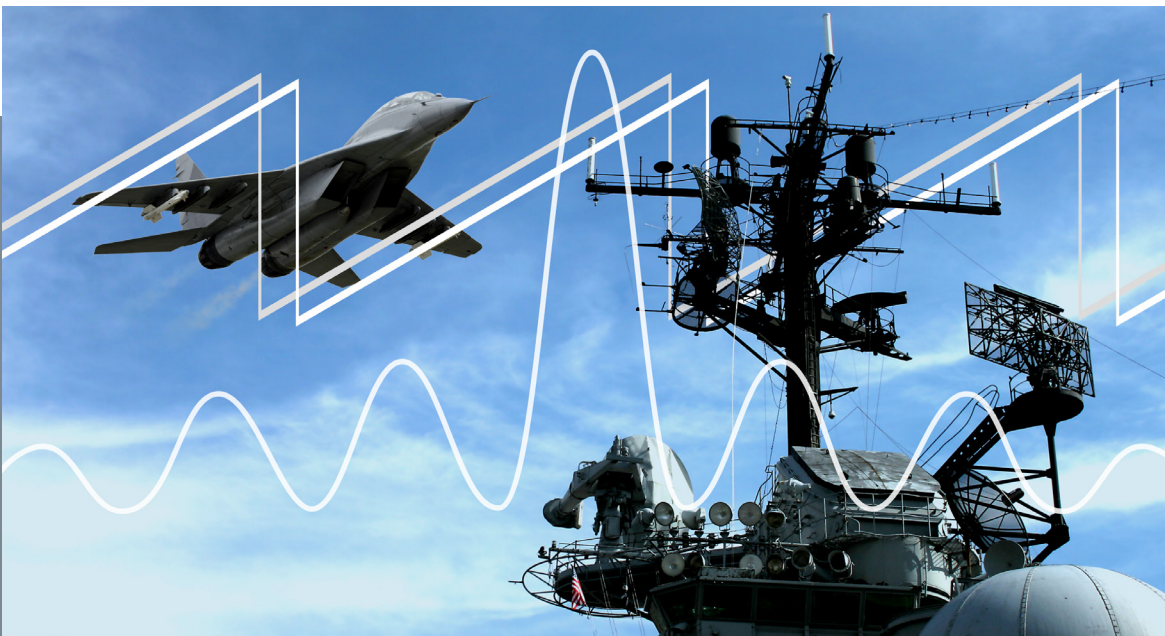


Generating Precise FMCW and Chirp Radar Test Signals with Low-cost Devices



RF/microwave signal generators offering high speed frequency modulated continuous wave (FMCW) and frequency modulation on pulse (FMOP), or “chirp” capabilities, are depended on by radar system engineers in many fields. In particular, those designing microwave test sets for receivers in highly precise radar systems, such as anti-spoofing and anti-jamming applications. To achieve the reliable FMCW and chirp modulation necessary, one would typically rely on a full-featured bench-top unit. But many are discovering that today’s robust, portable, and programmable RF/microwave signal generators offer a real, low-cost, and flexible alternative. This Tech Brief provides insight on this self-managed approach and offers tips and tricks on how to get up and running fast and with confidence in every pulse.



Introduction 2

FMCW and Chirp Modulation Radar 3

The Signal Generator's Key Role 5

Chirp Radar Field Test Challenges 6

Anti-jamming/Anti-spoofing Radar Test with Multiple Signal Generators 6

Conclusion 7

Testing in Remote Locations or in Harsh Conditions is a Challenge for Traditional Bench-top Test Instruments.

Frequency modulated continuous wave (FMCW) radar technology was developed back in the 1950s following World-War II to provide better resolution and discrimination of radar targets. Once unclassified in the 1960s, there has been steady development of radar technology beyond a simple linear FMCW chirp to more advanced radar technologies, such as coherent pulsed radar using pulse compression techniques. These techniques have resulted in frequency modulated chirp (FM Chirp), barker codes, and other more complex modulated pulse compression radar techniques.

