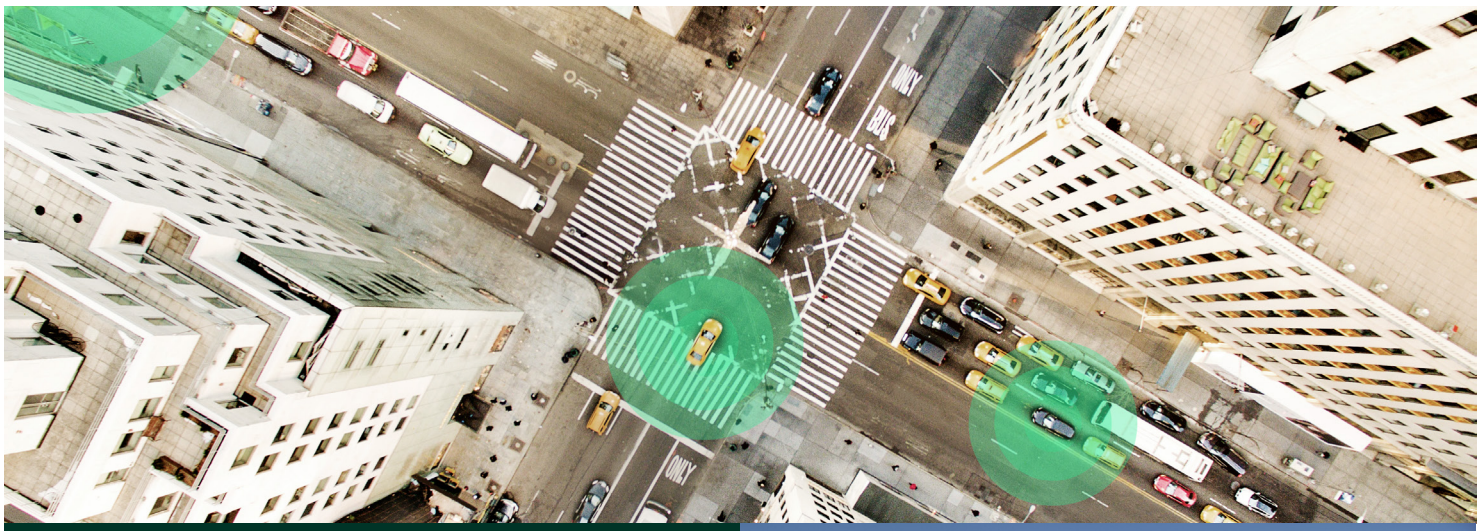

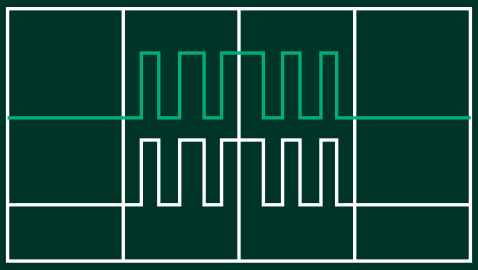

Solution Brochure

FMCW Radar Sensor Validation

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What is FMCW Radar?

Frequency modulated continuous waveform (FMCW) radar is a form of radar technology where the center frequency is varied, usually with a sawtooth or triangle modulation, as opposed to being constant. By modulating the frequency, there are many added benefits over traditional, pulsed radar:

- FMCW radar provides distance measurements along with speed measurements
- Simultaneous transmit and receive, unlike pulsed radar, which ensures there are no "blind spots"
- Simpler circuit designs that are smaller and cheaper to produce
- FMCW radar requires large bandwidths, but the larger bandwidth means better position resolution, estimation of object size, and measurable range

