PXI-based Radio Communications Testing

Reduce the size of your test bench at the same time you reduce cost while facilitating seamless automation.

Introduction

General radio communications testing often requires a suite of tests for design verification and/or manufacturing test which demand multiple pieces of test equipment, often coupled with hundreds of data point measurements requiring automation to acquire and process the data. One cost-effective solution is to integrate as many of these test functions as possible into one instrument such as a Radio Test Set or Communications Monitor.

Such customized equipment is available for a wide range of communication standards from Professional Mobile Radio (PMR) or Land Mobile Radio (LMR) (which includes the likes of Tetra, P-25, HPD, and MOTOTRBO, as well as legacy AM, FM, and SSB) to WiFi, WiMAX, and cell phone formats such as WCDMA and GSM. Even where a highly integrated instrument such as a RTS is used, however, there are still a handfull of common tests requiring extra signal generators or advanced analysis features in order to appropriately and completely characterize and/or validate radio conformance to a given applicable standard. Due to the miniaturization and integration capabilities of PXI-based instrumentation, systems which up until now have been cumbersome both in size and programmability may be consolidated to make them not just smaller but surprisingly portable, more technically integrated, and potentially quite a bit faster.

Basic Radio Communications Test

Basic radio communications testing of a transceiver requires measuring the receiver's sensitivity, selectivity, dynamic range, and a wide variety of demodulation measurements, depending upon the transmission standard in play. Many of these receiver tests can be performed with a single carrier, while some must be carried out in the presence of other signals (e.g. receiver blocking). Transmitter testing requires a series of in-band on-channel measurements, such as power and linearity, as well as out of band tests for spectral purity such as spurious and harmonics, and a range of modulation measurements. As an example, Aeroflex integrates a full suite of P-25, Tetra, HPD, MOTOTRBO, as well as legacy AM and FM test capabilities into the 3920 radio test set (RTS).

Considering the P-25 test capabilities of the 3920 as an example case, some of the highlights of the suite of receiver test capabilities include sensitivity (using standard 1011 tone) and BER, verification the receiver can decode signals with up to 5% error (using the Std Cal Tone), co-channel interference measurement, and extended receiver quality tests such as the silence pattern, which provides verification of audio cleanliness of a quieted receiver. On the transmit side, measurements include carrier frequency error, output power, C4FM modulation fidelity, symbol deviation, symbol clock error, and transmit BER, as well as more advanced complex modulation type verification such as linear simulcast EVM.

As a result of the high level of test system integration within a Radio Test Set, the capabilities of the Radio Test Set comprise probably 85% to 90% of the range of tests required for radio conformance verification, however, there are a few tests that inescapably require additional test equipment.

Adding Radio Conformance Capability to a Radio Test Set

Continuing to examine P-25 radio conformance as a type example of general radio conformance requirements, four additional tests must be added to the 3920's radio test capabilities to complete the required range of tests in order to fully verify transceiver conformance: Receiver Intermodulation, Receiver Adjacent Channel Rejection, Transmitter Harmonics, and Transmitter Adjacent Channel Rejection. In order to accomplish this, the receiver tests require two additional signal generators with very good SSB phase noise characteristics, while the transmitter tests requires a high performance spectrum analyzer or RF digitizer with excellent SSB phase noise, wide dynamic range, and a wide input frequency range. Even with the integration provided by the Radio Test Set, these additional instruments can consume a full size rack mount system, may cost several hundred thousand dollars, as well as requiring many hours to integrate an automated test executable capable of acquiring the hundreds of data points required for radio conformance verification.

The PXI Revolution

In the late 1980's VXI (Vme Extension for Instruments) was introduced as a standardized backplane that could accept a wide variety of test instruments such as voltmeters, signal generators, and power meters, etc., which would allow integrators to create uniquely customized test systems in a sort of snap-together, building block fashion. This standard was quite popular with the military because they could more easily and quickly create customized test systems on the fly which could survive ruggedized environments. Nearly ten years later, the late 90's saw a new smaller form factor begin to emerge in PXI (PCI eXtension for Instruments) backed by the PXI System Alliance (www.pxisa.org), which significantly reduced equipment size, provided improved integration features, and was based on the widely accepted standard PCI computer backplane. As an example, pictured on the previous page is a standard 3U 18 slot PXI chassis, which will fit comfortably in a standard 19 inch rack, that contains two RF signal generators, a RF digitizer, a RF combiner, a dual 6 way 100 W RF relay, and still has four slots left that could hold some of the more than 2,000 PXI products available on the market today.

