IEEE AUTOTESTCON 2008
Salt Lake City, UT, 8-11 September 2008

A PXI Fast Switching LO Synthesizer Enables 26.5 GHz Synthetic Instruments

Alexander Chenakin, Suresh Ojha and Charanbir Mahal
Phase Matrix, Inc.
109 Bonaventura Drive, San Jose, CA 95134
Phone: 408-428-1000, Fax: 408-428-1500, Email: *achenakin@phasematrix.com*

Abstract *– PXI synthetic instrumentation is an emerging technology that offers a cost-effective modular approach for building complex test and measurement equipment. The performance of synthetic instruments primarily depends on technical characteristics of their core modules such as a downconverter and LO oscillator. This paper presents a fast switching frequency synthesizer module, which covers 3 to 9 GHz frequency band with a 0.1 Hz step size. The developed module occupies two standard 3-U PXI slots and is used as an LO source for a 26.5 GHz harmonic downconverter. The module construction and test results are discussed.*

Keywords *– PXI, synthetic instrument, microwave downconverter, local oscillator, frequency synthesizer.*

I. INTRODUCTION

PXI synthetic instrumentation is an emerging technology that offers a cost-effective modular approach for building complex test and measurement equipment. It enables the emulation of various traditional bench-top instruments employed in automatic test systems using a reconfigurable combination of core hardware & software components [1-2].

The performance of synthetic instruments primarily depends on technical characteristics of their core modules. The need for a low-cost, high-performance frequency synthesizer as a key component of virtually any test and measurement system is recognized throughout the microwave community [3-5]. A key market demand is faster frequency tuning speed as dictated by the ongoing increase of the data rates of modern microwave systems [6].

This paper presents a novel 3-9 GHz fast switching frequency synthesizer module, which covers 3 to 9 GHz frequency band with a 0.1 Hz step size. The module occupies two standard 3-U PXI slots and can be used as a local oscillator source in a variety of PXI synthetic instruments. Specifically, the module has been used to drive a harmonic mixer in a 26.5 GHz PXI downconverter by utilizing the fundamental and third harmonics. The synthesizer module design, measurement data, and potential applications are discussed.

II. DOWNCONVERTER CONCEPT

The developed PXI downconverter system uses two core modules (the downconverter and LO synthesizer) as shown in Fig. 1. A harmonic mixer approach is used to cover 3 to 26.5 GHz as depicted in Fig. 2. This approach requires only 3 to 9 GHz frequency coverage from the LO source by utilizing its fundamental and third harmonics. This greatly simplifies the LO synthesizer design.

The modules are placed in a standard PXI chassis and are connected together with an RF cable to form a complete microwave downconverter system. Additional modules can be added to further extend the overall frequency coverage of the downconverter system as required. However, the LO module is a key part in the system, since the ultimate sensitivity of any downconverter depends on the LO signal parameters (phase noise, spurious). Thus, the LO module design principles are discussed below.