However, there are still uses and benefits to older radar techniques, such as linear FMCW for aircraft height measurement during landing procedures, automotive radar, smart ammunition sensors, liquid filling levels of tanks and bulk solids in silos, and naval tactical navigation radar.

An extremely useful tool in development and testing of FMCW radar and more advanced chirp radar is a [signal generator with frequency sweeping and with chirp modulation](#), which may also be used to develop and test pulse compression techniques and devices in

the laboratory or the field. In the case of field testing, chirp radar can be found in harsh environments from remote radar locations, naval platforms, aircraft maintenance facilities, or even servicing land-mobile systems wherever they may be.

Given that a significant amount of FMCW and chirp radars use frequencies well into the microwave and millimeter-wave spectrum, such as C-band, X-band, and Ku-band, the test equipment used to develop and test these radars are general large bench-top devices with a wide range of

built-in features and a price-tag to match their size. Moreover, large bench-top signal generators are typically designed for laboratory conditions, and usually don't operate well in extreme environments. This is especially true if there is a substantial amount of vibration or shock forces occurring during transportation of these units. Along with a high price-tag, these bench-top units are also generally expensive to repair and

re-calibrate, which most often must be done at a certified facility taking weeks of lead time on repairs.

A modern and much more viable solution for many space constrained and rugged applications is the use of a portable signal generator. However, most of the portable signal generators on the market do not reach common FMCW and chirp radar bands, and don't offer any form of chirp or pulse

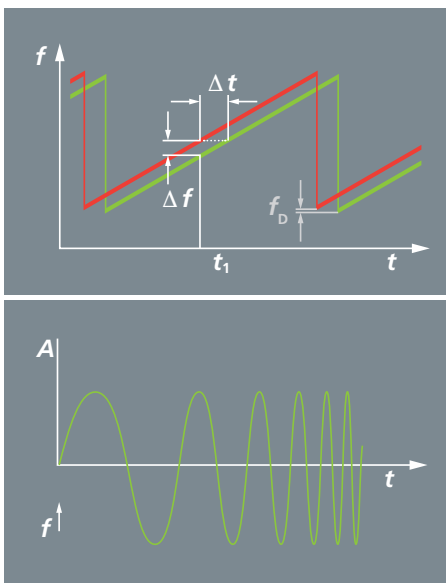
modulation. Fortunately, Vaunix produces [LabBrick signal generators that are portable, programmable, and can produce self-triggered and externally triggered chirp modulation](#), phase continuous linear frequency sweep, and pulse modulation. These devices aren't much larger than a standard wallet, and are available at a fraction of the cost of repairing a typical bench-top signal generator with the same capabilities.

FMCW and Chirp Modulation Radar

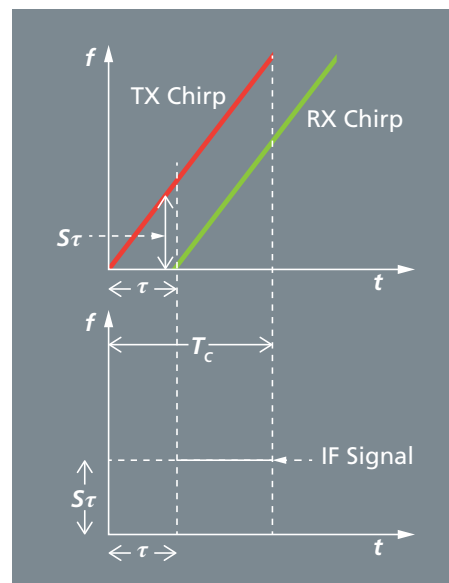
FMCW modulation is similar to continuous wave (CW) radar modulation with the exception that instead of holding a single tone the frequency of the CW radar increases or decreases linearly, or non-linearly. Common

FMCW waveforms are sawtooth, triangular, square-wave, and stepped, or staircase, modulation, though the most common is saw-toothed or "swept-frequency" FMCW radar.

