Time domain analysis of coaxial switches for CDMS calibration

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1 What is time domain analysis?

Time domain analysis refers to the measurement of electromagnetic signals in the time domain.

Vector network analysers (VNAs) are typically instruments which measure the complex S-parameters of a device under test in the frequency domain mode. However, VNAs can perform measurements in the time domain and to switch to the frequency domain, where FFT is applied to obtain the spectrum.

Therefore, the vector network analysis (VNA) tool equipped with a high-precision vector error correction method can accurately detect mismatches, similar to a traditional Time Domain Reflectometer (TDR) [1] .

Significant differences can be found between the way signals are compared when analysing in the time domain using a VNA compared to a TDR. While a TDR sends a step or pulse across the transmission line and compares the reflected signal with a broadband oscilloscope, a VNA uses narrowband tuned receivers to compare the swept frequency signal [2]. This difference allows the VNA to obtain a better signal-to-noise ratio [1]. In addition, it should be noted that the TDR is limited to the time domain only, while the VNA has the ability to work in both the time and frequency domain [3].

2 Experimental measurements

In this case, the object under test consists of two interconnected switches, which will later be used in Matera's VGOS project for the CDMS (Cable Delay Measurement System). This system measures the delays produced in the cable carrying the 5 MHz reference signal very accurately. However, a voltage proportional to the phase shift is obtained and therefore a calibration signal is necessary to perform the transformation. Therefore, this report aims to measure very precisely the path difference of two interconnected switches the calibration constant of this system.

2.1 Pre-calibration

Before the analyser could measure, it was necessary to calibrate the analyser.It should be noted that a single-port SOLT calibration was carried out using an electronic calibration device. Once this has been done, by activating the time transform in the VNA, it is possible to observe a time pulse as in the following illustration:

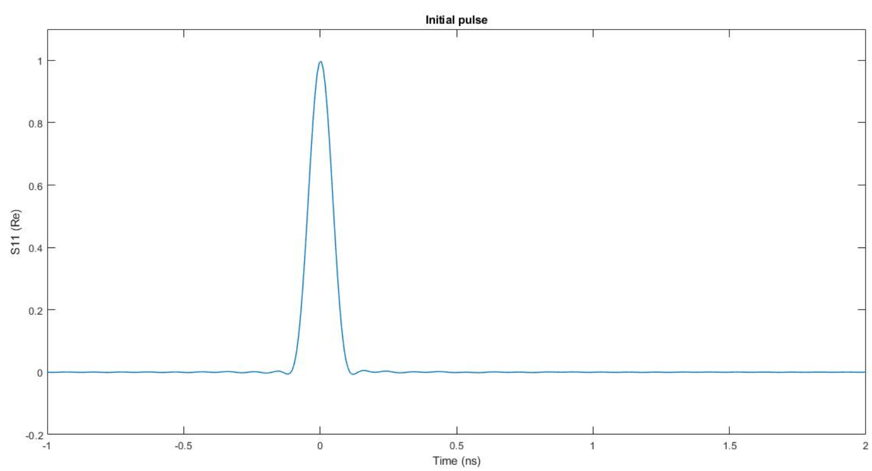

Figure 1: Initial pulse

2.2 Temporary displacements

Each termination that is added to the DUT will produce an increase in latency, which in the time domain will be translated as a shift of the pulse.

The reflection coefficient was re-measured by adding a 5 cm and a 10 cm wire respectively. In the following graphs, it can be seen that the initial pulse does indeed undergo a time shift; this is directly proportional to the length of the wire connected to the reference plane.