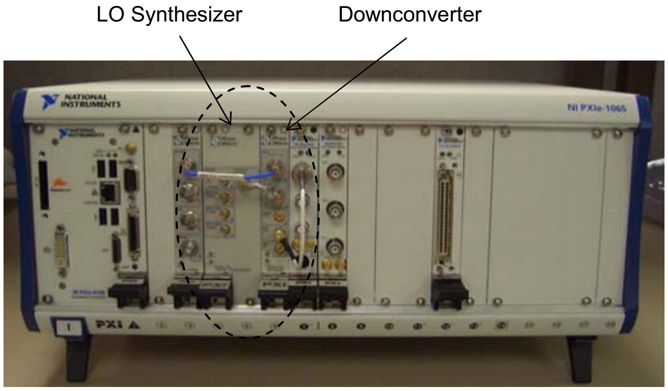


Fig. 1. PXI Downconverter System

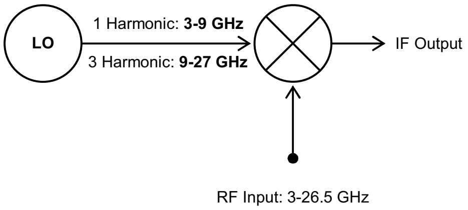


Fig. 2. Harmonic Mixing Approach

III. SYNTHESIZER DESIGN

The synthesizer module consists of two major parts: the microwave synthesizer and the reference block as shown in Fig. 3. The reference block is based on a 100 MHz highly stable ovenized crystal oscillator (OCXO) that serves as a reference for the microwave synthesizer.

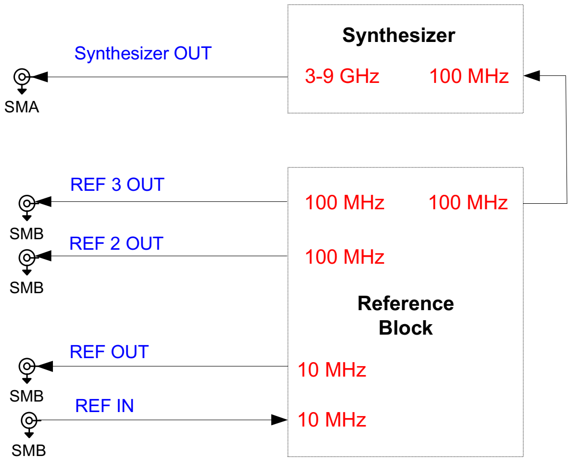


Fig. 3. Synthesizer Module Block Diagram

The reference block also includes a divide-by-10 divider to get a 10 MHz reference signal; both 10 MHz and 100 MHz outputs are available on the front panel of the module. The internal OCXO can drive the module itself or can be automatically locked to an external 10 MHz reference if required. The module constantly monitors the presence of an external reference and automatically locks to it once sensed.

The microwave portion is based on a 5-10 GHz, fundamental, solid-state, voltage-controlled oscillator (VCO) with an output that is split into two sub-bands as shown in Fig. 4. The upper branch utilizes a portion of the available bandwidth (5 to 9 GHz) that allows the use of a 9 GHz low-pass filter to suppress VCO harmonics from 10 GHz and above. The lower branch includes a divide-by-2 function in order to bring the output frequency down to 3 GHz. Similarly, the lower branch utilizes a portion of the bandwidth (3-5 GHz) in order to achieve adequate harmonic suppression above 6 GHz. This approach provides 3 to 9 GHz overall frequency coverage with reduced harmonic content.

The VCO is locked to a built-in DDS-based reference that provides sub-Hz frequency resolution without the common penalty of slower tuning and increased phase noise degradation. Since DDS-based designs are prone to increased spurious content, both hardware and software techniques are extensively utilized to suppress DDS spurs to negligible levels (in comparison with more copious PLL reference spurs) as discussed in more detail in [6]. PLL spurs can also assert themselves; however, they are easily managed by optimizing the loop filter. The VCO phase noise is effectively controlled by utilizing a relatively wide (a few hundred kHz) loop bandwidth as also suggested in [6]. Thus, the synthesizer phase noise within its PLL bandwidth mainly depends on the multiplied reference noise as well as residual noise characteristics of the locking mechanism. A high-frequency and fairly low-noise OCXO is utilized along with an advanced multiloop architecture to achieve desirable phase noise performance.

The synthesizer reference and microwave circuits are put into a metal housing (shown in Fig. 5) to prevent interference from the outside environment and possible signal contamination. A PXI interface board is placed on top of the housing to deliver all bias voltages and control signals from a PXI chassis.

