APPLICATION NOTE

A Measurement Technique Used to Determine the 3 dB Modulation Bandwidth of Skyworks PS094-315 Phase Shifter

Introduction

Under the control of an external signal, a phase shifter is typically used to shift the phase of a high frequency signal. An analog phase shifter may also be used as a phase modulator, in which case the external control signal is known as the modulating baseband signal.

A parameter of interest is the maximum baseband modulating frequency, which is typically defined as the frequency at which modulation sensitivity decreases by 3 dB. The "bandwidth" of an electronic component is defined as "The range of frequencies within which performance, with respect to some characteristic, falls within specific limits."[1]

In this case, the modulation bandwidth is defined as the range of frequencies in which modulation sensitivity is within 3 dB of the peak value. In basic electric circuit theory, the bandwidth represents the distance between the two points in the frequency domain where the signal is $1/\sqrt{2}$ of the maximum signal amplitude (half power). As an example, the 3 dB bandwidth of a low pass filter is depicted in Figure 1.

This Application Note describes a measurement technique used to determine the 3 dB modulation bandwidth of the Skyworks PS094-315 voltage variable phase shifter, operating in the 700 to 1220 MHz frequency band. For additional information about the PS094-315, refer to the device Data Sheet (document # 200240).

Modulation Bandwidth Measurement

Modulation bandwidth is a measure of control port frequency response. It can be measured using the test setup shown in Figure 2.

The procedure is to phase modulate the RF signal applied to the phase shifter with a lower frequency sine wave, then use a phase demodulator to recover the original modulating signal. As the modulation frequency is increased and the amplitude of the high frequency RF signal is held constant, the 3 dB modulation bandwidth can be determined as the modulating frequency at which the recovered modulating baseband signal is reduced in amplitude by 3 dB from its peak value.

In this case, the phase demodulator circuit is a double-balanced passive mixer. It is selected so it has a wider baseband bandwidth than that of the phase shifter.

Test Setup

A phase demodulator is constructed by using a power splitter and mixer. The frequency of the modulating signal is varied, while keeping its amplitude constant, starting from a frequency very close to 0 Hz until the oscilloscope display drops by 3 dB, or to 0.707 of its low frequency value. This frequency is recorded as the 3 dB modulation bandwidth.

