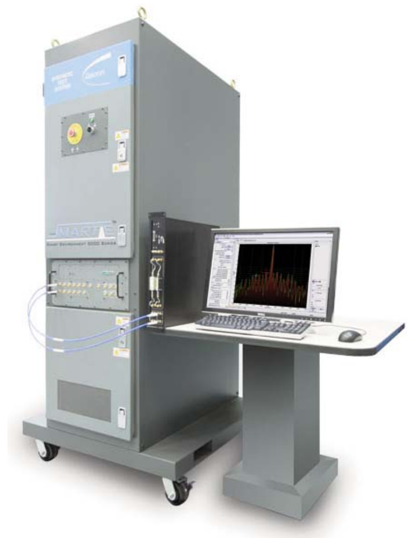
SMART^E™ 5000

SMART ENVIRONMENT 5000 SERIES

5100 T/R Module Test Environment

AEROFLEX
A passion for performance.



- **Complete Synthetic Test Environment**
  Hardware, software, processes, support
- **Optimized for T/R Module Test**
  Test module subassemblies, modules and multi-module assemblies on one system
- **Highest Test Throughput Available**
- **Proven Systems Deployment**
  5th generation solution – major customers worldwide
- **Full Range of Required Mixed Signal Capabilities**
  DC, digital, analog, RF/microwave
- **System Level Architecture**
  Calibration, verification, alignment
- **Open System Architecture**
  System hardware and software, TPSs

The SMART^E 5100 is a complete test environment for testing T/R (and other RF/microwave) modules. It provides the stimulus and measurement resources required for performing a complete suite of transmit and receive mode tests to ensure that the amplitude and phase control functions meet their specifications. The environment is particularly adept at high fidelity error-corrected s-parameter measurements at very high throughput rates.

The SMART^E 5100 T/R Module Test Environment is a member of the SMART^E 5000 Series, which is a complete test solutions environment from Aeroflex. The Model 5100 encompasses hardware, software, test practices and support along with standard and customizable test programs tailored to the specific problems of testing high performance modules utilized in a variety of phased array radars. The unique combination of integrated tests, system calibration methods and greater throughput in the 5100 provides a superior solution for the testing of the thousands of modules required for phased array radar.

The Aeroflex SMART^E 5000 Test Environment is based upon the 5th generation evolution of Aeroflex's synthetic test technology. Aeroflex synthetic test systems are successfully deployed in a variety of high performance test applications including satellite payload test, advanced T/R module test and military ATE.

Aeroflex began shipping synthetic test systems for T/R modules in 2001, providing the industry's highest available throughput and accuracy for testing of T/R modules. The product roadmap has evolved over the past several years from two-rack systems populated with proprietary components to systems composed primarily of COTS components at about half the size and cost of the initial systems. With these test systems, customers have reduced complex module test times from hours to, nominally, 5 minutes for the same test suite.

SMART^E 5140 40 GHz T/R Module Test Environment

SMART^E fundamentally brings about the advantages of integrating COTS system components from multiple vendors in the Aeroflex hybrid test environment thus providing a cost effective test solution fully optimized for the requirements of the devices to be tested.

The SMART^E 5100 provides greater configurability through COTS modularity characterized by the use of recognized and well established industry standards, a highly developed software suite, proven operational test practices, and long-term, leadership support programs. The finely balanced combination of these attributes is what makes SMART^E a complete environment offering with the convenience and advantages brought by a single-vendor system responsibility.

Synthetic test environments offer the lowest total cost of test, largest throughput increases, and typically take less than half the rack space, weight, and power consumption/heat generation of conventional, rack-and-stack instrument-based systems. In addition, even for hybrid configurations, the number of instruments and associated dedicated measurement paths is reduced. Thus, the scope and complexity of calibration is also reduced. Furthermore, since most groups of measurements for any given configuration utilize the same down-converter – digitization channel, there is a much greater time correlation and lower uncertainty among these measurements than when individual instruments are sequentially multiplexed.

Typical SMART^E 5100 Characteristics

A SMART^E Model 5100 T/R Module Test Environment may be flexibly composed of various combinations of the following hardware, software and support elements.