The basic concept of FMCW modulation is that the received signal from an object is mixed with the transmitted signal producing an intermediate frequency (IF) tone that is proportional to the delay, hence distance to the object. Multiple objects will produce multiple tones, which can be separated and identified using a Fourier Transform. The result is an FMCW radar that consists of a relatively simple circuit with a transmitter, receiver, FMCW synthesizer, mixer, digitizer, signal processor, and display. In the case of a radio altimeter, the IF signal is sent directly to an analog gauge with a frequency dependent coil meter that exhibits greater inductive impedance at higher frequencies (though not linear, this is still an effective method for determining relative altitude).



(Top) FMCW "chirp" signal as a function of time and frequency. (Bottom) FMCW "chirp" signal as a function of amplitude and time



FMCW radar response and processing.

TECHNICAL BRIEF

Generating Precise FMCW and Chirp Radar Test Signals with Low-cost Devices

The benefits of FMCW over CW is that the frequency modulation allows for much closer minimum range measuring capability, which is roughly limited to the transmitted signals wavelength. Moreover, FMCW radar enables the simultaneous measurement of a target's range and its relative velocity with much higher accuracy range measurements than CW. FMCW modulation also can be used to discriminate between multiple targets, requires relatively simple circuitry, and doesn't require any pulsing with high peak powers.

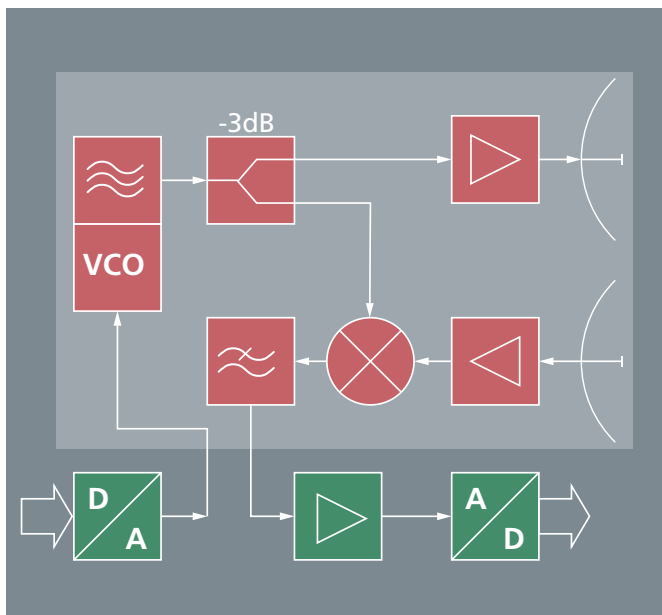
An advancement of this technique is to combine pulse radar concepts with intrapulse modulation/pulse compression. Pulsed radar performance benefits from extremely high pulsed power and short pulse width, as a pulse radar's range resolution is a

function of pulse width. However, high pulse powers and short pulse widths require specialized high power modulators and transmitters, which are generally large and expensive. Using solid-state technology, a pulsed radar can be made much smaller at a possible cost savings, though solid-state technology typically doesn't outperform vacuum tubes in high frequency and high pulse power applications.

