Cancellation of Amplitude-to-Phase Noise Conversion by Adjusting Sweet Point of the Mixer

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***Summary*—Mixer is usually used as the phase discriminator in a frequency transfer system, of which characteristics are directly related to the stability of the transfered signal. This experiment verifies the system characteristics of amplitude and phase noise conversion in mixers. The output noise of the mixer are minimum when two inputed signals are nearly orthogonal, which is called the Sweet Point. Compared with other cases, amplitude fluctuations at Sweet Point can be reduced by an order of magnitude and the measured instability can be improved.**

Keywords*—*mixer; sweet point; amplitude-to-phase noise conversion

I. Introduction

In highly stable systems of frequency transfer, any instrument characteristics would impact the stability of the signal, so we should know enough about the characteristics of each instrument. Mixer as phase discriminator is commonly used in a frequency transfer system, it can output the phase difference between two signals. It is convenient for us to further process and eliminate phase noise of two-channel signals, but at the same time, the output signal will be affected by the amplitude noise and phase noise of the input signal, resulting in low stability of the output signal. The relationship between amplitude and phase noise is analyzed in the references[1][2].

In this work, we test the characteristic of amplitude and phase noise of a mixer that can cancel with each other, the amplitude noise and phase noise of the signal can be cancelled by using this property so that the output signal has the characteristic of low noise and high stability. We usually call this particular phase Sweet Point. All the way in the experiment we use signal generator generates 100 MHZ sine wave reference signal. One uses the same frequency of the sine wave as the carrier, at the same time using the low frequency sine wave amplitude modulation. The purpose is to use the modulation signal to simulate the amplitude noise of the signal. Then the two signals are connected to the Local end and the Radio end of the mixer respectively. We collect the output data of the mixer at the output end and adjust the phase difference of the two signals to find the minimum amplitude fluctuation of the output signal, which is the Sweet Point we are looking for.

II. Methods/Results

The purpose of this experiment is to verify the amplitude and noise conversion characteristic of the mixer, and we choose a two-channel Signal Generator as the source. The system diagram is as shown in Fig1.

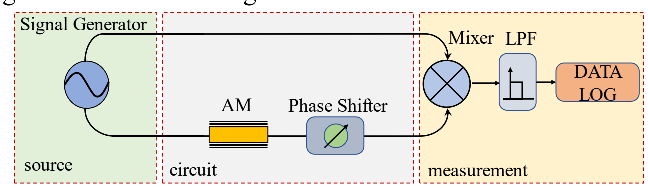

Fig1. System diagram.

In the experiment, the amplitude modulation (AM) is used to simulate amplitude noise. The signals at the two inputs of the mixer are represented by the following formulas,

$$V_{\mathrm{Local}} = V\cos(\omega_0 t) \quad (1)$$

$$V_{\mathrm{Radio}} = [1+m(t)]V\cos(\omega_0 t + \Delta\varphi). \quad (2)$$

In (1) and (2), V_{Local} represents the input signal of the Local end of the mixer and V_{Radio} represents the input signal of the Radio end of the mixer. V in (1) and (2) is the amplitude of the carrier wave, and *m(t)* in (2) is the sinusoidal wave modulated on the carrier wave, with a frequency of 0.5 Hz and a modulation depth of 10%. Where ω_0 represents the angular frequency of the carrier signal and $\Delta\varphi$ represents the phase difference between two signals.

The signal that passes through LPF after mixing the two signals is expressed as follows:

$$V_{\mathrm{out}} = V_{\mathrm{max}}[1+m(t)]\cos(\Delta\varphi + \delta\varphi). \quad (3)$$

In (3), V_{max} is the maximum value of the measured signal after mixing, $\delta\varphi$ represents the phase noise from average relative phase difference $\Delta\varphi$. Here, assuming that $\delta\varphi$ is small, (3) can be written as follows:

$$V_{\mathrm{out}} \approx V_{\mathrm{max}}[1+m(t)][\cos(\Delta\varphi) - \delta\varphi\sin(\Delta\varphi)] \quad (4)$$

$$= V_{\mathrm{max}}\cos(\Delta\varphi) + m(t)V_{\mathrm{max}}\cos(\Delta\varphi) - \delta\varphi V_{\mathrm{max}}\sin(\Delta\varphi) - m(t)\delta\varphi V_{\mathrm{max}}\sin(\Delta\varphi). \quad (5)$$

In (5), the first term is the DC component, and the second and third terms are voltage fluctuation caused by amplitude noise and phase noise, respectively[3]. Moreover, the second and third different signs can offset each other. When they offset each other, the output voltage fluctuation is the smallest. The last term of (5) contains two kinds of noise, but this term is much smaller than the middle two terms, we will not consider the last term here. On this basis, we tested two kinds of mixers.

Firstly, we tested the Sweet Point of ZAD-1+mixer. In this test, a total of 21 points were selected near the quadrature of the two signals, ranging from 80° to 100°, and the step length was

1°. In this experiment, the average value of the collected data is used to evaluate whether the phase difference is accurate. The maximum value of the output voltage minus the minimum value is used to evaluate the stability of the signal. The output voltage fluctuation of the mixer is tested as shown in the Fig2.

