A Receiver-based RF Attenuation Measurement System

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***Abstract*—This paper presents a receiver-based attenuation measurement system supporting 1 MHz to 1 GHz frequencies for a 0 to 80 dB attenuation range with an uncertainty of 0.006 dB. The system is designed to efficiently support the change of frequency and connector interface without requiring time-consuming system modifications. The proposed approach is benchmarked through a detailed comparison with a traceable calibrated attenuator up to 80 dB.**

***Index Terms*—RF, attenuation, attenuator, WBCO, IF-substitution, microwave measurement, calibration, uncertainty.**

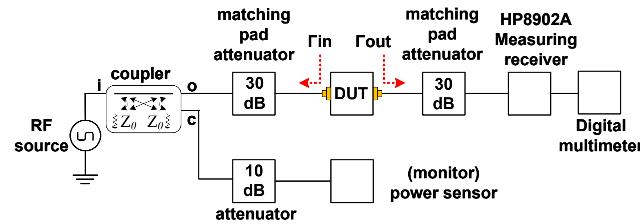

Fig. 1. A system-level overview of the proposed receiver-based attenuation system.

I. Introduction

RF attenuation standards are employed for calibration of automated step attenuators used for accurately characterising RF instrument linearity. A Vector Network Analyser (VNA) is one such instrument, considered the backbone of any RF measurement laboratory.

Whereas primary attenuation standards, such as the Waveguide Below-Cutoff (WBCO) [1], [2] or the intermediate-frequency (IF) substitution system [3], produce the best measurement accuracy, they support limited frequency points and connector interfaces. For example, IF-substitution system test-ports often require time-consuming fine-tuning of impedance tuner stages [4] to minimise mismatch errors when changing operational frequency or connector interface. In [5] a receiver-based attenuation measurement system was proposed with the expanded standard uncertainty of 0.004 dB/20 dB.

In this paper, a receiver-based measuring system is proposed for RF attenuation measurements up to 80 dB with an uncertainty of 0.006 dB at frequencies from 1 MHz up to 1 GHz. The system is designed to support measurements in precision coaxial connector interfaces, i.e. type-N, 3.5-mm and 2.4-mm connectors, by only changing the pre-selected test-port matching pads. Furthermore, the matching pads are selected such as to result in mismatch errors smaller than 0.001 dB across the entire operating frequency range.

II. Measurement System

Fig. 1 depicts a system-level overview of the receiver-based attenuation measurement system up to 80 dB. Two 30-dB attenuators are used as test-port matching pads, with a test-port input reflection coefficient better than 0.005 in linear magnitude for each supported connector interface. The 30-dB attenuation also minimises the mismatch error contribution from the generator output and receiver input impedance. Continuous measurement with a monitor power sensor ensures the test signal integrity during the thru and attenuation measurements. The measurement receiver offers a variable gain or attenuation at the input and IF stages to ensure the best signal-to-noise (SNR) ratio, see Fig. 2. The gain and loss at each receiver stage are selected to produce a relatively constant IF signal level throughout the 0 to 80 dB RF attenuation range. Maintaining a constant signal level at the IF stage minimises the non-linearity error of the IF synchronous detector and the corresponding digital voltmeter measuring the voltage output. The offset correction values of the receiver ranges are determined using a traceable automated attenuator calibrated at 30 MHz for attenuations up to 80 dB. The relative attenuation value is determined using the following equation:

$$Attenuation\ (dB) = 20 \cdot \log(\frac{P_{att}}{P_{thru}}), \qquad (1)$$

with P_{thru} the power reading of the thru measurement and P_{att} the power measurement of the attenuation measurement.

III. Measurements and Discussion

For validation of the proposed approach, the relative attenuation of an automated step attenuator is measured up to 80 dB

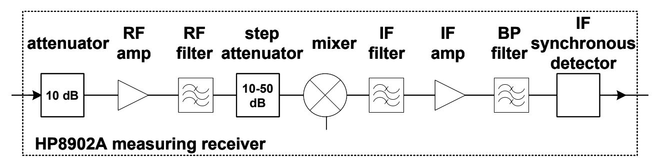

Fig. 2. A detailed overview of the measuring receiver employed in the proposed system.

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using the proposed system and compared with reference values acquired through traceable calibration at National Metrology Institutes METAS and NPL. The step attenuator is mounted with type-N pin and socket connectors and is characterised at 50 MHz and 1 GHz frequencies.