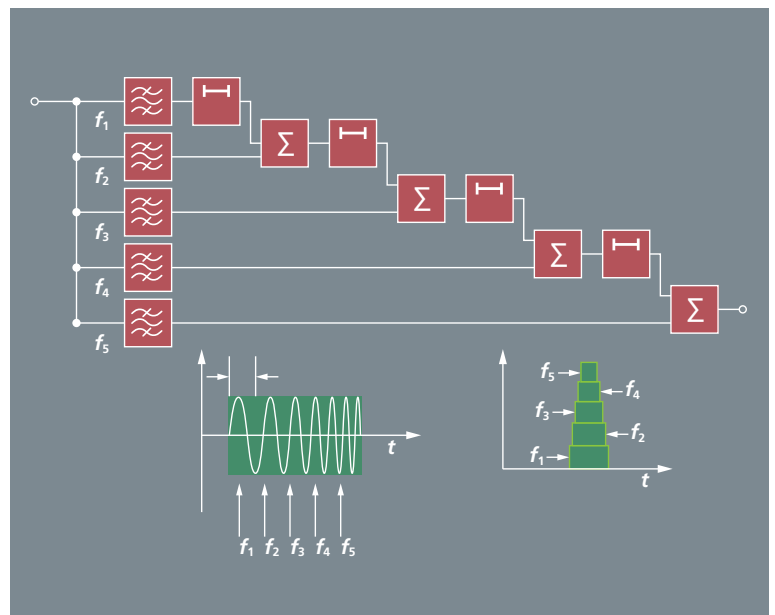
Hence, the use of intrapulse modulation and pulse compression allows for longer pulse widths at relatively high power levels. By modulating a pulse, the benefits of range resolution and multi-object discrimination can be achieved. Pulse compression is a technique where a longer pulse is processed in shorter sub-pulse segments, thus mitigating the loss of

range resolution experienced by pulse radars with long pulse widths while maintaining a high energy pulse without extremely high peak power levels. Frequency modulation on pulse, or FMOP, is often referred to as "chirp" radar, though somewhat confusingly, linear frequency modulation is also often called a chirp signal.

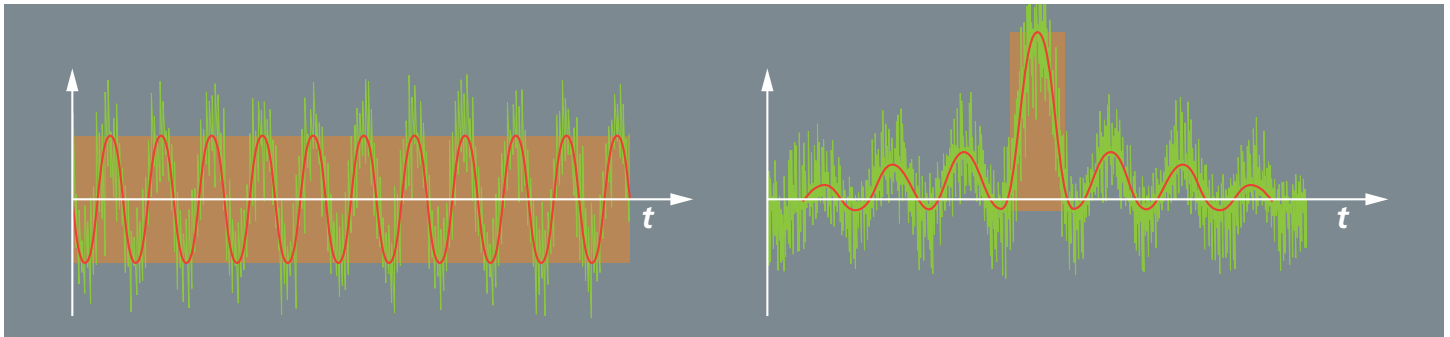
Additional benefits of chirp radar is that the broadband and random distributed noise in the receiver is greatly reduced by the pulse compression filtering process, which allows for the sensing of signal returns that are below the noise floor of the pulse. This is commonly known as the pulse compression gain (PCG). Moreover, the pulse compression filter adjusts the relative phases of the receive signal frequency components, which actually yields better maximum range than



FMCW radar block diagram



A diagram of the pulse compression circuitry for a linear FM chirp radar.



The input and output signals of a pulse compression state with the receive signal within the noise and output echo clearly discernible.

would be predicted by the standard radar range equation. This phenomenon is known as the pulse compression ratio (PCR).

The performance of FMCW and chirp radar depend on the performance of the radar components. Hence, added noise/noise figure, linearity, phase noise, and spurious harmonics are all key parameters for the active components within a radar system. While any of the active and passive components within a radar's transmit/receive signal chain can substantially degrade the performance of the radar system, it is extremely important that the frequency synthesizer excels.

