Research on calibration method of comb generator

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***Abstract*—We describe two calibration methods of comb generator(CG) as harmonic phase reference, one is based on digital sampling oscilloscope(DSO) and the other is based on electro-optic sampling system(EOS). We calibrate Agilent U9391F CG using these two methods and compare the differences between the results. The conclusion of the research has the potential to serve the phase calibration of nonlinear instruments and devices like nonlinear vector network analyzer(NVNA), large signal network analyzer(LSNA), amplifier, etc.**

I. INTRODUCTION

Recently, comb generator(CG) is widely used as harmonic phase reference in calibration of NVNA, LSNA, etc. These new applications require the relative phase of each harmonic component of the harmonic phase standard has been calibrated. Thus the calibration of CG is becoming a valuable problem to solve. The common method of CG calibration is measuring the output pulse waveform of CG by means of time domain measurement instruments. We obtain the phase spectrum from the temperal pulse using Fourier transform, and then the relative phase of each harmonic component can be determined which enable CG as phase reference to be calibrated. The measurement accuracy in CG calibration relies on the accuracy of time domain measurement. Theoretically, the more accurate time domain signal is, the more precise phase information can be. We outline two calibration methods of CG, one is based on DSO and the other is based on EOS. We compare and analyze differences of the calibration results between two methods.

II. CALIBRATION METHODS

A. Digital Sampling Oscilloscope

DSO is a powerful instrument for time domain waveform measurement, which is widely used in applications such as high-speed signal measurement, jitter analysis and etc. The first CG calibration method described in this paper is that measuring the output signal of CG utilizing DSO which can achieve the accurate calibration.

Block diagram of the method based on DSO is shown in figure 1. A synthesizer provides a sinusoidal signal to drive the CG, and a band-pass filter is included to keep all higher order input harmonic levels much lower than the fundamental. We used two splitters to derive the DSO's trigger, the excitation signal for CG and the two quadrature timing signals from the synthesizers. The two quadrature timing signals are used to correct the DSO's time base. The 10MHz reference out of synthesizer 1 is connected to the 10MHz reference input of synthesizer 2 so that the two synthesizers are synchronous.

We calibrate Agilent U9391F CG using the setup shown in figure 1. The output frequency of synthesizer 1 is 10GHz, and the output amplitude is 0dBm. The output frequency of synthesizer2 is 1GHz, and the output amplitude is 10dBm. We set the horizontal scale of 70GHz DSO 100ps/div so that the waveform acquisition window is 1ns. We can obtain the waveform data of CG measured by DSO using a personal computer.

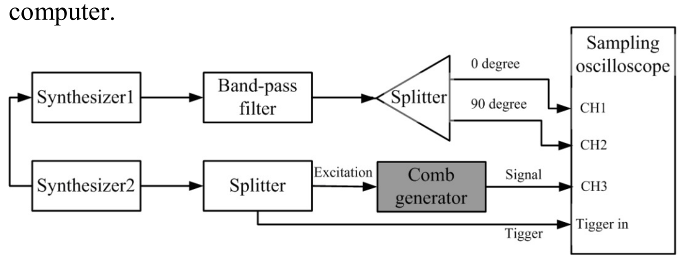

Fig. 1. Block diagram of the method based on DSO

B. Electro-optic Sampling System

The second calibration method is based on waveform measurement system using electro-optic sampling technique. Electro-optic sampling is a merging technique of waveform measurement, which utilizes electro-optic effects of crystals and ultrafast laser pulse to achieve the equivalent sampling of the electrical signal. It's a combination of linear electro-optic effects and time-variant sampling technique. The refractive index of crystal changes corresponding with the intensity of the electric field acting on it, and the polarization of the sampling beam propagating in the crystal changes with the refractive index. By measuring the changes of the polarization, we can get the intensity of the electric field acting on the crystal using the method of inversion. We change the delay between sampling beam and the measured signal using motorized stage so we can measure the whole waveform of the signal.

The unique advantages of the electro-optic sampling are listed below. It's a pure optical system with good anti-electromagnetic interference ability. The measurement bandwidth of the system can even reach hundreds of gigahertz. The resolution of system depends on the width of the ultrafast pulse laser. These advantages of the system fit the calibration requirements of wideband CG as harmonic phase standard. In this paper, calibration of harmonic phase standard based on EOS is firstly proposed, and it hasn't be seen in public reports.

Block diagram of the method based on EOS is shown in figure 2. We split the femtosecond laser into two beams, one is used as excitation beam and the other is used as sampling beam. The excitation beam is firstly chopped by a chopper and then coupled into optical fiber through a focus lens. The output of the fiber is connected to the photodetector to create a series of electrical pulses. The pulses pass through the narrow band filter, and then connected to CG as a drive signal. We couple the output signal of CG into the coplanar waveguide(CPW) through a microwave probe. We pass the sampling beam through a variable optical delay, and focus it through the gap in our CPW. The electric field between CPW conductors changes the polarization of the optical beam passing through the wafer. We compensate the inherent phase shift of the crystal using a polarization compensator. The balanced photodetector detects the changes of the polarization and output a signal whose voltage is proportion to the electric field of the measured signal. The signal is in the order of several microvolts, so we transmit it to a lock-in amplifier to detect it. The function generator provides the reference signal for the lock-in amplifier so that the signal can be measured by the lock-in amplifier. By changing the delay of the sampling beam using a motorized stage, we incrementally adjust the relative time at which the sampling optical pulse reaches the surface of the CPW: we are thus able to trace out the electrical waveform on the CPW as it evolves with time.

