LXI™-Certified Multi-Harmonic Automated Tuners

DATA SHEET / 4T-050G09

MODELS:
XT981ML01
XT982ML01
XT982ML03
XT983ML01

Maury Microwave

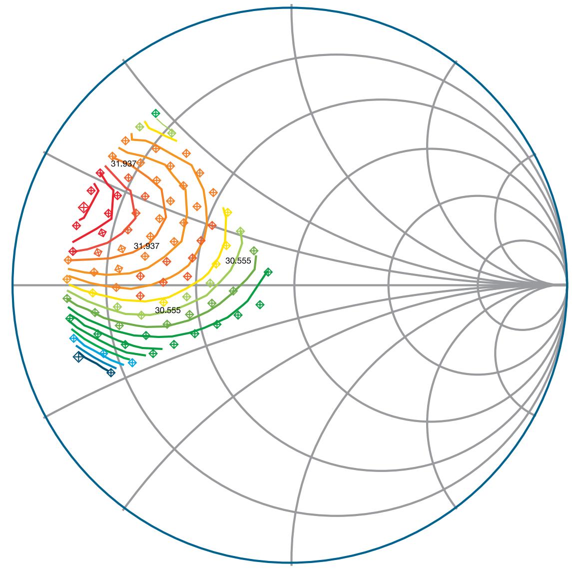
// MAY 2019

What is load pull?

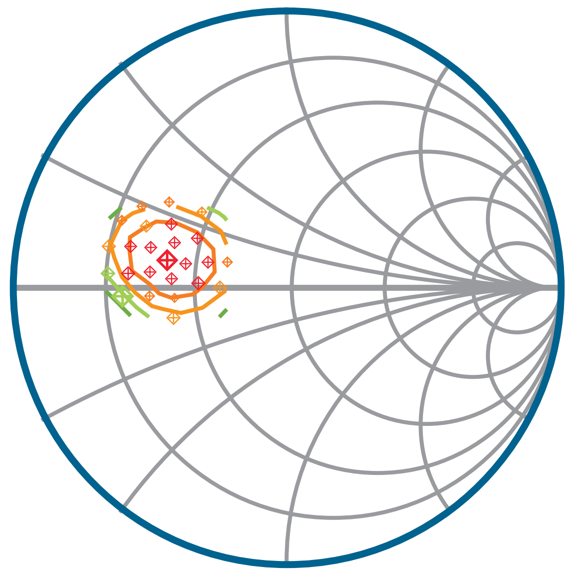
Load Pull is the act of presenting a set of controlled impedances to a device under test (DUT) and measuring a set of parameters at each point. By varying the impedance, it is possible to fully characterize the performance of a DUT and use the data to:

- Verify simulation results of a transistor model (model validation)
- Gather characterization data for model extraction (behavioral model extraction)
- Design amplifier matching networks for optimum performance (amplifier design)
- Ensure a microwave circuit's ability to perform after being exposed to high mismatch conditions (ruggedness test)
- Confirm the stability or performance of a microwave circuit or consumer product under non-ideal VSWR conditions (stability/performance/conformance/antenna test)

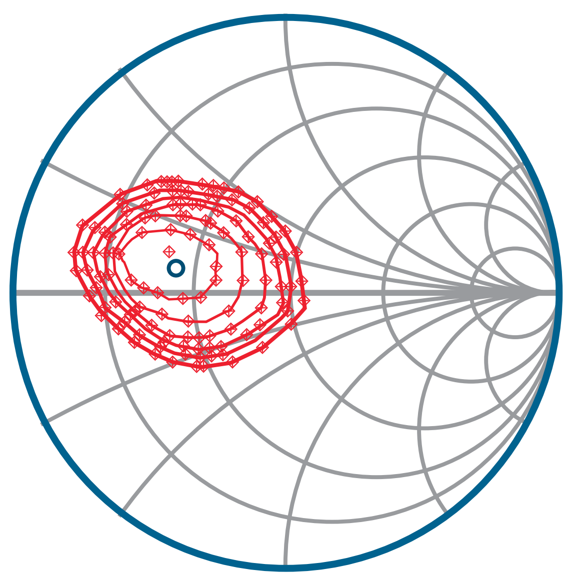
Example of load pull measurements with Output Power (Pout) contours plotted on a Smith Chart.



