Ten Things about the Giga-tronics 2500B series Microwave Signal Generators

Application note

High-Performance Microwave Signal Generators

The fast frequency switching of the Giga-tronics 2500B series Microwave Signal Generators pays dividends in any test environment where large amounts of data are collected or where frequency hopping is required for signal simulation applications. The high signal purity with ultra-low phase noise and exceptional narrow pulse performance are critical for Radar and EW testing. The following ten reasons demonstrate why the Giga-tronics 2500B series Microwave Signal Generators are the best solution for meeting your most demanding analog signal generator needs.

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#1 Fast Switching Speed and High Signal Purity

If you are calibrating high-performance EW or Radar receivers or simulating an agile Radar signal, the 2500B series Microwave Signal Generators provide industry leading frequency switching speed with no compromise in phase noise and harmonics performance.

Giga-tronics knowledge of advanced YIG-tuned oscillator (YTO) design enables VCO tuning speed with the better spectral purity of a YTO. The heart of the signal generator is the Accumulative High Frequency Feedback (AHFF™) Technology. This patented technology was developed by Giga-tronics engineers to overcome the limitations of fractional-N synthesizers. The AHFF technology achieves low N numbers and fine resolution in a single loop by making use of a high frequency reference source with a variable component to drive the PLL. Additionally, the PLL uses high frequency, fractional frequency pre-scaling to allow the ratio for the reference frequency to the output frequency to be quite low compared to traditional PLL synthesis methods (see Figure 1).

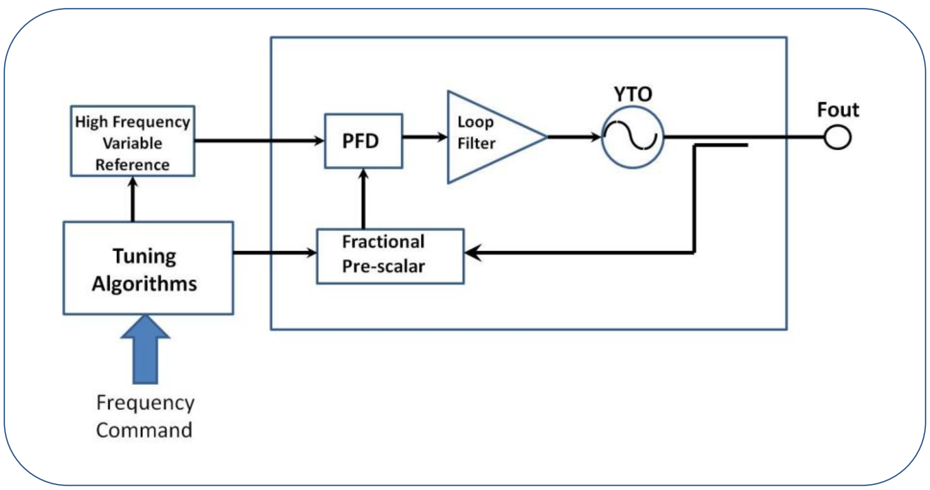

Figure 1. 2500B Frequency Synthesis Phase-Lock-Loop Block Diagram

Since every component in the frequency synthesis PLL can have an effect on the phase noise, the phase-frequency detector (PFD) and pre-scaling circuitry are Giga-tronics proprietary low-noise designs, and careful power supply filtering and mechanical shielding is also essential.

The frequency synthesis phase-locked-loop is optimized to maximize frequency switching speed. This includes the YTO, the loop filter, and the tuning algorithms. A fast "List Mode" engine steps frequency and amplitude from an embedded table eliminating bus transfer delays. The ALC loop is optimized for fast amplitude switching speed.