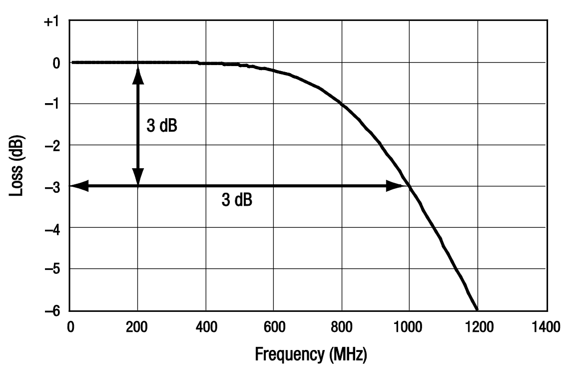

Figure 1. Example of The 3 dB Bandwidth of a Low-Pass Filter

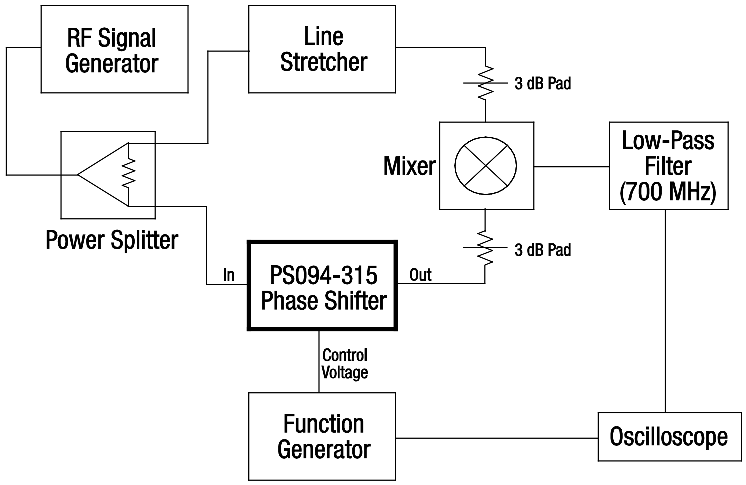

Figure 2. Modulation Bandwidth Test Setup

Table 1. Test Equipment

Equipment	Manufacturer	Part/Model No.
RF signal generator	Rohde Schwarz	SME03
Function generator	Agilent	81150A
Power splitter	MiniCircuits	ZFSC-2-2
Line stretcher	Arra	DN2448A
Mixer	MiniCircuits	ZFM-2000
Oscilloscope	LeCroy	44XS

The RF signal generator provides a high frequency continuous wave (CW) signal that is divided into two in-phase, equal-amplitude signals by the power splitter. One of these signals is phase modulated by the PS094-315 phase shifter. The other signal is the high frequency reference signal for the mixer.

The amplitude of the output signal from the mixer is proportional to the relative phase of the reference signal and the phase-modulated output signal from the phase shifter. The output signal from the mixer is sent to an oscilloscope through a low-pass filter to suppress higher frequency harmonics generated by the mixer.

A function generator provides the modulation signal that is applied to the phase shifter control voltage port. The amplitude of the output signal of the function generator was held constant by adjusting the voltage amplitude as the frequency of its output signal was changed. The line stretcher adjusts the phase of the high frequency reference signal to maximize the amplitude of the recovered modulating signal, as measured by the oscilloscope. The 3 dB pads are added to improve the RF match at the mixer.

Measurement Test Conditions

Measurements were performed using the test set up shown in Figure 2 and equipment listed in Table 1. The ambient temperature was +25 °C. The control port decoupling networks (10 pF capacitors) were removed from the standard Skyworks PS094-315 Evaluation Board (refer to the PS094-315 Data Sheet for the schematic).

The modulation signal was a sine wave with an amplitude of 9 V peak-to-peak. The carrier RF frequency was 940 MHz. The carrier frequency output power from the signal generator was +11.5 dBm.

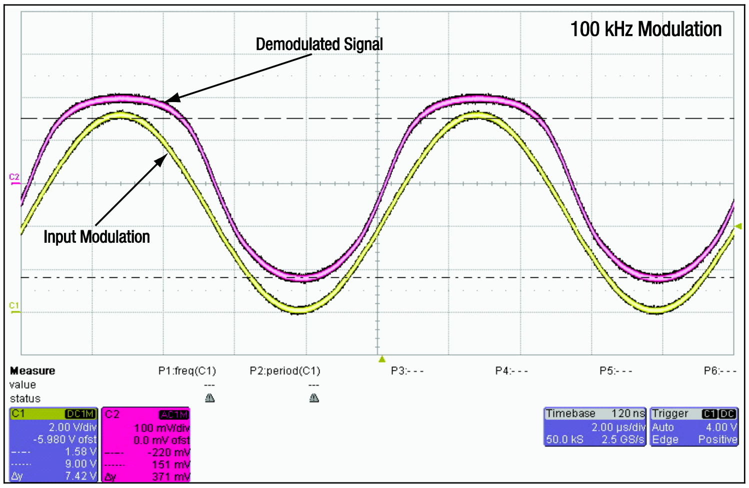

Figure 4. 100 kHz Modulation Demodulator Output Voltage Response

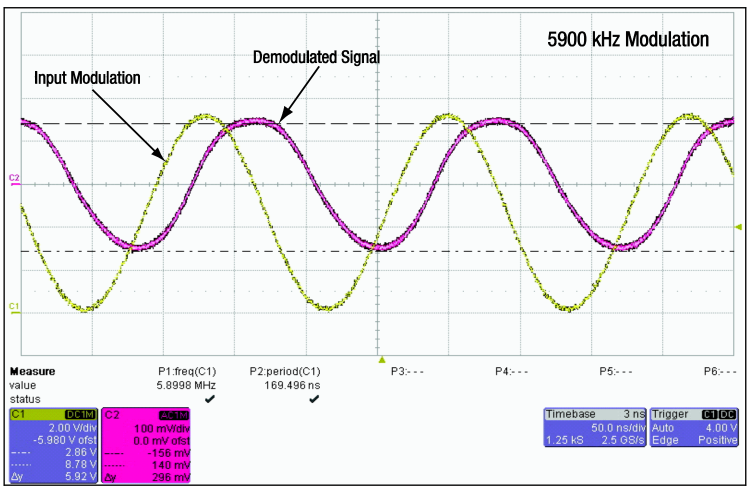

Figure 5. 5900 kHz Modulation Demodulator Output Voltage Response (3 dB Bandwidth)

