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Improvement of Agilent 3458A performances in wideband complex transfer function measurement

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***Abstract* — The phase and ratio errors of transducers for distribution electrical grids can be measured, in a wide frequency range, by a synchronized couple of digitizers Agilent 3458A working in DCV mode. The high metrological performances of the digitizers is degraded by the input low pass filter cut-off frequency, which depends on the selected range. This paper proposes a technique to identify and model, for each range, the filter complex function up to several tens of kilohertz. First tests show its potentiality in reducing the errors introduced by the digitizers, when set on different ranges, in frequency calibration of voltage/current transducers.**

***Index Terms* — Measurement, measurement standards, measurement techniques, measurement uncertainty, precision measurements, uncertainty.**

I. INTRODUCTION

Thanks to the high metrological performances and the available ranges (from 100 mV to 1 kV), the use of a synchronized couple of digitizers Agilent 3458A working in DCV mode can allow the accurate measurement of the ratio and phase error of voltage and current transducers for electrical distribution and transmission grids over a wide frequency range. The DCV mode is the most accurate sampling mode with the highest input impedance. However, the input low pass filter cut-off frequency, which depends on the selected range [1], is by far the most significant source of errors in particular for the phase error measurement, when different ranges are set.

An accurate identification of the actual complex transfer function of the low pass filter, for each range, can overcome this drawback allowing post-correction of the errors introduced by the digitizers. Previous work [2] considered the frequency dependence correction for the amplitude of the Agilent 3458A low pass input transfer function in the acoustic range.

This paper describes a procedure for the measurement of the Agilent 3458A input filter frequency behavior up to 100 kHz and for the identification of the complex transfer function, which best fits the measured data.

II. MEASUREMENT SET-UP

A. Filter responses identification

The measurement set-up, which provides the transfer function of the digitizer, is constituted by a couple of Agilent 3458A multimeters externally triggered by a TTL signal given by a Fluke 397. A voltage calibrator Fluke 5500 applies the same signal to the input of the two multimeters. One of them is set in DCV sampling mode and is the device to be characterized while the other, which works as a reference for the frequency response, is set in DSDC (Direct sampling) mode. The DCV function provides the best accuracy, but the bandwidth is limited (80 kHz, 30 kHz, 150 kHz for 100 mV, 1/10 V and 100 V/1000 V respectively). On the contrary, DSDC function provides higher uncertainty, but with a 12 MHz bandwidth. The measured values of the multimeter transfer function are the input of the next step, where the analytical function which best approximates the measured data is identified.

B. Bandwidth extension through aliasing exploitation

The main drawbacks using a multimeter in DSDC mode are the reduction in the accuracy and the lower maximum sampling frequency. The maximum sampling frequency using the DSDC mode is limited at 50 kHz [1]. Anyway, in the actual measurement system the achievable sampling frequency is reduced to around 40 kHz limiting the analysis to 20 kHz.

To overcome this limit, a modified subsampling technique is proposed, exploiting the aliasing phenomenon. With the proposed method, the signal is given automatically without any need of the data manipulation required in the classical subsampling technique. This result is achieved using an appropriate choice of signal and sampling frequencies, according to (1), where f and f_s are the signal and sampling frequency respectively, n is the number of periods used for the

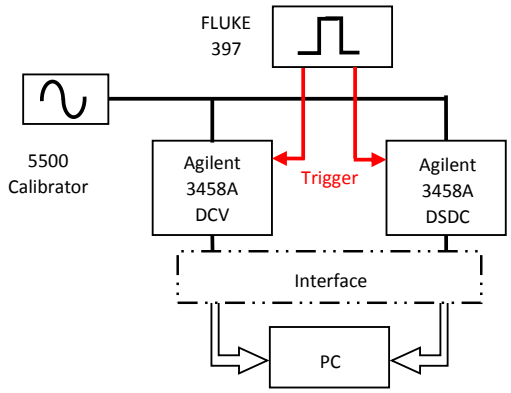


Fig. 1. Measurement set-up

modified subsampling technique, k is the number of points per equivalent period and h is an integer number.

$$\begin{cases} f = \frac{n}{k} \cdot f_S \\ x = \frac{T_S}{k} \\ n = h \cdot k \pm 1 \end{cases} \quad (1)$$

Considering the available hardware, the characterization frequency range has been extended to 100 kHz.