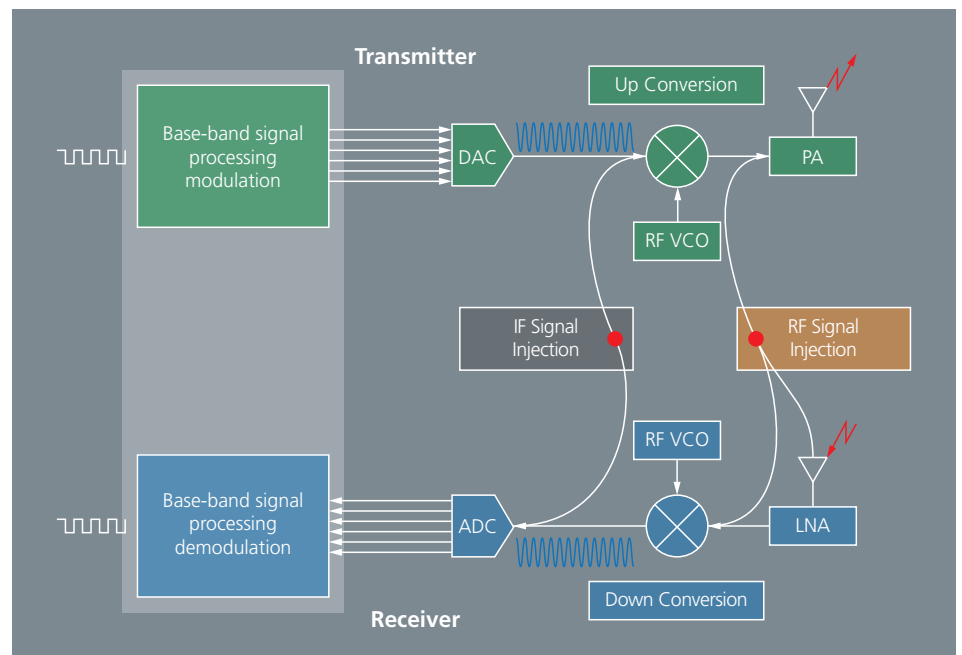
The Signal Generator's Key Role

Though there are more complex radar modulation schemes, FMCW and chirp radar are still very common in a variety of applications, including air defense, marine navigation, automotive

advanced driver assistance systems (ADAS), and aerospace altimeter and other sensing applications. There are also many legacy radar systems that are still in use today in aircraft and naval ships that require servicing and retrofit testing.

[Signal generators](#) are a key test instrument for radar testing, and are most often used to gauge the performance of the radar receiver

circuitry. Long test ranges and precise positioning of radar targets would otherwise be required to test radar in the field, where a signal generator with the appropriate modulation could be used instead to simulate radar targets. Moreover, high purity signal generators can also be used to test the radar receivers signal-to-noise (SNR) performance, which can be used to determine the maximum range capability of the radar and if that falls within the



FMCW radar block diagram

specification for a given radar. Pulsed chirp modulation signal generators can also be used to test the pulse compression circuitry of a radar receiver by sending calibrated compressed pulses to the pulse compression delay lines and measuring how well these circuits meet specifications.

A radar receiver may also be tested under varying signal conditions using degraded radar signal characteristics and noise. This can be done with multiple signal generators, one producing the simulated radar response and another producing the calibrated impairments, such as in-channel and out-of-channel interference signals and noise. This type of testing can be used to determine the anti-blocking and sensitivity of a radar receiver.

Radar transmission circuitry may also be tested using a signal generator in place of the radar systems frequency synthesizer. In this way, prototype radar transmission circuitry may be tested and undergo troubleshooting separately from the frequency synthesizer and modulation circuitry.