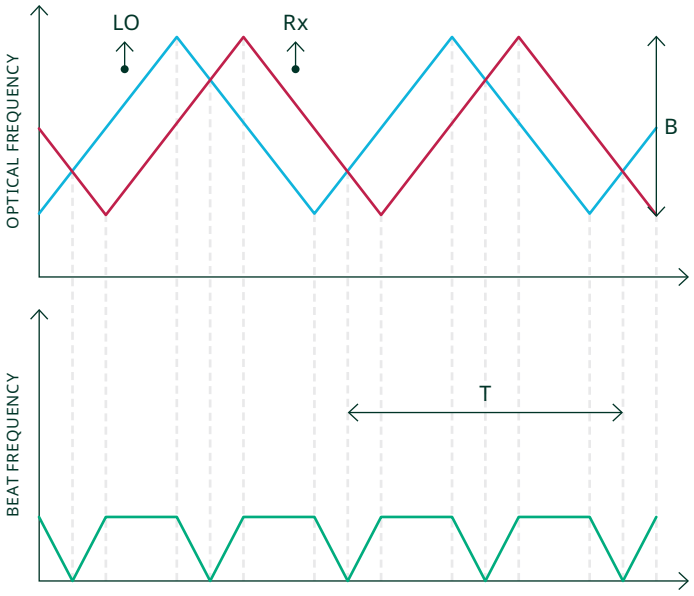


FIGURE 1
Spectrum View of FMCW Radar Waveforms

Because of these characteristics, FMCW chipsets can be used as early warning radar, proximity sensors, or "radar altimeters," and can determine position and velocity incredibly well. However, these characteristics also mean that the technical challenges for implementation, and for test and validation, are stringent. Accurate pulse measurements, generating wide RF bandwidth, and acquiring waveforms at very high center frequencies, just to name a few, are a must.

Why FMCW?

FMCW technology and chipsets have been around for some time, but there have been recent changes where new device types and applications are leveraging this technology in new ways. This has increased demand for these kinds of radar transceivers dramatically. Chief among these is advanced driver assistance and autonomous driving systems in the automotive industry. As autonomous driving systems become more ubiquitous in modern automobiles, so does the need for more accurate and safer systems. FMCW chipsets present a safe and reliable option for radar sensing while being small and easy to manufacture.

Additionally, the same FMCW technologies and processes being developed for the automotive industry have the potential to be used in a wide range of other applications such as:

- Presence detection
- Noninvasive vital sign reading
- Fall detection
- Gesture detection
- Better multitarget proximity sensors
- Autonomous drones; smaller unmanned vehicles and robots

Testing Radar Sensors

Due to the technical requirements of FMCW radar sensors, there are several challenges to overcome when setting up a fully functioning and capable test system. Radar sensors operate in mmWave frequencies in bands centered around 24 GHz and 50–75 GHz. Additionally, bandwidths of FMCW radar can be up to 5.5 GHz. Meeting these test requirements means configuring a very capable and high-performance test system that also has the performance and measurement capabilities necessary for thorough and accurate validation of these devices.