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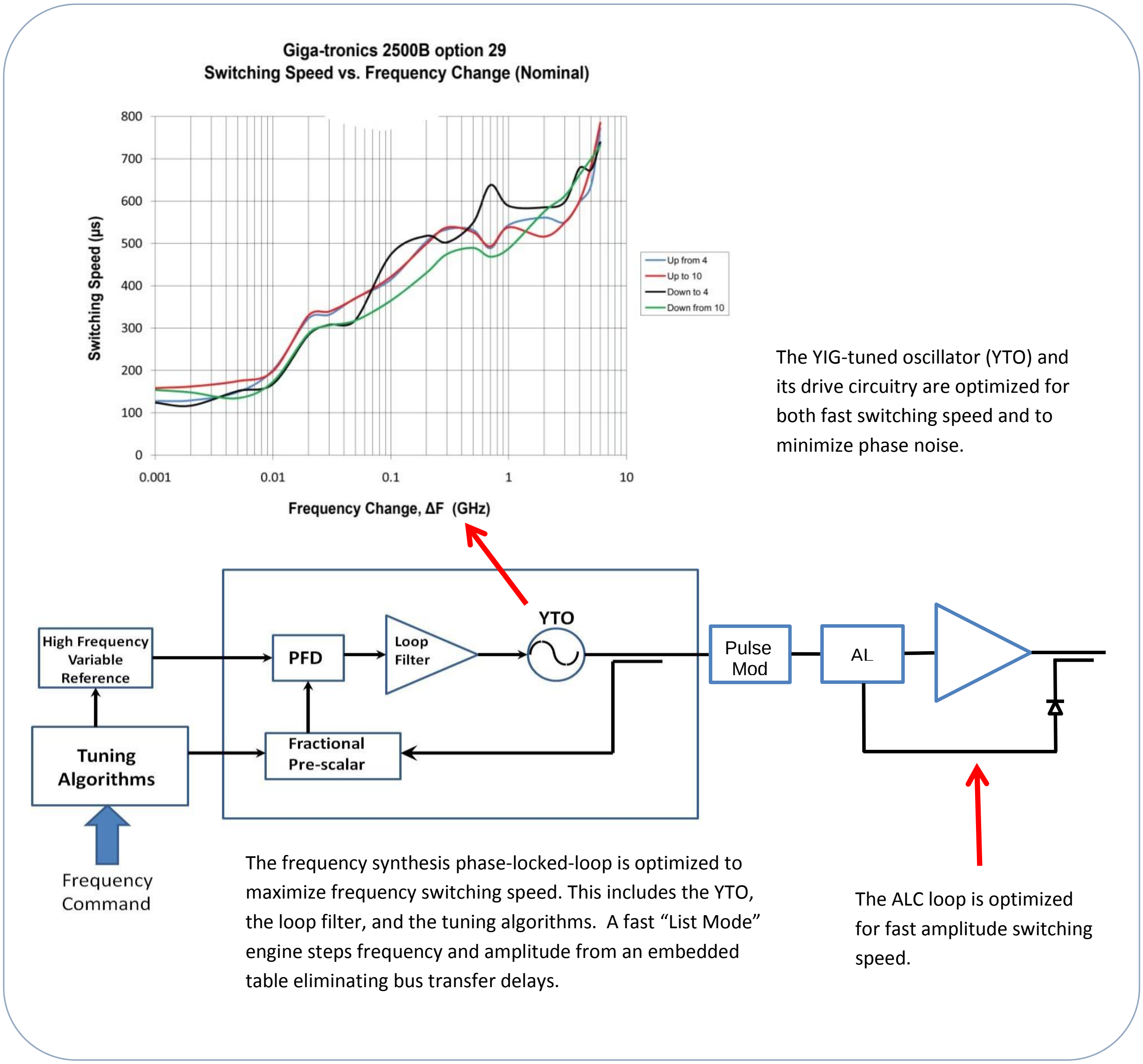

Figure 2. 2500B Frequency Synthesis Phase-Lock-Loop, Pulse Modulator and ALC Block Diagram

As shown in Figure 2, the frequency switching speed depends on the frequency change ΔF, where ΔF is defined as:

ΔF = | (F stop x N stop) – (F start x N start) | where N is the value in the 2500B Frequency Band Table

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The significance of this is that in the higher frequency bands, from 10 to 50 GHz, the YTO moves less for the same size frequency change, resulting in faster switching speed for the same step size. Conversely, the switching speed may be slower for the same step size in the divided bands below 4 GHz.

For example, a 100 MHz step in the fundamental 4 to 10 GHz band typically takes 400 µs, while a 100 MHz step between 10 and 20 GHz would typically take only 200 µs, but between 2 and 4 GHz would typically take 800 µs (still much faster than most other signal generators).

Frequency Range	N value
1 to 2 GHz	4
2 to 4 GHz	2
4 to 10 GHz	1
10 to 20 GHz	1/2
20 to 40 GHz	1/4
40 to 50 GHz	1/6

Table 1. 2500B Frequency Band Table

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#2 Phase Noise versus Frequency Range and Reference

Many applications demand a microwave signal stimulus either, CW or modulated, at 10 GHz, 18 GHz, 40 GHz or 50 GHz. To achieve these high frequencies, microwave signal generators multiply a fundamental oscillator to produce the required range of frequencies. As each frequency multiplication will degrade the instrument's phase noise, a key design criteria employed in the 2500B was to make the fundamental frequency as high as possible. Consider the following:

Phase noise increases by 6 dB each time frequency is doubled. (It also decreases by 6 dB each time frequency is divided by two). The general formula is:

$$\mathcal{L}(f_x) = \mathcal{L}(f_o) + 20 \log n$$

Where $\mathcal{L}(f)$ is the phase noise and n is the frequency multiplication (or frequency division) number.

The 2500B series Microwave Signal Generators use a wide-range 4 to 10 GHz YIG-tuned oscillator. Then, 10 to 20 GHz is provided by x2 multiplication, 20 to 40 GHz by x4 and 40 to 50 GHz by x6. Comparing this to other microwave signal generators, the 2500B series may have better phase noise performance at 40 GHz or 50 GHz, because of lower multiplication factors. In a carefully designed signal generator, less multiplying also generates fewer spurious and harmonic signals.