Hardware

Stimulus Subsystem Including

- One or more Synthetic RF/microwave stimulus channels operating from DC to 8, 12, 20, 26.5 or 40 GHz in pulsed, CW or AWG source modes
- Noise generator
- Auxiliary stimulus channel(s) for multi-tone measurements or other multi-source applications
- Power amplifier units
- High performance digital I/O (DIO) modules up to 100-MHz clock rates in configurable control word widths and serial bit depths, with timing synchronized to the T/R control signals and pulse modulation edges
- General purpose DIO modules providing up to 400 MHz clock rates at LVDS levels, up to 200 MHz at programmable levels
- Configurable COTS DC modular or other DC power supplies
- Numerous choices of other mixed signal stimulus components.

Measurement Subsystem Including

- One or more synthetic RF/microwave response measurement channels configured for operation to 8, 26.5 or 40 GHz with an RF bandwidth of 400 MHz, and either narrowband or both narrowband and broadband digitizer subsystems
- Optional auxiliary measurement channels implemented as synthetic channels or as specific purpose instrumentation components
- Switched low-noise amplifier units
- Interrupt-enabled DC power supply monitoring subsystem with programmable limits
- High performance digitizers which may be used for any of a variety of signal capture functionalities.

Signal Calibration and Routing

- Local Calibration Unit (LCU) for calibrating RF/microwave signals to NIST traceable standards
- RF Switch matrix for multiplexing RF/microwave I/O signals to multi I/O-port UUTs – standard and customized designs available
- s-parameter test set for microwave vector measurements

Software

- Microsoft Windows® operating system with Microsoft Office®
- National Instruments TestStand - Test Management Software
- Aeroflex Measurement Console (AMC) - sequencer and user operating interface
- Aeroflex designed API DLL functions enabling customer driven interfaces to be connected to the system
- T/R module measurements library
- General measurements library
- Test customization
- Simulator software

Test Practices

- Hierarchical Calibration
  - Base, operational, reference plane extensions
  - Base Cal requires calibration of only a few transfer standards, not the synthetic components (i.e., the test environment does not require disassembly)
- System verification while the Unit-Under-Test (UUT) is connected
- Built-in reference plane extension from the calibration plane to the test ports plane via measurements or s-parameter files
- Uncertainty specifications at the system level

Support

- System Diagnostics to Field Replaceable Unit module level
- Regional spares pools
- Guaranteed response-time service
- Customer self-support training
- Remote expert direct connect – assistance via internet

T/R Module Testing Using the SMART^E 5100

Aeroflex has more than seven years of experience in fielding synthetic test systems specifically configured for T/R modules used to build state-of-the-art phased array radar systems. Customers also utilize these same systems for testing sub-system components associated with these modules as well as RF/microwave components and subsystems in general.

There are numerous similarities among T/R modules across the many vendors who supply them. On the other hand, no two modules are exactly alike and no two manufacturers have precisely the same test strategies and methodologies. Consequently, while there are many common core elements among each of the T/R module test systems implemented and sold by Aeroflex, there are also unique aspects for systems provided to any single customer.

From a test system vendor perspective, the objective is to create a tester solution based upon a necessary and sufficient core capability set which addresses the common aspects of T/R module test but remains flexible enough that it can be easily customized to match the unique requirements of any given module and associated customer.

In moving to its 5th Generation SMART^E test environments, Aeroflex first changed the implementation of the core RF/microwave functions to be more modular in terms of the frequency ranges and power characteristics to be provided for the various applications. In fact, T/R modules operate at different frequencies and different power levels depending upon the system application/mission to which they are applied. Frequency and power are two of the most basic cost drivers for microwave equipment. Consequently, the most cost efficient solution is inevitably going to be associated with the test system that optimally and dynamically matches the range of frequency and power characteristics of the modules to be tested.

Thus, configuration of a SMART^E solution begins with the selection of the stimulus and measurement channel modular base components associated with the required operating frequency ranges. Subsequently, an assessment is made for the selected modules to be able to handle the overall power levels required by the test plan and T/R module characteristics. As a result, either standard modules/system input/output power will be sufficient, or a customized variable attenuator/power amplifier subsystem option will be seamlessly added to the standard modular solution. Like power levels, signal routing and multiplexing may also be implemented by means of standard or customized sub-assemblies to address specific module characteristics. Each module to be tested may include a single T/R circuit or multiple T/R circuits. All modules must be tested with minimal uncertainty for phase and amplitude control characteristics – typically 64 to 256 amplitude states and 64 phase states controlled via a digital command usually in a serial format. Amplitude and phase error corrected vector measurements are core requirements and an s-parameter test set is a standard element of the test system.

