# IMPLEMENTING IEEE 1641 – RF STIMULUS & MEASUREMENT

**Matt Cornish**
**EADS T & S (UK) Ltd**
**matt.cornish@eads-ts.com**

**David Poole**
**Aeroflex**
**david.poole@aeroflex.com**

**Malcolm Brown**
**DLO, TES, MOD, UK,**
**testmgats1b@fox.mod.uk**

**Abstract – This paper documents a study & demonstration exercise, carried out on behalf of the UK MoD, to show the applicability of IEEE Std. 1641 Signal & Test Definition [1] to complex RF testing - particularly complex RF measurement. Additionally, the applicability of 1641 to synthetic instrumentation has been investigated through the use of the Aeroflex AccSynt, as the chosen ATS (automatic test system).**

**The UUT (unit under test) was representative of a spacecraft communications LRU (line replaceable unit), operating in the microwave ($K_u$ band) region; test signals were defined and encapsulated as reusable test elements (1641 TSFs [Test Signal Framework]), using EADS T&S's newWaveX™; these 1641 test signals were called from a test sequence, written using NI TestStand; a 1641 run-time system was developed for the AccSynt ATS using EADS T&S's newWaveX; finally, the test sequence (executed by Test Stand) called the 1641 interface (created by newWaveX) to apply the signals (through the AccSynt) to the LRU. The tests implemented were *Spectrum Measurement*, *Gain Transfer* and *Spur Search*.**

**In order to verify the 1641 signal & measurement definitions against those applied to the UUT, signal data captured from the AccSynt was compared with simulation data, generated through 1641's Signal Modelling Language.**

## INTRODUCTION

IEEE Std. 1641 Signal & Test Definition [1] is an entirely signal based test definition language that has attracted international attention. It is a requirement of UK MoD ATS (Automatic Test System) Policy, forms part of the XML (eXtendable Mark-up Language) based IEEE P1671 ATML (Automatic Test Mark-up Language) [2] and, also, has strong support for synthetic instrumentation.

AutoTestCon 2005 included a paper titled 'A Demonstration of Portability' [3], which described the implementation and execution of the same 1641 test definitions on three separate & unique ATS, for an in-service LRU (line replaceable unit). This study also showed how 1641 may be used to describe instrument capability and enable resource allocation (the descriptive part of which, in essence, is being incorporated into ATML).

A second phase of this study exercise has now been undertaken for RF testing, with particular emphasis being placed on the applicability of 1641 to complex levels of testing. Of particular importance is complex measurement.

For this second 1641 study phase, the UUT (unit under test) and ATS are an Aeroflex demonstration LRU and its host AccSynt SI (synthetic instrument) based ATS, respectively.

### *A Definition of Complex Test*

Within 1641, BSCs (Basic Signal Components) define only the most basic of measurement steps (such as <RMS type='Power'…). Where more complex measurements are required, multiple BSCs are connected together to define such measurements as a peak search within a frequency spectrum.

It is this type of measurement (termed 'analysis' within the world of 1641) that this study is intended to demonstrate.

## UNIT UNDER TEST

The UUT (unit under test) chosen for this study is a filter, designed to model certain aspects of an up/down converter LRU, used as part of a spacecraft microwave ($K_u$ band) communication system. This particular unit is more typically used to demonstrate the capabilities of the AccSynt ATS; and, a suite of tests exists to support this. It was from this suite of tests that the complex tests for this study of 1641 were chosen.

## SYNTHETIC INSTRUMENTATION

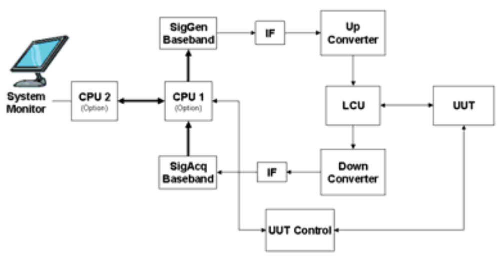


Figure 1 – AccSynt SI Architecture

There is a natural link between 1641 and synthetic instrumentation because of the SML (Signal Modelling Language) that 1641 uses to define the behaviour of its BSCs. Waveform arrays can directly be generated from any 1641 measurement or stimulus signal definition and mapped onto the digitised arrays of a synthetic instrument.

