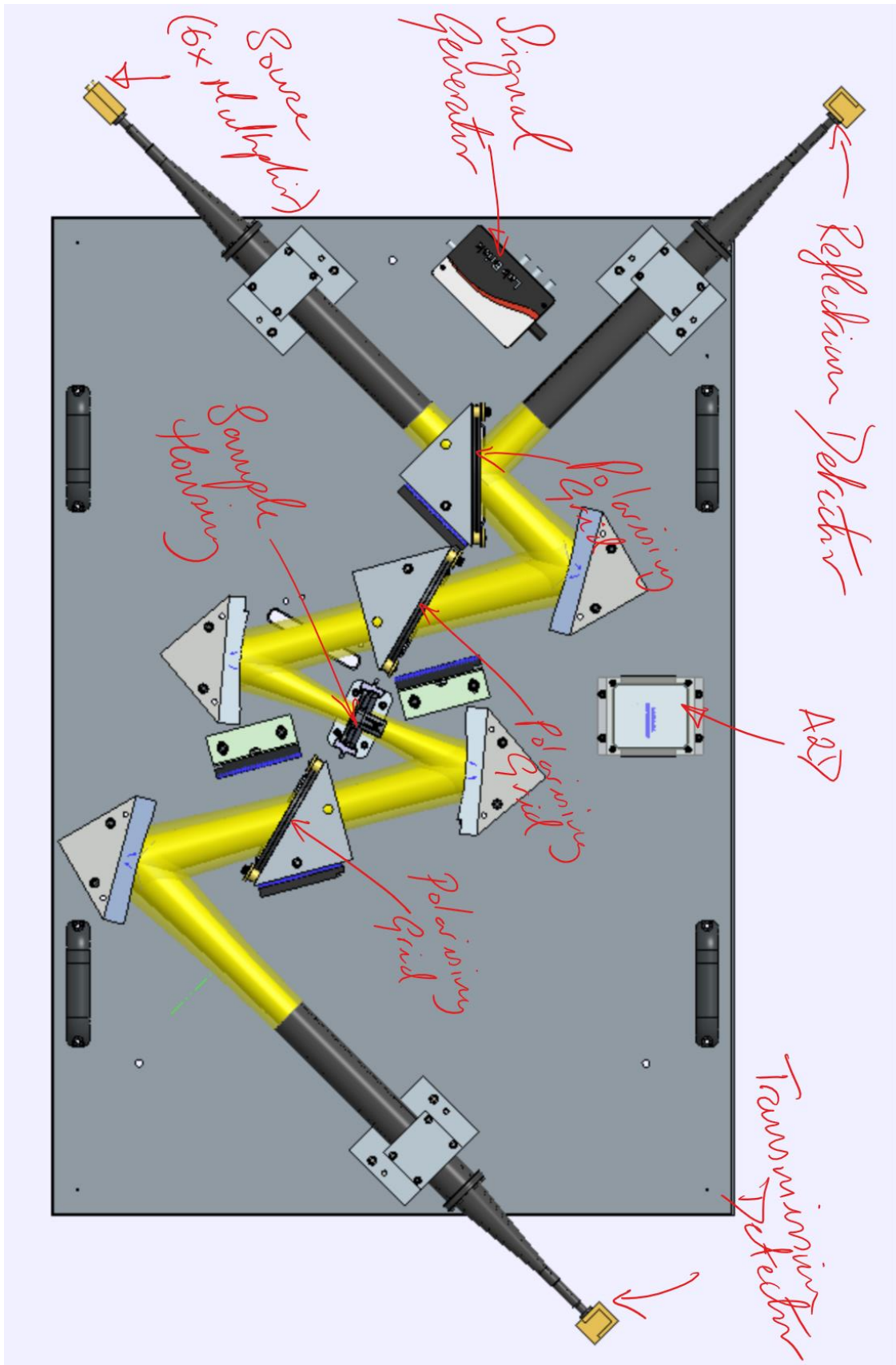*Figure 1 –E-band Scalar Network Analyser*