The s-parameter test set provides the forward and reverse ports which can be applied to all transmit and receive port-combinations associated with the T/R module function. Transmit tests are usually pulsed while receive functions are tested in CW mode.

Accordingly, the Model 5100 provides modular capabilities for pulse generation and digital I/O requirements and timing relationships are programmable and very tightly controlled. The fundamental DIO control is implemented via 32-bit modules operating at the tester interface at LVDS levels. Level circuits for LVDS levels translation may be integrated into the DIO interface either at the test interface panel or remotely in order to optimize pulse fidelity.

While a variety of COTS options are available for the digital functionality required in the tester, the Aeroflex modules are designed for minimum programming overhead. Since the fundamental control of the T/R module is an "inside test loop" function which is exercised every time a state of the T/R module is changed during a test, throughput optimization requires that the overhead costs of this programming be minimized. The Aeroflex implementation is optimally designed to fully minimize this cost function.

Pulse generator modules provide combinations of edge and pulse width programmability with internal and external synchronization and clocking, four sets of PRF, delayed edge and pulse width events from a module, with multimodule configurations also supported. This collection of signals and states is utilized for T/R modulation as well as for any of a variety of required time-based event programming.

The Aeroflex supplied standard tests library designed to address these types of tests is reported in Table 1.

s-parameters	Frequency
DC Control	Pulse Measurements
Harmonics	Spurious
Noise Figure	Third-Order Intercept
Pout vs. Pin	Total Absorbed Power

Table 1. T/R Module Test Library

A typical T/R module test plan with the associated test sequences is briefly reported in Table 2.

Typical Module Test Plan	
TX	RX
s-parameter (pulsed)	s-parameter (CW)
Phase Setting	Phase Setting
Amplitude Setting	Amplitude Setting
Pout versus Pin	Pout versus Pin
Power Added efficiency (PAe)	Third-Order Intercept (TOI)
Total Absorbed Power	Total Absorbed Power
Harmonics	Noise Figure
Spurious	
Pulse Profile	
Amplitude and Phase	
Droop Across Pulse	

Table 2. Typical T/R Module Test Plan

In developing the SMART^E environment for the new Model 5000 Series product, Aeroflex has introduced a universal test management interface called the Aeroflex Measurement Console (AMC). From this interface the test engineer or operator may select and execute tests, create sequences of tests, input variable parameters, access test results, set up default settings and parameters, and perform a wide variety of test related functions.

Figure 1 illustrates the topology of the AMC User Interface. This includes a tree view of test sequences saved in a file, an area for user interactive input of variable parameters presented by the test sequence, and a window for viewing the results of the tests. Test data are presented in graphs, and tables and records of various scalar values associated with the test. Examples include test execution times and all the parameter settings active at the time of execution of the test, as well as error logs or logs of the steps individually followed in executing the test.

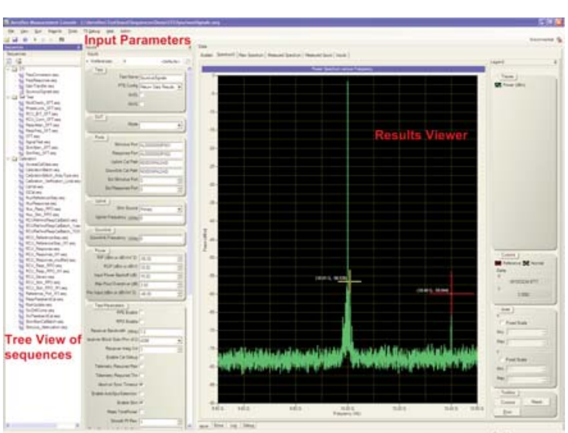


Fig 1. Topology of the Aeroflex Measurement Console (AMC)

Figure 2 depicts the application of the AMC to a T/R module test sequence when a pulse characterization test has been executed and displayed in a graph showing pulse shape as a function of time.