The step attenuator is sequentially switched between the thru and the attenuation states, resulting in relative attenuation measurements ranging from 0 dB to 80 dB with 10 dB steps. At each state, one hundred measurement values were acquired to determine the measurement noise, as shown in Fig. 3.

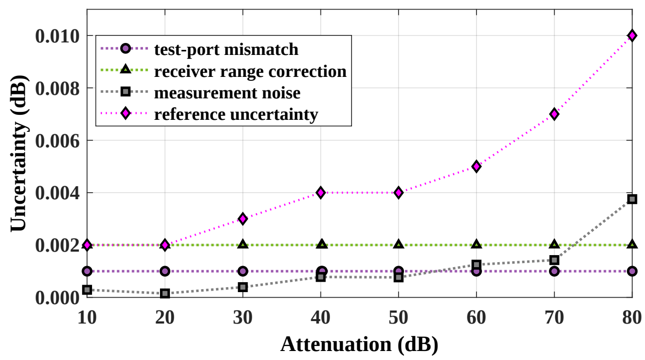

Fig. 3. Measurement uncertainty corresponding to the test-port mismatch, measurement noise and reference values at 0 to 80 dB attenuation states of the step attenuator.

The system noise is estimated at 0.001 dB for attenuation up to 70 dB, while it increases to 0.004 dB for 80 dB attenuation. The two 30-dB matching pads used to suppress the mismatch error degrade the signal-to-noise (SNR) at 80 dB attenuation. At the same time, the monitor power sensor established unwanted drift and variations in the input signal power level, as shown in Fig. 4.

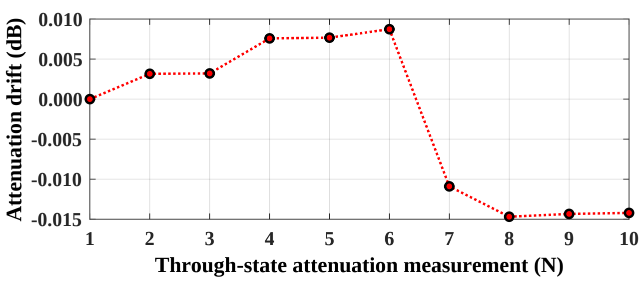

Fig. 4. The test signal drift and power level variations estimated for the step attenuator through-state measurements with the monitor power sensor.

The dominant uncertainty sources of the proposed system are shown in Fig. 3, which depicts the uncertainty contributions concerning the system test-port mismatch, measurement noise, and the measuring receiver range correction uncertainty, respectively. To improvement the uncertainty at the highest attenuation values, 20-dB attenuators might be used as test-port matching pads to reduce measurement noise at 80 dB with an acceptable increment in mismatch uncertainty.

Fig. 5 shows the excellent agreement in the results of the comparison between the values achieved with the proposed system and the reference values. Furthermore, the differences are smaller than the uncertainty estimates corresponding to the proposed method and the reference. This indicates that the measurement accuracy of the proposed system for attenuations up to 60 dB is better than the estimated combined standard uncertainty of 0.006 dB.

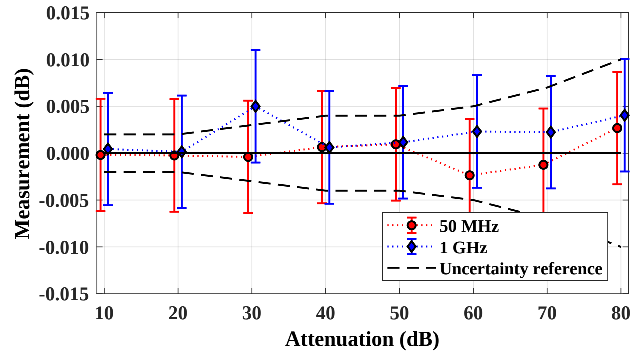

Fig. 5. Measurement comparison results for 0 to 80 dB attenuation states of the step attenuator.

IV. Conclusion

A receiver-based RF attenuation measurement system is built and subsequently validated through a detailed comparison of results on a step generator with known reference values at 50 MHz and 1 GHz frequencies for relative attenuation up to 80 dB. The measurement uncertainty is estimated at 0.006 dB for 80 dB attenuation and is confirmed by the comparison results. A significant advantage of the new system is that it can switch to a different coaxial connector interface by simply changing the test-port matching pads.

Acknowledgment

This project (20IND03 FutureCom) has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme. Additional funding was received from the Dutch Ministry of Economic Affairs and Climate.

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