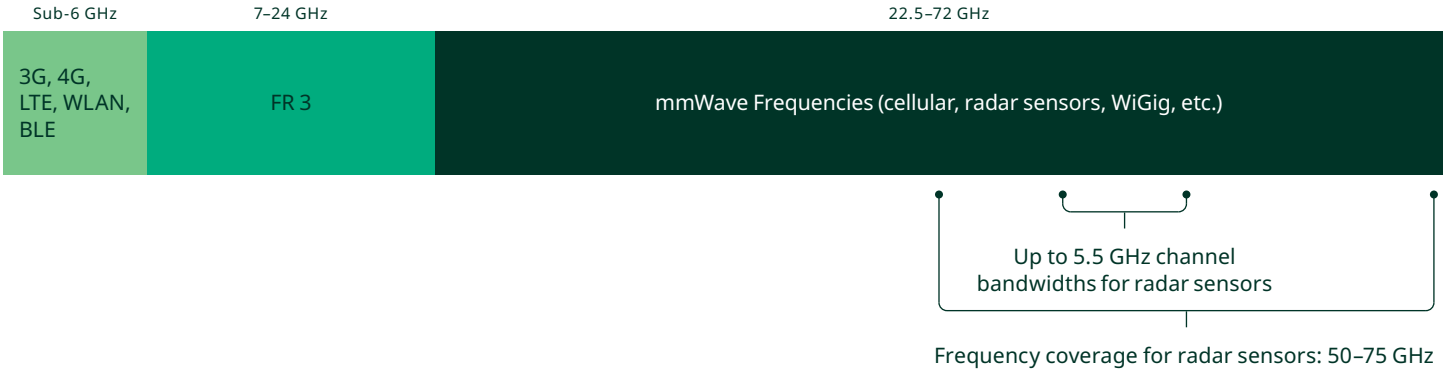


FIGURE 2

Frequency Use of Common Wireless Applications

The high frequencies and wide bandwidths of FMCW radar do have their advantages. The higher center frequency means there is better Doppler resolution and sweep bandwidths. Similarly, as bandwidth increases there is finer resolution and better object positioning accuracy. However, due to the nature of wideband mmWave test, different procedures, instrumentation, and best practices are required for accurate test.

Test Challenges

01

Antenna Size
The high frequencies of operation mean that antennas are small and FMCW chipsets are often antenna-in-package (AiP) devices. As a result, OTA test is often necessary for proper validation.

03

Spectrum Coverage
Radar sensors can span from 24 to 75 GHz. That means any test equipment needs to span over 50 GHz of RF spectrum for full coverage.

02

High Frequency Characteristics
Test at mmWave frequencies requires unique components, procedures, calibration, and best practices.

04

Wide RF Bandwidth
With RF bandwidths of up to 5.5 GHz, it is necessary to use high-performance RF instruments for FMCW radar sensor validation.

05

Pulsed Measurements
With both distance and velocity measurements and simultaneous transmit and receive capabilities, there are numerous parameters that must be tested for such as beat frequency, chirp length/rate, sweep bandwidth and more.

06

Measurement Uncertainty
The nature of wideband, high frequency test means that measurement uncertainty is increased.

NI FMCW Validation Solution Benefits

01

Superior RF Performance
PXI VSTs, at the core of FMCW test, offer excellent RF performance including fast tuning times, pulsed signal generation and analysis, and wide instantaneous bandwidth.

02

Scalability
Built on the PXI platform, NI's FMCW test solutions offer unmatched scalability and versatility, with options for additional DC, RF, or analog I/O in the same PXI form factor.

03

Synchronization
PXI is designed with timing and synchronization in mind. Through the PXI backplane, all instruments can operate together in very tight synchronization.

04

Seamless Integration
All instruments can operate as one cohesive test system for FMCW radar sensor test.

05

Versatility
PXI can easily adapt to the needs of your specific application with each slot in the PXI chassis able to accommodate a wide variety of module types.

06

Cost-Effective
With multiple instruments in the same chassis, PXI can be very cost-effective, especially when adding multiple instruments to the same chassis.