### Verification through Synthesis and Simulation

Although not the ultimate conclusion of this study phase, such a technique as described above is used to verify the test definitions developed.

This comparison was used to form the proof of the applicability of 1641 to define tests which require complex levels of stimulus and measurement.

## TEST SELECTION

The test selection criteria for this study and demonstration of 1641 were:

- Significantly exceed the complexity of those tests seen in the previous 1641 study.
- Be readily understood by all interested parties.
- Complex enough to stress the 1641 environment.
- Supported by the existing software environment on the AccSynt.
- Test programs already available for the AccSynt to enable a comparison of test results & implementation cost vs. 1641 equivalents.
- Tests should comprise both signal generation and signal measurement.

With these selection criteria in mind, the following were selected from the suite of tests available for the AccSynt ATS, showing a selection of typical tests for an LRU used in a spacecraft microwave ($K_u$ band) communications system:

- Spectrum - Common RF test (amplifier, etc) to characterise input/output frequency (pass-band) transfer functions (power out vs. frequency).
- Gain transfer - Common RF test (amplifier, etc) to characterise input/output power transfer functions (power in vs. power out).
- Spur Search - Common RF test (amplifier, etc) to characterise the presence of unwanted spurious signal artefacts (spur frequency, level), including the exclusion of known wanted artefacts.

These tests exceed the complexity of those seen in the previous 1641 study, which were limited to discrete V, I & R measurements, solely in the time domain. *Spur Search* adds the complexity of distinguishing between AOI (areas of interest), which must be identified before a subsequent measurement can be made.

**Such *analysis* is often captured by test equipment as a single test action; however, this hides the details of the test action and can be problematic when sourcing a replacement for an obsolete instrument or designing for interoperability.**

## TEST SIGNAL DEVELOPMENT PROCESS

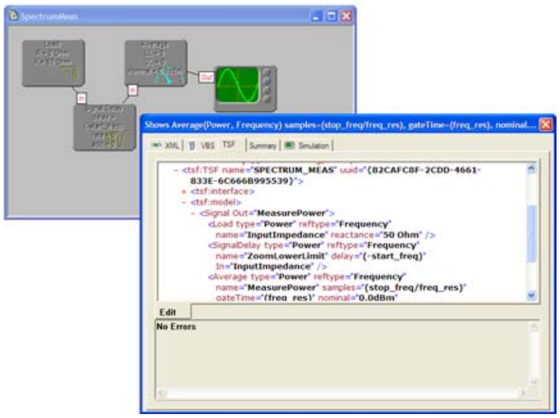


Figure 2 – Test Signal Development

TSFs were designed and validated for this study using EADS T&S's newWaveX's Signal Development environment. newWaveX makes use of the 1641 standard's Signal Modelling Language to produce simulations of signal designs for test verification and, also, implementation verification. newWaveX is also able to output validated, 1641 compliant XML, seen above; and, 1641 compliant IDL (Interface Definition Language) – which was used in this study to produce a 1641 interface, through COM objects, supplying the TSF functionality.

### Test Signal Information

Test signal information came from a variety of sources:

- Test requirements documentation.
- Metrologist, in lieu of IP protected, detailed measurement documentation.
- Existing test code.

It was necessary to look to a variety of sources for test information because, as is almost always the case, many changes are made during test implementation which are not necessarily fed back into the original specification. This was also experienced in phase 1.

According to the IEEE 1641 standard, test definition through signals should capture all the information needed to recreate a test, solely in terms of the UUT. That is, a description of the signal characteristics (both stimulus and measurement) for which test resources must be sourced. This is in contrast to traditional test requirements, which often refer to the test instrumentation available at the time of writing or implementation.