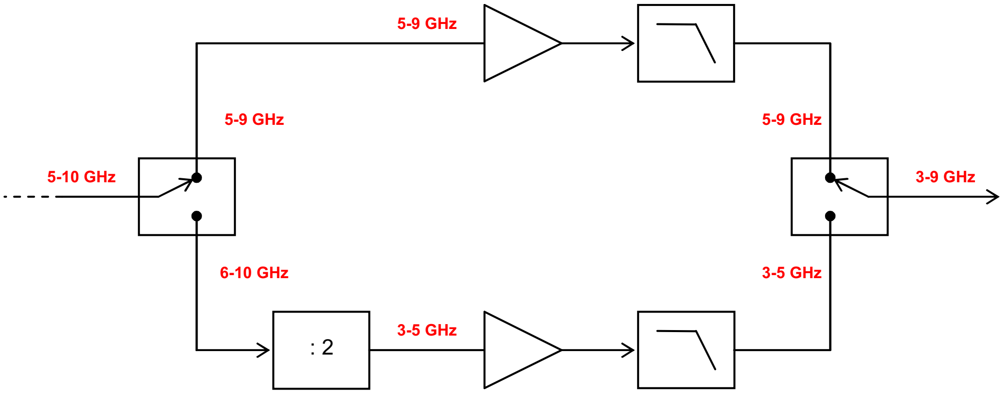


Fig. 4. Block Diagram of the Synthesizer Output

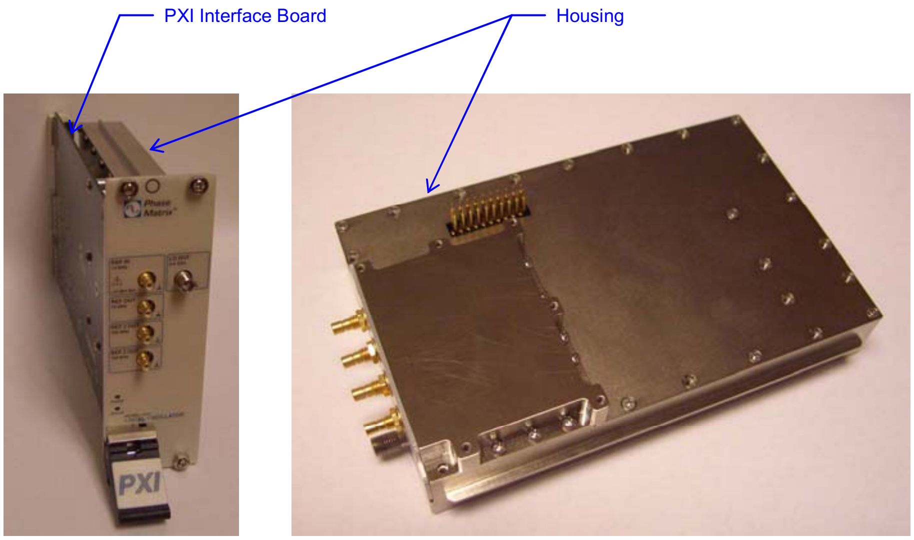


Fig. 5. PXI Synthesizer Assembly

IV. MODULE CONTROL

The module is controlled through the PXI bus with a LabView GUI, which is hosted on an external computer. The GUI (Fig. 6) allows the user to set a desired output frequency, monitor frequency lock, and mute the synthesizer output as required. The user can independently mute 10 MHz and 100 MHz outputs, monitor the presence of an external 10 MHz signal, and check the reference lock. The software also allows sweeping the synthesizer across the entire frequency range with programmable frequency step and dwell time.