FMCW Radar Sensor Validation Solution Overview

System Diagram

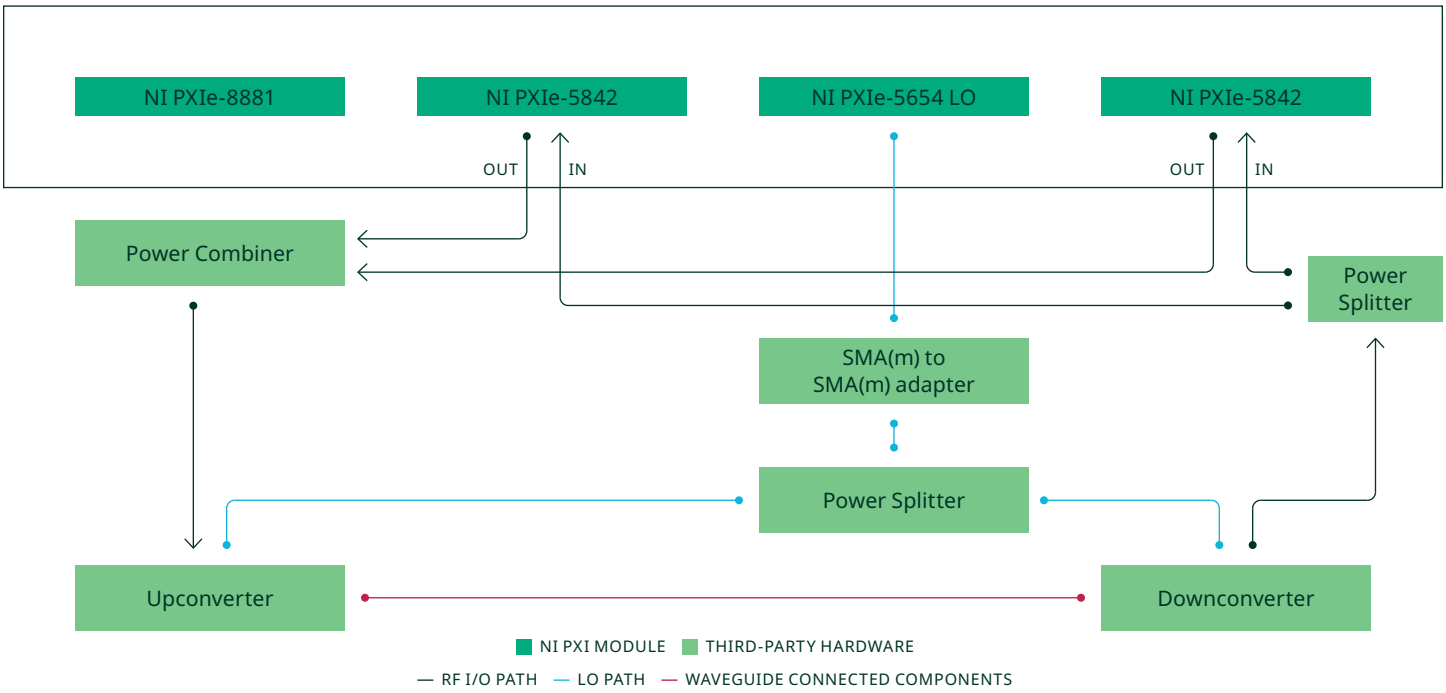


FIGURE 3
FMCW Radar Sensor Validation System Diagram

Key Features

- Frequency coverage from 50–75 GHz with Eravant frequency up/downconverters
- Simultaneously generate and acquire waveforms with up to 7 GHz instantaneous RF bandwidth
- Built-in system calibration for external attenuators, frequency converters, and other components
- Integrated pulse measurements for FMCW radar, including beat frequency, chirp length/rate, Doppler, and more.

High-Performance RF Instruments for FMCW Radar Validation

NI's family of RF hardware and software built on the PXI platform provides a high-level starting point for FMCW radar sensor validation. By combining scalable, versatile, and high-performance instrumentation with application-specific software, this solution seamlessly combines both NI and third-party hardware components for initial device bring-up and automated characterization of FMCW radar sensors.

Choose from different options for RF instruments, including frequency range, bandwidth, and additional DC, analog, or digital instruments for a tailored test system suited exactly to the needs of your application.

Eravant Downconverter

The STC-N12-15-S1 is a V-Band downconverter that converts millimeter wave signals from a frequency range of 50 to 75 GHz. It has low harmonic levels and excellent gain flatness, making it a good candidate to extend low frequency test equipment for millimeter wave testing purposes.

Eravant Upconverter

The STV-00-15-S1 is a V-Band upconverter that converts IF signals from a frequency range of DC to 25 GHz. It has low harmonic levels and excellent gain flatness, making it a good candidate to extend low frequency test equipment for mmWave testing purposes.

NI PXI Vector Signal Transceivers (VSTs)

PXI VSTs combine an RF and baseband vector signal analyzer and generator with a user-programmable FPGA and high-speed serial and parallel digital interfaces for real-time signal processing and control from baseband to mmWave. The core of NI's family of PXI VSTs is the PXIe-5842. On its own, the NI PXIe-5842 is capable of frequency coverage from 30 MHz to 26.5 GHz, 4 GHz of instantaneous RF bandwidth, and has excellent RF performance—such as best-in-class EVM and phase noise.