### *Metrology Role in 1641*

Where test algorithms are currently produced by a metrologist – as code or through some other development package – it is suggested by the experience of this study that a 1641 development process should see metrologists producing their test algorithms in the form of TSFs.

### *Test Requirements*

1641 test signals may now be considered the new test requirements. Test requirements written as 1641 signals represent only those actions which must be applied to or measured from the UUT and, as such, are independent of the ATS. This is of great benefit when seeking an open architecture; interoperability; obsolescence management; and, the ability to define an exit strategy (from the point of view of a customer being free to choose or change supplier – and, from the point of view of a supplier, the ability to bid into existing programmes on a level playing field).

## TEST SIGNAL FRAMEWORK

TSFs, developed to implement each of the three tests in this study, are described in the following sections.

## CW_SIGNAL (Spectrum & Gain Transfer Tests)

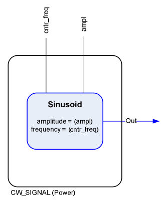


Figure 3 – CW_SIGNAL TSF

A *Sinusoid* BSC, fixed in the Power domain with control over amplitude and frequency attributes.

## SPECTRUM_MEAS (Spectrum Test)

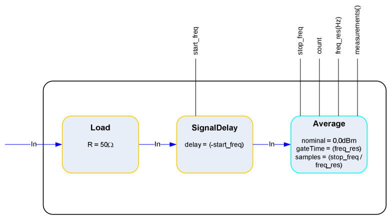


Figure 4 – SPECTRUM_MEAS TSF

A permanent input *Load* of 50 Ω; followed by a *SignalDelay* in the Frequency domain, to exclude frequencies below the start_freq; then, measure the *Average* Power of each freq_res band, up to the stop_freq, to create a 'zoom' into the required frequency range. A nominal value of '0.0 dBm' specifies that Power should be returned as a gain in dB, with reference to 1 mW.

## *A Note on 1641 Tolerance/ErrLmt*

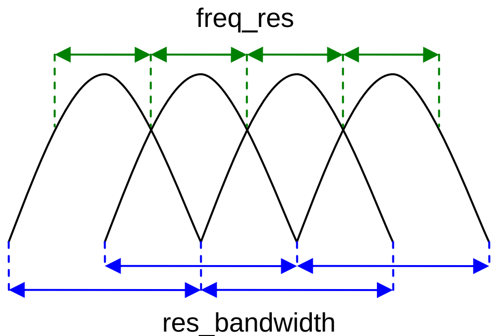


Figure 5 – Frequency Resolution Versus Resolution Bandwidth

It was noted that, in some cases (for example, resolution bandwidth – shown in Figure 5, above), there may be implementation dependent roll-off in the bands used by the algorithm. This may equate to up to 90% error at some points, but approaching 0% elsewhere.

In this case, specifying a single accuracy does not map appropriately to all implementations (test hardware or software algorithms). Therefore, it may be necessary to consider some type of a 'roll-off' modifier, within the standard, to be used in such cases. Roll-off could also benefit specification of filter requirements.

## *IP (Intellectual Property)*

It may be considered that what has happened in the above 'resolution bandwidth' scenario is that a minimum requirement for the test of the UUT has been defined. Whereas, in a traditional test program, the implementation of this test would be required to transport it to an alternative ATS, it can be seen that, with 1641, it has been possible to capture the test requirements without revealing implementation specifics (in other words, without revealing the IP).

For example, a requirement of the Spectrum Test is to view a power spectrum to a frequency resolution related to the UUT signal being measured. Typically, an algorithm specification would contain the windowing method used for the implementation of the test, but this may represent intellectual property or some other reason for not wishing to share the information. Being able to describe the accuracy in sufficient detail, such as those described above could enable an alternative test system can be sourced, without knowing the content of the original vendor's private test implementation specification.

