

An Analysis of Radio Frequency Connector Insertion Loss Measured by Network Analyzer From 300 kHz Until 8.5 GHz

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ABSTRACT – This paper is an analysis of Radio Frequency (RF) connector insertion loss measured by network analyser from 300 kHz until 8.5 GHz. The chosen connector was a 3.5 mm male to 3.5 mm female connector as device under test (DUT). The purpose of the study is to study the characteristic of the DUT insertion loss against the frequency swept across it. Meanwhile the reference standards used in this study were National Instruments PXIe-5632 network analyser and National Instruments Automatic Vector Network Analyzer (VNA) calibration module.

1. INTRODUCTION

VNA was widely used in the RF instruments to measure the port match or return loss. VNA was using the Automatic VNA calibration module to characterize the VNA before it can perform the measurement. It is applying the transfer method in the characterization. The DUT to be measured will traceable to the Automatic VNA calibration module. In order to meet the international standard practice in manufacturing production, both network analyzer and Automatic VNA calibration module must calibrated with valid calibration interval. It is to maintain the unbroken chain traceable to International System of Units (SI) specifically mention as previous study [1]. The main objective by using the calibrated equipment is to measure the DUT more precision and accurate at the end of this study. The results of the RF connector insertion loss will be benefic to other researchers. It is to highlight that a metrology grade 3.5 mm connector wasn't lossless transmission line.

2. METHODOLOGY

The results of analysis will deliver a possible solution on how to measure and characterize an unidentified RF connector either in good or bad condition before placed into used. As previous study [2] explains on the S-parameter characteristic from low frequency to high frequency. The VNA will be performed full two ports calibration together with the Automatic VNA calibration module. The full two ports calibration technique consists of 12 error terms. It was identified as 6 forward and 6 reverse direction parameters. The total of 12 error terms will be characterize by the Automatic VNA calibration module and compensate the error terms become idle case or lossless transmission line for the VNA.

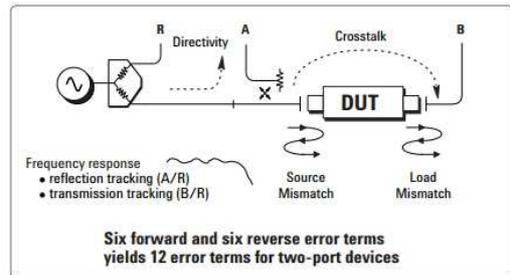


Figure 1 Error terms in a VNA

Calibrate RF connector by using S21 method on a 3.5 mm dimension would be follow as previous study [3]. The previous study was operated up to 50 GHz. Figure 2 shows the overall process required to perform the RF connector insertion loss.

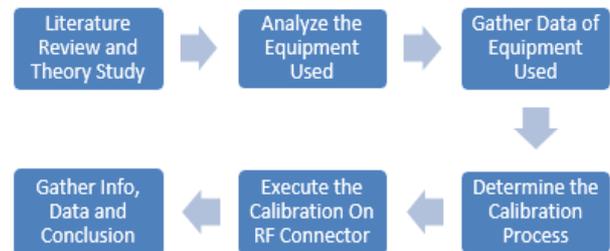


Figure 2 RF connector calibration flow

Full two ports calibration consists of port 1 to port 2 at the VNA. An external electronic module used to characterize the VNA as shown in Figure 3 (left). The experimental was carry out in a FR laboratory with well controlled environment at $23 \pm 0.5^\circ\text{C}$. Figure 3 (right) was the experimental on the DUT. The VNA will measured the forward insertion loss S12 and reverse insertion loss S21 automatically as previous study [4].

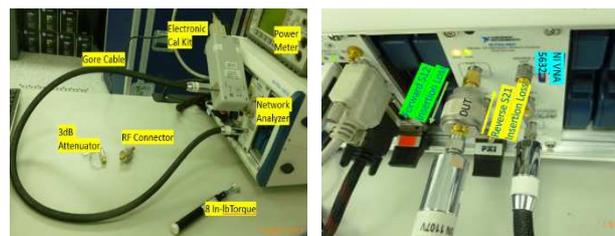


Figure 3 Automatic VNA calibration (left) and DUT full two ports calibration (right)

3. RESULTS AND DISCUSSION

The experimental measured on the DUT saved the forward and reverse insertion loss results under “real and imaginary (.cti)” format from the VNA. The results measured required to interpret in Microsoft Excel and applying mathematic calculation towards the real and imaginary results. It is to re-calculate the insertion loss in the Microsoft Excel shown in Equation (1), (2) and (3) respectively.

