Testing RF Signal Sources Frequency Transient Performance

Frequency Versus Time

We think of frequency sources such as RF and microwave signal generators as well controlled sources of frequency. It is easy to verify signal source performance using standard test equipment such as spectrum analyzers, frequency counters, or signal source analyzers. These instruments are fine so long as the signal source is relatively stable at a fixed frequency. But what if you need to analyze what happens as the frequency source slews from one frequency to another such as in the case of a sweep generator, frequency synthesizer or simple VCO? You won't have much luck using conventional instrumentation to measure these. What is needed is an instrument that can measure frequency versus time.

Spectrum analyzers can only display frequency vs time. Signal source analyzers are essentially spectrum analyzers but have additional capabilities for quantifying modulation and signal purity such as phase noise. Neither of these instruments can provide frequency vs time information, at least not instantaneously.

Oscilloscopes can measure and analyze amplitude events or transients vs time. Oscilloscopes are getting more sophisticated as they utilize high speed digital data acquisition techniques. It should be possible for a high speed oscilloscope to quantize a transient signal source and produce frequency vs time data but even the fastest oscilloscope would be limited to testing relatively low RF frequencies. And even at low frequencies the frequency vs time data is not readily available and requires additional customer analysis software.

A frequency counter can measure frequency and, if configured with data logging computer system, can record frequency change over time. Allan variance and Allan deviation is measured this way but AVAR and ADEV are measurements that are made over long periods of time, seconds to thousands of seconds. A specialized form of frequency counter is the modulation domain analyzer (MDA). An MDA can make fast frequency vs time measurements on the order of microseconds. However these are specialized and expensive instruments that are not commonly found in a typical electronics lab.

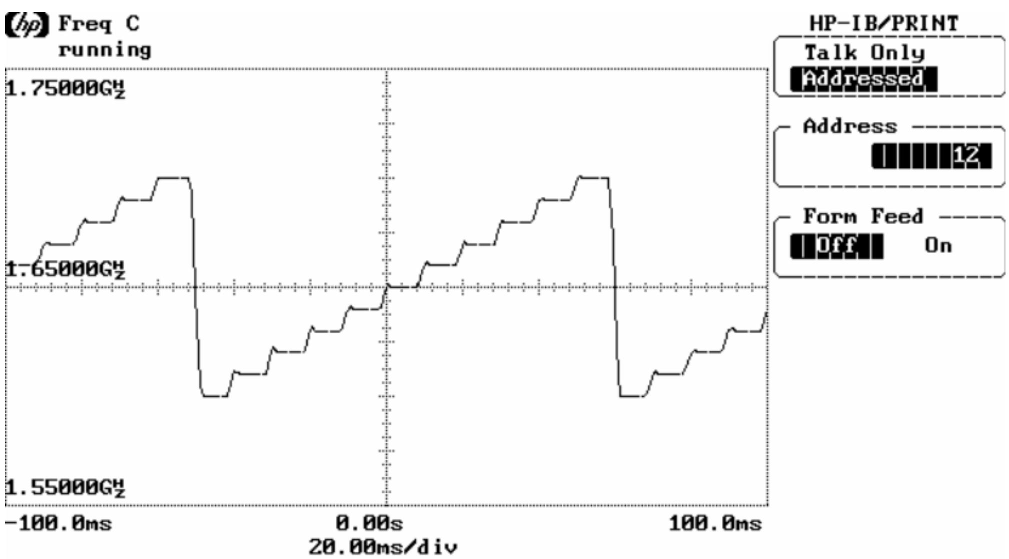

Figure 1 Typical MDA plot showing a frequency synthesizer stepping from 1600MHz to 1700MHz in 10MHz steps at a 10ms rate using an HP 53310A.

With the possible exception of the oscilloscope, these instruments are single-channel devices and generally lack the ability to simultaneously display other events. A typical 2-channel measurement might be to measure a VCO output frequency and tuning voltage versus time. Or a more complex example would be characterizing the frequency switching performance of a frequency synthesizer where it is necessary to view the RF frequency along with, for example, the PLL tune voltage, digital programming signals, and the lock detector outputs simultaneously.

Delay Line Discriminator (DLD)

A perfect solution to this measurement problem is the DLD. The delay line discriminator has been employed in radar warning receivers for making instantaneous frequency measurements (IFM) of chirp radar signals. The DLD is also a common technique for measuring phase noise in signal sources. The delay line discriminator typically consists of a power splitter, a suitable length of delay line, and a phase detector as shown in the figure below.