Some frequencies lower than $f = 10$ kHz have been analyzed with and without the proposed aliasing-subsampling method and the data resulted compatible with relative errors in the order of 100 ppm and 100 µrad for the amplitude and phase evaluation respectively.

IV. Experimental Results

All the Agilent 3458A ranges have been analyzed. The two characterized instruments are nominally equal, but they are part of different series and have been built in different years and factories. The measured data show a relevant discrepancy between them, but only the results related to one of them are reported for brevity reasons.

By considering both the filter magnitude and phase, it can be seen that the one pole representation is not satisfactory. Moreover, the 100 mV range shows an overshot in the filter magnitude around 10 kHz.

So, a transfer function made by two poles and one zero has been used to approximate the filter frequency response for 1 V, 10 V, 100 V and 1 kV ranges. For the 100 mV range, one zero and a couple of complex conjugate poles have been considered.

An optimization problem has been solved to identify the poles and zero frequencies that best approximate the measured behavior. Fig. 2 gives a comparison between measured and computed filter transfer function related to the 100 mV range.

As a first test, a low voltage resistive-capacitive divider, with scale factor 100 V/V, has been characterized between 10 Hz and 10 kHz. A supply voltage of 7 V has been applied, thus involving the digitizers' ranges 10 V and 100 mV.

Fig. 3 highlights the strong deviation, at high frequency, between the measured scale factor and phase from the computed ones, obtained from the divider components

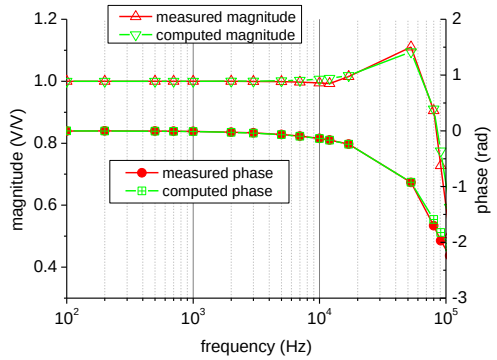


Fig. 2. Magnitude and phase of the filter transfer function related to 100 mV range.

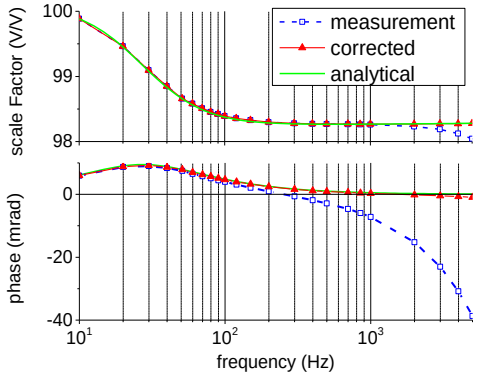


Fig. 3. Comparison between analytical, measured and corrected divider scale factor and phase.

measurement. Application of the corrections considerably reduces the discrepancy between the measured and computed waveforms. The residual deviation between them is within 0.4 mrad and 1.8 mrad at 1 kHz and 10 kHz respectively, proving the validity of the present method.

VI. Conclusion

A method has been presented for amplitude and phase frequency characterization up to 100 kHz of Agilent 3458A, when used in DCV sampling mode, and for compensation of its ratio and phase errors by identification of suitable complex transfer function. First experimentation shows its potentiality in reducing input filter complex errors introduced when a couple of digitizers, set on different ranges, is used in the calibration of non-conventional voltage/current transducers. Residual correction errors as a function of frequency and range involved is presently under evaluation

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