2.2.1 5 cm cable

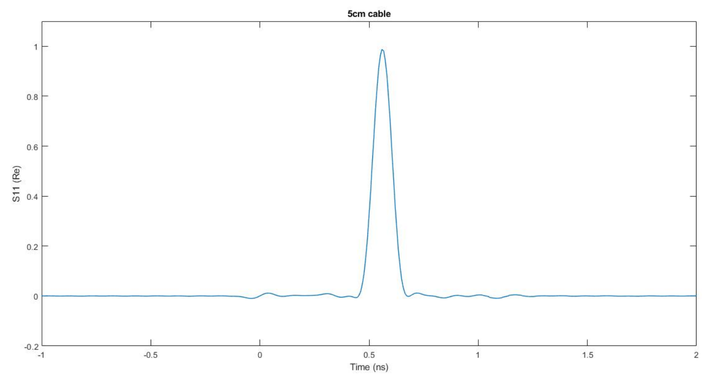

Figure 2: Pulse displacement in the time domain by connecting a 5 cm cable

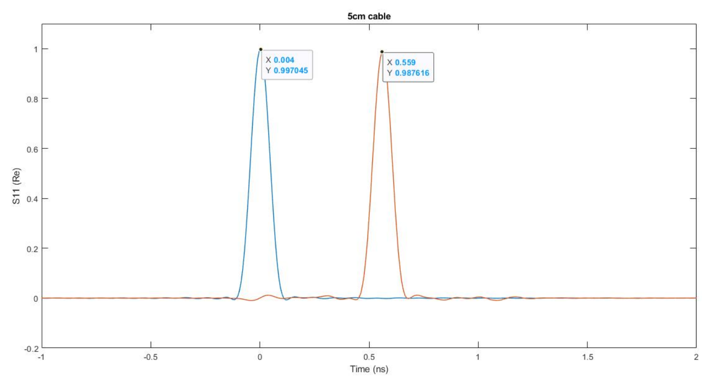

Figure 3: Comparison of the initial pulse with the pulse when a 5 cm cable is connected

In this case, a difference of 0.555ns is observed with respect to the original pulse.

2.2.2 10 cm cable

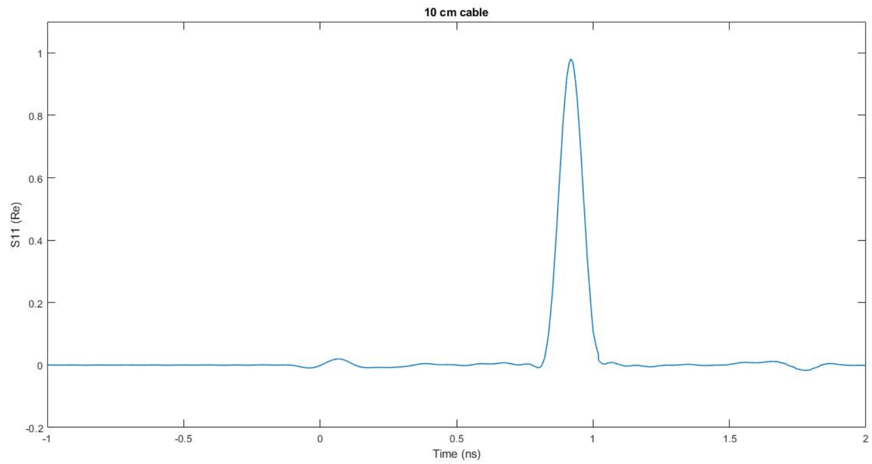

Figure 4: Pulse displacement in the time domain by connecting a 10 cm cable

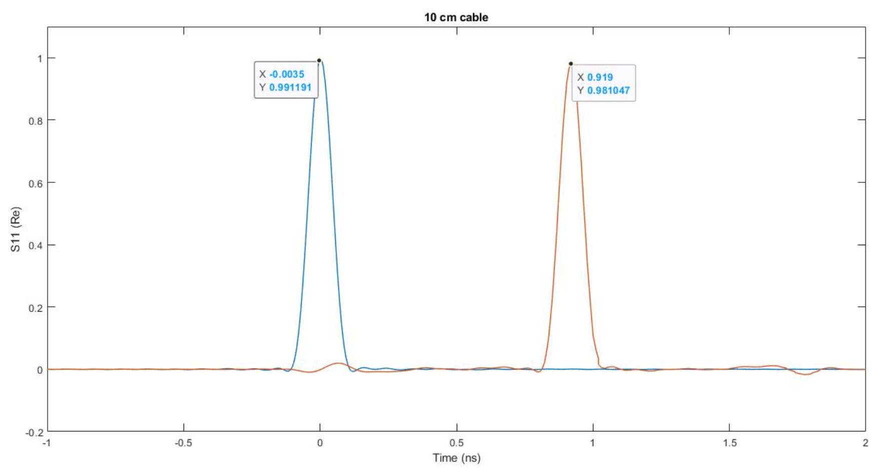

Figure 5: Comparison of the initial pulse with the pulse when a 10 cm cable is connected

When connecting the 10 cm cable, the displacement will theoretically be twice that previously observed, and a difference of 0.922 ns is observed with respect to the original pulse. Likewise, comparing both pulses when passing through the 5 cm cable and the 10 cm, a time difference of 0.36 ns is noticeable.