Measurement Procedure

1. Apply the 9 V peak-to-peak sine wave with a 100 kHz modulation signal to the phase shifter $V_{CONTROL}$ pin. Observe this signal on an oscilloscope to confirm its frequency and amplitude.
2. Set the RF signal generator to 940 MHz with output power equal to +11.5 dBm.
3. Adjust the line stretcher to maximize the voltage at the output of the low-pass filter. The response is shown in Figure 4.
4. Record the peak-to-peak voltage at the low-pass filter output.
5. Incrementally increase the modulation signal frequency until the voltage measured at the output of the low-pass filter is 0.707 of its value at 100 kHz as recorded in step 4.

   It may be necessary to adjust the modulating signal amplitude to keep its magnitude constant at 9 V peak-to-peak while increasing its frequency.

The frequency at which the output voltage as measured at the output of the low-pass filter is reduced to 0.707 of its peak value; this is the upper bound of its modulation bandwidth. Since the lower bound of the modulation bandwidth is 0 Hz, the upper bound frequency is also the modulation bandwidth.

The response is shown in Figure 5. All of the test results are plotted in Figure 6.

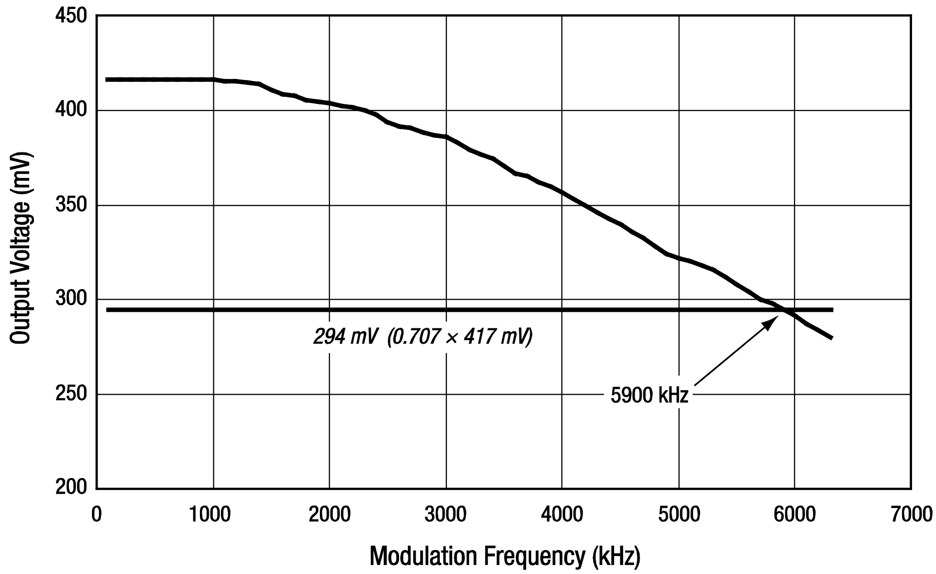

Figure 6. PS094-315 Demodulated Output Voltage vs Modulation Frequency

Conclusions

The 3 dB modulation bandwidth is determined by phase modulating an input RF signal with a lower frequency sine wave, then using a phase demodulator to recover the original modulation.

The 3 dB modulation bandwidth of the PS094-315 phase shifter was determined to be 5900 kHz at an RF frequency of 940 MHz using the technique described in this Application Note. This methodology may also be used to measure the modulation bandwidth of other analog phase shifters.

References

1. *The IEEE Standard Dictionary of Electrical and Electronics Terms*, current edition.