Iso Pout Contours Measured @ 1.85 GHz

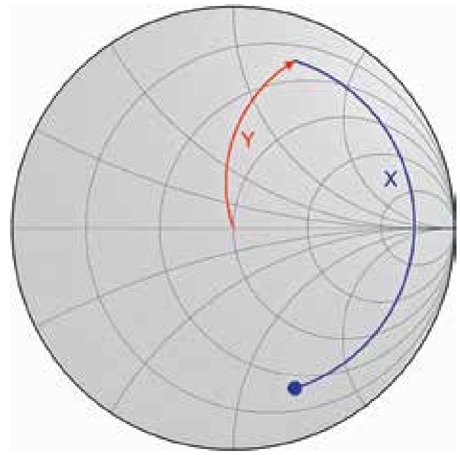


Iso Pout Contours Simulated @ 1.85 GHz

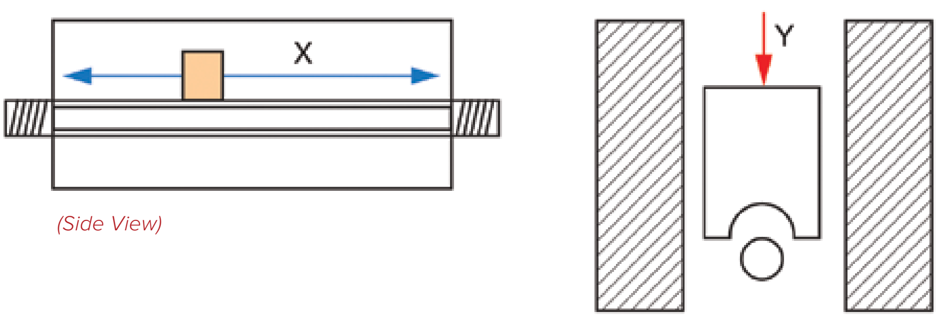


Slide-Screw Impedance Tuner

One tool available to vary the impedances presented to a DUT is the slide-screw impedance tuner. The slide-screw tuner is based on a 50Ω slabline and a reflective probe, sometimes referred to as a slug. Ideally, when the probe is fully retracted, the tuner presents a near-50Ω impedance represented by the center of a normalized Smith Chart. As the probe is lowered into the slabline (Y-direction) it interrupts the electric field that exists between the center conductor and walls of the slabline, reflects some of the energy back towards the DUT, creates a capacitance and increases the magnitude of reflection (represented by the red curve on the Smith Chart at right). As the probe travels along the slabline (X-direction), the distance between the probe and the DUT is altered, thereby rotating the phase of the reflection (represented by the blue curve on the Smith Chart). It is therefore possible to recreate nearly any arbitrary impedance without the need of discrete components (lumped elements or transmission lines).



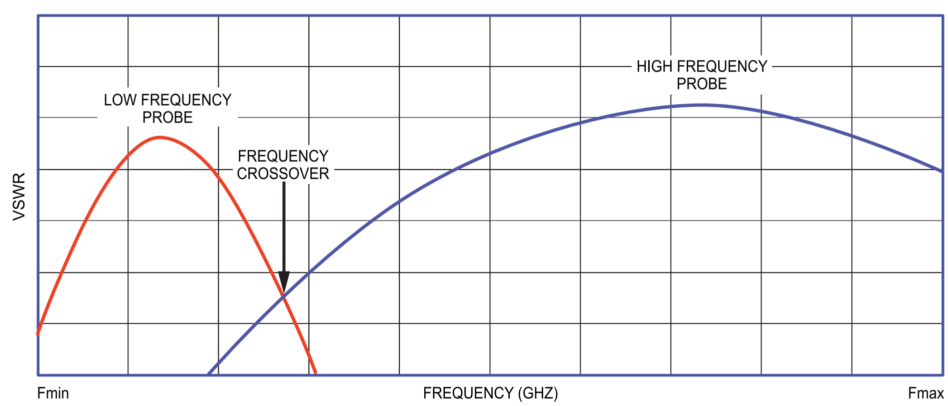
Simplified representation of a slide-screw tuner.



