Implementing IEEE 1641 - Amplifier Characterisation on Multiple Test Platforms

Matt Cornish
EADS TES (UK) Ltd
matt.cornish@eads-ts.com

Malcolm Brown
DES SE TLS-SP-ATS, MoD
DESSETLS-SP-ATS@mod.uk

Johannes Ganzert
Rohde & Schwarz
Johannes.Ganzert@rohde-schwarz.com

Abstract - **A fourth in a series of studies, sponsored by the UK MoD, explores gain and 1 dB compression point, for a mobile communications device, through IEEE Std. 1641™ Signal & Test Definition [1]. The study adds depth to the use of load, Power and Physical types, along with methods for capability description of test resources, through IEEE ATML [2]. In addition, comparison is made with previous studies, in particular that into RF stimulus & measurement [5]. The implementation platform consists of Rohde & Schwarz's Vector Signal Generator, Spectrum Analyser & Vector Network Analyser.**

The tests are defined using the Standard's Test Signal Framework (TSF); use is made of the Standard's Signal Modelling Language to validate the behaviour of the test signals; IEEE ATML Test Station is used to describe the mapping onto the test resources; an XML document is written to describe the mapping to the test resource IVI drivers; and, an IEEE 1641 defined COM interface is used access these documents. By producing a test program that conforms to the IEEE 1641 defined interfaces, it is shown that the defined tests can be validated, translated to the test platform's native IVI and executed, all using the same source.

Keywords – IEEE; 1641; Signal; ATML; Implementation; IVI

I. INTRODUCTION

As with the previous phases of the MoD IEEE 1641 study programme, this study takes the form of an implementation of a particular set of tests, for a particular UUT (unit under test), on a particular set of test resources. The choice of tests, UUT and test resources have been made to show the applicability of IEEE 1641 to a previously un-trialled area of test.

The selected UUT is a Mini-Circuits® amplifier, typically used in communications, RADAR & instrumentation, in the range 0.02 to 3 GHz.

1 dB compression point has been selected because, though the concept is relatively easy to understand, its implementation can be tedious, prone to error and there exist numerous techniques for its implementation. 1641 signal modelling provides a consistent definition of this measurement, which can be validated independently of its implementation.

Gain (S-Parameter S21) has already been implemented in a previous phase of IEEE 1641 study and, since it is a precursor to the 1 dB compression point measurement, the opportunity will be taken to make a comparison of the two approaches.

A. Instrumentation

Two sets of instrumentation were provided that are able to implement the above tests:

Set 1:
- Rohde & Schwarz Vector Signal Generator R&S® SMJ 100A
- Rohde & Schwarz Spectrum Analyser FSG

Set 2:
- Rohde & Schwarz Vector Network Analyser ZVB 8

All instruments are remote controlled via LAN (Gigabit Ethernet, VXI11).

B. Signal Modelling

newWaveX™ Signal Development, IEEE 1641 graphical signal modelling software, is used to generate and validate XML signal libraries and test definitions.

newWaveX Platform Development is used to create a translation service between the 1641 test program and the IVI test program.

II. BASE-LINE TEST PROGRAM & RESULTS

Test programs were generated in C#, using IVI drivers for the two sets of Rohde & Schwarz test equipment. The test programs were executed against the Mini-Circuits ZJL-3G Amplifier (the UUT) to create the base-line test results, for later validation of the 1641 test programs.

III. TSF (TEST SIGNAL FRAMEWORK) DESIGN

A. UUT Power Supply

This TSF defines the UUT power requirement, for use during testing.

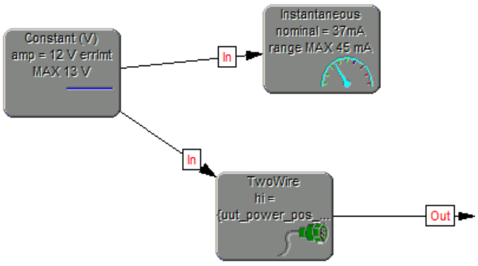


Figure 1 - UUT Power Supply TSF

Figure 1 shows the UUT PSU (Power Supply Unit) TSF. At its most basic, this is a Constant voltage applied to the UUT power pins through a TwoWire connection. In this model, however, the maximum permissible voltage is specified through the 'errlmt MAX' modifier of the Constant's amplitude property, as 13 V.