Most relevant for FMCW radar sensor test applications, the PXIe-5842 is an extremely scalable and versatile instrument, whose capabilities can be significantly enhanced with the integration of additional instruments. This is done in several ways. One way is to combine the vector signal analyzers and generators of two PXIe-5842 VSTs for extreme wideband signal generation and analysis up to 7 GHz instantaneous RF bandwidth. Another way is to combine the PXIe-5842 with third-party frequency up and downconverters for increased frequency coverage. When combined, these capabilities are the building blocks of a highly versatile, scalable, and high-performance RF test system, capable of almost every RF test application, including FMCW radar sensor test.

NI PXIe-5842 Vector Signal Transceiver

Third-Generation VST

Core Instrument Capabilities

- Frequency coverage from 30 MHz to 26.5 GHz
- 2 GHz instantaneous RF bandwidth (4 GHz in specialized variants)
- Industry-leading EVM for Wi-Fi and cellular applications

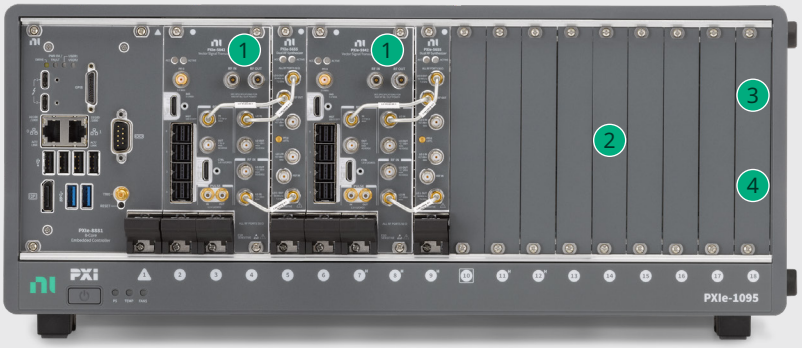
Leverage Third-Party UDCs

- Combine with third-party UDCs for almost unlimited frequency coverage from LF–sub-THz
- Built-in system calibration that includes UDCs
- LO for UDCs added directly into the same PXI chassis

Frequency Stitching

- Combine two PXIe-5842 VSTs for up to 7 GHz instantaneous RF bandwidth
- Connected to single embedded controller for operation as one cohesive test system

Frequency Stitching



1. Combined VSAs and VSGs for up to 7 GHz instantaneous bandwidth
2. Add external LOs for external UDCs, or additional instruments for digital DUT control, DC power, and other I/O
3. Synchronization through PXI backplane
4. Two VSTs integrated seamlessly into one PXI test system