Integrating the Solution

Figure 1 shows a block diagram of the PXI system pictured above. The benefit of this system is that, by using a wideband dual coaxial relay, all four additional tests mentioned above (receiver intermodulation, receiver adjacent channel rejection, transmitter adjacent channel power, and transmitter harmonics (to the 10th harmonic for VHF and 400 MHz radios, to the 7th harmonic for 800 MHz band radios)), as well as the wide range of Radio Test Set functions mentioned above, can all be tested without removing the coax from the Unit Under Test (UUT).

In addition, the entire test system can be contained in two portable, rack mountable cases. Furthermore, because the system controller (the large module pictured at the left end in the PXI rack above) is a full featured computer with the equivalent capabilities of a personal computer, an individual could conceivably use that to run his test executable, controlling the PXI modules, as well as controlling the 3920 via Ethernet, making this a self-contained, portable, and fully automatable radio test system.

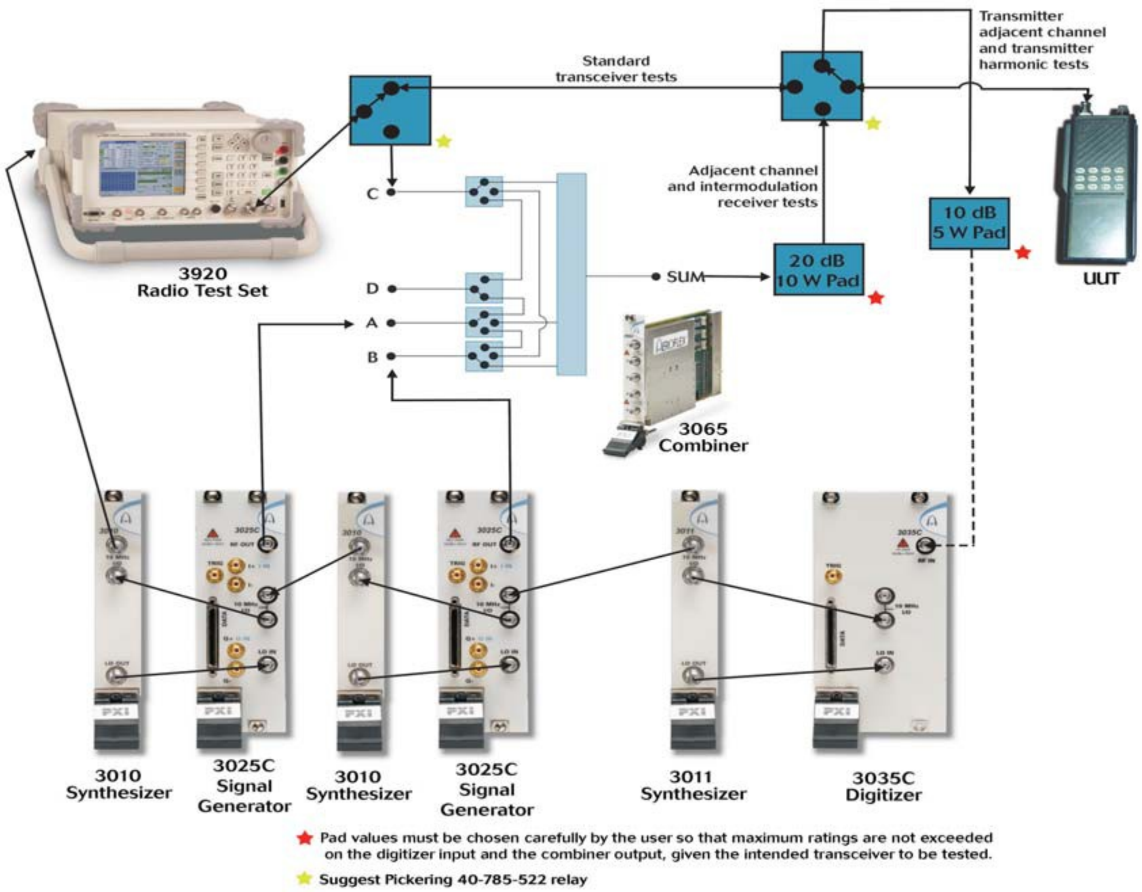

Figure 1 - Radio Conformance Interconnect Using 3920 and PXI

The Nature of Receiver Intermodulation Testing

The effects of intermodulation distortion can be observed in both the transmitter or receiver portion of a transceiver. Receiver intermodulation, sometimes referred to as receiver blocking, requires three signals: a desired signal and two interferers. As shown in Figure 2, the interferer closest to the desired is a CW signal, usually located several channels away, while the farthest interferer is typically modulated.