The current that a UUT might consume has, previously, not been considered in detail, since IEEE 1641 defines tests intentionally independently from their implementation (i.e. the test requirement is for a Constant Voltage; the amount of current drawn is not part of the signal model; a problem being that, if the wrong resource is chosen, the Constant Voltage may not be maintained). However, in order to maximise the efficiency of allocation of a sensible resource, this information is required. For example: A precision voltage supply and a heavy duty power supply may both be capable of supplying a Constant 12 V; the former might have a very small current capacity, whereas the latter may require a minimum current drain in order to provide proper regulation.

In order to indicate the range of possible current drain for the UUT, a concept of 'capability' has been added to the UUT power supply TSF. This stipulates that, during the test, if the Instantaneous current were to be measured, it would nominally be 37 mA, with a range of upto 45 mA (i.e. 37 mA range MAX 45 mA). The Instantaneous BSC (Basic Signal Component) does not have an Out connection, so is, therefore, not a 'test requirement'.

B. RF CW Stimulus

Both 1 dB Compression Point and Gain tests require a known RF (Radio Frequency) CW (Continuous Wave) stimulus signal be applied to the UUT before any measurements are taken.

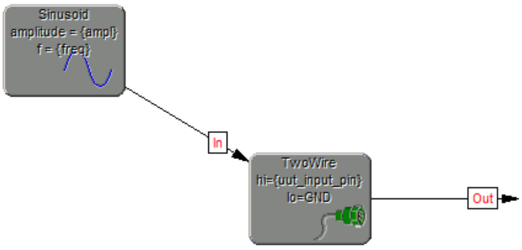


Figure 2 - RF CW Stimulus TSF

Figure 2 shows the RF CW Stimulus TSF.

1) Type Power vs. Voltage

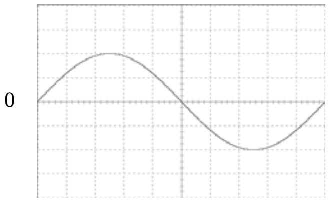


Figure 3 - Example of IEEE 1641 Sinusoid BSC

Figure 3 illustrates the reason for using a 1641 Sinusoid of type Voltage to represent a Power signal. IEEE 1641 signals are modelled in the same way, irrespective of type. For type = Voltage, this is reasonably intuitive. However, for type = Power, the Sinusoid in Figure 3 is not what we require.

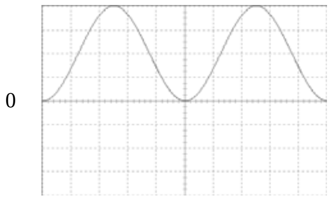


Figure 4 - Example of Sinusoidal Power

Figure 4 shows what we might have expected from a Power signal; i.e. a Product of Voltage and Current.

2) Impedance Matching

In order to apply a Voltage, such that a given power is transferred, it is often required that the impedance of the recipient of the power transfer (in this case the UUT) be known.

IEEE 1641 defines a value modifier, 'load', that is to be used to specify the impedance of a recipient of a power (or similar) transfer, where 'load' has a default value of 50 Ohm.

Note that, in this case, the use of a Load BSC, to represent the input impedance of the UUT, has been superseded by the above use of the 'load' modifier of the Sinusoid's amplitude value.

C. 1 dB Compression Point TSF

A particular approach was taken to define this TSF such that it defines the point where 1 dB compression occurs, rather than a process to locate it.

To locate the 1 dB compression point requires a series of measurements, each iteration based on the previous. By defining the target rather than the process, the implementation independence of 1641 signal-based test definition is shown.