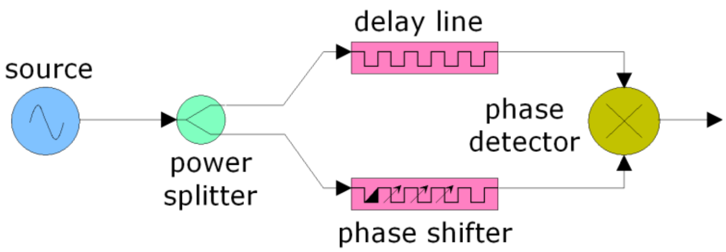

Figure 2 Delay line discriminator block diagram

The phase shifter is not essential if you have a number of different length cables and are willing to do some experimenting until you get a suitable phase shift.

The figure below shows how to set up a simple DLD using a **Valon 4002 Phase Gain Detector**. Our **Valon 5009** synthesizer is the DUT and is connected to the power splitter. One output from the power splitter is connected to the 4002 RF2 input with small SMA cable (30CM). The other output goes to the phase shifter and then the 4002 RF1 input. The Phase Detector output is the DLD "discriminator" output.

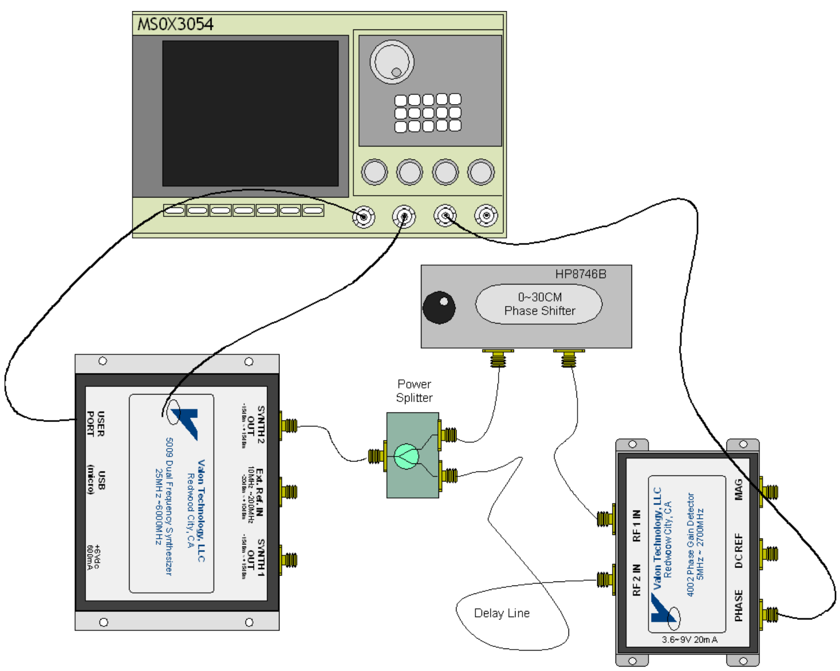

Figure 3 Lab setup delay line discriminator for measuring sweep frequency vs. sweep enable output.

In the setup above, the Valon 5009 is source and device under test (DUT). The power splitter in this case is a Mini-Circuits ZAPDQ-2-S. The phase shifter is barrowed from an HP8746B S-parameter test set. The phase detector is a Valon 4002 Phase Gain Detector. The unique feature of the Valon 4002 is its XOR type phase detector which is quite linear over the ±90° phase range. The 4002 XOR type phase detector is superior to using a balanced mixer for a phase detector in a delay line discriminator setup.

Sweep Characteristics

The sweep characteristics are analyzed with the 5009 set up as follows:

- Mode Sweep
- Start 1600MHz
- Stop 1700MHz
- Step 10MHz
- Rate 10ms
- Run/Halt Run

The phase shifter is adjusted until a monotonic frequency stair-step ramp is displayed from the 4002 Phase output. If a phase shifter is not available, try changing the frequency range, and or adjusting the cable lengths from the splitter to the phase detector until a useable frequency scale is achieved. The frequency discriminator output is taken from 4002 Phase Out connector directly and no other amplification or signal processing is needed. The oscilloscope plot in the figure below shows the relationship between 5009 sweep frequency on the top yellow trace and the Sweep Sync output from the USER PORT pin-7 on bottom green trace. The blue trace is obtained at by probing the 5009's VCO tune voltage inside the 5009. Note also that the Sweep Sync output is active (high) during the start of the sweep and stays high for the first frequency step. The Sweep Sync then goes low and stays low for the remaining sweep step time.