Phase noise is a function of the internal oscillator and any external frequency reference used. Different microwave signal generators use different loop bandwidths when locking to an external frequency reference. A narrow bandwidth on the external frequency reference input can help minimize the effects of phase noise resulting from a noisy external frequency reference signal. Some signal generators use a wider bandwidth to allow more stable phase tracking of multiple signal generators, but that makes them more susceptible to phase noise degradation from the external frequency reference. Giga-tronics overcomes this trade-off limitation by providing the capability to phase track using an internal 100 MHz oscillator with wide loop bandwidth while keeping a narrow bandwidth on the 10 MHz external frequency reference input (see Figure 3).

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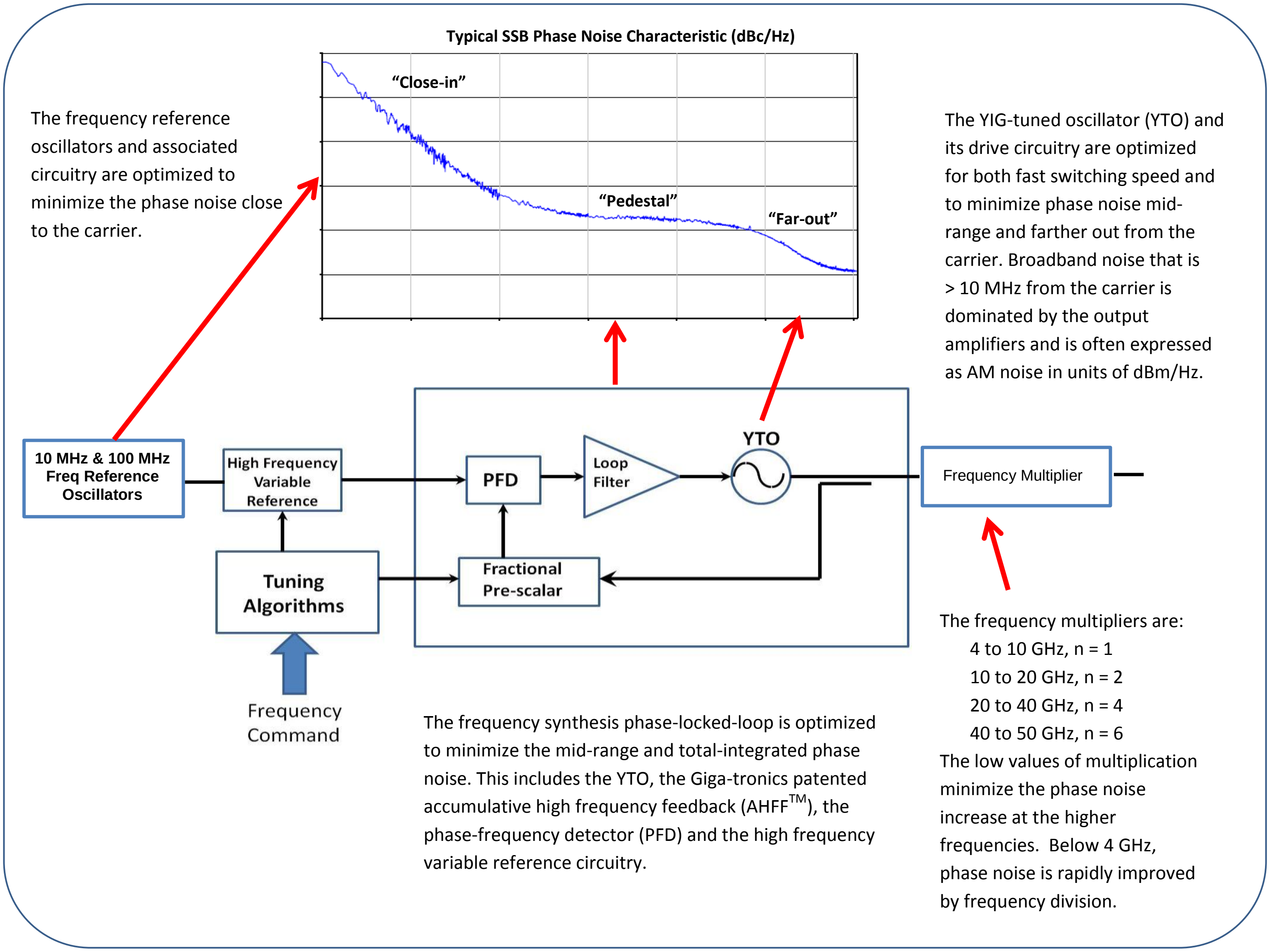

Figure 3. 2500B Frequency Synthesis Phase-Lock-Loop with Frequency Multipliers Block Diagram

There are many examples of why low phase noise is important. Phase noise is the limiting factor in applications that require detecting signals that may present near the carrier. One example is detecting low speed targets with Doppler Radar. The ability to detect and measure the Radar return signal from slow moving targets is limited by the LO phase noise close to the carrier.

Doppler Radar works by measuring the frequency shift of the Radar return signal (echo) from the target. Traditionally, targets were fast moving objects such as fighter jets or other airplanes. Today many targets are slow moving ground vehicles and objects being monitored from UAVs. The Doppler frequencies have decreased with the slower speed of these new targets. While an airplane at hundreds of mph generated Doppler shifts of kHz frequencies, slow moving targets in tens of mph generate Doppler shifts of a few hundred Hertz or less.