Real and Imaginary convert to Lin. Mag.

$$Lin\ Mag = \left(\sqrt{(Real^2 + Imag^2)} \right) \quad (1)$$

Conversion for Lin. Mag. to loss in dB

$$Loss\ in\ dB = \left(20\ Log\ \sqrt{(Real^2 + Imag^2)} \right) \quad (2)$$

Conversion for real and imaginary into degree

$$Degree = \left(\tan^{-1} \frac{Imag}{Real} \times \frac{180}{\pi} \right) \quad (3)$$

The real and imaginary results converted into loss in dB and plotted the data as Figure 4.

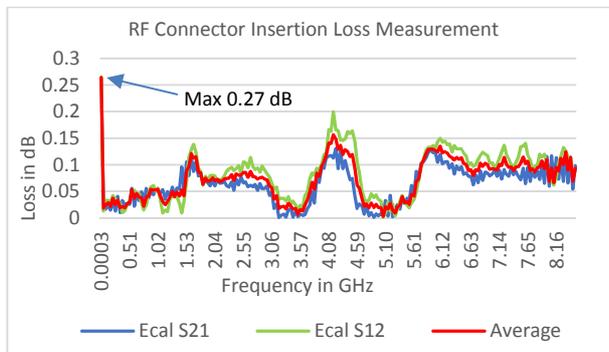


Figure 4 Results of experimental measured on a DUT

Refer to Figure 4, Ecal S12 is the forward insertion loss and S21 is the reverse insertion loss. Red line represents the average of S12 and S21. The results show that S12 and S21 measured in strong correlation. However, at 300 kHz, it was measured 0.27 dB. It is the highest loss from 300 kHz until 8.5 GHz.

The highest loss at 300 kHz triggered an alert in the calibration for further analysis on the stand alone VNA only. The VNA required to measure by itself without the DUT attach in the system. Figure 5 shows the results for the entire range of frequency.

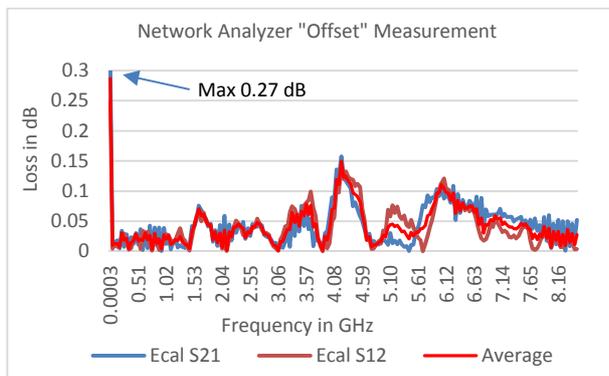


Figure 5 VNA standalone analysis

From the Figure 5, it shows that the VNA itself does measure highest peak at 300 kHz. It was identical with the experimental tested with a DUT. It has come to another analysis that was offset the VNA standalone analysis into the DUT results by applying the Equation 4. Equation 4 used to calculate the total offset by the VNA and compensate the loss into the DUT results. The purpose of Equation (4) is increased the accuracy of the test system.

Compensation VNA loss into DUT results

$$NR = \left(1 - \left[\frac{(O_{s21}^2 \times O_{s12}^2)}{(O_{s21} + O_{s12})} - \frac{(A_{s21}^2 \times S_{s12}^2)}{(A_{s21} + A_{s12})} \right] \right) \quad (4)$$

Figure 6 compute the data analysis before and after the DUT compensate by VNA offset measurement. After applying Equation 4, The DUT results (Ecal After Offset) shows closer to the nominal point at 0 dB. At 300 kHz shows significant improvement. Initially was measured at 0.27 dB above the nominal point and after applying Equation 4, 300 kHz was measured at -0.02 dB below the nominal point.

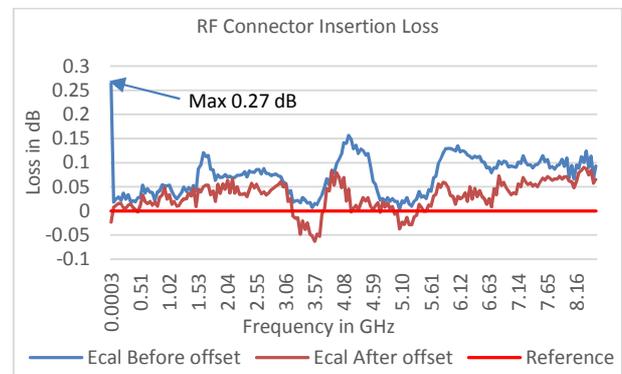


Figure 6 The differences before and after applying Equation 4 in the DUT measurement

4. CONCLUSIONS

Conclude that this study guides the operation of a VNA and Automatic VNA calibration module to perform the calibration according to the standards procedures. With the additional equations applying towards the results, it can compute the results with higher precision and accuracy and well establishing to evaluate the technique of full two ports calibration.

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