Figure 2 –E Band Scalar Network Analyser: annotated diagram

Quasi-optics

Quasi optics is used to transmit the radiation through free-space. At high frequencies, transmission through free space gives extremely low losses when compared with wave-guide counterparts. Matched corrugated feedhorns provide extremely low losses and reject any radiation from the surrounding environment. A beam-waist is created at the centre of the housing with a radius (1/e amplitude) of 9.6 mm. The beams are focused by mirrors and polarisation is controlled by free space polarizing wire grids. TK RAM (Radar-Absorbing Material) tiles, exhibiting extremely low return losses (better than 40dB) , are used to absorb any unwanted reflections/dump power.

As mentioned above, the multiplier chain is run in saturation to provide stability. This produces large amounts of power: – 15 dBm. The detectors should not be exposed to more than 5dBm – otherwise they are likely to be damaged. It is therefore necessary to dump the majority of the power from the source – this is done by rotating the source feedhorn with respect to the first grid. The polarisation of the feedhorn is aligned with respect to the screws in the base as illustrated in the diagram below:
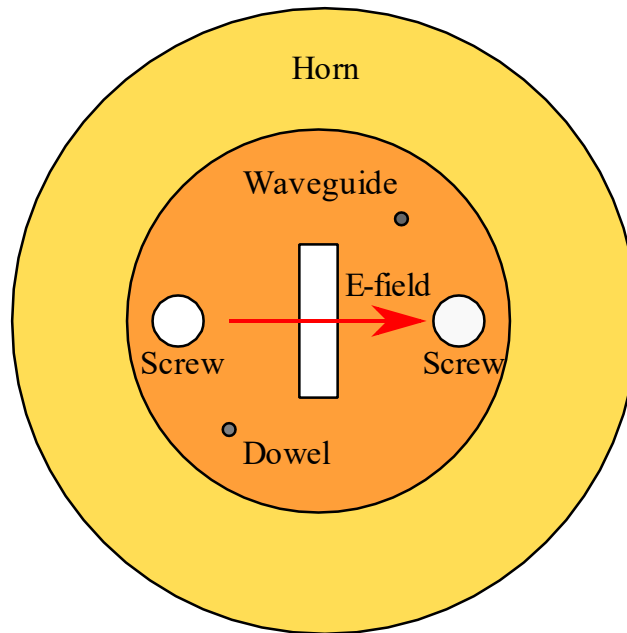

Figure 3 – E-field orientation looking down feedhorn with respect to dowel & screw positions.