Chirp Radar Field Test Challenges

Though virtually any signal generator capable of linear FM chirp pulses can be used to test such radar in the field, most signal generators with frequency capability of C-band and beyond are relatively expensive units and are not

designed to be carted into in the field and set up in potentially harsh conditions. These units often cost upwards of \$100,000 and are large/heavy units that contain their own displays and computing processors. A downside of this complexity and one-size-fits-all approach is that these units tend to become inoperable if any of the components fail, which is likely under the harsh travel and field conditions these units are exposed to. Costs for repairing these units can be in the area of a quarter of the cost of a new unit, and can take several weeks to months.

These units also often have a variety of features that are unnecessary for this type of testing, which only complicates the test procedures. Some full-feature signal generators may be externally programmable and triggerable, which can be advantageous in reducing the complexity and time of the testing setup, but often require the purchase and use of proprietary software specific to the test instrument brand.

Another more affordable and practical approach to chirp radar field testing is to use PC-driven and portable signal generators that are already designed to be compact, rugged, and easy to use. An example of this is the Vaunix [LabBrick Signal Generator LMS-183CX](#). This signal generator provides a calibrated signal output from 6 GHz to 18 GHz with frequency sweep, linear FM chirp modulation, and pulse modulation that can be internally triggered (programming or PC-control)

or externally triggered (pulse trigger port). Advantageously, the LMS-183CX can be purchased for roughly a third of the price of repairing a typical bench-top signal generator with comparable performance. Also, the PC-driven nature of the Vaunix LabBricks allows for the testing personnel to use their own secure PCs or laptops, and no testing information is stored on the LabBrick, unlike with bench-top test units with their own processors with networking capability.

Anti-jamming/Anti-spoofing Radar Test with Multiple Signal Generators

In the case of newer radar and during retrofitting of radar systems on older platforms, testing and maintaining the radar once installed is essential. As radar technology has progressed, so has radar jamming and spoofing technology. This is why it is important to not only test the operation of radar, but also their anti-jamming/anti-spoofing capabilities. With modern software defined radar, new anti-jamming/anti-spoofing techniques can be implemented in existing radar by changing the programming.

Testing the effectiveness of this programming, however, is much more complicated. In some cases, it may be useful to test anti-jamming/anti-spoof-

TECHNICAL BRIEF

Generating Precise FMCW and Chirp Radar Test Signals with Low-cost Devices

ing techniques using signal generators simulating various radar targets and jamming/spoofing systems. In these situations multiple signal generators are extremely useful to simulate the targets and jamming/spoofing systems. PC-driven and low-cost portable signal generators with a compact footprint can be extremely beneficial in these testing situations, as multiple-synchronized signal generators can be used simultaneously to simulate a more realistic scenario than a single bench-top signal generator, still at a fraction of the cost. Signal generators, such as [Vaunix Lab Bricks](#), are even rugged enough to be deployed in field testing scenarios of anti-jamming/anti-spoofing technology with minimal environmental protection.

Conclusion

Signal generators are a key tool for the development, testing, and maintenance of critical FMCW and chirp radar technology. Though traditional bench-top signal generators may have their place in the development and testing of radar, there are many circumstances where the cost, size, complexity, and fragility of these units mitigates their usefulness. In these cases, rugged and portable signal generators, such as Vaunix Lab Bricks, can be a low-cost and extremely adaptable solution to solving a variety of challenging radar testing scenarios.

Lab Brick signal generators are a rugged, low-cost, adaptable solution for radar testing.






vaunix

Next Steps:

Shop Vaunix's entire line of [Signal Generators](#).

Download additional [Tech Briefs](#):

-  [10 Signal Generator Features You're Probably Paying Too Much For](#)
-  [Modular Test Approaches for SSR Signal Analysis in IFF Applications](#)
-  [Insights on Evolving 5G MIMO Networks and Test Methods](#)

Visit our [Support Page](#) for our additional technical resources and to request application assistance.

➔ **Lab Bricks are Available for Immediate Delivery From Stock**