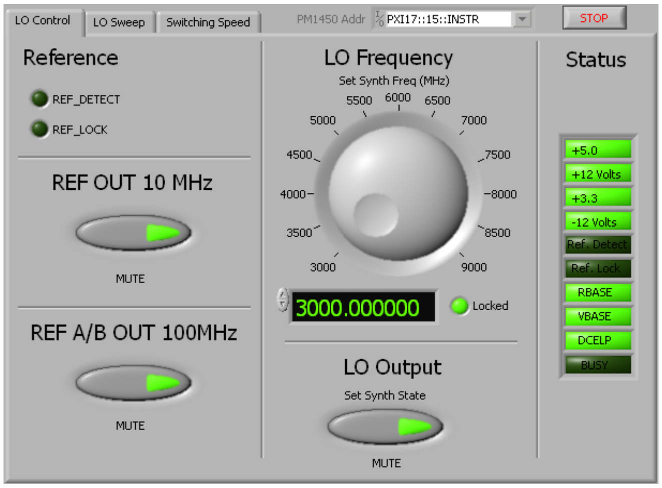
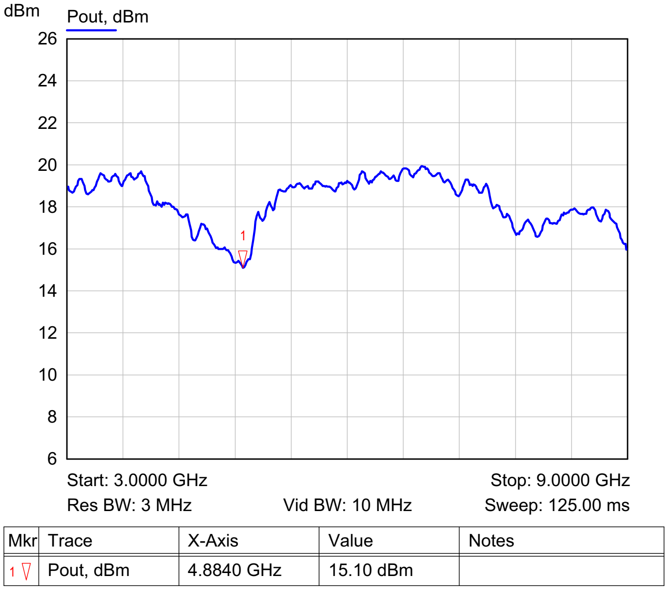


Fig. 6. Synthesizer Control

V. TEST RESULTS

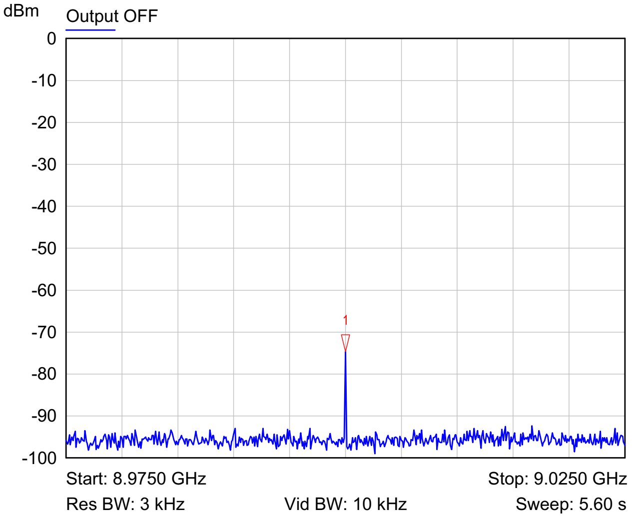
The synthesizer module provides 3 to 9 GHz frequency coverage with 0.1 Hz step size and less than 500 μsec switching time. The maximum (unleveled) RF output power varies between +15 and +19 dBm as shown in Fig. 7. The variations are mainly due to the utilized low-pass filters. The output power can be leveled at the maximum level of +15 dBm by adjusting the gain in the both RF paths.