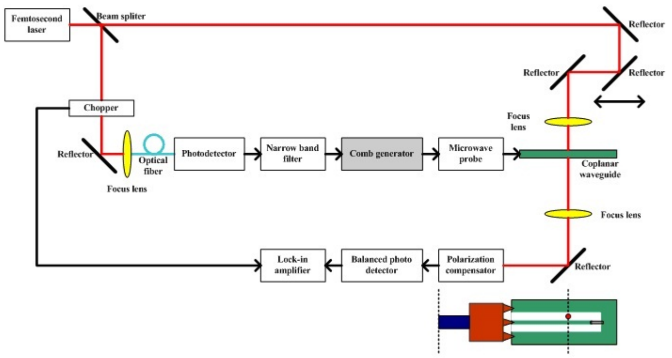

Fig. 2. Block diagram of the method based on EOS

We calibrate Agilent U9391F CG using the method shown in figure 2. The full width at half maximum (FWHM) of the femtosecond laser pulse is less than 100 fs; the repetition rate is 80MHz and the average power 200mW. We write software to control the motorized stage and the amplifier and measure the pulse waveform of CG propagating in the CPW.

III. RESULTS

We compare the calibration results of the method based on DSO and EOS. Two key specifications of CG are taken into account. One is the FWHM of the pulse, and the other is the phase flatness. We also analyze the reason that causes the differences between two results.

The waveform calibration results are shown in figure 3. These two waveforms show great agreement, the FWHM of the time domain pulses are all 16.7ps. However, the waveform measured by EOS is smoother and with lower noise.

The phase calibration results are shown in figure 4. Phase spectrum measured by EOS has less fluctuation intensity and smaller phase flatness, while phase spectrum measured by DSO doesn't perform well. The phase flatness measured by EOS is 7.6 degree while that measured by DSO is 10.4 degree in the range of 1GHz-30GHz. The results don't show much differences because the 70GHz DSO used in this paper satisfies the calibration requirements in this frequency range. When we expand the frequency range to 1GHz-50GHz, the phase flatness measured by EOS is 8.3 degree while that measured by DSO is 25.6 degree. The phase flatness measured by EOS is much smaller than that measured by DSO.

IV. SUMMARY

We use two methods described in this paper for Agilent U9391F CG calibration. By analyzing and comparing the results of two methods, we confirm that the calibration method based on EOS is more potential and suitable for wideband or even ultra wideband CG calibration. Calibration method based on DSO can be used in lower band CG calibration when the calibration cost is taken into account. Research on calibration method base on EOS is meaningful for harmonic phase reference.

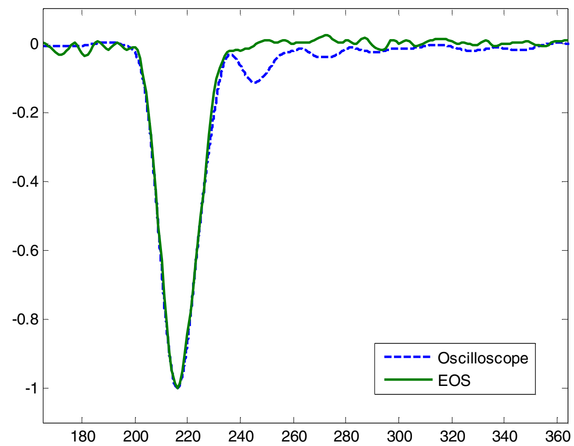

Fig. 3. Comparison of waveform calibration results of comb generator

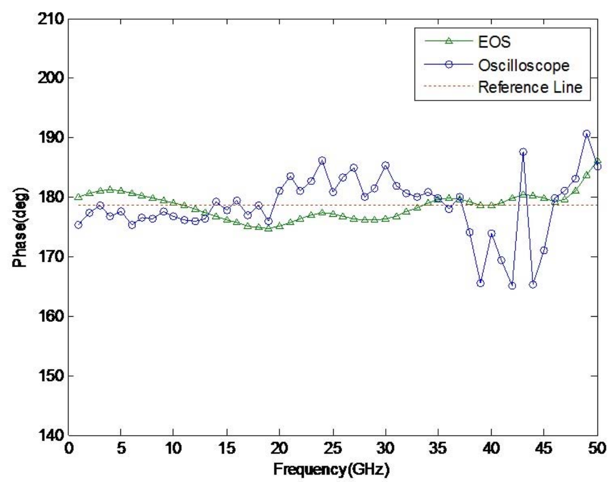

Fig. 4. Comparison of phase calibration results of comb generator

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