The interferer frequencies are chosen so their 3rd order intermod product falls directly on the desired frequency. For legacy measurements the modulated interferer will typically carry a different tone than the desired signal, while digital systems will most likely use a particular PRBS (pseudo-random bit sequence) modulation at the correct symbol rate rather than using valid protocol. The desired signal is then raised slightly above the radio's sensitivity (e.g. 3 dB) and two interferers are then raised until they degrade the radio's BER by the prescribed amount, effectively "blocking" the desired signal. Legacy analog systems, on the other hand, would instead usually look for a certain level of degradation in SINAD.

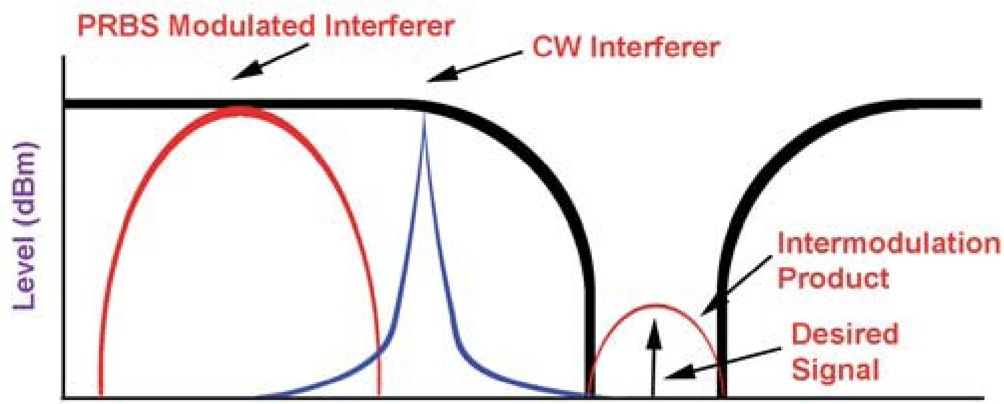

Figure 2 - Intermodulation Blocking Test

The Nature of Adjacent Channel Testing

Receiver Adjacent Channel testing puts a very large modulated interferer in the adjacent channel next to the desired. The desired, like the receiver intermodulation test, is raised slightly above the receiver's threshold of sensitivity (e.g. 3 dB) while the interferer is then raised until a certain level of receiver degradation is reached. As Figure 3 describes, this test effectively verifies the receiver's dynamic range by placing a high level signal at very close offset, which requires an adjacent channel interferer with sufficient SSB phase noise characteristics to support the measurement.

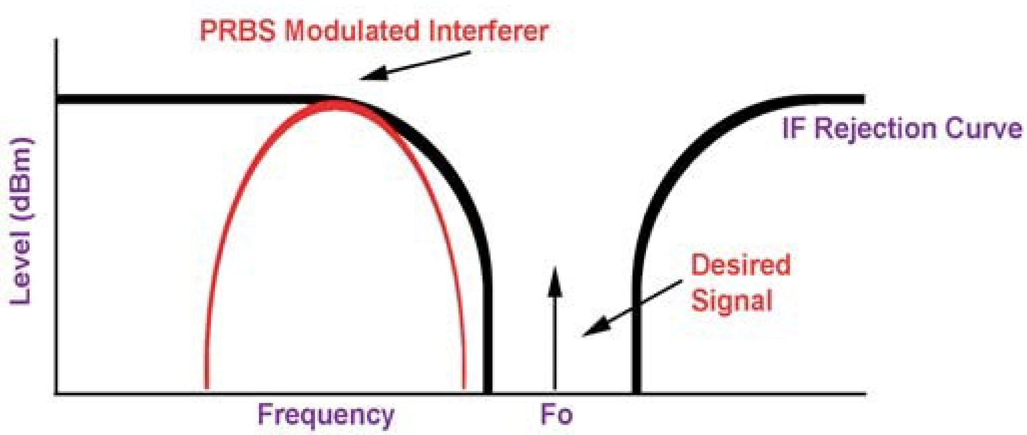

Figure 3 - Adjacent Channel Test

In the case of both Intermodulation, as well as Adjacent Channel measurements, sometimes the goal of the test is to characterize "how good" it is with an actual relative value (e.g. dBc), while in the case of some standards, fixed values are assigned and the test goal is to simply identify pass/fail criteria. Table 1 gives several examples of such requirements for different radio systems.