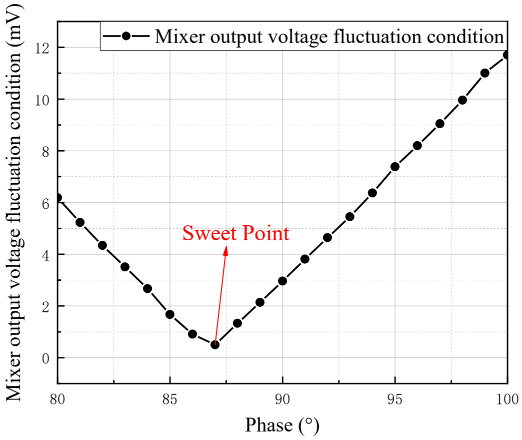

Fig2. Fluctuation of output voltage with phase difference of two signals (mixer ZAD-1+) .

In the test process, a phenomenon was found: theoretically, after an AM signal is mixed with a carrier with the same frequency and passes through a low-pass filter, the modulation signal should be output. However, in the experiment, we found that the minimum value of output voltage fluctuation is always accompanied by the distortion of the output modulation signal, The experimental results are shown in Fig3.

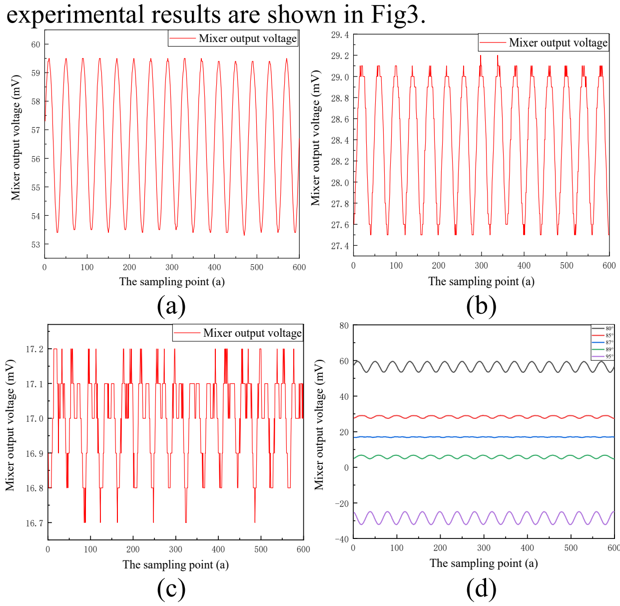

Fig3. Graph (a) , (b) , (c) show the output waveform changing as the phase gradually approaches the Sweet Point, and graph(d) shows the output waveform selected at the phase near Sweet Point and observed at the same scale.

The corresponding phases of waveform in Fig3. (a) , (b) , (c) are 80°, 85° and 87° respectively. Sweet Point is near 87°. It can be seen that when it is close to Sweet Point, the original demodulated sine wave gradually becomes distorted. When the phase is at Sweet Point, the waveform distortion is the most serious. It can be seen from Fig3. (d) that when several waveforms are observed at the same scale, it can be clearly seen that when the phase gradually approaches 87 °, the wave fluctuation is smaller.

We also tested another mixer (ZFM-150+) , its output waveform with phase change is basically the same as ZAD-1+mixer. The output voltage fluctuation of the mixer is tested as shown in the Fig4.

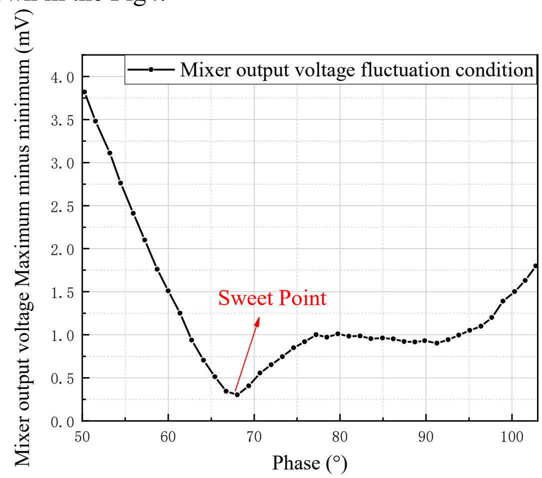

Fig4. Fluctuation of output voltage with phase difference of two signals (mixer ZFM-150+) .

III. DISCUSSION/INTERPRETATION

In this experiment, when the phase is at Sweet Point, the waveform generated by demodulation is distorted, which proves that the modulated signal is damaged in the mixing process, leaving only the DC component in the output, which is exactly corresponding to (5) , and proves that the noise at this time is minimal. We can use this characteristic of the mixer to improve the stability of the signal. In the frequency transfer system, we can set the working point of the phase discriminator at Sweet Point, which can improve the stability of the transfered signal and reduce the Allan deviation.

IV. CONCLUSIONS

We experimentally verify the existence of the Sweet Point in the mixer and verify that the amplitude noise and phase noise of the signal are cancelled at the Sweet Point, which can be proved by the distortion of the modulated signal. Compared with other points than Sweet Point, amplitude fluctuation at Sweet Point can be reduced by an order of magnitude and signal stability can be improved. This characteristic of mixer can be applied to some areas requiring high precision, especially some projects using mixer to realize phase discrimination.

REFERENCES

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