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Pout, dBm	4.8840 GHz	15.10 dBm	

Fig. 7. Output Power Variations

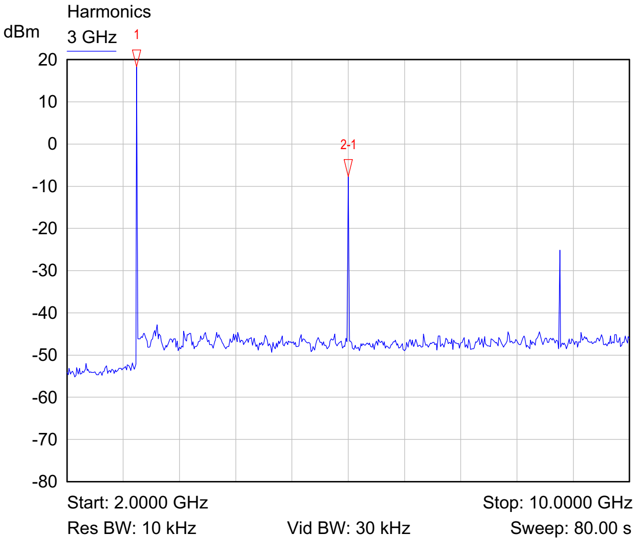
The signal output can be muted to about -75 dBm level (worst case) without disturbing the synthesizer VCO (Fig. 8). Since the VCO remains locked, the muting is inherently fast and, therefore, can be utilized for pulse modulation with a uSec pulse width and on/off ratio greater than 80 dB.



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Output OFF	9.0000 GHz	-74.60 dBm	

Fig. 8. Output Power Mute

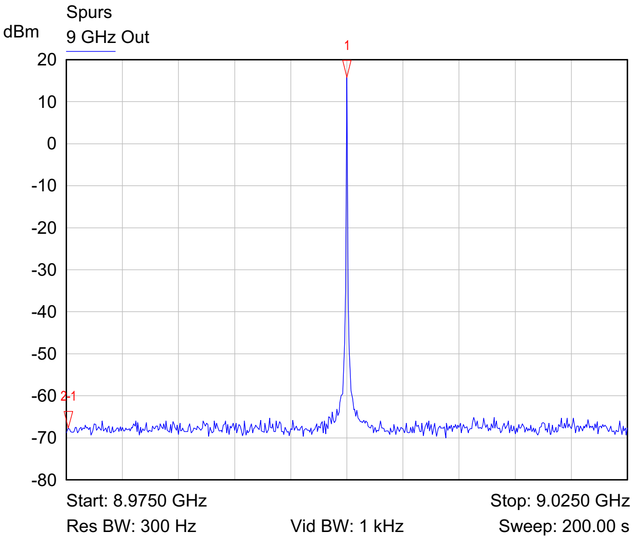
The synthesizer's output spectrum purity is depicted in the next few plots. The harmonics do not exceed the -25 dBc level across the entire band; the worst case at 3 GHz is shown in Fig. 9.



Mkr	Trace	X-Axis	Value	Notes
1 ▽	3 GHz	2.9920 GHz	18.41 dBm	
2-1 ▽	3 GHz	6.0000 GHz	-26.04 dB	

Fig. 9. Synthesizer Harmonics

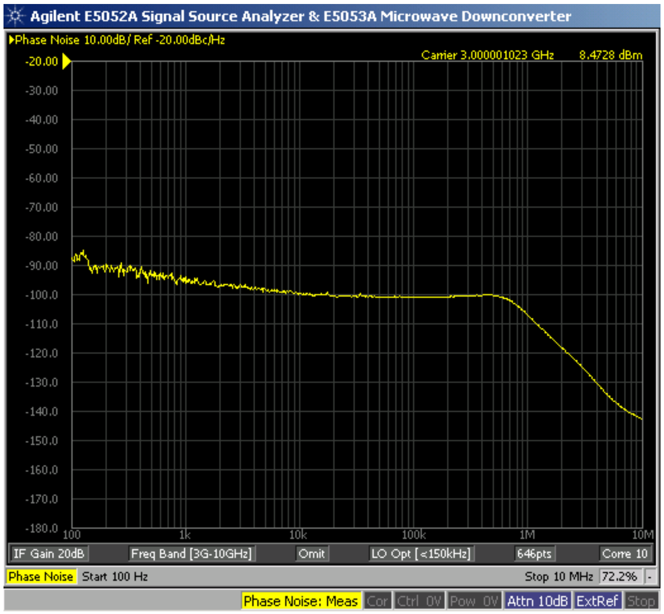
A typical spurious plot is presented in Fig. 10; the spectrum looks clean and free of obvious perturbations down to the -80 dBc level. This is a direct consequence of the hardware and software based DDS spur suppression algorithm as well as careful loop filter design.