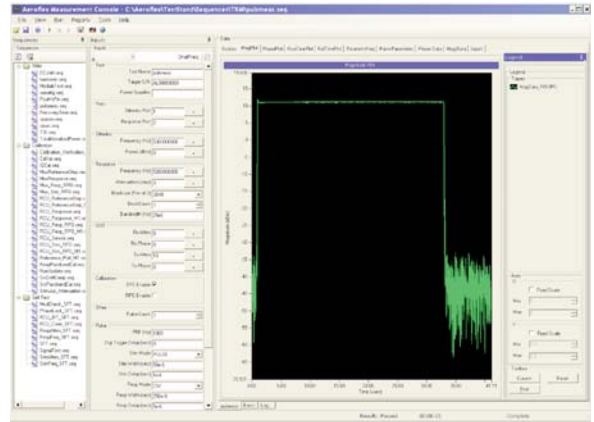


Fig 2. Transmit Mode Pulse Measurement

Selecting another tab in the results display window (Figure 3) provides access to the rise time characteristics of the pulse as derived from the magnitude-time samples which were measured.

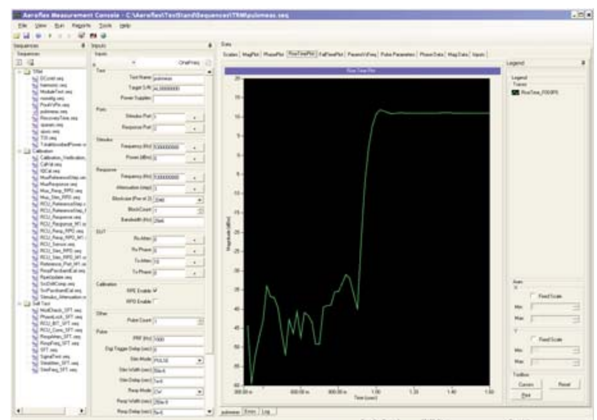


Fig 3. Transmit Mode Pulse Risetime

The test results area is programmed as a tabbed window where various result format choices and derivative tabulated data sets may be presented as seen in Figure 4. Results can be automatically saved to files with formula names reflecting tests, and date and time of execution. Integration with existing data storage schemas is easily implemented. All results can be exported to Excel and XML.

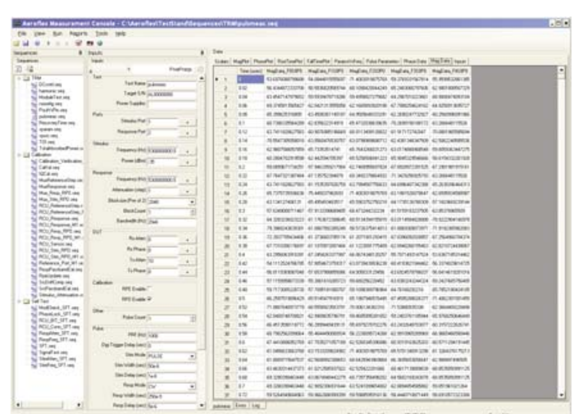


Fig 4. Tabulated Measurement Results

In this case the test system utilizes one of two digitizers configured in the baseband of the measurement response channel; one for narrow band measurements and one for broadband measurements, to be applied to time measurements such as rise time.

The test results may be transferred to an Excel workbook with the tabbed results mapped to spreadsheets on a one-to-one basis as illustrated in Figure 5.

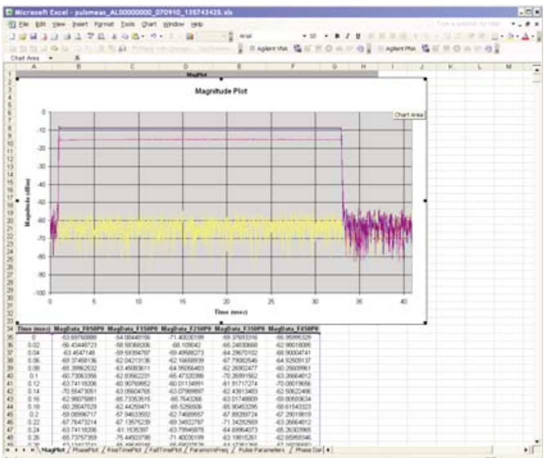


Fig 5. Test Results Exported to Excel Workbook

Graphical analysis and interpretation tools are provided in conjunction with the results window. Figure 6 shows the results of an s21 measurement with markers activated for interactive use in interpreting the results of the sparameter measurement.

