Investigation of Peak Envelope Power Measurements and Uncertainties

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Abstract — **This paper reports recent works on calibrating peak power sensors with the measurement traceability to a primary power standard, *microcalorimeter*. Several practical measurement setups have been evaluated and compared. Those uncertainty components relevant and significant to the calibration process are also discussed.**

Index Terms — **Measurement standards, peak power, RF power, uncertainty.**

I. INTRODUCTION

Precision peak envelope power (PEP) measurements are increasingly demanded due to both commercial and military applications. PEP can be measured using a peak power sensor calibrated in time domain and traceable to the pulse parameter standards using a sampling oscilloscope normally [1].

Recently, Lee *et al*. [2-3] proposed a calibration method for peak power sensors in frequency domain. A peak-to-average power ratio (PAR) calculated from the modulation index of an amplitude modulation (AM) signal was used as the reference with traceability to RF power standards [3].

In Singapore, measurements and calibrations of RF average power sensors have been investigated in detail in the past [4]. As a continuation, we started to set up a system for traceable peak power sensor calibrations. In this paper, theoretical background and practical setups of peak envelope power measurement system under development will be reported, and those uncertainty components relevant and significant to the calibration process are also discussed.

II. THEORETICAL BACKGROUND AND PRACTICAL SETUPS

A. Theoretical Model

Double Sideband Large Carrier (DSB-LC) AM modulation has been implemented for calibrating the peak power sensor with a power meter. As discussed in [2-3], a modulation index m which measures the degree of modulation of an AM modulated signal comparing to its unmodulated carrier signal, can be calculated through,

$$m = \sqrt{2\left[\frac{P_{av.AM}}{P_{av.cw}} - 1\right]}. \qquad (1)$$

Here, $P_{av.AM}$ is the average power of AM modulated signal and $P_{av.cw}$ is the average power of unmodulated carrier signal. It is noted that both $P_{av.AM}$ and $P_{av.cw}$ can be accurately
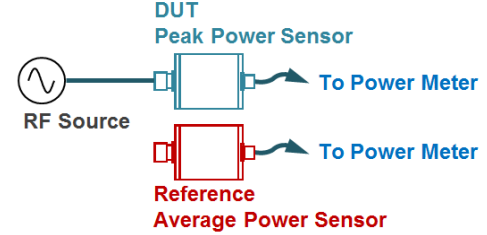
(a) Alternative connection of the DUT and reference standard to a RF source directly (Case 1)
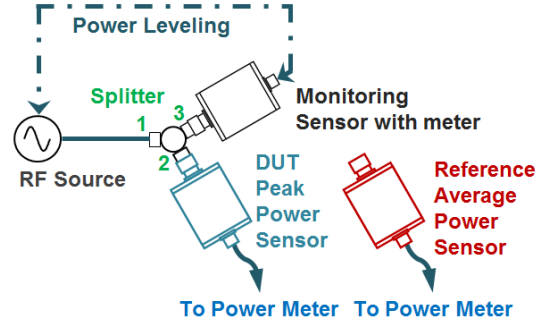
(b) Indirect connection to a RF source using a power splitter (Case 2)

Fig. 1.   Measurements and calibration of a peak power sensor.

measured by a traceable average power sensor only when the modulating frequency is much smaller than the carrier frequency so that the sidebands of modulated signal can fall into its measurement range.

The reference peak envelope power P_{PEP-R} can then be determined through,

$$P_{PEP-R} = P_{av.cw}(1 + 2m + m^2), \qquad (2)$$

and thereby the correction factor (CFP) for peak envelope power sensor can be obtained as

$$CFP = \frac{P_{PEP-m}}{P_{PEP-R}} = \frac{P_{PEP-m}}{P_{av.cw}(1 + 2m + m^2)}. \qquad (3)$$

Here, P_{PEP-m} is the measured peak power of the modulated signal using a peak power sensor with power meter under calibration.

B. Practical Setups

Calibration of a peak power sensor using (3) can be carried out with alternative connection of the reference standard and device under test (DUT) to a RF source directly (Case 1) or

indirect connection to a RF source using a power splitter (Case 2, a modified *direct comparison transfer* technique [4]) as shown in Fig.1.

In this investigation, an Anritsu MA2491A power sensor is used as the DUT together with a ML2487 power meter. The reference standard is an Agilent 8481A power sensor (traceable to the microcalorimeter at the National Metrology Centre of Singapore) used with a E4418B power meter. The DUT is tested at a frequency of 2 GHz with input power of 0 dBm. The signal is AM modulated with a modulation index of 80% and a modulating frequency of 1 kHz.

III. RESULTS AND ANALYSIS

A. Experimental Results

Calibration of the Anritsu MA2491A power sensor has been performed using the two setups as shown in Fig.1. With the calibration model (3), correction factor (*CFP*) of the peak power sensor is experimentally estimated and shown in Table 1, together with the evaluated expanded uncertainty ($k = 2$, a level of confidence of approximately 95 %).

Table 1. Estimated correction factor (*CFP*) at 2 GHz.

Setups	Correction Factor (*CFP*)	Uncertainty
Case 1 [Fig.1(a)]	112.79 %	2.45 %
Case 2 [Fig.1(b)]	112.60 %	1.94 %

From the results shown in Table 1, it can be found that the estimated *CFP* for the Anritsu MA2491A power sensor is very close for both the calibration setups (112.79 % vs 112.60 %). The main difference for the two setups is the estimated measurement uncertainties. From the analysis, it is found that the significant uncertainty components relevant to the calibration process are from the reference standard and impedance mismatch of the power sensor with the RF source/ power splitter.

B. Uncertainty Analysis

The method with direct connection of reference standard/ DUT to RF source (Case 1) as shown in Fig.1(a) is very simple. However, the impedance mismatch between RF source and power sensors cannot be corrected normally since in most of cases only specified value of magnitude of input reflection coefficient Γ_G of a RF source is known. The worst-case mismatch uncertainty $u_{mismatch}$ is considered and can be estimated as [5]

$$u_{mismatch} = \frac{2|\Gamma_G||\Gamma_L|}{\sqrt{2}}, \qquad (4)$$

where Γ_L is the input reflection coefficient of power sensor.

For the modified *direct comparison transfer* (Case 2) shown in Fig.1(b), an equivalent source match term Γ_{EG} is used but

not Γ_G. Γ_{EG} can be obtained through scattering parameters of the power splitter as [6],

$$\Gamma_{EG} = S_{22} - \frac{S_{21}S_{32}}{S_{31}}. \qquad (5)$$

It is noted that since the magnitude and phase of Γ_{EG} can be accurately obtained, mismatch can then be corrected and therefore a smaller mismatch uncertainty.

Therefore, calibration setup in Fig.1(a) is not recommended, since it is usually difficult to get the input reflection coefficient of an active source accurately, and then results in a larger evaluated uncertainty. However, this setup is very simple, and it could be used by those calibration laboratories with a proper attenuator used between RF source and power sensor to improve the source mismatch.

Moreover, comparing to the work reported in [3], the main reason for the larger uncertainty reported in Table 1 is due to the reference standard used (a thermocouple power sensor, Agilent 8481A), while the reference standard reported in [3] is a thermistor mount which has a better performance.

IV. CONCLUSION

This paper reported recent works on calibration of peak power sensors in frequency domain, with establishing the measurement traceability to a primary power standard.

Two practical measurement setups have been evaluated and compared. It is noted that the mismatch between RF source and power sensor is very significant to the calibration process, and needs to be carefully addressed in uncertainty evaluation.

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