Table 1
Receiver Tests

	APCO P-25	Tetra	Legacy FM	Legacy AM
Intermodulation Rejection	50 to 80 dBc depending on type and class	-47 dBm	50 to 75 dBc depending on type and class	-82 dBc
Applicable standard	TIA-102.CAAB-B, section 3.1.10	ETSI EN 300 394-1, section 7.2.7	TIA-603-C, section 3.1.9	RTCA-DO186B 2.2.10 (avionics MOPS)
Adjacent Channel Rejection (dBc)	50 to 60 dBc depending on type and class	C/Ia = -40 dB for MS and C/Ia = -45 dB for BS	40 to 45 dBc @ 12.5 kHz offset depending on the radio class	-45
Applicable Standard	TIA-102.CAAB-B, section 3.1.7on the radio class	-45ETSI EN 300 394-1, section 7.2.4	TIA-603-C, section 3.1.6	RTCA-DO186B 2.2.16 (avionics MOPS)

Other tests demanding multiple signal generators may also be required, such as cross-modulation (an unmodulated carrier with a high level modulated interferer), desensitization (a modulated desired with a high level CW interferer) and possibly spurious response, depending on how the test is conducted.

Receiver Intermodulation and Adjacent Channel Power Performance
Using the 3060 or 3065 in combination with our PXI signal sources, such as the 3025C, provides excellent intermodulation characteristics, on the order of -85 dBc at -15 dBm output, guaranteeing generous dynamic range for this PXI based intermodulation test system.

The ability of this PXI based system to support receiver adjacent channel rejection measurements owes to the 3025C and its companion 3010 or 3011 synthesizer's excellent SSB phase noise to providing the required measurement margin. As a worst case example, 850 MHz represents the highest synthesizer noise multiplication factor for P-25 and Tetra (resulting from the ratio of the output frequency divided by the reference frequency, i.e. 850 MHz/10 MHz is a noise multiplication factor of 85). Using the 1 GHz data point on the SSB phase noise graph in figure 4 below as a reference (yet even a higher frequency!), at 12.5 kHz offset the chart shows a noise level of -122 dBc/Hz, which would be roughly 40 dB worse in a 10 kHz receiver bandwidth or -82 dBc. This provides plenty of dynamic range to make the required 60 dBc receiver adjacent channel rejection measurement required by the P-25 standard, for example (and is fairly typical for other narrow band standards).

Because the signal source and the digitizer utilize the same common synthesizer technology (the TCXO based 3010 or the OCXO based 3011), this excellent SSB phase noise performance could also be expected from the digitizer, providing plenty of dynamic range to measure the -67 dBc adjacent channel power measurement. Moreover, one can see from the chart below that, as carrier frequency goes down, this excellent performance only increases yet further, providing even greater test margin.