Mkr	Trace	X-Axis	Value	Notes
1 ▽	9 GHz Out	9.0000 GHz	15.82 dBm	
2-1 ▽	9 GHz Out	-24.8000 MHz	-83.55 dB	

Fig. 10. Spurious Performance

Measured phase noise performance for a 3 GHz output is presented in Fig. 11. The noise between 10 and 100 kHz is mainly attributable to the PLL components; above 1 MHz the VCO's free-running noise dominates.



Phase Noise 10.00dB/ Ref -20.00dBc/Hz

Carrier 3.000001023 GHz 8.4728 dBm

IF Gain 20dB Freq Band [3G-10GHz] Omit LO Opt [<150kHz] 646pts Corre 10

Phase Noise Start 100 Hz Stop 10 MHz 72.2%

Attn 10dB ExtRef

Fig. 11. Phase Noise at 3 GHz

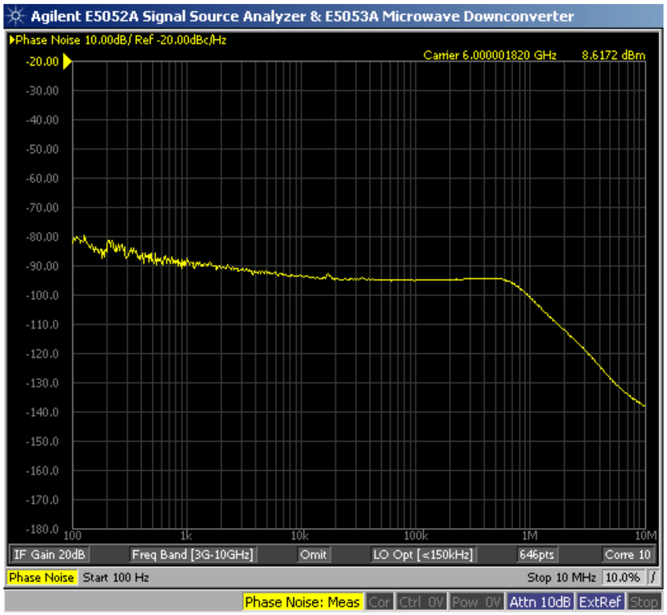


Fig. 12. Phase Noise at 6 GHz

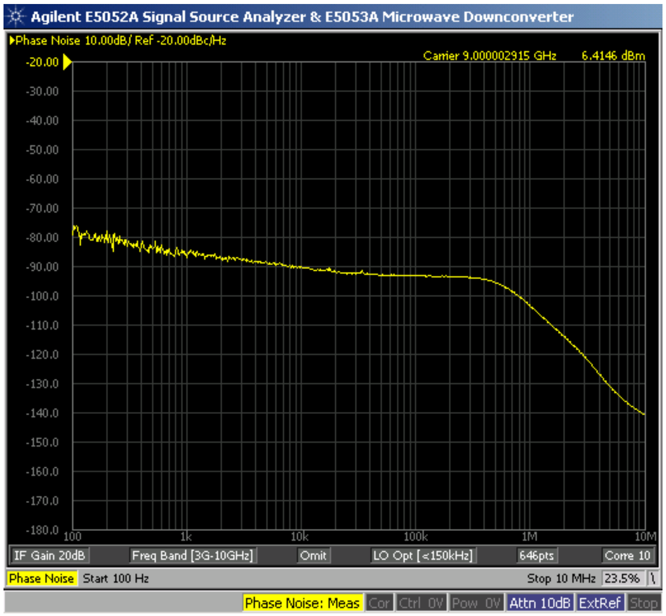
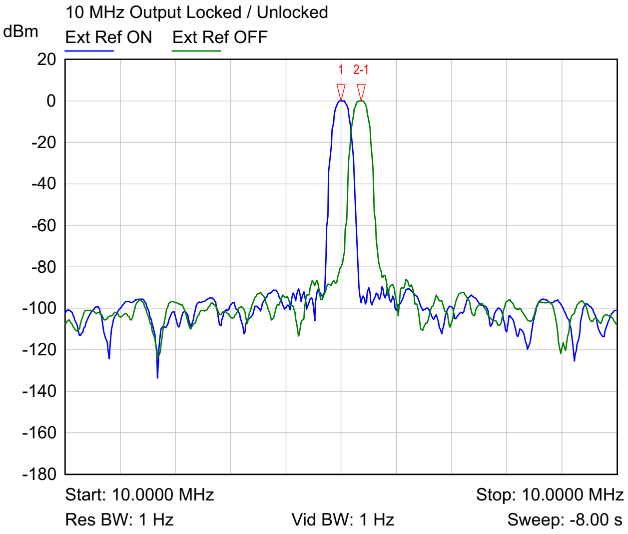


Fig. 13. Phase Noise at 9 GHz

The module exhibits about -100 dBc/Hz phase noise at 10 and 100 kHz offsets at a 3 GHz output. Noise performance at higher frequencies increases at 6 dB per octave due to the employed frequency plan; 6 and 9 GHz plots are presented in Fig. 12 and 13 respectively. The noise plots also reveal the loop bandwidth of a few hundred kHz that results in the fast tuning speed mentioned above.

The output power of the 10 and 100 MHz reference signals is measured at 0 dBm and can be independently muted if required.



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Ext Ref ON	10.0000 MHz	0.10 dBm	
2-1 ▽	Ext Ref OFF	1.8000 Hz	0.11 dBm	

Fig. 14. Reference Alignment