3 Measurements of the entire system

3.1 System to be measured

As we can see, the system consists of two switches that switch if they are powered at 28 volts. In the IN port the signal generator will introduce the signal and depending on whether the switch is active or not, it will pass the signal through output 1 or output 2; in this case through the 5-centimetre cable (1) or through the 10-centimetre cable (2).

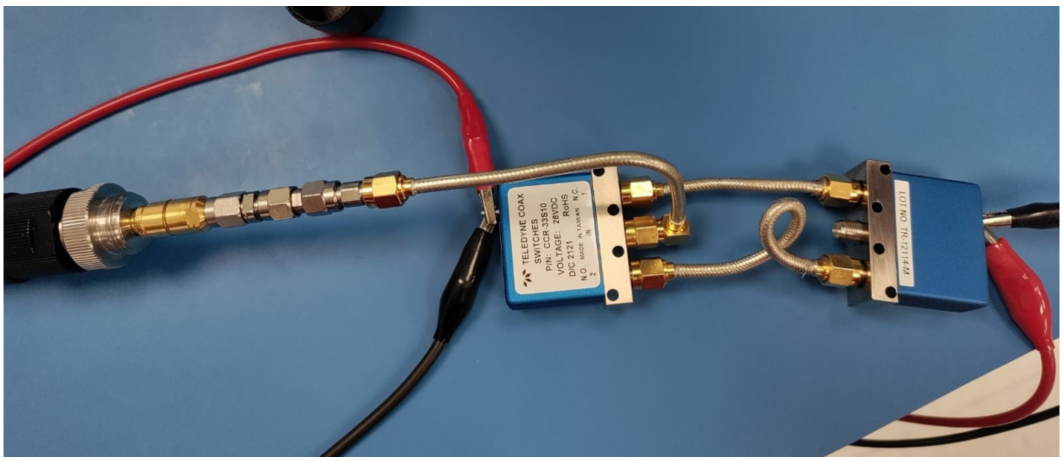

Figure 6: System to be measured

3.2 Time domain representation of the system

We initially set the analyser to a resolution of 401 points (red pulse). However, to seek greater precision in the measurements, the VNA port was recalibrated, this time adjusting the window, in order to concentrate as many points as possible in a shorter time interval and setting 1001 points (orange pulse).

Comparing both cases, an error of approximately 0.2ns is obtained.

The peaks appearing at less than 0 volts refer to the transitions of the input and output wires, which appear with greater intensity when the system is adjusted with a higher number of points.