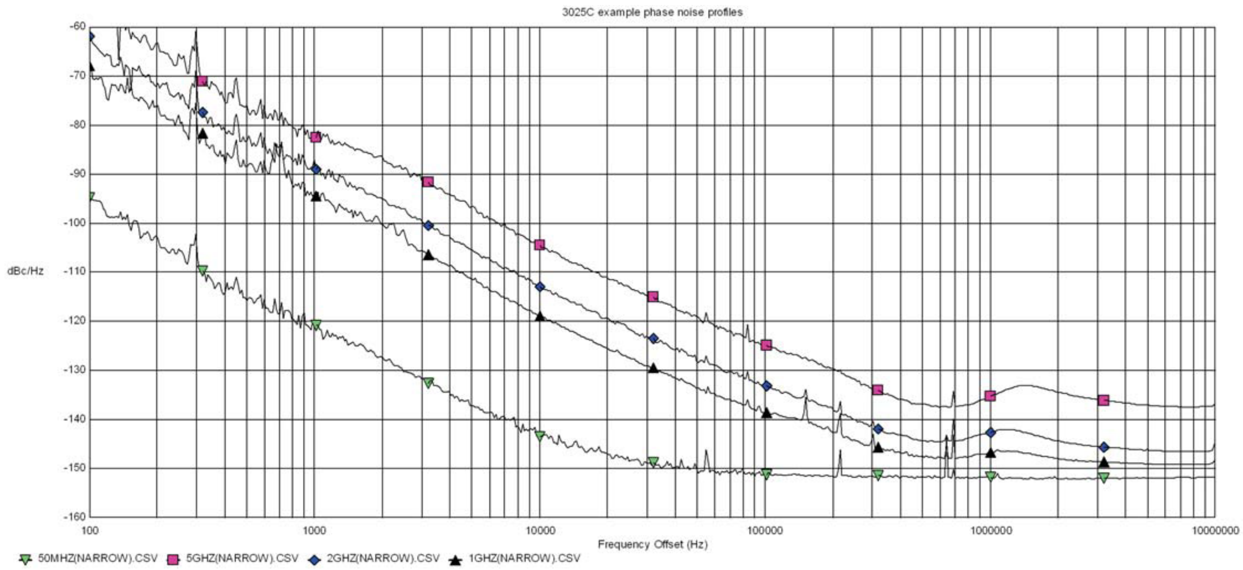

Figure 4 - Typical SSB Phase Noise Performance of PXI Signal Generators

General Signal Generator System Performance

Looks can sometimes be deceiving. Due to PXI's small size, one might question just how robust the RF performance might be for the 302x series of PXI signal generators. However, figure 5 below demonstrates the level repeatability, as an example, for a sampling of production PXI modules over an output range of +6 dBm to -120 dBm. Level repeatability and linearity can be seen here to be contained within less than 0.2 dB over a 100 dB dynamic range.

In addition, standard frequency settling times in these modules are less than 1 ms, which is superior to most conventional GPIB instruments, however, the 302x series sources also have an option to tune nearly 4 times faster, where extreme speed is required. Thus, both the PXI stimulus and analysis modules support automated test with world-class speed.

Transmitter Linearity Performance Analysis

Transmitter Adjacent Channel Power (ACP) testing not only verifies the transmitter's SSB phase noise is adequate, it also tests the linearity of the transmitter's modulator. If the modulator has poor linearity it will exhibit "spectral regrowth" of the in channel spectrum in the adjacent channel, causing poor ACP.