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The Doppler Radar return signal (echo) becomes impossible to detect and measure if it is obscured by the close-in phase noise of the carrier (see Figure 4).

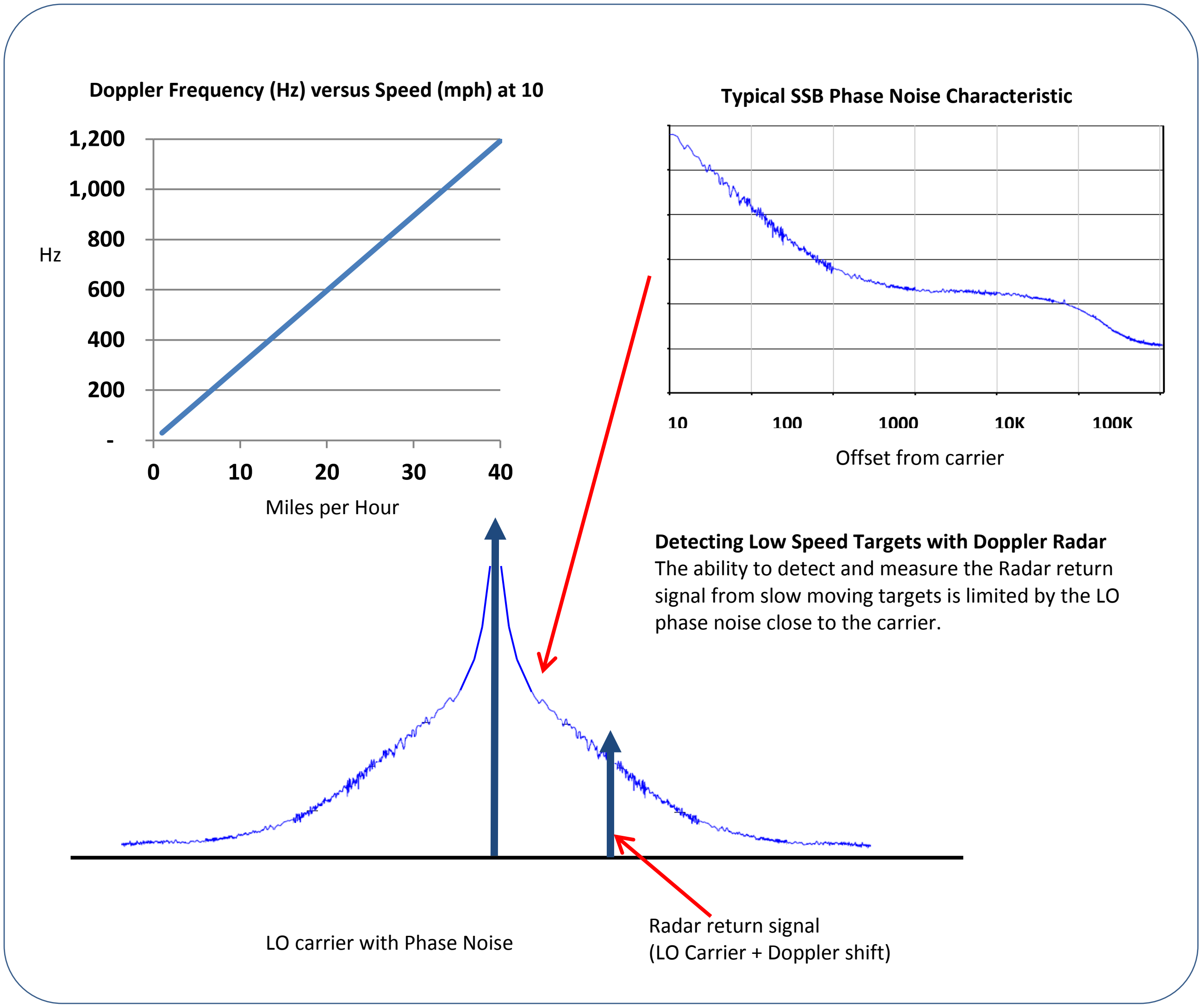

Figure 4. Slow Moving Targets with Small Doppler Frequency Shift Require Ultra-Low Phase Noise to Detect

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#3 External Frequency References and Phase Tracking Multiple 2500B Signal Generators

Some applications require phase stability between multiple signal generators sharing the same frequency reference. However reference phase errors are easily multiplied. For instance, if the phase drifts 0.1° in the 10 MHz frequency reference, then the RF phase at 1 GHz could have a drift of 10°. For this reason, the 2500B accepts both a 10 MHz and 100 MHz external frequency reference that automatically disconnects the internal 10 MHz reference oscillator and phase locks the external reference with the 2500B's internal 100 MHz reference oscillator. This ability to share a reference frequency between two or more signal generators at 100 MHz rather than at 10 MHz leads to much greater stability (over time and temperature) for phase tracking multiple signal generators.

While it is common practice in the industry to share a 10 MHz frequency reference, when very stable multiple signal generator phase tracking is needed, the 100 MHz reference should be used. Note that the 2500B series has a ± 360 degree phase adjust range with 0.1 degree resolution.

