

# Power sensor reflection analysis from 300 kHz until 8.5 GHz

Tan Ming Hui<sup>1,2,\*</sup>, Ahmad Yusairi Bani Hashim<sup>2</sup>, Mohd Rizal Salleh<sup>2</sup>

<sup>1</sup>Radio Frequency Calibration Laboratory, National Instruments (M) Sdn. Bhd, 11900 Malaysia

<sup>2</sup>Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

\*Corresponding e-mail: ming.hui.tan@ni.com

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**ABSTRACT** –Power sensor is widely used in radio frequency manufacturing production floor. The power sensor needed to perform the annual calibration. Annual calibration would improve manufacturing downtime and operational costs in order to preserve the traceability of the power sensor to the next higher stage and to conform with the ISO 17025 certified test and calibration criteria as in the previous study [1]. The key objective of this study is to minimise downtime demand by introducing a new principle of in-house power sensor optimization at reduced running costs.

## 1. INTRODUCTION

Production equipment needed traceability to SI units. When the power sensor is shipped out for annual calibration, it will require roughly 1 month of downtime in manufacturing. Investment costs for the development of radio frequency stations are very costly. Typically, a power sensor hardware and calibration cost per unit is MYR 18,377 and MYR 17,280 shown by Figure 1. Calibration of the power sensor needed to ensure traceability at reduced operating and downtime costs in manufacturing. The key concept is to make good use of current test and measurement equipment and resources to accomplish the goal without an expensive power sensor to be bought as a backup. A power sensor reflection coefficient S11 parameter evaluation is conducted before calibration is carried out in the calibration laboratory.



Model: USB-5681	
Part Number: 781214-01	
<a href="#">Datasheet and Specifications</a>	
USB-5681	MYR 18,377.00
Hardware Services	MYR 17,280.16
<b>Subtotal</b>	<b>MYR 35,657.16</b>

Figure 1 Typical power sensor operating cost

## 2. METHODOLOGY

The power sensor will be performed the Scattering parameter by using the NI PXIe-5632 Vector Network Analyzer (VNA). The VNA will measure the VNA port 1 reflection coefficient (S11) reference at 0 dBm power level as previous study [2]. The reflection coefficient of the power sensor will be evaluated as below:

- S11 characteristic by using electronic calibration kits
- S11 characteristic by using mechanical calibration kits
- E9304A turn on with power meter and perform S11 characteristic with using electronic calibration kits

Compare the results and choose the appropriate method in terms of frequency response from 300 kHz until 8.5 GHz and reflection coefficient in Rho ( $\Gamma$ ) in linear magnitude. The VNA will generate the results in real and imaginary numbers. These numbers involved to re-calculation of the insertion loss shown by Equation (1), (2) and (3) respectively as previous study[3]. Real and Imaginary numbers are stored in the VNA. It is required to convert these numbers to linear scale that is Linear Magnitude as Equation 1.

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

Linear scale is unitless. It could not direct compute the measurement loss unit in Decibel (dB). Equation 2 will conversion the linear scale to loss in dB. The measurement unit converted into dB will analyze the ratio between reference calibration kit and power sensor reflection measured in the VNA.

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

The reflection coefficient ( $\Gamma$ ) was unitless. This mismatch conversion will apply the Equation 3.

$$\text{Mismatch Loss in dB} = -10 \text{Log}(1 - \Gamma^2) \quad (3)$$

It will be measure from 0 until 1.  $\Gamma = 0$  is lossless condition.  $\Gamma = 1$  is all the power reflected to the radio frequency generator which means that the power generated from the radio frequency generator could not transmitted to next device example Figure 2 for a Radio Frequency calibration system.