A schematic of the optical path is shown in Figure 4 below:
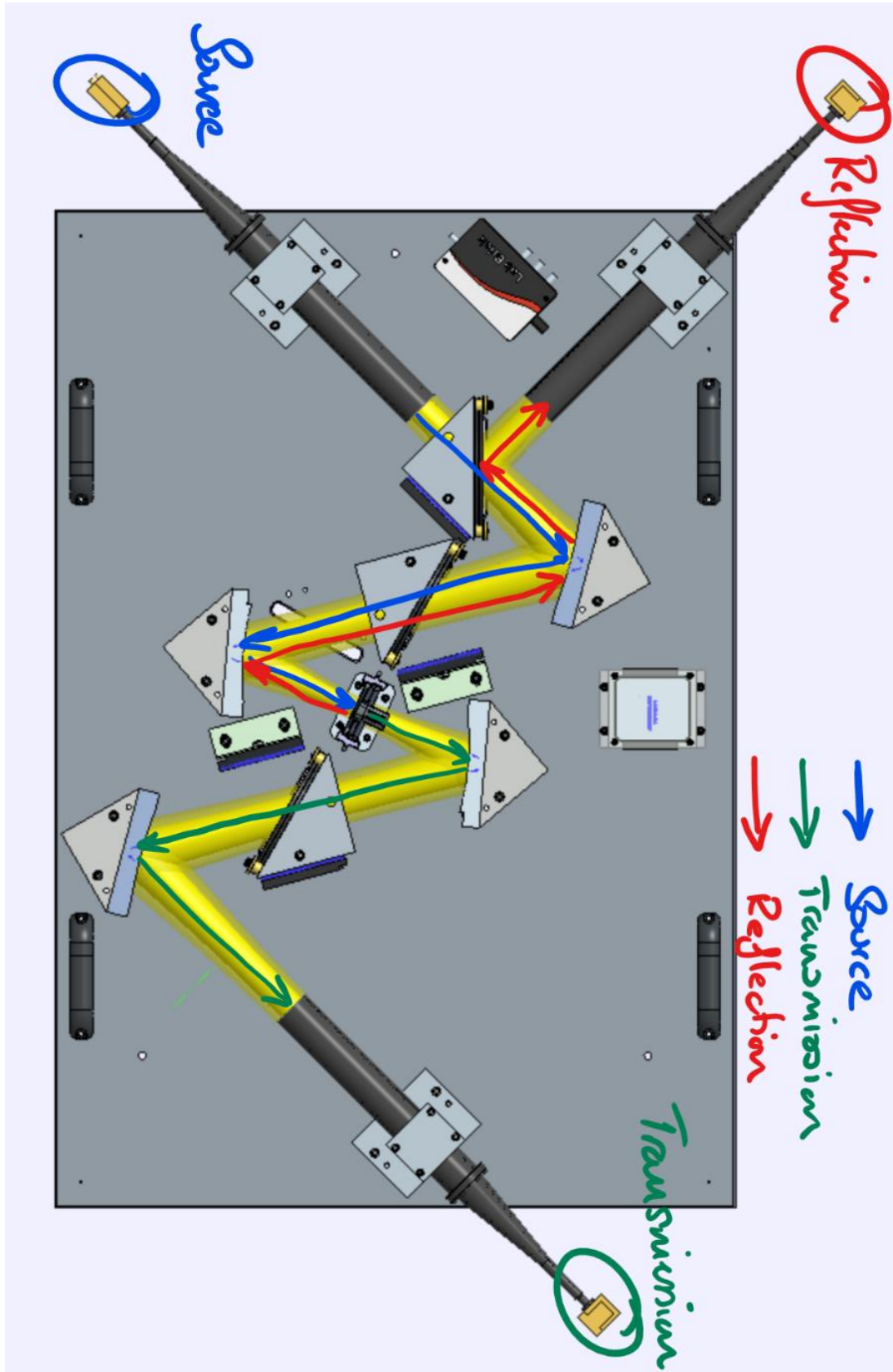

Figure 4 – Schematic of optical path.

The first grid passes radiation with the E-field aligned vertically. The second grid is at 45 degrees to the first grid and dumps half the power. The beam then hits the sample, where it is transmitted, reflected, scattered, or absorbed. The reflected beam travels back through the second grid and hits the first, where half is reflected into the detector, and half transmitted through to the source (sadly creating standing waves from the detector or source miss-match). The beam transmitted through the sample hits the third grid, where half the power is dumped, before going into the transmission detector.

NB: It is important (except for the source for which we are dumping power initially) to align the feedhorn waveguide with the grid immediately before the feedhorn. This ensures that the horn does not act as a mirror by rejecting the component of the beam polarized in the orthogonal plane to the waveguide's polarisation axis.