There is an important caveat with the use of external references that even the most experienced engineers and ATE system developers sometimes overlook. That caveat is this: if the external reference has excessive noise or drift, this will degrade the performance of the 2500B. The ultra-low phase noise of the 2500B can be corrupted by a noisy external frequency reference.

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#4 Leveling Narrow Pulses

One of the largest challenges in any broadband Radar application is controlling the signal's power when the pulse widths of very short duration are used. The 2500B series Microwave Signal Generators are designed to maintain level accuracy with pulse widths as narrow as 10 ns with typical rise and fall times of 3 ns. The ALC circuit often becomes the limitation. Fortunately, the 2500B's ALC circuit can level pulses down to an industry leading 350 ns with a level accuracy of ± 0.5 dB. For pulse widths less than 350 ns, an open-loop calibrated mode is used.

The 2500B ALC is optimized for narrow pulse level control (See Figure 5). Three ALC modes for pulse modulation exist. In the "Always On" mode the ALC automatically maintains the pulse amplitude accuracy for pulse widths as narrow as 350 ns over the full amplitude range, or as narrow as 100 ns at maximum leveled output power. In the

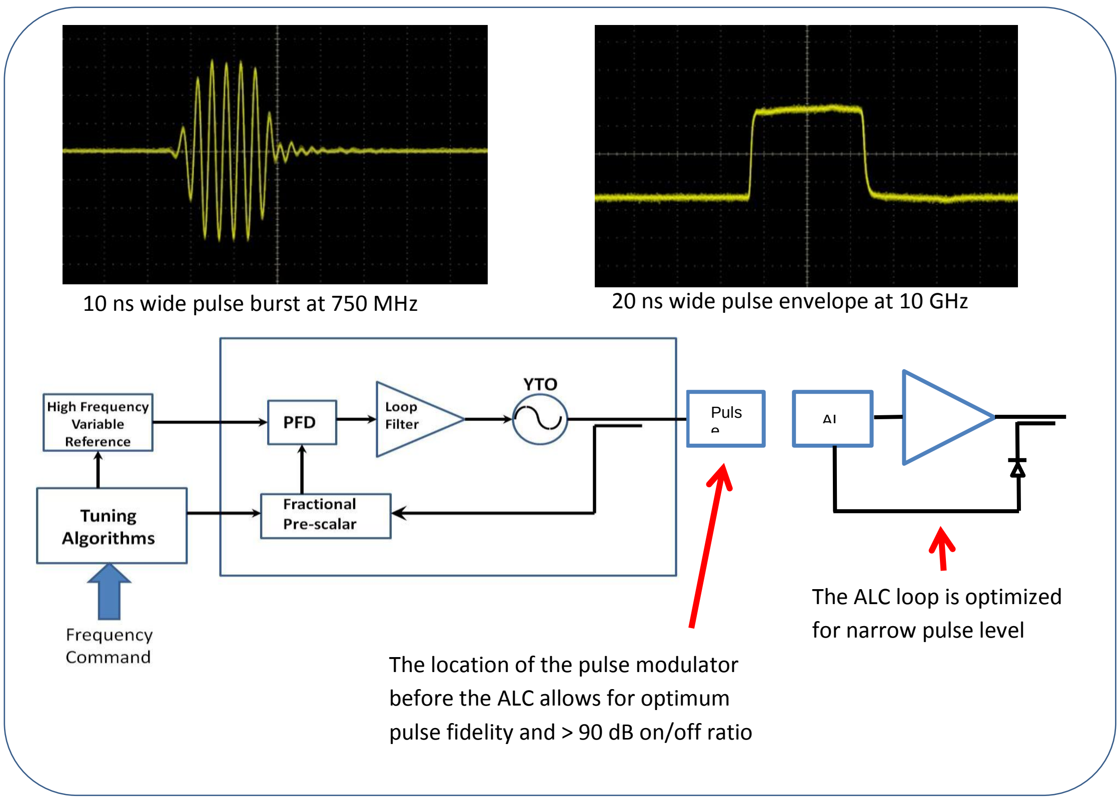

Figure 5. The 2500B Pulse Modulator and ALC Block Diagram is optimized for Narrow Pulse Performance

"Always Off" mode the ALC provides accurate power output for pulses as low as 10 ns. Whenever RF is turned on, or the frequency or power settings are changed, the ALC turns on the RF on for 1 millisecond to calibrate the output power. After this initial calibration leveling is completed, the RF is turned off and pulse operation resumes. In the "Off for pulse widths < 1 us" mode the ALC automatically reengages leveling whenever the pulse width exceeds 1 µs. This provides automatic closed loop leveling for pulse widths greater than 1 µs while still providing accurate output power for pulse widths as low as 10 ns.

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When pulse modulation is initiated in the open-loop calibrated range of operation, the circuitry performs a closed-loop calibration of pulse amplitude adjusting the amplitude to the desired setting, then opening the ALC loop while holding the pulse amplitude until the settings are changed. The time required to perform the closed-loop calibration varies, from a 1 ms for the Giga-tronics' microwave signal generators to as much as 50 ms in competitive microwave signal generators. During this calibration time the RF output is on, and caution must be taken to prevent this single initial calibration pulse width from damaging sensitive loads.