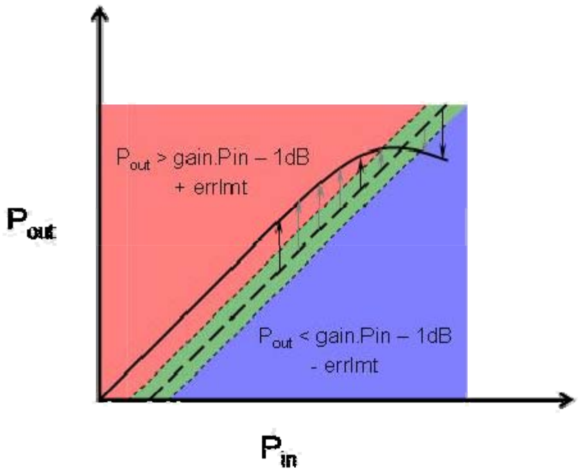
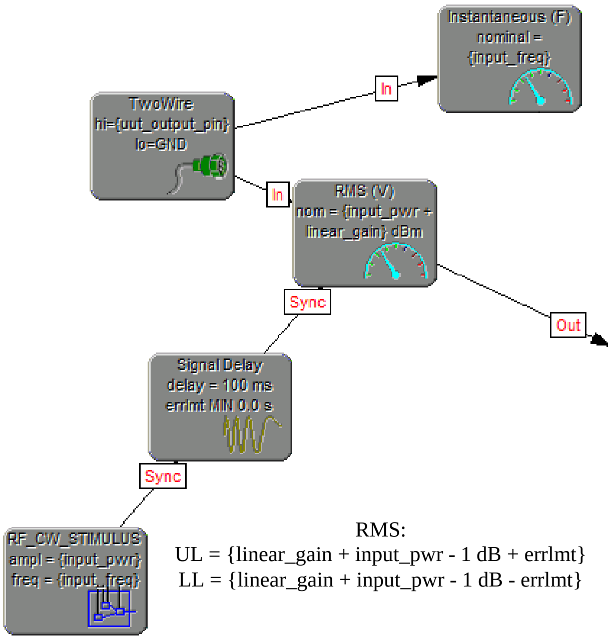


Figure 5 - 1 dB Compression Point Formula

Figure 5 illustrates the formula for determining the 1 dB compression point. The solid black line shows power (in) vs. power (out) for the UUT. It is known that this line will curve downwards as the amplifier runs into 'compression'. The heavier dashed line is calculated to be 1 dB below a line projected upwards from the 'small signal gain' (linear region) until it intersects with the measured line. The finer dashed lines encapsulate the region coloured green, which defines the error limit for the measurement.

The TSF defines attributes to indicate whether the 1 dB compression point has be reached or exceeded and an error limit that creates a region of success around that point.

To measure the 1 dB compression point, a test program typically takes measurements, denoted by the vertical arrows in the diagram, along the solid black line until the measured value is in the region coloured green. These measurements might be in a sequence of very small steps (small enough not to step past the green region); or, might be initially large, stepping back & reducing in size each time the green region is stepped past. This illustrates the implementation independence of IEEE 1641.



RMS:
UL = {linear_gain + input_pwr - 1 dB + errlmt}
LL = {linear_gain + input_pwr - 1 dB - errlmt}

Figure 6 - 1 dB Compression Point TSF

Figure 6 shows the TSF design for the 1 dB compression point test.

By including the RF_CW_STIMULUS, through a Sync connection, the TSF is defining that the stimulus signal must be applied to the UUT before the measurement is taken. A SignalDelay is used to define a minimum settling time for the UUT.

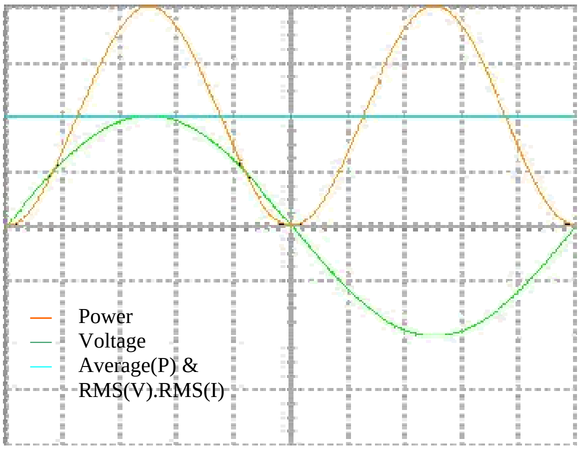


Figure 7 – Example Average Power vs. RMS(V).RMS(I)

Figure 7 illustrates the how correct RMS measurement of Power may be achieved through a product of Voltage and Current measurements. This would, in fact, be mathematically equivalent to an IEEE 1641 Average Power measurement (i.e not RMS Power).

Note that, in practise, it is not necessary to measure the RMS current, since this can be calculated from the voltage and input impedance.

Note, also, that, where voltage and current are out of phase with each other, an Average Power model may be more appropriate.