Software

The signal generator and detectors are controlled and measured by LabVIEW software. The software is designed for ease-of-use and rapid measurements of housings. Data is stored automatically in .xml file format.
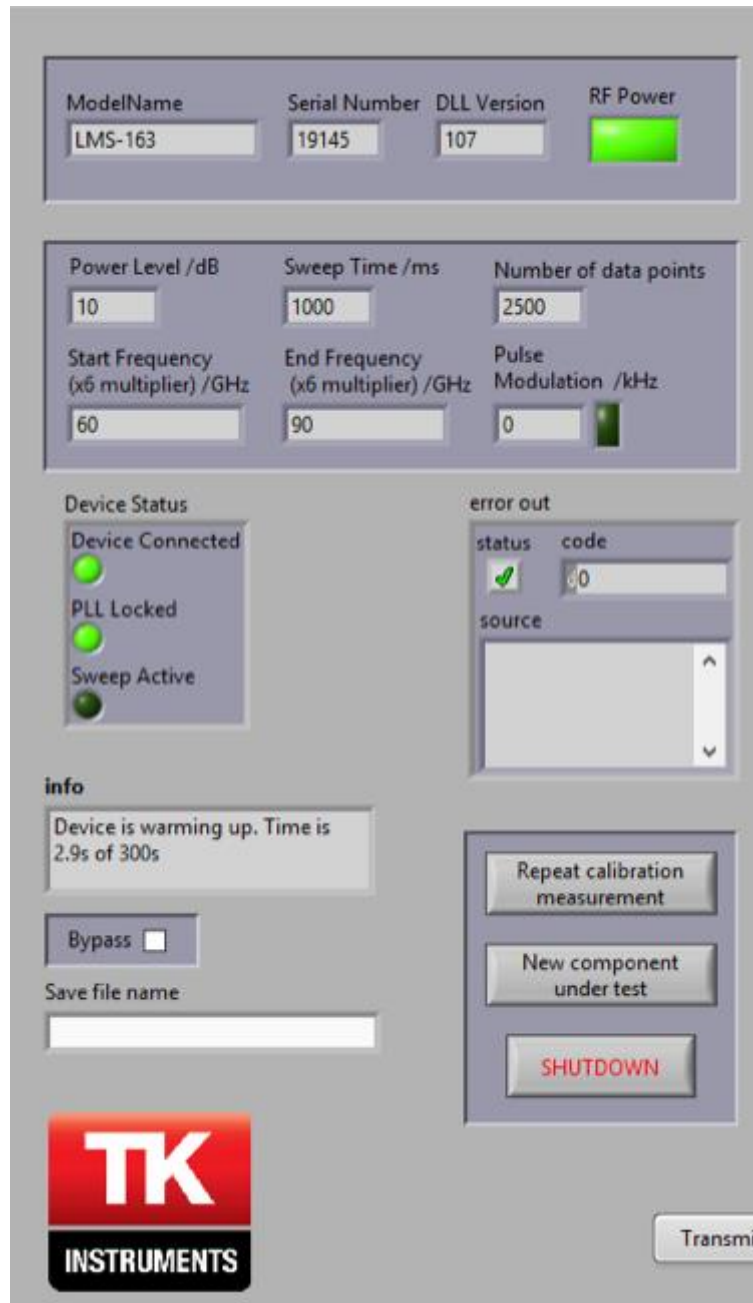

Figure 5 – Left hand side of UI

The UI is divided into three primary sections. Starting at the top of the left-hand side (shown above), we have the serial number and model of the signal generator – and a green light to shown when the RF power is on. In the box below are the measurement settings. These cannot be altered in the program but can be changed in a text file called 'Initial Settings'. This file is found in the program

directory. Note – it is important that the text is not altered – otherwise the program will not be able to read the values. The file is tab delimited. The settings are as follows:

Power   9

>   This value controls the LAB BRICK power output – leave at 10dBm.

Start Frequency 10

>   Start sweep frequency – note will be multiplied by 6.

End Frequency   15

>   End sweep frequency – note will be multiplied by 6.

Sweep Time   1000

>   Sweep time in ms – increasing this will lower noise.

Number of data points   1000

>   (This alters the number of points used by the polynomial fitting function – the A2D samples at 50kHz and the resulting points are averaged to the number of points selected here. This value also selects the number of points saved in the .xml output, and the number of points displayed graphically by the UI.

Fast pulse   0

>   Setting can be 0 (off) or 1 (on). When on the signal generator is modulated by a 1kHz sine wave – this can be used to lock-in and reduce noise, however was not found to be necessary and so is left at 0 (off).