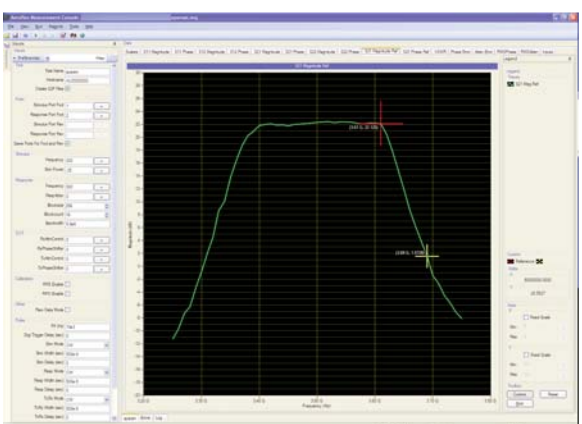


Fig 6. s-parameter Plot with Cursors Activated

SMART^E 5100 Summary Options

The following table lists the baseline components and options for the 5100.

Item	Description
Frequency Ranges	Base system frequency coverage: ■ 50 MHz to 8 GHz Options: ■ Extend stimulus and response to 12 GHz ■ Extend stimulus and response to 20 GHz ■ Extend stimulus and response to 26.5 GHz ■ Extend stimulus and response to 40 GHz
Output Power (typical)	Base system output power: ■ 0.5 to 8 GHz 12 dBm ■ 8 to 12 GHz 12 dBm ■ 12 to 20 GHz 9 dBm ■ 20 to 26.5 GHz 5 dBm ■ 26.5 to 40 GHz 0 dBm High power options available up to 30 dBm
Stimulus Modulation Modulation Options:	Base system modulation: ■ CW, pulse ■ AM, FM, PM ■ Narrowband arbitrary stimulus waveforms ■ Wideband arbitrary stimulus waveforms
Number of Ports	Base system ports: ■ Two bi-directional ports (typically forward and reverse) Options: ■ 6 ports and 12 ports ■ Other customer options available
Additional Sources	One or more additional sources available
DUT Control	Baseline: ■ 32 bits at 50 MHz or 16 bits at 100 MHz, LVDS ■ Up to 4 programmable timing signals (pulses) Options: ■ Level shifting to any customer defined levels ■ Additional timing signals (pulses) ■ PXI COTS digital I/O
DUT Power Supplies	Options: ■ 50/100 W modules in programmable mainframe ■ High current individual programmable power supplies
Standard Available Measurements	■ Pout vs. Pin ■ Output power ■ s-parameters ■ Spurious ■ Harmonics ■ Third-Order intercept (TOI) ■ Noise figure ■ Pulse measurements ■ Total absorbed power ■ DC control

PERFORMANCE SPECIFICATIONS

- ***TR Module testing features***
  - *The SMART^E 5100 configuration is optimized for measurements of TR modules*
  - *The SMART^E provides CW and pulsed high power measurements*
  - *Control of the Device Under Test (DUT) is tightly coupled with measurements*
  - *DUT control is provided via a programmable pattern generator and interfaced via a DUT.dll that may be developed by the customer*
  - *Programmable DUT power supplies can be included in the system and are tightly integrated with the data collection*
- ***SMART^E 5100 Performance Specifications***
  - *The stimulus, response and measurement performance of the SMART^E 5100 system is specified for typical operating conditions*
  - *The majority of the specifications apply at the forward and reverse ports of the system*
  - *Some measurements are specified at both the forward and reverse ports as well as at the interface ports of a standard Aeroflex 12 port MUX*
- ***The following measurement types are supported by the SMART^E 5100***
  - *DUT operating voltages and power consumption*
  - *Output power vs. input power and DUT efficiency*
  - *RF Frequency*
  - *Harmonic Levels*
  - *Noise Figure*
  - *Time Domain pulse measurements; rise and fall times*
  - *DUT recovery time*
  - *Fully corrected s-parameters, both CW and pulsed*
  - *Spur Searches*
  - *Two-Tone measurements and third-order intercept*
- ***The performance is specified for the following measurement elements***
  - *RF Power*
  - *S-Parameter*
  - *Spectrum*
  - *Noise Figure*
  - *Time Domain*
  - *Frequency*

The following tables list the specifications for the SMART^E 5100. Specifications are subject to change without notice.