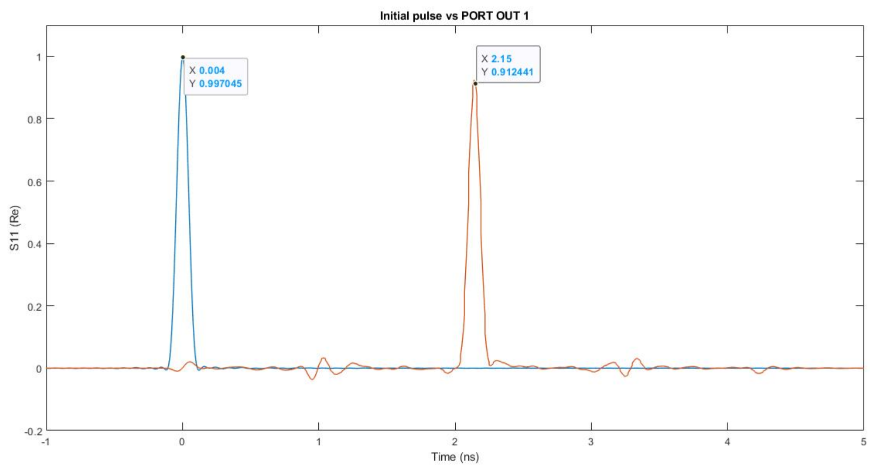

Figure 7: Initial pulse compared to the output of port 1

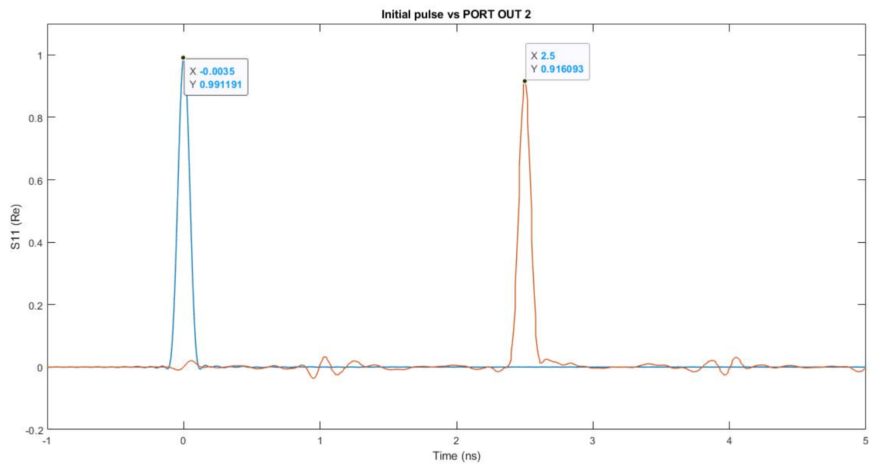

Figure 8: Initial pulse compared to the output of port 2

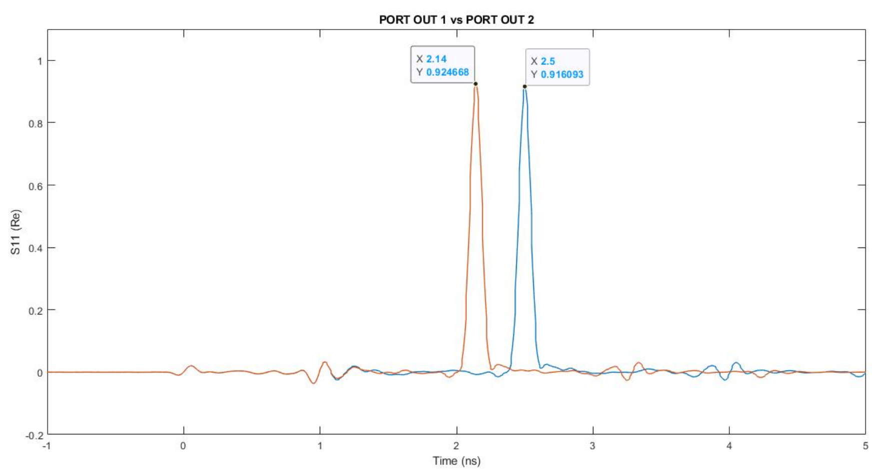

Figure 9: Output signal from port 1 vs. from port 2

Comparing the pulses above, there is a latency of 0.36 ns, which agrees with the comparision made with the 5cm and 10cm cables. This therefore leads us to conclude that the system works as expected.

References

[1] Final Test, " ART-03 Test and Calibration Box for Fuel Injectors and Pumps ", Available at: https://www.finaltest.com.mx/product-p/art-03.htm.

[2] J. García-Pérez, "Análisis del dominio del tiempo con analizadores vectoriales de red de Copper Mountain Technologies (VNA)", Trabajo Fin de Grado, Universidad Politécnica de Madrid, Madrid, España, 2020. Available at: https://docplayer.es/189237434-Analisis-del-dominio-del-tiempo-con-analizadores-vectoriales-de-red-de-copper-mountain-technologies-vna.html

[3] R. Dorado-Barragan, "Diseño y construcción de un sistema de control de acceso basado en NFC y Raspberry Pi", Proyecto Fin de Carrera, Universidad Carlos III de Madrid, Madrid, España, 2013. Available at: https://e-archivo.uc3m.es/bitstream/handle/10016/11111/PFC_Rocio_Dorado_Barragan%20.pdf?