Transmission freq. lower limit   75

>   The UI has pass/fail criteria in the frequency range over which the maximum transmission can lie. If the central transmission peak is within the range, the button at the bottom of the UI lights up green and says 'pass'. If the transmission peak is outside of this range, the button lights up red and says 'fail'.

Transmission freq. upper limit   85

>   See explanation above. Sets the upper limit on the pass/fail criterion.

The Device Status shows when the LAB BRICK is connected. Sweep Active lights up when the device is performing a measurement.

The info box counts to 300s when the program is first started, this is to allow the system to warm up – it can be skipped by pressing the Bypass box below.

Save file name can be used to amend a filename to the data saved by the program. The program automatically adds the date and time to the file name (after whatever is written into the field).

Repeat calibration measurement starts the calibration process. When the program starts you can also opt to load a previous calibration if required.

New component under test takes (and saves) a sample measurement using the current calibration.

SHUTDOWN powers off the LAB BRICK and turns off the RF power. SHUTDOWN should be used prior to shutting down the program. The PC powers the LAB BRICK, if the computer is shut down the RF power will be switched off as well.

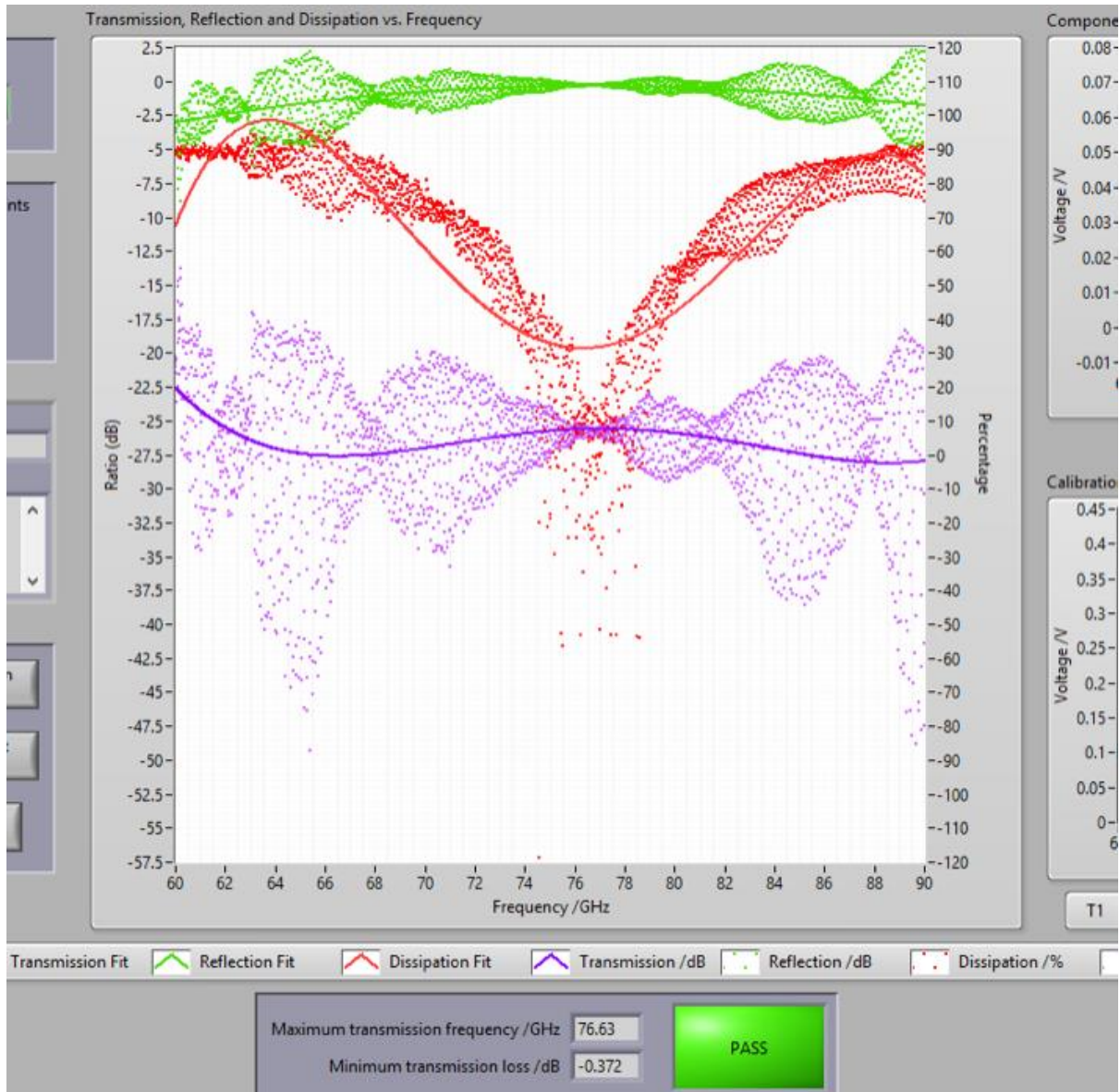Bypass will skip the 5 minutes warm-up time.