D. Gain TSF

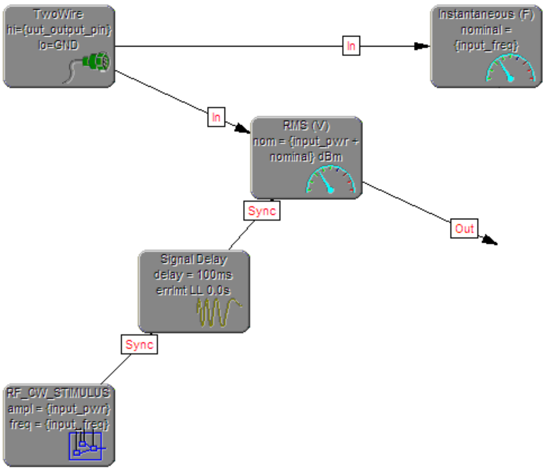


Figure 8 - Gain TSF

Figure 8 shows the TSF design to determine gain. Key points to note are the inclusion of the RF_CW_STIMULUS TSF, used to sync the measurement; the RMS measurement of type voltage, used to measure power; and, the Instantaneous frequency measurement, used to specify capability requirement.

These points will not be discussed here as they have already been covered in section III.C - 1 dB Compression Point TSF.

E. IEEE 1641 Demo Phase II - Gain Transfer TSFs

For Brevity, the IEEE 1641 Demo Phase II Gain Transfer TSFs will not be detailed here. This information can be found in either of AutoTestCon paper [4] or full report [5].

Note that two TSFs were provided to implement gain transfer; one stimulus and one measurement. The formula to calculate the gain from these two TSFs resides in the test program, in this case. Also, that the measurement is made in the frequency domain (i.e. spectrum analysis), whereas the TSFs defined in this phase measure in the time domain.

IV. SIMULATION

In order to simulate the defined tests, C# test programs were written to call the above TSFs.

newWaveX, providing the signal modelling environment, was used to export the TSF libraries in IDL and XML formats. The IDL was compiled to create a 1641 compliant interface wrapper through which the C# test program could call newWaveX's simulation framework.

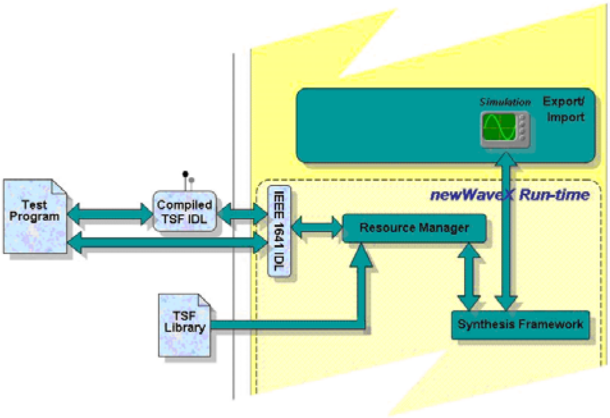


Figure 9 - newWaveX IEEE 1641 Interface

Figure 9 illustrates the architecture of the simulation, showing the exported IDL interface, along with the XML TSF library, which contains the definitions of the TSFs signal models, used for simulation.

A. UUT Modelling

In order to create the test simulations, a mock UUT was implemented using Attenuator (with a gain greater than 1) & Limit BSCs and this is shown in Figure 10. The Attenuator is used to model the small signal gain (linear region of the amplifier) and the limit provides a basic model of the gain roll-off region of the amplifier.

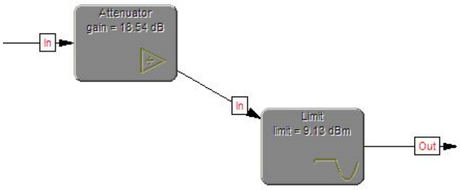


Figure 10 - Modelling the UUT Using 1641 BSCs

B. 1 dB Compression Simulation Results

The UUT model serves to show that the 1 dB Compression & RF CW Stimulus TSFs are able to detect the output level of the UUT at the point where its gain falls 1 dB below its small signal gain. This is, naturally, the same value as that of the Limit BSC and this value is correctly measured to be 9.13 dBm.