STIMULUS SPECIFICATIONS

PARAMETER

Frequency Range

50 MHz to 40 GHz

Frequency Setability Resolution

4 Hz (RF Stimulus Channel)

Maximum Output Power

	LCU (dBm)	MUX (dBm)
0.5 to 5 GHz	12	11
5 to 8 GHz	12	10
8 to 12 GHz	12	10
12 to 20 GHz	9	5
20 to 26.5 GHz	5	0
26.5 to 40 GHz	-3	-10

OUTPUT POWER RANGE

<2 GHz

95 dB

>2 GHz

100 dB

Output Power Resolution

0.02 dB

Spectral Purity

General spurious	-60 dBc
Power line related	-50 dBc

Modulation Capability

CW, Pulse, Arbitrary[1]

Calibration Uncertainty

0.05 to 18 GHz	+ 0.2 dB
18 to 26.5 GHz	+ 0.3 dB

At LCU interface Typical values. Actual values should not exceed these by more than 3 dB

26.5 to 40 GHz	+ 0.5 dB
0.05 to 18 GHz	+ 0.3 dB
18 to 26.5 GHz	+ 0.4 dB At MUX interface
26.5 to 40 GHz	+ 0.6 dB

Phase Noise

Phase noise values are in dBc/Hz

FreqOffset	0.05-8 GHz	8-26.5 GHz	26.5-40 GHz
10 Hz	-65	-50	-45
100 Hz	-80	-75	-65
1 kHz	-90	-90	-85
10 kHz	-90	-90	-85
100 kHz	-110	-110	-100
1 MHz	-120	-120	-110

Notes:

1. Requires Arbitrary waveform generator option.

RESPONSE SPECIFICATIONS

PARAMETER

Frequency Range
50 MHz to 40 GHz

Power Measurement Range
+30 to -100 dBm (Noise floor is lower)

Residual Noise Level
< -110 dBm Residual (Noise Level with Input Terminated)

Maximum Input Power (Average)
2 Watt Reverse port, at Input Attenuator >0
High power dissipation loops/pads
required in MUX for higher power

Maximum Input Power (Pulsed)
30 Watt Pulse width ≤ 250 µs

Calibration Uncertainty At LCU interface

0.05 to 18 GHz	+ 0.2 dB
18 to 26.5 GHz	+ 0.3 dB
26.5 to 40 GHz	+ 0.5 dB

Calibration Uncertainty At LCU interface At MUX interface

0.05 to 18 GHz	+ 0.3 dB
18 to 26.5 GHz	+ 0.4 dB
26.5 to 40 GHz	+ 0.6 dB

S- PARAMETER MEASUREMENT SPECIFICATIONS

PARAMETER

Frequency Range
500 MHz – 40 GHz

Modes
CW, Pulsed

S21 Amplitude Uncertainty (±)(at 10 dB insertion loss) At LCU Interface

50 MHz to 20 GHz	0.125 dB
20 GHz to 26.5 GHz	0.25 dB
26.5 to 40 GHz	0.25 dB

S21 Amplitude Uncertainty (±)(at 10 dB insertion loss) At MUX Interface

50 MHz to 20 GHz	0.2 dB
20 GHz to 26.5 GHz	0.4 dB
26.5 to 40 GHz	0.4 dB

S21 Phase Uncertainty (±)(at 10 dB insertion loss)
At LCU Interface

50 MHz to 20 GHz	1.5 deg
20 GHz to 26.5 GHz	2.0 deg
26.5 to 40 GHz	3.0 deg

S21 Phase Uncertainty (±)(at 10 dB insertion loss)
At MUX Interface

50 MHz to 20 GHz	2.1 deg
20 GHz to 26.5 GHz	2.8 deg
26.5 to 40 GHz	4.0 deg

S11 Reflection Coefficient Uncertainty
(±, Linear) At LCU Interface

50 MHz to 20 GHz	0.015
20 GHz to 26.5 GHz	0.020
26.5 to 40 GHz	0.025

S11 Reflection Coefficient Uncertainty
(±, Linear) At MUX Interface

50 MHz to 20 GHz	0.020
20 GHz to 26.5 GHz	0.030
26.5 to 40 GHz	0.035

Total Dynamic Range
110 dB

Instantaneous Dynamic Range
70 dB

SPECTRAL MEASUREMENT SPECIFICATIONS

PARAMETER

Frequency Range
50 MHz to 40 GHz

Resolution Bandwidth Range
1 Hz to 10 MHz

Video Bandwidth Range
RBW / N where 1< N < 65536 (N = powers of 2)