The unit also accepts an external 10 MHz reference between -15 and +15 dBm to align the internal reference as shown in Fig. 14. The synthesizer module power consumption does not exceed 15 Watts.

VI. CONCLUSIONS

A 3 to 9 GHz, fast switching speed frequency synthesizer module has been developed for use as an LO source in a PXI downconverter system. Third harmonic content of the synthesizer is used by the downconverter to extend the operational range to 26.5 GHz. The synthesizer employs a multiloop VCO-based design that delivers +15 to +19 dBm power. An internal DDS, driven by a sophisticated spur suppression algorithm, provides a fine frequency resolution of 0.1 Hz with excellent spurious and phase noise performance. The synthesizer also presents the ability to mute the RF output signal to -80 dBc levels which can be used as pulse modulation. The synthesizer module features low power consumption and can be used in a variety of PXI synthetic instrumentation applications.

REFERENCES

[1] M. Granieri, “Synthetic Instrumentation: An Emerging Technology,” RF Design, February 2004, pp. 16-25.

[2] D. Menzer, “Synthetic Instruments: A New Horizon,” Microwave Journal, March 2006, pp. 22-36.

[3] J. Browne, “Frequency Synthesizers Tune Communications Systems,” Microwaves & RF, March 2006.

[4] V. Kroupa, “Frequency Synthesis Theory, Design and Applications,” New York: Willey, 1973.

[5] V. Manassewitsch, “Frequency Synthesizers Theory and Design,” Third Edition, New York: JWiley, 1987.

[6] A. Chenakin, “Frequency Synthesis: Current Solutions and New Trends,” Microwave Journal, May 2007, pp. 256-266.