## TONE_POWER (Gain Transfer Test)

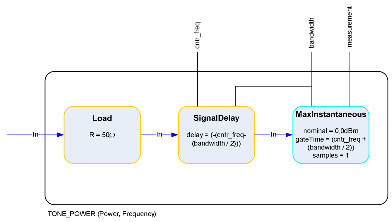


Figure 6 – TONE_POWER TSF

A permanent input *Load* of 50 Ω; followed by a *SignalDelay* in the Frequency domain, to exclude frequencies below the start_freq; then, a measurement of a single *MaxInstantaneous* value, representing the maximum Power value in the whole spectrum. A nominal value of ‘0.0 dBm’ specifies that Power should be returned as a gain in dB, with reference to 1 mW.

### *Missing 1641 Attribute Modifiers*

An improvement to this test might come from one of the areas of improvement currently under consideration for the IEEE 1641 standard: It would be advantageous to specify a ‘resolution’ for the gateTime attribute of the *MaxInstantaneous* BSC, relating to the expected bandwidth of the signal to be measured. Not specifying this characteristic may lead to a resource being allocated which fails to detect the CW_SIGNAL that has passed through the UUT or which detects something else instead.

## SPUR_SEARCH (Spur Search)

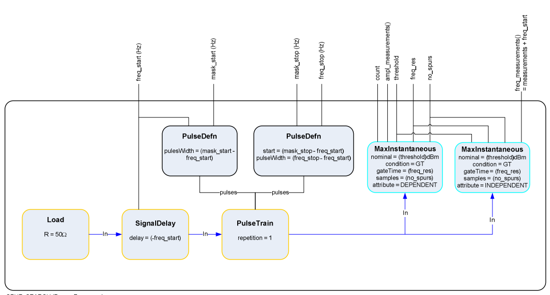


Figure 7 – SPUR_SEARCH TSF

A permanent input *Load* of 50 Ω; followed by a *SignalDelay* in the Frequency domain, to exclude frequencies below the start_freq; then, pulses create masks for the frequency ranges of interest (mask_start to mask_stop). A specified number of *MaxInstantaneous* measurements (being the number of spurs to be detected) are made at the specified frequency resolution (freq_res), where the specified threshold is exceeded.

### *A Note on 1641 Events*

The method used here to create masks of the areas in the spectrum which are of interest is valid and works for this case. However, it may be considered that what was intended was that the masked region of the spectrum should be *ignored* – i.e. it is not necessary to set it to zero power as has been done in the TSF above. This is analogous to the use of the 1641 Gate Event, in the time domain.

Though in 1641 Events can only exist in time, it is considered here that a similar behaviour is required for other domains – such as Frequency.

## Missing 1641 Attribute Formulae

One issue that the SPUR_SEARCH TSF raised is that it can sometimes be necessary to modify read attribute values by formulae. In this case, it was necessary to adjust the measured frequencies (read only) in line with the frequency shift, implemented by the SignalDelay. If this were a single measurement, a formula might be ‘freq_measurement = measurement + start_freq’. In the case of SPUR_SEARCH, it would be ‘freq_measurments[1] = measurements[1] + start_freq; freq_measurments[2] = measurements[2] + start_freq; and so on’ [4].

# 1641 DEMONSTRATION ARCHITECTURE

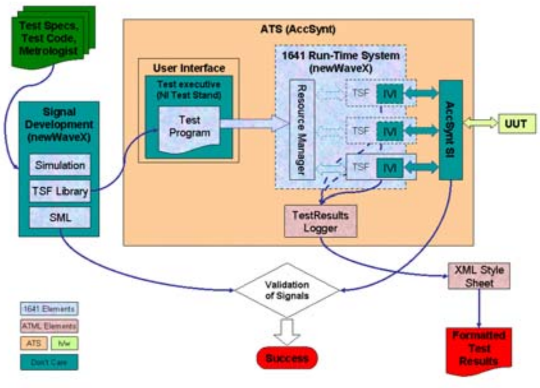


Figure 8 – Demonstration Architecture

Figure 8 shows how the AccSynt and newWaveX were combined to create a 1641 ATS for the purposes of this demonstration; and, how the test programs were created and verified.

## Test Information

Test information was collated and used to develop 1641 TSFs, using newWaveX. Additionally, test verification code was generated in the form of 1641 SML. This enables simulation data to be produced both at design time (to assist with the design process) and during implementation, to verify the correct application and measurement of signals at the UUT.