Reference Level Range
+30 dBm to noise level

Amplitude resolution
Same as power resolution, 0.02 dB

Relative Power Uncertainty

Input level > -60 dBm	0.5 dB
-90 dBm < Input level < –60 dBm	1.0 dB
-100 dBm < Input Level < -90 dBm	2.0 dB

Spurious Free Noise Residual Floor -
110 dBm With input terminated

Noise Power in 1 Hz Bandwidth
-144 dBm At 10 GHz

Spurious Free Dynamic Range
~ 75 dB

NOISE FIGURE MEASUREMENT SPECIFICATIONS[1]

PARAMETER

Frequency Range
50 MHz to 40 GHz

At LCU interface

50 MHz to 20 GHz	0.3 dB
20 GHz to 26.5 GHz	0.5 dB
26.5 to 40 GHz	0.5 dB

Measurement Uncertainty (±) At MUX interface

50 MHz to 20 GHz	0.5 dB
20 GHz to 26.5 GHz	1.0 dB
26.5 to 40 GHz	1.0 dB

Notes:
1. For gain noise figure product > 30 and DUT input VSWR better than 1.9:1.

TIME DOMAIN MEASUREMENT SPECIFICATION

PARAMETER

Frequency Range
50 MHz to 40 GHz

Sensitivity
-60 dBm

Time Domain Measurement Resolution

Narrowband[1]	20 nsec minimum
Wideband	1 nsec

Notes:
1. Narrowband measurements can utilize the hardware decimator and provide lower sample rates.

FREQUENCY MEASUREMENT SPECIFICATION

PARAMETER

Frequency Range
1 MHz to 40 GHz

Frequency Resolution
1 Hz

Time base Accuracy
See frequency reference specifications

Sensitivity
-60 dBm

ENVIRONMENTAL SPECIFICATIONS

PARAMETER

Input Voltage(1)(V)
230 VAC, 50 Hz

(Single Phase)
110 VAC, 60 Hz

Power Consumption (excluding DUT power supplies) (VA)
< 3000

Temperature Range of Operation
10°C to 40°C

Humidity Range of Operation
10-90% RH (non-condensing)

Temperature Range for Storage
0°C to 45°C

Humidity Range for Storage
5-93% RH (non-condensing)

Safety Standards
EN 61010-1, IEC 61010-1

EMC Standards
EN 61326-1, IEC61010-1

Cabinet Dimensions
37" (w) x 42.25" (d) x 81.5" (h)

Notes:

1. Un-interruptable Power Supply is specified based on input voltage

FREQUENCY REFERENCE SPECIFICATIONS

PARAMETER

External Reference Input

Frequency	10 MHz
Amplitude	0 +/- 3 dBm

External Reference Output

Frequency	10 MHz
Amplitude	0 +/- 3 dBm

Internal Reference (Features low phase noise rubidium standard.)

Frequency	10 MHz
Long term stability	<1 x 10-12 / month
Short term stability	3 x 10-11 / sec

REGULATORY COMPLIANCE

The SMART^E 5100 system is CE marked and complies with all relevant Eurpoean Directives as listed below.

Application of Council Directive
72/23/EEC (Low Voltage Directive)

Standards to which Conformity is Declared
BSEN 61010-1:2001 (LVD)

Application of Council Directive
89/336/EEC and Amending Directive 92/31/EEC

Standards to which Conformity is Declared
BSEN 61326:1998

Manufacturer Name
Aeroflex

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Type of Equipment
Professional Laboratory RF Test Equipment

Model Number
SMART^E 5000

Serial Number
ALL

First Year of Manufacture
2006

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Our passion for performance is defined by three attributes represented by these three icons: solution-minded, performance-driven and customer-focused.

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