FIGURE 4

Features of PXI for Frequency Stitching

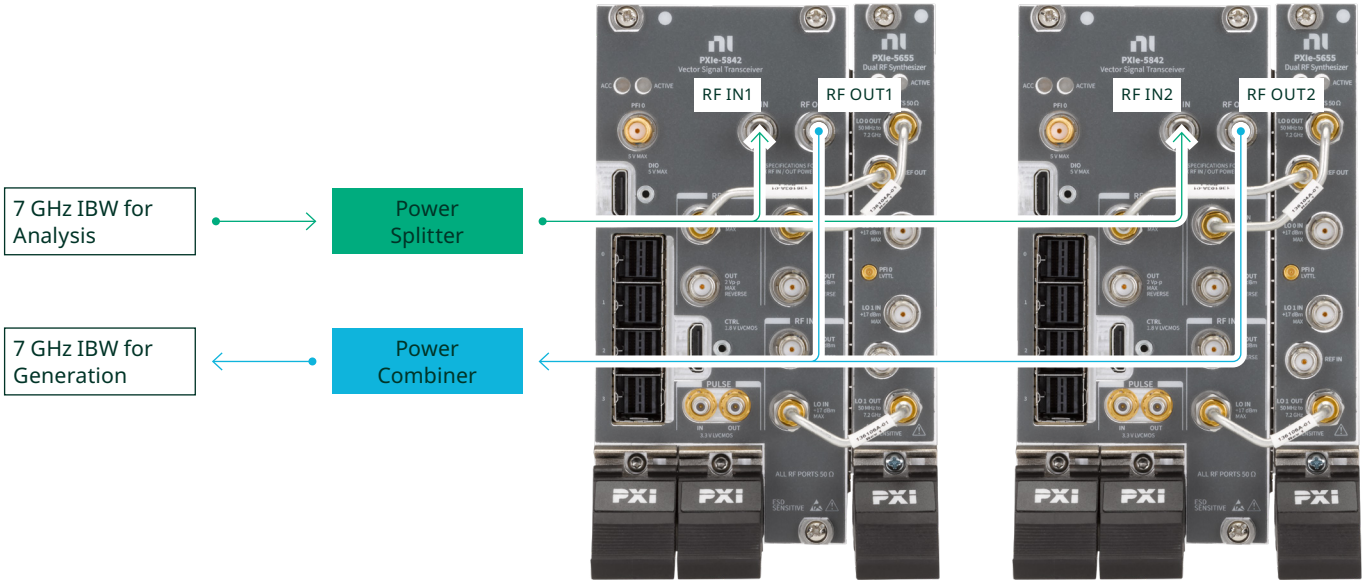


FIGURE 5

PXI Test System for Frequency Stitching Applications up to 7 GHz Instantaneous RF Bandwidth