## Run-Time System

A 1641 run-time system was implemented using newWaveX and installed on the AccSynt to provide a 1641 interface to the AccSynt's SI. The test program, executing in TestStand, makes calls to this 1641 interface to apply and measure signals on the UUT.

# RESULTS

## Comparison of 1641 Vs. Existing Methodology

### *Test Results Data*

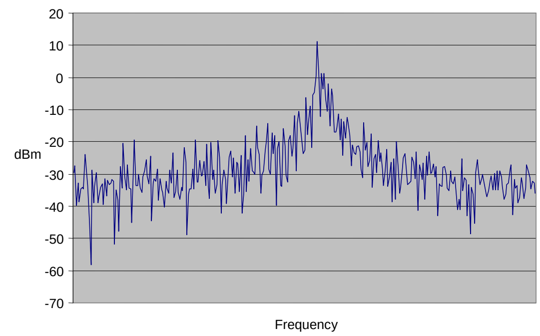


Figure 9 – Raw SI Data, Processed by 1641

Figure 9 shows the results of applying the SPECTRUM_MEAS TSF signal model to the raw data obtained from the AccSynt SI. These test results are identical to those obtained from the AccSynt UI on the ATS.

### *Development Costs*

There was a significant overhead in the transition from the AccSynt's existing test development and run time methodology to IEEE Std. 1641. The general factor governing this overhead was that some aspects of the application of 1641 were not (yet) intuitive to metrologists/test engineers working on the programme.

Given the appropriate training and an already 1641-enabled ATS, it is estimated that implementing test specifications on that ATS will be an order of magnitude faster/cheaper than for an arbitrary ATP (application test package), on a ATS with a proprietary architecture.

### *Speed of Execution*

No significant difference between the existing and 1641 methods was found in the speed of execution for the tests that were implemented as part of this study.

## CONCLUSIONS

Within the scope of this study:

- 1641 appears to be capable of defining typical tests in the power and frequency parametric domains for both conventional and SI ATS

- There is a significant effort required to extract test specification data from traditional or proprietary data processing functions and implement them in 1641.

- No significant differences were observed in test signal generation, data processing, or test speed between the existing AccSynt and 1641 AccSynt methodologies.

- Test implementation under 1641 is potentially an order of magnitude faster than non-standard/proprietary methods, given a 1641-enabled instrument and appropriate training.

- It has been possible to capture the test requirements without revealing implementation specifics (in other words, without revealing – or, at least, reducing the revelation of – IP).

## RECOMMENDATIONS

The following recommendations on IEEE 1641 arose from this study:

- Within a 1641 development process it is suggested that metrologists should produce their output as TSFs, rather than other non-1641 formats.

- Test signals as test requirements are of great benefit when seeking an open architecture, interoperability, obsolescence management and the ability to define an exit strategy (from the point of view of a customer being free to choose or change supplier – and, from the point of view of a supplier, the ability to bid into existing programmes on a level playing field).

- It may be useful to consider some type of a 'roll-off' *modifier*, or equivalent, within 1641, to be used in such cases as filter specification.

- Further support is given by this study to the inclusion of a 'resolution' *modifier for* attributes in 1641.

- Though in 1641 Events can only exist in time, it is considered by this study that a similar behaviour is required for other domains – such as Frequency.

- Just as TSF Interface attributes may be modified by formulae, as they are applied BSCs within the Model, so, too, should techniques be described for modifying attributes that are read from TSF Interface attributes, including arrays.

## REFERENCES


[1] *IEEE Std. 1641-2004, Signal & Test Definition, IEEE, 2004*

[2] *IEEE P 1671, Automatic Test Mark-up Language, IEEE 2004*

[3] *Implementing IEEE 1641 - A Demonstration of Portability, AutoTestCon 2005*

*[4] A Review of Signal-Based Measurement for both Traditional and Synthetic Instrumentation, Utilising IEEE Std. 1641; IEEE; 2005*