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#5 2500B Step Attenuator Options

Many receiver calibration or sensitivity test applications require a signal generator with a very wide amplitude range. The 2500B mechanical or electronic step attenuator options extend the amplitude range of the instrument from a maximum output power of +25 dBm (with X-Band Power Boost enabled) to a minimum power level of lower than -100 dBm.

Mechanical step attenuators have the best frequency range and response with the trade-off of slower switching speed and a specified number of switching cycles in their lifetime.

Electronic step attenuators have an unlimited number of switching cycles with very fast switching speed, with the trade-off of limited frequency range and response.

The mechanical step attenuator is used when a wide frequency range is required. This device is composed of cells, each having a pair of single-throw, double-pole mechanical switches. Between one pair of switch throw positions is a low-loss through path. Between the alternate pair of throw positions is a precision attenuator. By cascading three or four cells, precision “steps” of attenuation can be switched in or out. A common arrangement includes a 10 dB, 20 dB, and two 30 dB cells. By switching different combinations of cells, 10 dB steps from zero to 90 dB can be had. Since the ALC (or AGC) network can easily adjust itself over a 20 dB range, it is now possible to continuously adjust power or gain over a 110 dB range.

The mechanical step attenuator is the appropriate choice where the widest frequency ranges and lowest insertion loss in the “0 dB” state is necessary. The mechanical step attenuator does have a limited lifetime, typically 10 million cycles. By its very nature, it is prone to eventual mechanical fatigue, and ultimately failure. Another parameter to take into account when designing a test system is the time it takes for the signal amplitude level to settle to its final value. The mechanical switch is spring-loaded, and as such is subject to “chatter”, or it experiences the intermittent closing and opening of the switch as it changes state. Typically, this time interval is measured in milliseconds, and is often specified in the 10 to 20 millisecond range for high performance mechanical step attenuators.

The electronic step attenuator, is not prone to mechanical fatigue and has very fast switching speed, in the microsecond range, but with limited frequency range (10 MHz to 8 GHz) and with higher insertion loss resulting in a decrease in the maximum leveled output power. The electronic attenuator is the best choice for applications with a very large amount of attenuation switching cycles or where very fast amplitude switching speed is required.

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#6 2500B Power Offset, Power Slope and Power Sweep Functions

The 2500B can sweep both output frequency and output power. Frequency and power sweeps are independent, or can be combined in List Mode where both frequency and power can be specified for each step in the list. Frequency sweep can be set for start and stop frequencies or for a center frequency and span, covering the full frequency range of the signal generator with frequency resolution of 0.001 Hz. Frequency sweep is fully synthesized, meaning that the frequency is accurate (phase-locked) at each frequency step. The 2500B includes Analog Sweep mode. Analog Sweep is a very fine resolution frequency sweep, for use with scalar network analyzers.

The Power Offset feature increases the instrument's output power by the amount of the Power Offset setting, without changing the power level shown in the display. This allows you to compensate for a fixed value of insertion or conversion loss of components that are attached to the instrument's RF output. The power offset range is 0 to 10 dB with 0.01 dB resolution.

The Power Slope feature increases the instrument's output power linearly as a function of the frequency. The Power Slope function allows you to automatically compensate for insertion or conversion loss of components attached to the instrument's RF output that exhibit a linear loss with frequency. The power slope range is 0 to 0.5 dB/GHz with 0.01 dB/GHz resolution.

The Power Sweep feature is the steady increasing or "ramping" of the output power at a fixed frequency. Ramp power sweep is actually a series of up to 2000 amplitude steps scaled to the power sweep time setting. The power level is controlled by the ALC and is accurate at each step. The ramp power sweep range is 0 to 25 dB with 0.01 dB resolution. Ramp power sweep time range is 30 ms to 200 sec with 10 µs resolution.

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#7 2500B External Cable Loss Correction "Cable Cal" Feature

The Cable Cal function on the 2500B Series Microwave Signal Generators gives you the ability to apply a level correction table to compensate for external losses or power variations in an external signal path. This feature is available with the 2500B series and the Giga-tronics 8560B series Universal Power Meter. (See Figure 6)

Figure 6. External Cable Loss Correction Factors can be stored in the 2500B

When the Cable Cal function is executed on the 2500B series Microwave Signal Generator, it will automatically control the 8650A Series Power Meter to measure power variations at the output of the external signal path over the full frequency range of the signal generator. The signal generator automatically puts the power meter into a "Swift Buffered" measurement mode, which commands the power meter to store all the measured data inside the power meter's internal data buffer until all the measurements are finished. This allows extremely fast measurements, versus that of the traditional measurement methods where a power meter would send each measurement result back to the host after each measurement.

After all the measurements have been made, the signal generator reads back the power level information from the power meter and creates a table of correction values for each frequency point. The correction table is made up of 1001 data points (frequency/amplitude data pairs). This table is stored in the signal generator's non-volatile memory. It takes about 30 seconds for the entire process to run.