Using PXI VSTs with Third-Party UDCs

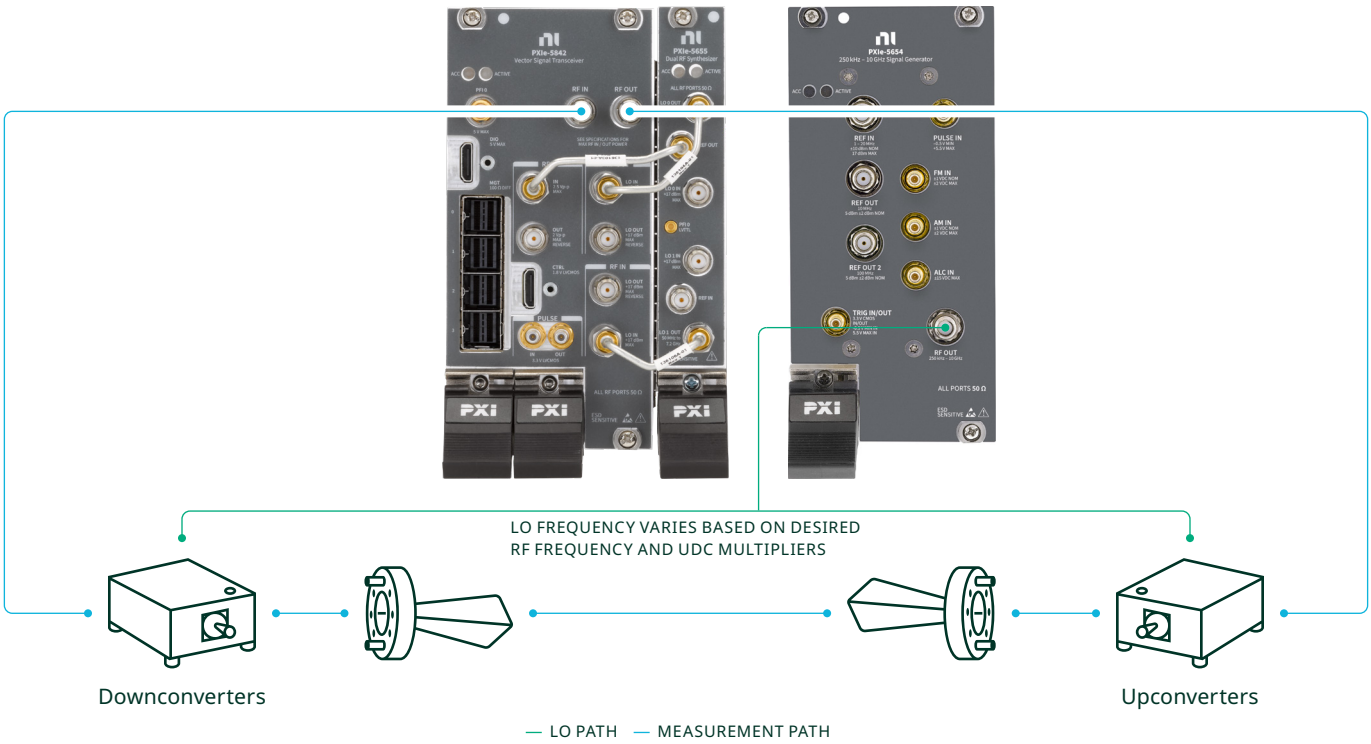


FIGURE 6

PXI Test System for Frequency Stitching Applications up to 7 GHz Instantaneous RF Bandwidth

PXI VSTs can be combined with third-party UDCs to extend frequency coverage up to sub-THz frequencies. For FMCW radar sensor validation, Eravant UDCs with frequency coverage from 50 to 75 GHz provide the ideal range combined with excellent RF performance. The required LO for the external UDCs can be included within the same PXI system. Additionally, system calibration assumes the inclusion of UDCs to provide a fully integrated and calibrated test system.

Extensible RF Hardware Platform

All-In-One RF Test Instrument

The core performance of PXI VSTs combined with optional extensible capabilities means that these instruments are ideally suited for FMCW radar sensor validation, as well as most all other RF test applications. The PXI VSTs used in FMCW test configurations can be used independently for RF front end measurements such as EVM, ACLR, harmonics, TxP, SEM, occupied bandwidth, phase noise, noise figure, multitone generation, and general spectrum analysis for Wi-Fi, Bluetooth® wireless technology, and cellular test applications. They can also be combined with other third-party UDCs for coverage up to sub-THz frequencies for wireless research applications. PXI VSTs can even be used with other hardware such as external driver amplifiers and load-pull tuners, for applications such as GaN PA validation, impedance matching, and more. Whatever the RF test application you have, PXI VSTs have the capabilities to effectively meet those needs as an all-in-one RF test instrument.

Add More Functionality to Your RF Instruments

Built off the PXI platform, there are many additional benefits to using PXI VSTs. You can choose to add s-parameter capabilities with the NI PXIe-5633 VNA add-on module, include real-time data streaming with the NI PXIe-7903 FPGA Coprocessor, or add mmWave capabilities by including the NI RMM-5585 mmWave head. This is in addition to adding extra RF channels for MIMO applications, or additional I/O for DC, digital, and analog test requirements. Use NI PXI VSTs and the PXI platform to tailor your test system exactly to your needs.

Additional Applications for VST

01

mmWave Cellular

The PXIe-5842 with 54 GHz Frequency Extension is well suited for full coverage of 5G FR1 and FR2 frequency ranges. When paired with RFmx NR, this instrument provides full standard-specific test capabilities.

02

WiGig (60 GHz Wi-Fi)

A potential area of interest for Wi-Fi 8 is use of the 60 GHz range. With Eravant UDCs, PXI VSTs provide the necessary spectrum coverage, bandwidth, and performance for future Wi-Fi test in this range.

03

Sub-THz RDP

Sub-THz test requires use of specialized hardware and process. With PXI VSTs at the core, build a custom test system for unique sub-THz test needs.

04

5G FR3

The core capabilities of the PXIe-5842 with frequency coverage up to 26.5 GHz position it well for FR3 test for cellular use cases.

05

Wireless Connectivity

With industry-leading EVM performance, PXI VSTs are well suited for the requirements of Wi-Fi 7 test as well as legacy Wi-Fi and Bluetooth standards.