Figure 6 – Centre of UI – primary graphical display

In the centre of the UI, shown above, lies the primary graphical display of the data. The graph contains the following plots. The number of data points shown is given by the number of data points in the initial settings file. These points are the mean values of the raw signal captured by the A2D (sampling at 50kHz). The frequency range on the x-axis is taken from the Start Frequency and End Frequency values.

Transmission Fit (green line) – polynomial fit to ratio of transmission calibration voltage to sample transmission voltage (dB scale – left axis).

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Reflection Fit (red line) – polynomial fit to ratio of reflection calibration voltage to sample reflection voltage (dB scale – left axis).

Dissipation Fit (purple line) – polynomial fit to one minus the sum of the reflection ratio and transmission ratio (percentage scale – right axis)

Transmission data points (green) – raw data points of ratio of transmission calibration voltage to sample transmission voltage (dB scale – left axis).

Reflection data points (red) – raw data points of ratio of reflection calibration voltage to sample reflection voltage (dB scale – left axis).

Dissipation data points (purple) – raw data points of one minus the sum of the reflection ratio and transmission ratio (percentage scale – right axis)

The box below the primary graphical display contains the Maximum transmission frequency – this frequency corresponds to the maximum value of the transmission polynomial fit.

Minimum transmission loss is the loss in dB at the maximum transmission frequency.

PASS/FAIL lights up according to whether the maximum transmission frequency lies within the limits set in the Initial settings file.
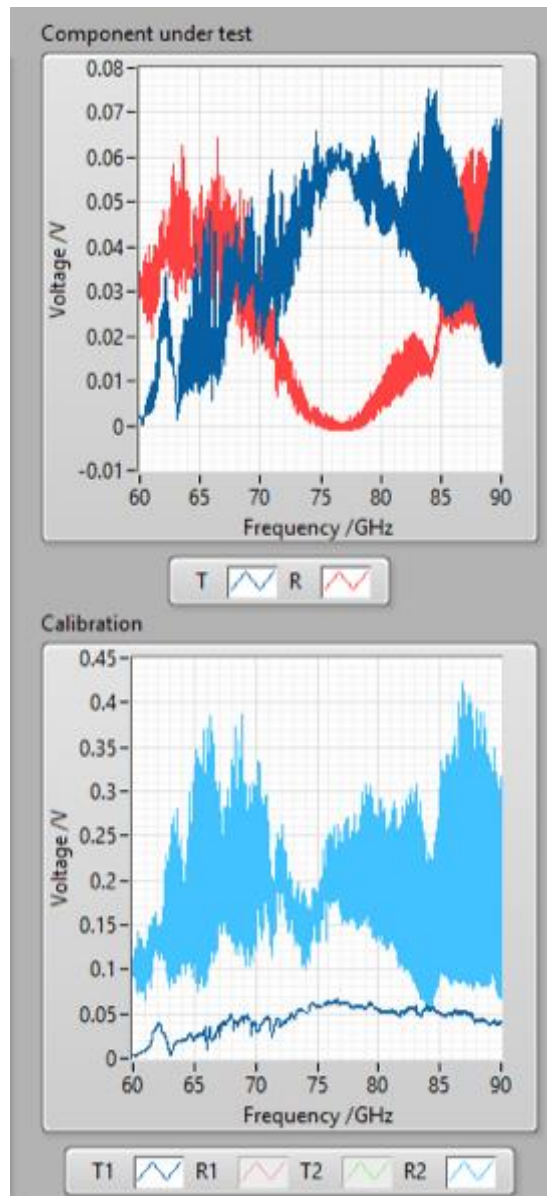
Figure 7 – Right side of UI: raw voltage output from detectors