C. Gain Simulation Results

Again, the UUT model shows that the signal model correctly measures the value entered. In this case, the gain of the Attenuator is correctly measured by the Gain TSF as 18.54 dB.

D. IEEE 1641 Demo Phase II Gain Transfer Simulation

In order to provide a meaningful simulation of the Tone Power TSF, real waveform data was downloaded from the Rohde & Schwarz Spectrum Analyser, during an execution of the baseline test program.

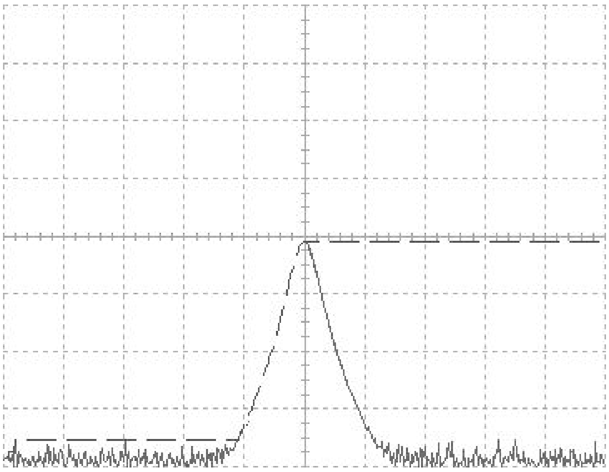


Figure 11 - Tone Power TSF Simulation

Figure 11 shows the simulation of the Tone Power TSF, using actual data from the execution of the gain test in this demonstration phase. The real waveform data is the lower trace in the graph and the measured tone power is the dashed upper trace. Again, the measured value for the gain was correctly determined to be 18.49 dBm, consistent with the base-line test results.

The significance of this effort is that it has been shown through IEEE 1641 signal modelling & validation that both the Phase II and Phase II.V tests can be implemented interchangeably, across multiple test platforms, with predictable results.

V. IVI TEST PROGRAM

The final stage of this study was to use the 1641 test program produced for simulation to produce a validated IVI test program, to implement the tests on the Rohde & Schwarz Vector Signal Generator, Spectrum Analyser and Vector Network Analyser.

A. IEEE ATML Capability Description

The use of an instrument capability description, in terms of IEEE 1641 signals, is well documented, in particular IEEE 1641 Demo phase 1 [3] and subsequently IEEE ATML [2] Instrument Description & Test Station.

ATML provides two principal methods to describe instrumentation capability: Instrument Description and Test Station. Instrument Description describes instruments on an individual basis and Test Station deals with capabilities that may be the product of more than one instrument. Since this study requires capabilities that are distributed across more than one instrument, the decision was taken to create a single Test Station Description.

An instance of ATML Test Station was produced to describe the capabilities of the Rohde & Schwarz signal generator, spectrum analyser and vector network analyser in terms of the TSFs defined by this study. An XSD for the TSFs, needed for validation, was exported from the signal model in newWaveX.

B. Extracting Signal-based Capability Information from an Instrument Datasheet

There is significant complexity in determining signal-based capability information for such complex instruments as those used in this study and it is beyond the scope of this paper to discuss. A brief summary of the issues is provided below:

Spectrum Analyser: For the measurements in this demo, absolute and relative level accuracy are the relevant parameters.

Since all measurements are done at one frequency, the level linearity is the key parameter for the accuracy of the gain measurements. However, absolute level accuracy is relevant for the compression point measurement.

Signal Generator: If the test system is calibrated, the signal generator does not contribute to measurement accuracy, because the actual output level of the signal generator is determined during calibration.

Network Analyser: The gain measurement is one of the fundamental measurements performed with a network analyser. Gain accuracy translates to transmission measurement accuracy.

Calibration: In order to provide the specified measurement accuracy, a reference measurement must be made for normalisation. This normalisation eliminates the level accuracy error of the signal generator. This calibration step, required to initialise the test station to its specified accuracy, may also be described using ATML.

C. IEEE 1641 to IVI Translation

The programming interface elements defined by IEEE 1641 (e.g. Require, Run, Change, etc), along with elements for attributes, are used in an XML schema document, by newWaveX, to capture the native driver code (e.g. IVI) required to implement each of those elements. This enables a translation between IEEE 1641 signal requirements into instrument driver specific code (e.g. IVI). An instance document using this XML schema was produced, describing the IVI driver functions for the Rohde & Schwarz signal generator, spectrum analyser & vector network analyser, corresponding to the IEEE 1641 capabilities, defined in the ATML Test Station instance.