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#8 Using the 2500B with External Microwave Power

The 2500B offers standard and optional power output levels. For example, the 2520B specifies +14 dBm standard and +20 dBm with its high power option, without degradation in any of the spectral purity specification. However, some test and measurement applications need higher power levels than are available from the signal generator. Giga-tronics offers external microwave power amplifiers to complement the 2500B microwave signal generators, including the GT-1000A, GT-1040A and GT-1050A microwave power amplifiers. These microwave power amplifiers are solid-state, very broadband, low noise and highly reliable. The GT-1000A covers 2 GHz to 20 GHz with up to 10 Watts of output power. The GT-1050A covers 10 MHz to 50 GHz with ¼ Watt at 50 GHz.

Should you choose the high power option to a microwave signal generator or opt for an external power amplifier instead? The trade-offs are not always obvious. While adding the high power option to a microwave signal generator may seem an easy solution, remember that the tradeoffs may be increased harmonics and IMD, as well as the practical limits to how much power can be added. Choosing an external amplifier usually results in better overall performance, with better signal purity and higher power levels available. Signal purity and very linear amplification are critical for modulated signals and that often requires operating backed off from the maximum power levels.

An additional advantage of that using an external amplifier is that it provides you with the ability to physically position the amplifier closer to the device under test (DUT) or antenna. By placing the amplifier closer to the DUT (or antenna), you may be able to reduce cables losses and achieve higher powers at the DUT. Since most external amplifiers have relatively high gain, moving the cable loss to between the signal generator and the amplifier rather than between the amplifier and DUT achieves the desired results. Close proximity to the DUT (or antenna) may also reduce the magnitude of ripple and standing waves in the cabling if the impedance match to the DUT or antenna is not good. Both the effects of cable loss and mismatch reflections become more problematic as the frequencies increase. These effects may be minimized by moving the long cable to between signal generator and amplifier (where the match is better, reducing reflections) and keeping the cable length short between amplifier and DUT to minimize the standing waves.

It's also important to consider the price-performance tradeoff. High power options to microwave signal generators can be very expensive, over $40K in some cases, while an external microwave power amplifier may be considerably less expensive, as well as providing higher power and lower harmonics. Harmonics are a function of power level. While a "1 Watt" high power option to a microwave signal generator may have harmonic levels of -25 dBc at +25 dBm, a less expensive "10 Watt" external microwave power amplifier could have harmonic levels of -35 dBc at the same +25 dBm (and same frequency) because it's operating well below its maximum output power.

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An additional consideration is safety and the prevention of high power levels causing damage to the DUT. Using an external microwave power amplifier allows the user to activate the high power only when needed. The signal generator can be turned on and set up prior to turning on the high power. While some microwave signal generators try to compensate by offering a power clamp capability, it is important to remember that there may be a delay of many microseconds before the power clamp can respond, allowing a potentially damaging pulse to occur. Power clamps are designed for CW operation and may be of no practical use in narrow pulsed mode applications.

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#9 X-Band Power Boost

While external microwave power amplifiers are the best solution for many applications, especially those covering wide frequency ranges or where very high levels of power are needed, the 2500B does have a feature that increases the output power over a select band of frequencies. X-Band Power Boost is a special feature included in the 2520B model with high power option, and when enabled, increases the maximum unleveled output power to +23 dBm from 4 to 12.7 GHz. This feature more than doubles the available output power over this frequency range, but with higher harmonic levels. (See Figure 7).

The trade-off of power for harmonics may not be an issue when working in a banded application, such as testing a narrow band receiver, or driving a high Q antenna.

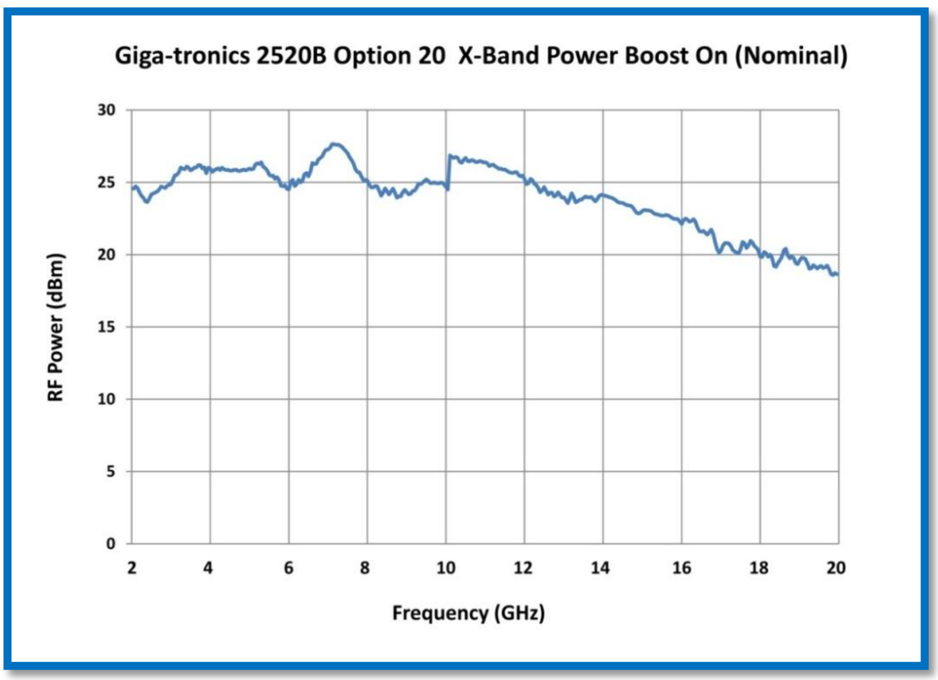

Figure 7. 2520B X-Band Power Boost Feature Doubles the Output Power from 4 GHz to 12.7 GHz