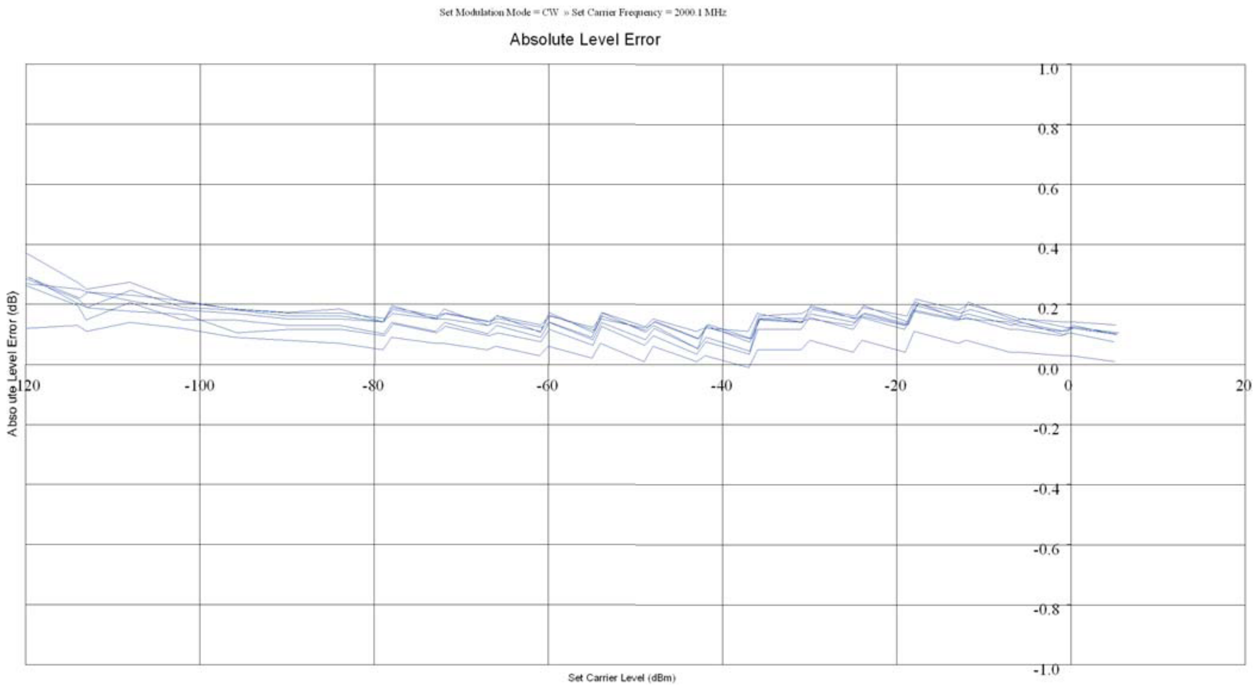

Figure 5 - Typical Level Repeatability of PXI Signal Generators

In order to perform transmitter adjacent channel power measurements, not only does the SSB phase noise of the analysis tool need to be excellent, the linearity of the digitizer RF front end must be outstanding. Figure 6 below demonstrates this dynamic range, showing the spectral regrowth on an actual wide band (5 MHz) CDMA signal measurement indicating -68 dBc.

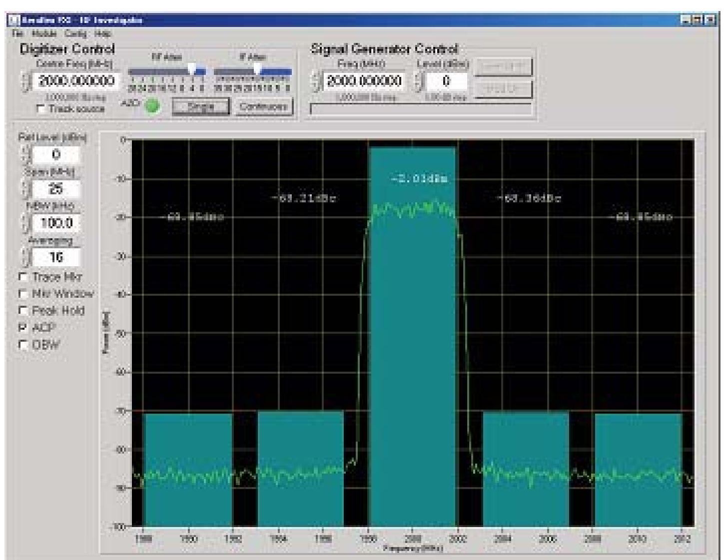

Figure 6 - Typical ACP Response of PXI Digitizers (3gpp, TM1, 64ch)

Finally, table 2 gives a small cross section of example transmitter tests for a variety of radio standards.

Table 2
Transmitter Tests

	APCO P-25	Tetra	Legacy FM	Legacy AM
Adjacent Channel Power Ratio (ACPR)	> 67 dB	-50 dBc due to switching and -60 to -70dBc due to modulation levels, depending upon offset	Between -50 and -70dBc, dependant on several conditions	-45dBc, 3.2k-5kHz -60dBc, 5k-15kHz
Applicable Standard	TIA-102.CAAB-B, section 3.2.8	ETSI EN 300 394-1, section 7.1.3	TIA-603-C, section 3.2.14	RTCA-DO186B 2.3.13 (avionics MOPS)
Harmonic Spurious	50 + 10log(P) dB, or 70 dB, whichever is the lesser attenuation	-36 dBm	43 + 10 log10 (power out in Watts) or an equivalent absolute level of -13 dBm (50 W)	-60dBc
Applicable Standard	TIA-102.CAAB-B, section 3.2.7	ETSI EN 300 394-1, section 7.1.5	TIA-603-C, section 3.2.13	RTCA-DO186B 2.3.7 (avionics MOPS)
Non-harmonic Spurious	Same as Harmonic Spurious	-36 dBm	Same as Harmonic Spurious	
Applicable Standard	TIA-102.CAAB-B, section 3.2.7	ETSI EN 300 394-1, section 7.1.5	TIA-603-C, section 3.2.13	

Conclusion

By combining the integration of Aeroflex's radio test sets with the integration, performance, and speed benefits of Aeroflex's latest PXI modules releases, the 3025C signal source and 3035C RF digitizer, a full range radio conformance test suite can be performed with only two rack mountable chassis. This system could be adapted for use with P-25, Tetra, legacy AM and FM, as well as advanced radio test systems such as HPD and MOTOTRBO and more. This concept effectively reduces system cost and physical test system footprint, while the advanced speed features can reduce test time.

For more information, go to www.aeroflex.com

Editor note: The newly introduced, high power 3026C would add roughly 11dB of additional measurement dynamic range over using 3025C.