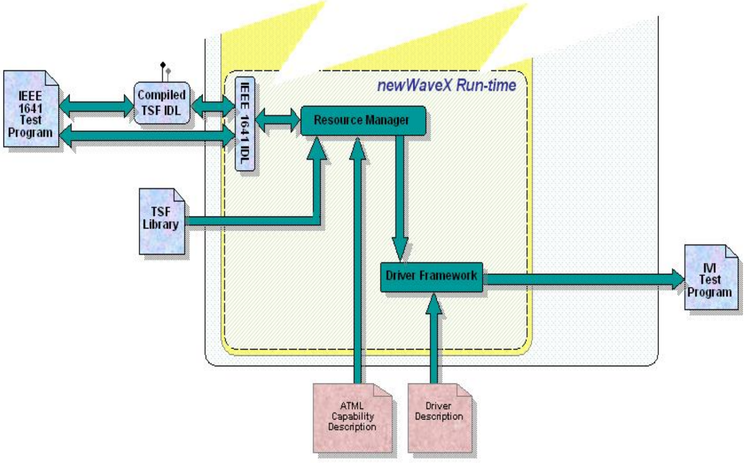
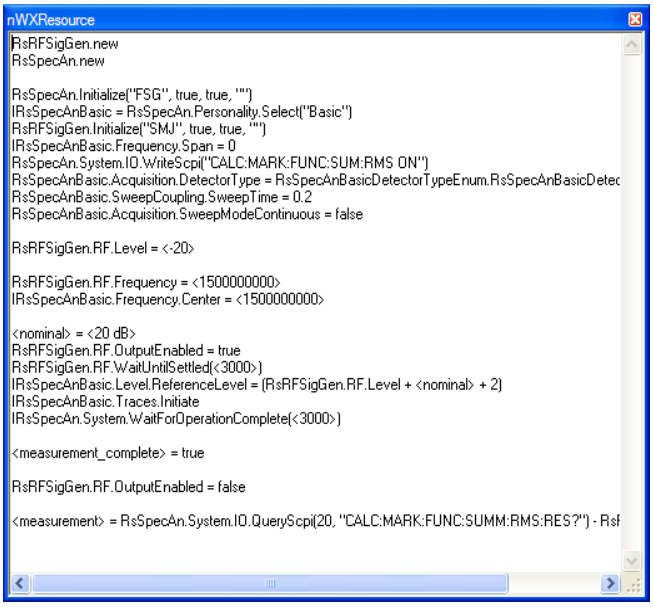


Figure 12 – Signal to Driver Translation Process

Translation from IEEE 1641 to IVI is achieved by matching the signal requirement in the 1641 test program (typically the TSF) to the signal capability in the ATML Test Station document. The resource identified in the Test Station document is located in the in the driver description and the IVI driver commands are assembled. Figure 12 shows an illustration of this process.

Now, when the test program is executed, the corresponding IVI driver code is output, as shown in Figure 13, and may be substituted into the test program to produce to produce the final IVI test program.

