PRACTICE 04 – 2-PORT AND 4-PORT NETWORKS

INSTRUMENT: Agilent N5230A (10 MHz – 20 GHz) PNA

1. CALIBRATION

1.1 Calibrate PNA between 1 GHz and 8 GHz (**full 2-port**), verify the calibration measuring a direct connection between the ports. Save the calibration in a file inside the directory **LaboratoryElectronics1** on the desktop of the instrument **(REPORT).**

2. PASS-BAND FILTER (Mini-Circuits VBFZ-3590+)

(frequency span 1-8GHz)

2.1 Turn off the calibration. Connect the filter between the two ports of the PNA. Measure the |S21| and save data. **(REPORT).**

2.2 Calibrate PNA in response mode (only Thru). Measure the |S21| and save data **(REPORT).**

2.3 Turn on the full 2-port calibration saved previously. Measure |S21| and save data. Plot with MATLAB the 3 filter responses overlapped. Add a plot zooming the pass-band and highlighting the effect of the different calibrations. **(REPORT).**

2.4 With the full 2-port calibration evaluate the bandwidth (at 3 dB) and the two frequencies where the loss is 25dB with respect to the maximum transmission. **(REPORT).**

2.5 With the full 2-port calibration, measure the reflection parameters by overlapping the |S11| and |S22| in the same plot **(REPORT).**

2.6 From the measurement (full 2-port calibration) of ∠S12 in the filter bandwidth and using a linear fit, evaluate the filter delay τ (with uncertainty). To avoid the discontinuity of the phase, you can use the MATLAB command **unwrap**. The final plot must include ∠S12 (dashed black line), the result of the unwrapped measurement (red line) and the linear fit (dashed blue line). **(REPORT)**

3. T-JUNCTION AND POWER DIVIDER

(Frequency span 1-3GHz)

3.1 **T-junction**. Measure the 9 parameters of the scattering matrix by taking for each parameter the average value (MATLAB command mean(formattedData)) within the span; moreover, for each parameter evaluate the standard deviation (MATLAB command std(formattedData)). Compare the result with the theoretical expectations **(REPORT).**

3.2 **Power divider**. Measure the 9 parameters of the S matrix by taking for each parameter the average value (MATLAB command mean(formattedData)) within the span; moreover, for each parameter evaluate the standard deviation (MATLAB command std(formattedData)). Compare the result with the theoretical expectations **(REPORT).**

4. 20-dB DIRECTIONAL COUPLER (Mini-Circuits ZX30-17-5)

4.1 In the device band (**1-2GHz**), measure the insertion loss, isolation, coupling, directivity and return loss for each port. Produce 5 plots, one for each quantity (thus the return loss plot will have 3 lines). In the report, include also the formulae used to derive each quantity from the VNA measurement. **(REPORT).**

5. 90-DEGREE HYBRID COUPLER

The 4-port device on the desk is a 90-degree hybrid coupler in the **2-3GHz band**.

5.1 Measure the coupling C between each input port and the 2 output ones; produce 2 plots, one for each input port (thus, each plot has two lines). **(REPORT).**

5.1 Measure the isolation I between the input ports and the decoupled ones; produce 1 plot (with two lines, one for each input ports). **(REPORT).**

5.2 Labelling **1** an input port and **3, 4** the output ports, measure ∠S13 and save it in **Memory** (Display). Then measure ∠S14 and plot **Data/Mem** to show that the device is a 90-degree hybrid coupler **(REPORT).**

6. AMPLIFIER AND POWER SWEEP (Mini-Circuit ZFL-500LN-1)

The supply voltage is **+15 V** (~50 mA); there is a 10dB attenuator at the amplifier output. Connect PNA port 1 (port 2) at the input (output). Set a **POWER SWEEP** with Sweep Type -> Power Sweep -> Start -30dBm Stop -10dBm and **CW Freq = 250 MHz**

6.1 Use the |S21| to measure the gain and the 1dB compression point Post-process the data to remove the effect of the attenuator **(REPORT).**

6.2 Measure the input reflection coefficient and the input impedance as a function of the input power. Comment on the results. **(REPORT)**

7. WR-90 WAVEGUIDE COMPONENTS

Connect to the PNA cables the transitions from coaxial cable to WR-90 waveguide (X11644A kit).

7.1 Calibrate S21 **response-normalize** between 6.56 and 13 GHz, using axles and clips for locking. Measure |S21| and ∠S21. **(REPORT)**.

7.2 Connect the waveguide from the calibration kit between the calibrated ports. Measure the ∠S21 (**Unwrapped)** and derive the propagation constant β. Produce a plot comparing the measured β with the theoretical one β_{TH} (fc = 6.55 GHz) and with the free-space β_{AIR}.

$\beta_{TH} = (2 \pi f / c) \operatorname{sqrt}(1 - (fc/f)^2)$ $\beta_{AIR} = 2 \pi f / c$ **(REPORT)**

7.3 Connect the attenuator and measure the attenuation (at 5, 10 and 15 dB) for 3 different positions. Evaluate the reflection attenuation and the dissipation attenuation (use the uncalibrated S11) **(REPORT)**

7.4 Connect the waveguide from the calibration kit between ports. Set **START -> 2 GHz** and **STOP -> 20 GHz** (losing the calibration). Measure |S21| and |S11|; comment the result. **(REPORT)**