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#10 Replacing Obsolete Signal Generators with the 2500B

Replacing obsolete signal generators with minimal changes to your Test Program Sets (TPS) is a significant challenge for engineers and managers supporting many defense automated test systems. Aging test instrumentation is a concern for engineers supporting old automated test equipment (ATE) systems. Users of these systems are faced with the dilemma that test instruments in these aged systems are no longer available, are becoming too costly to maintain and repair and are no longer supported by the original equipment manufacturer. One solution is to replace the obsolete model altogether. The primary concern when replacing old test equipment is editing the existing TPS or ATE program code. This can be a time consuming and costly solution. In some cases it is almost impossible to reprogram the existing code because some of the TPS use older compilers that are no longer available.

The 2500B series Microwave Signal Generators have several emulation command sets, which enable the signal generator to emulate other manufacturer's microwave signal generators. These command sets enable the signal generator to accept and respond to programming commands as if they were an instrument from a different manufacturer. These command sets facilitate the replacement of many of the most popular signal generators, such as many Hewlett Packard signal generators, found in test systems that are still in service today. The 2500B signal generators and the emulation modes have been successfully used to replace old and obsolete test equipment.

One Giga-tronics signal generator is capable of emulating several other models of signal generator s. The benefit of a single signal generator capable of replacing multiple signal generator models is that the need to maintain spares for each of the replacement models is reduced to one signal generator model whenever a unit is in need of service or calibration. All the previous series of Giga-tronics signal generator command sets are standard on the 2500B signal generators. The only caution is that some features and functions of the obsolete signal generator may not be available on the 2500B. Giga-tronics will provide engineering support for companies using the 2500B in replacement applications. Contact your local sales representative or Giga-tronics to determine if a 2500B signal generator is the right model for replacing your obsolete signal generator.

The 2500B series Microwave Signal Generators are capable of emulating the following obsolete signal generators:
• HP 8370 Series • HP 8340 Series (compatible with the 8757D Scalar Network Analyzer)
• HP 8350 Series • HP 8360 Series • HP 8663 Series • HP 8673C/D Series

As an example of obsolete signal generator replacement, consider Scalar Network Analyzers. Scalar analysis of microwave devices such as filters, attenuators, switches and amplifiers is a popular cost effective measurement method for device characterization. As a result, a significant number of scalar network analyzers are still being used extensively throughout the world. Many of these scalar network analyzers such as the Giga-tronics 8003 Scalar Network Analyzer and the HP 8757D Scalar Network Analyzer are still in use today. The 2500B was designed for use with the Giga-tronics 8003 Scalar Network Analyzer. The 2500B operating in emulation mode can also be used with the HP 8757D Scalar Network Analyzer.

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Two common microwave signal generators that were designed to work with the 8757D are the HP 8340 and HP 8350 series signal generators. The 8757D would automatically communicate with these two signal generators via its private IEEE 488 bus. However, these signal generators are obsolete and are no longer supported. Because of the unique IEEE 488 communications protocol used by the 8757D, replacement microwave signal generators must be designed to communicate like the HP 8340 or HP 8350 signal generators, which require that the signal generators remain in “Local mode”. This enables the user to set sweep parameters of the scalar network analyzer/signal generator system locally by manually using signal generator’s front panel controls and not by sending remote commands from a computer. When parameters such as start frequency or power level are changed, the signal generator notifies the scalar network analyzer that a change has been made. The scalar network analyzer queries the signal generator for changes and updates its display to the new instrument settings.

The Giga-tronics 2500B Microwave Signal Generators have a HP 8340 emulation mode, which causes it to behave like the HP 8340 signal generators. This allows it to automatically communicate with the 8757D over its private GPIB bus. The 2500B comes standard with a ramp sweep mode. This feature also includes a power sweep function, which can be used with the 8757D to perform gain compression measurements or swept power responses. The 2500B signal generator’s control signals include Ramp Out and Blanking. The connections for these control signals can be found on the rear panel in a Network Analyzer connector group.

The 8757D has an AC detection mode that is used when low power measurements are required. In some cases the broadband thermal noise present in the system is greater than the test signal magnitude. This method pulse modulates the swept signal that is filtered and detected by the scalar network analyzer. The 8757D Modulator Drive BNC port connects to the signal generator’s “Pulse In” BNC port and provides the drive signal to modulate the output. To use the 8757D AC detection mode with the 2500B signal generators, order option 17B external modulation suite, which includes pulse modulation capability.

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