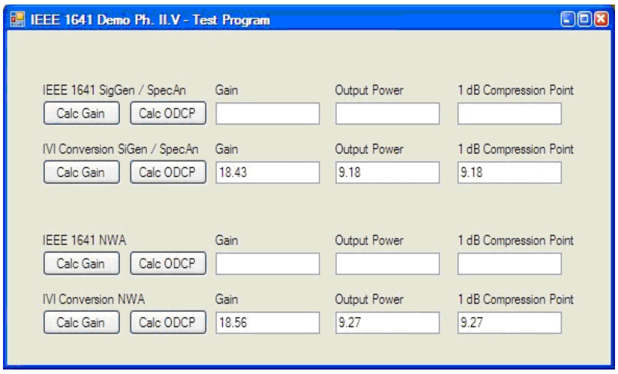


```
RsRFSigGen.new
RsSpecAn.new

RsSpecAn.Initialize("FSG", true, true, "")
IRsSpecAnBasic = RsSpecAn.Personality.Select("Basic")
RsRFSigGen.Initialize("SMJ", true, true, "")
IRsSpecAnBasic.Frequency.Span = 0
RsSpecAn.System.IO.WriteScpi("CALC:MARK:FUNC:SUM:RMS ON")
RsSpecAnBasic.Acquisition.DetectorType = RsSpecAnBasicDetectorTypeEnum.RsSpecAnBasicDetec
RsSpecAnBasic.SweepCoupling.SweepTime = 0.2
RsSpecAnBasic.Acquisition.SweepModeContinuous = false

RsRFSigGen.RF.Level = <-20>

RsRFSigGen.RF.Frequency = <1500000000>
IRsSpecAnBasic.Frequency.Center = <1500000000>

<nominal> = <20 dB>
RsRFSigGen.RF.OutputEnabled = true
RsRFSigGen.RF.WaitUntilSettled(<3000>)
IRsSpecAnBasic.Level.ReferenceLevel = (RsRFSigGen.RF.Level + <nominal> + 2)
IRsSpecAnBasic.Traces.Initiate
IRsSpecAn.System.WaitForOperationComplete(<3000>)

<measurement_complete> = true

RsRFSigGen.RF.OutputEnabled = false

<measurement> = RsSpecAn.System.IO.QueryScpi(20, "CALC:MARK:FUNC:SUMM:RMS:RES?") - Rsf
```

Figure 13 - newWaveX Resource Manager Code Generator Window

D. *Executing the IVI Test Program*

When the Generated IVI test program is executed on the two sets of Rohde & Schwarz test equipment, the results are displayed in the dialog shown in Figure 14. These results match those obtained in the original base-line.


IEEE 1641 Demo Ph. II.V - Test Program

	Gain	Output Power	1 dB Compression Point
IEEE 1641 SigGen / SpecAn			
IVI Conversion SiGen / SpecAn	18.43	9.18	9.18
IEEE 1641 NWA			
IVI Conversion NWA	18.56	9.27	9.27

Figure 14 – Executing the IVI Test Program

VI. CONCLUSIONS

A validated path has been shown between IEEE 1641 signal-based test definitions and the resources used to implement them. Furthermore, the implementation of these tests through IVI presents a portable driver framework that is the native programming environment of choice for the implementer.

Resolution has been provided on the use of IEEE 1641 to define input and output impedances; that are particularly relevant to the test domain that is the chosen subject for this study.

Again, pertinent to the domain of study, it has been shown how Power (W) may be better represented through the use of Voltage (V), when applied through a matched impedance.

It has been shown how Sync (IEEE 1641 synchronisation provider) can been used to define a sequence of what might otherwise have been a sequence of test steps in a test program. This approach secures the entire test definition in one place, rather than spread between two data files.

Distinct from previous approaches, it has been shown how TSFs (in particular, the 1 dB compression point) can be implemented in different programmatic sequence, while retaining the same test definition. In particular, it has been shown how different programmatic sequences open up the use of these TSFs to re-implementation to provide improved execution speed.

A concept of ‘capability requirement’ has been presented, to capture information essential to resource allocation. For example, the current that the UUT might draw leads to a capability requirement on a power supply.

Comparison with the Phase 2 TSFs for gain transfer has shown the equivalence of signal definitions based in the time and frequency domains. This equivalence has been shown through the Standard’s Signal Modelling Language and shows how seemingly disparate resources may be compared using automated techniques.

The use of automated software tools (in this case, newWaveX) has been shown generating and exchanging the XML, XSD & IDL signal definition formats provided for by the Standard. In particular, the IDL has be shown used to develop programming interfaces for the TSFs, to enable their use in C# test programs.

ATML Test Station Description has been used to provide automatic resource allocation, through software tools (in this case newWaveX). This has been supplemented with an XML file describing IVI driver functions, to automatically translate IEEE 1641 into IVI. This represents a distinct difference from previous run-time implementations of 1641 test programs to what might be considered a compile-time approach to the native conventions of a test system.

VII. RECOMMENDATIONS

One of the purposes of this programme of studies is to clarify and reinforce the correct use of the IEEE 1641. Full details are provided in the report: [6] IEEE Std. 1641™ Demo - Gain & 1 dB Compression Point, with a Translation to an IVI Implementation, through Signal Description of Test Resources

VIII. REFERENCES

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[2] IEEE Std. 1671™–2008, IEEE Standard for Automatic Test Mark-up Language

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