(Side View)

(End View)

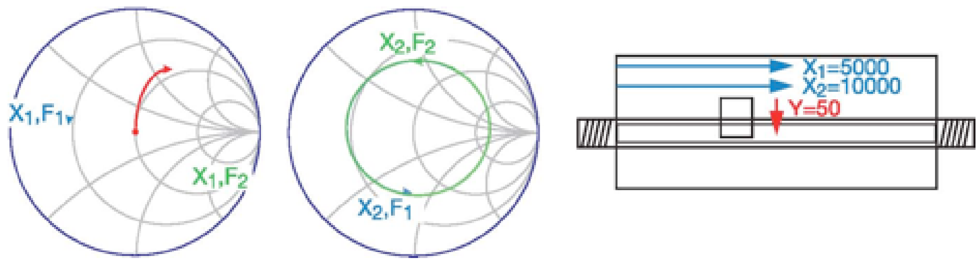
The probes used in slide-screw tuners are wideband in nature, and have similar reflective properties over a wide range of frequencies. In order to increase the overall useful bandwidth of the tuner, two probes of varying dimensions are independently used within a tuner; one for low frequencies and one for high frequencies. In this manner, it is common for slide-screw tuners to achieve an overall frequency range of several octaves to over a decade.



VSWR versus Frequency of a two-probe slide-screw tuner.

Cascaded Harmonic Impedance Control

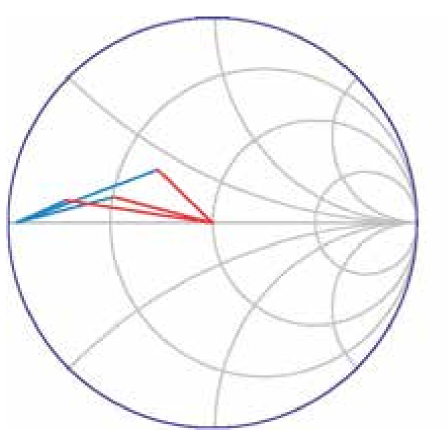
As noted, the probes used in a slide-screw tuner are wideband in nature; the response over several octaves (or even a decade) is quite linear. For instance, if we were to present a reflection coefficient of Γ=0.8 at the fundamental frequency, the reflection coefficient at the second and third harmonics would be close to Γ=0.8 with highly rotated phases. It is the frequency-dependent phase which changes rapidly and is critical when cascading tuners. The figure below depicts the vector representation of the probe; notice that a small movement along the slabline has a large effect on the phase of harmonic frequencies.



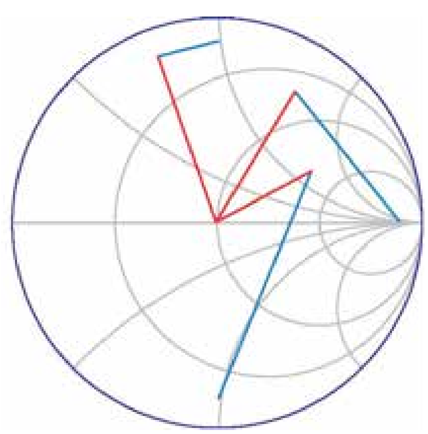
Reflection coefficients at second and third harmonics exhibit high linearity with highly rotated phases

Each probe can also be looked upon as a "degree of freedom", or a vector. With a single probe, there is only one possibility of positioning so that a given impedance at a specified frequency is achieved. This physical probe position has a fixed response for the harmonics, so that each harmonic will reside at a fixed impedance with no possibility of control. When cascading two probes, it becomes possible to control the impedance at two frequencies independently; likewise three probes for three frequencies. The overall reflection looking into the cascaded-probe combination is equal to the complex reflection of the first tuner added to the complex reflection of the second tuner multiplied by some insertion/reflection factor.