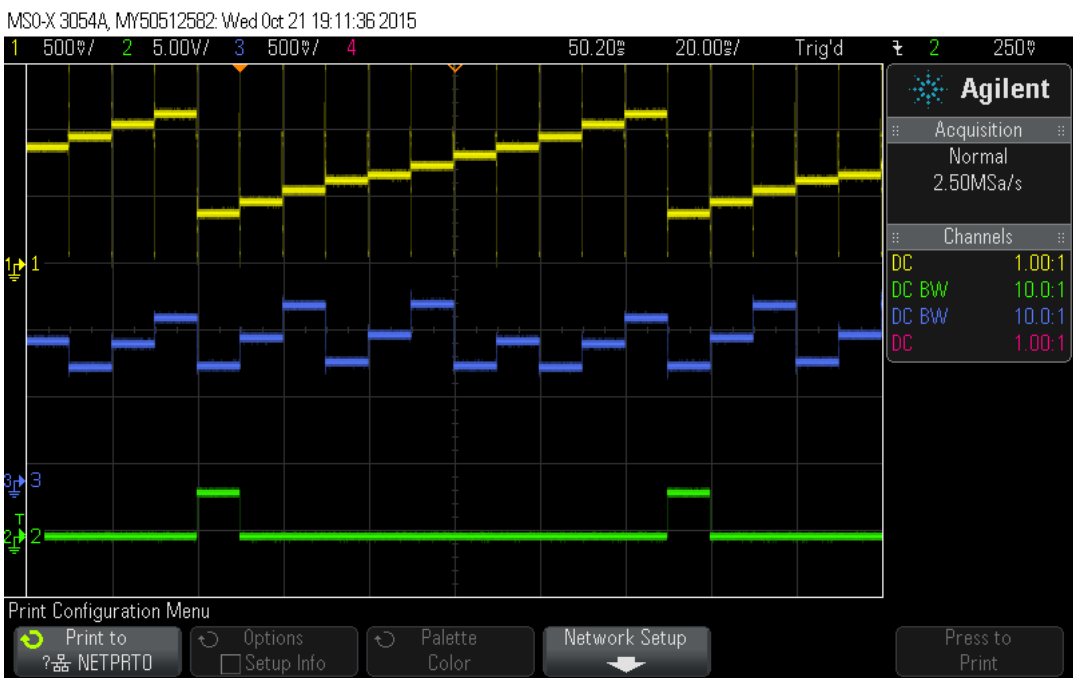

Figure 4 From the lab setup with the 5009 sweeping from 1600MHz to 1700MHz in 10MHz steps at 10ms/step. Yellow trace is 4002 Phase output, green trace is Sweep Sync output at the USER PORT pin-7. The blue trace is the internal PLL VCO tune voltage.

The VCO tune voltage steps do not always increase with increasing sweep frequency. This is because the 5009 synthesizer uses a number of VCOs to cover this frequency range and an adaptive VCO selection process. The 1650MHz step uses a different VCO than 16 1660MHz step. This is evident by the large VCO tuning voltage step at this transition.

The yellow frequency stair-step trace shows that there are large frequency excursions occurring at every frequency step transition. This behavior is more evident in the expanded plot below. This plot is expanded about the transition from 1600MHz to 1610MHz, the first step after the start frequency. Here we see the Sweep Sync pulse going low. The VCO adaptive selection is evident from the yellow frequency discriminator trace. The blue trace shows the tuning voltage to the internal VCO and pink trace is the digital lock detector output.