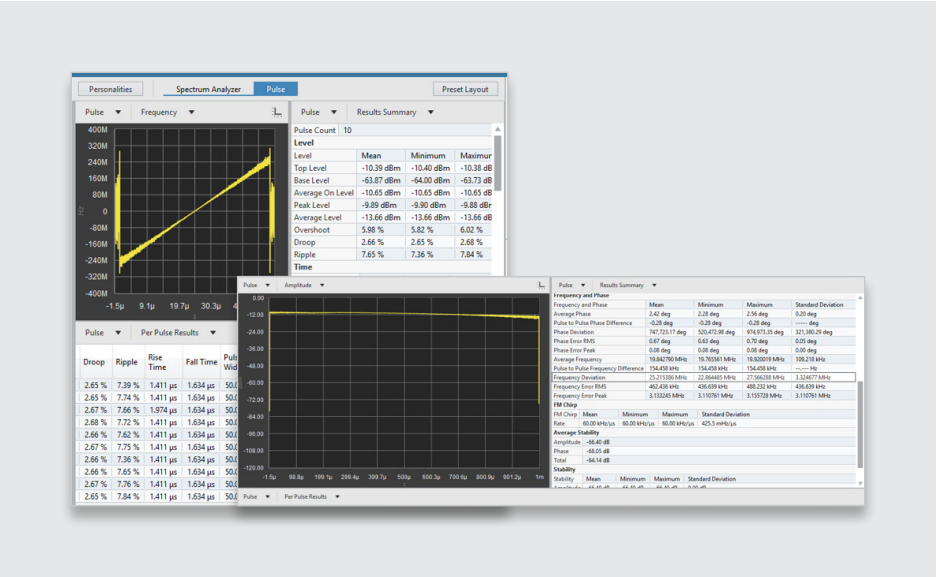
06

Legacy Cellular

PXI VSTs can be used to test legacy cellular standards, on their own and to test for compatibility with 5G NR for multi-RAT components and systems.

Measurement Capabilities with RFmx Pulse

The requirements of FMCW radar sensor test mean there are many types of measurement capabilities that need to be accounted for in proper validation and characterization. Since FMCW transceivers transmit and receive simultaneously while also resolving for both speed and velocity, there are many concurrent complex measurement types to factor into the test process.



Measurements:

- Chirp analysis (chirp up/chirp down)
- Stability
- Amplitude
- Frequency
- Wrapped phase
- Beat frequency
- Doppler (range and speed)
- Sweep bandwidth
- Signal power
- Occupied bandwidth
- Phase noise
- FM sweep linearity
- Chirp length and chirp rate

The NI RFmx Pulse measurement personality provides much of the functionality required for FMCW radar sensor test with an out-of-the-box experience. With just a few clicks, configure pulse measurements for chirp analysis, beat frequency, and much more in NI InstrumentStudio™ Software's easy-to-use and customizable Soft Front Panel. Or, leverage the RFmx API to build and configure customer automated test sequences for fast automated characterization.

The Value of NI for FMCW Test

Best-In-Class RF Performance	• Excellent amp. accuracy and RF performance from the PXIe-5842 VST combined with the stability of Eravant's frequency converters • Integrate two VSTs as one instrument for up to 7 GHz instantaneous bandwidth • Flexible choice of frequency coverage with third-party UDCs
Superior Synchronization and Scalability	• All required RF instrumentation integrated seamlessly into the same PXI chassis • Industry-leading timing and synchronization through PXI backplane • Add additional RF instruments, LO, analog, DC instruments in the same test system
Integrated System Calibration	• Integrated calibration routines • External components and UDCs accounted for in full system compensation
Cost-Effective and Smaller Footprint	• Lower overall cost of ownership with PXI • Same instrument footprint when integrating additional instruments • Upgradeable, future-proof RF instruments • Leverage the same RF instrument platform for almost any RF test application

NI provides a scalable, cost-effective, and high-performance test system for FMCW radar sensor test. By providing a versatile and customizable high-level starting point, users can adapt their test system specifically to the needs of their application while maintaining a small and cost-effective form factor.

Additionally, NI PXI instruments are built with open and adaptable APIs, able to work seamlessly with the programming language of your choice or used together in the no-code InstrumentStudio environment.

System Integration on Your Terms

NI offers a variety of solution integration options customized to your application-specific requirements. You can use your own internal integration teams for full system control or leverage the expertise of our worldwide network of NI Partners to obtain a turnkey system.

Contact your account manager or call or email us to learn more about how NI can help you increase product quality and accelerate test timelines at (888) 280-7645 or info@ni.com.

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