The right hand of the UI, shown above, shows the raw voltages on the detectors – the bottom right graph shows the relevant calibration transmission/reflection voltages, while the top right graph shows the component under test voltages. The detectors have a linear output when the output voltage is below 60mV. The power in the system should be tuned so that this is the case – especially for the transmission detector where the transmission loss is calculated. Standing waves are present in the system – more so in the reflection path – and can be seen in the detector voltages. It should be emphasised that these oscillations are stable and are not noise. The standing waves are inherent in the system due to the low loss nature of the optics. T/R stand for Transmission and Reflection, respectively – and T1/R1, T2/R2 stand for transmission reflection in the transmission calibration step (T1/R1) and the reflection calibration step (T2/R2), respectively. Note – R1 and T2 are blacked out because they are not the relevant calibration voltages, however they can be seen by right clicking on the graph and selecting 'plot visible'. Note – this is not saved by the program and must be selected each time if desired.

Calibrating the system

When the system is first started, after warming up/or bypass being selected, it will ask if you wish to make a calibration – if you say no, then you must load a calibration file – stored in the program directory under *Calibration Data*. If a calibration file is not loaded the system must be calibrated. The first measurement is the reflection calibration – you must ensure that there is a reflecting sample (metal plate) in the sample holder – it is important that the reflection is performed where the sample is to be measured (at the beam waist). An easy solution is to coat the inside of a housing with metal foil, and such a sample was provided

The system will then perform the transmission calibration, followed by a baseline measurement. Please ensure that the sample holder is empty when prompted. The baseline will give you the noise floor of the system (approximately minus 26/27 dB).

A calibration file will automatically be saved after each calibration process – the calibration is saved in *Calibration Data* in .xml format. The following raw voltage measurements from the two detector channels are saved:

- Transmission calibration – transmission voltage
- Transmission calibration – reflection voltage
- Reflection calibration – transmission voltage
- Reflection calibration – reflection voltage

Making a measurement

After calibration the system will perform a baseline measurement automatically. The results from this, and all subsequent measurements, are stored as .xml files in the program direction in the folder *Component Under Test Data*. The saved filename can be modified (before a measurement is made) by entering the desired name into the save file name box in the bottom left corner of the UI.

The following data is stored:

- Frequency
- Transmission Ratio /dB
- Reflection Ratio /dB
- Dissipation /%
- Component transmission voltage
- Component reflection voltage

A housing can be measured by inserting it into the sample holder and selecting New component under test. The data is displayed on the primary graph – displaying transmission, reflection and dissipation – and the raw voltages are displayed in the top-right graph. Again – the results are automatically saved as discussed above.

After each measurement – the frequency of maximum transmission will be displayed under the central graph and the PASS/FAIL box will indicate whether this value lies between the values set in the Initial Settings.txt file.

Shutting down the system

To turn of the system – please first select SHUTDOWN, then exit the software. SHUTDOWN ensures that the RF power from the signal generator is powered off – however, as the signal generator is USB powered, if the computer is also shutdown then the signal generator will also be powered off.

The power to the 6x multiplier chain must then be switched off. This can be done by unplugging the power supply from the optical bench or turning it off at the mains.