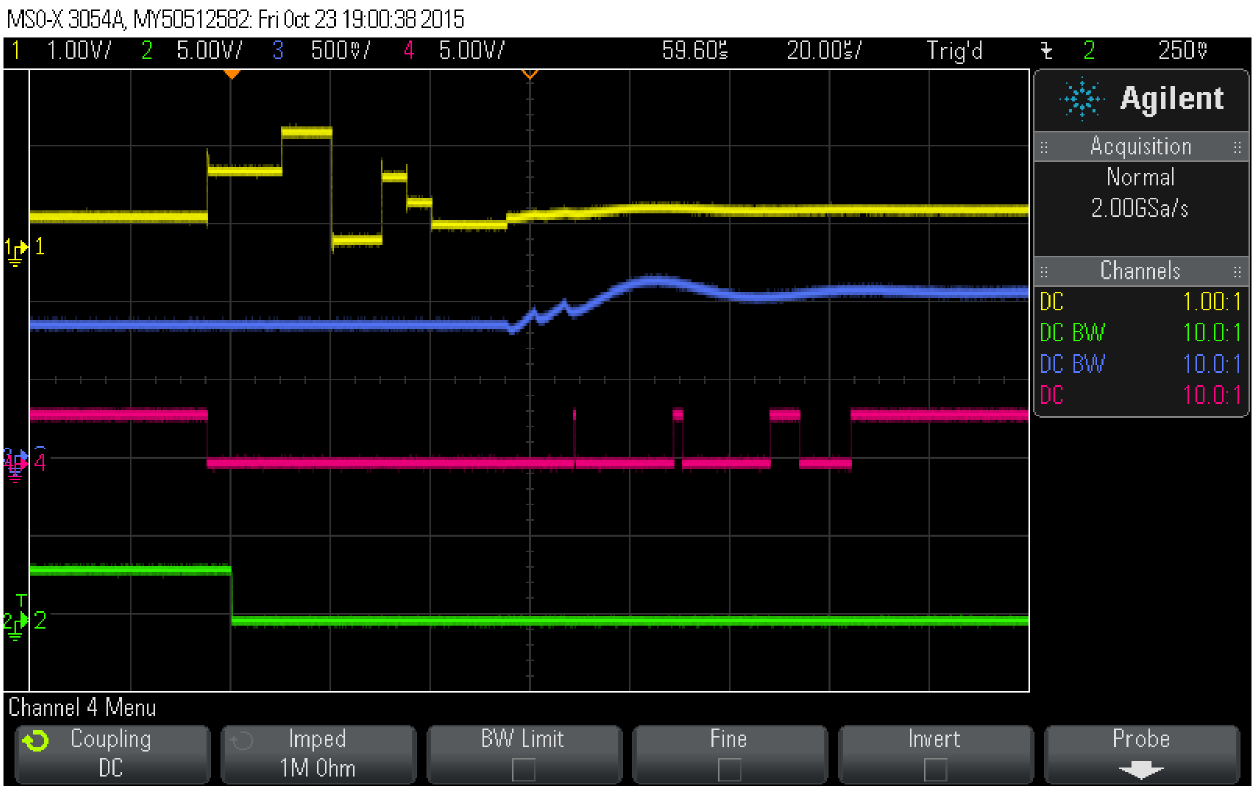

Figure 5 From the lab setup with the 5009 sweeping from 1600MHz to 1700MHz in 10MHz steps at 10ms/step. Yellow trace is 4002 Phase output, green trace is Sweep Sync output at the USER PORT pin-7. The blue trace is the internal PLL VCO tune voltage and the pink trace is the internal lock detector status signal. Note the sweep step transition take approximately 150us.

From the plot above, it is clear that the large frequency excursion will occur at the sweep step frequency transitions. From the previous plot the scale of the discriminator output is ~150MHz/V. This plot shows the frequency excursion to be ~ 170MHz.

As you can see, it is fairly simple to make this difficult measurement of frequency vs time just using some simple RF lab components and our 4002 as the phase detector. And since this measurement uses an oscilloscope for the display, the number of simultaneous signals that can be analyzed is only limited by the number of channels available.

For more information on how to make the measurement for your application please feel free to contact us.

Stuart Rumley, President
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Appendix A

The phase shifter for this lab setup is taken from an obsolete HP 8746B S-parameter test set. The 8746B was a component in the also now obsolete HP8410 network analyzer system.

Figure 6 HP8746B S-parameter test set.

This instrument covers the frequency range of 100MHz to 12.4GHz and used a variable phase shifter to adjust the reference arm delay. While the instrument is obsolete, its internal phase shifter is quite valuable for use in the microwave lab. These 8746B internal phase shifters are superior to any other phase shifter available today. They cover dc to well over 13GHz and have an effective phase shift of 30cm. They are very stable and reliable. The phase shifter includes a mechanical digital phase extension counter dial that is quite accurate. These old test sets can be obtained at flea markets and from eBay at reasonable prices. The actual phase shifter can be extracted with a little effort. The only issue with these is that the phase shifter has APC-7 connectors. With some skill you can actually make your own APC-7 to type-N adapters.

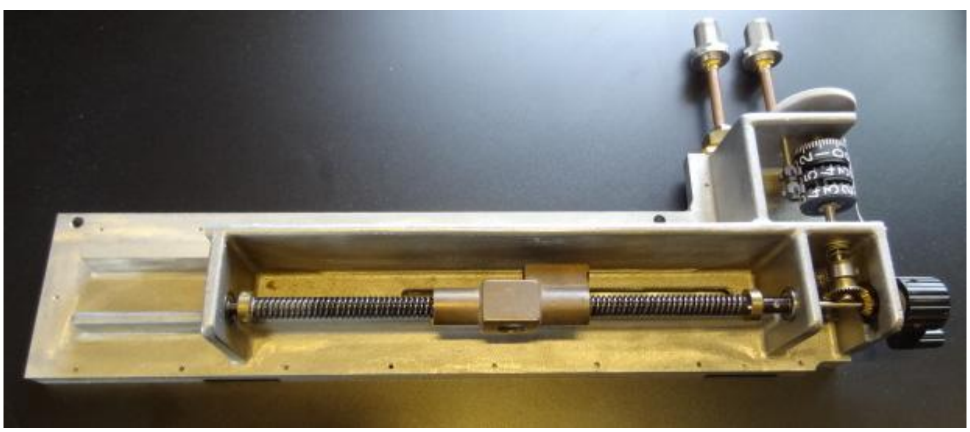

Figure 7 Magnificent phase shifter from HP8746B. Note the homebrew APC-7 to type-N female adapters.