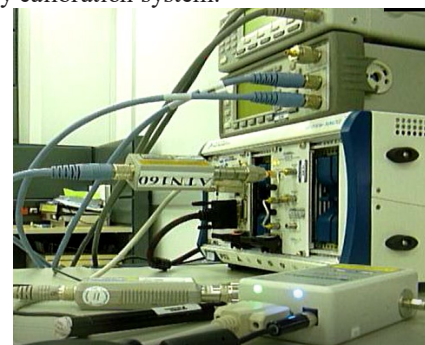


Figure 2 Power Sensor Calibration Set Up

## 3. RESULTS AND DISCUSSION

Figure 2 reveals that the electronic calibration kit

and the power sensor will be turned on with the power meter and S11 features with the electronic calibration kit graph with a strong correlation from 300 kHz to 8.5 GHz. Meanwhile, the mechanical calibration kits demonstrated a clear association with 2 other methods only up to 6 GHz. From 6 GHz to 8 GHz, it was found that the S11 power sensor was measured with a higher return loss.

Figure 3, it was found the maximum return loss is 1.32 times higher reflection from minimum return loss. The minimal return loss measured by the power sensor is turned on with the power meter and S11 is measured at 8.5 GHz with 0.001 in Rho that is equal to -58.2 dB. The maximum return loss determined by mechanical calibration kits at 7 GHz measured 0.055 in Rho or equal to -25.067 dB. The difference between maximum and minimum return loss is 33.13 dB.

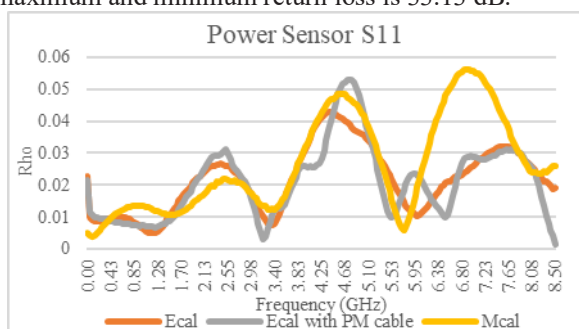


Figure 3 S11 Characteristic by using 3 different method

Equation 3 will show clearer comprehension of the loss of mismatch measured in dB. The minimum and maximum mismatch loss were 0.000 dB at 8.5 GHz and 0.013 dB at 7 GHz respectively. The loss of mismatch indicates the power dissipated from the generated power. In other words, the decline in dB in S11 is close to the previous study[4].

The lower return loss reflects a stronger mismatch of the power sensor attached to another device or system design. This would improve the principle of maximal power conversion to decrease the error of mismatch. In terms of time ability to implement the assessment of the S11 power sensor shown in Table 1.

Table 1 Time Track of S11 Measurement

Method	Consuming time
Electronic Calibration Kits	1 hour
Mechanical Calibration Kits	1.5 hours
Power Meter with Electronic Calibration kits	2 hours

From Table 1, it was observed that the maximum amount of time it takes 2 hours. The overall time able to execute the S11 calibration greatly decreases compared to the power sensor shipped back to the original equipment manufacturer's calibration, requiring about 1 month with hardware calibration cost MYR 17,280 per unit. While this analysis only covered S11, it is strongly recommended that the calibration component of the power sensor analysis be continued in calibration factors and uncertainty components to fulfil ISO17025

standard.

#### 4. CONCLUSIONS

This research successfully conducts the calculation of the VNA port 1 power sensor S11 reflection parameter. This technique applied to any type of power sensor, as the fundamentals of the S11 calibration technique traceable to the same NI PXIe-5632 VNA and the electronic calibration kits being used in this study. In order to satisfy the requirements of ISO 17025, the power sensor scattering parameter port 1 VNA calculation needed to perform the Type A statistical analysis as per the ISO Guide to Expression of Uncertainty in Calculation (GUM) approach as in the previous study[5]. Together with the uncertainty of type B in the estimation, the S11 parameter in the measurement, it fulfils the ISO GUM criterion. Considering the benefits of conducting S11 calibration, it is proposed to expand the study of the power sensor calibration element by using the same package of equipment. Then, compare the effect calibration factor of the power sensor to the design of the finished component used in the production process. The comprehensive analysis would profit the business by preventing long station downtime and power sensor calibration costs in production's hardware maintenance .

#### ACKNOWLEDGEMENT

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