When tuning impedances with two probes, we are able to achieve the same fundamental impedance with various combinations of vectors. We can use the first probe and disregard the second, or we can use the second probe and disregard the first, or we can use more of the first tuner and less of the second, and so forth. Each solution will result in the same fundamental impedance but very different harmonic impedances. The figures below show multiple vectors to the same fundamental impedance but very different 2Fo impedances. (For simplicity, higher-order harmonics have been left off the diagram, but are still very much present.)



Multiple paths to ΓFo=0.95∠180°



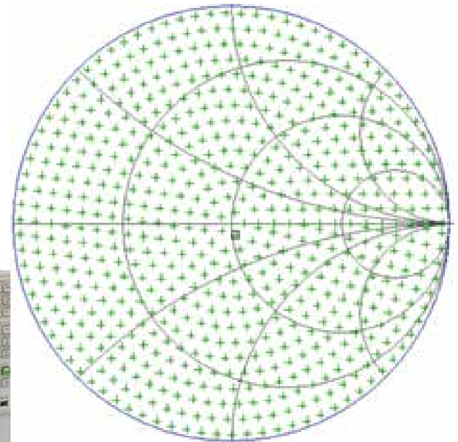
Resulting Γ2Fo positions (0.9∠0, 90, 270°)

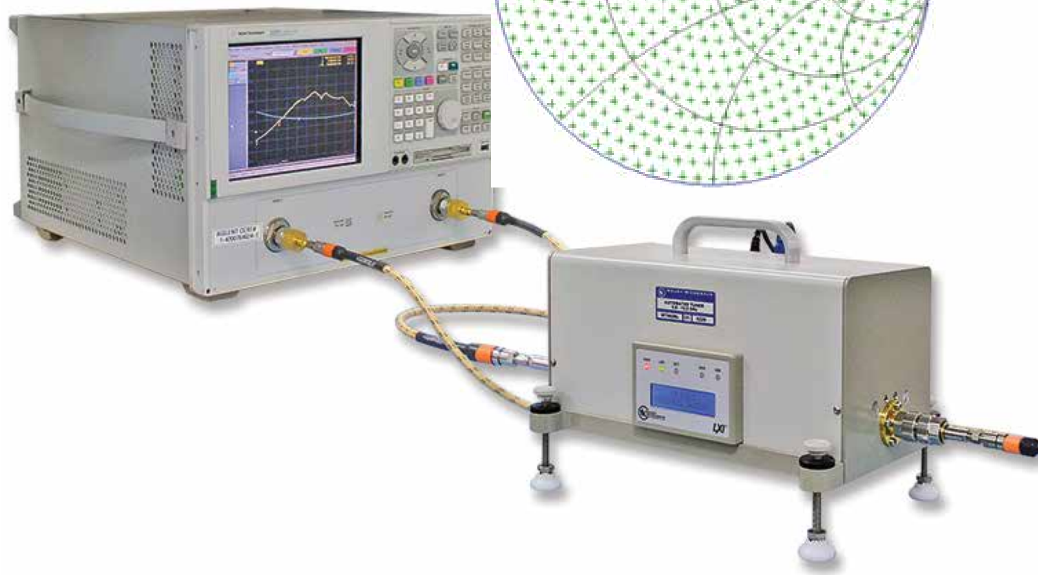
Pre-Calibration (Pre-Characterization)

Slide-screw tuners are available in both manual and automated varieties. While they both work on the same slabline and capacitive probe technique, automated tuners have the ability to be pre-calibrated. Pre-calibration involves recording the s-parameters of each probe at varying X and Y positions for the frequencies of interest using a calibrated vector network analyzer. In general, X and Y positions are selected such that an even distribution of impedances are recorded over the Smith Chart. Once the calibration data is stored in a lookup table, the VNA is no longer required to use the tuner; the tuner 'knows' how to present impedances accurately without VNA verification.

Tuner Repeatability

Tuner repeatability is defined as the vector difference between the pre-calibrated s-parameter data and subsequent s-parameter measurements after movement, when returning the probe to a given X and Y position. Since the impedances presented to the DUT are reliant on the tuner's ability to accurately return to pre-calibrated states, repeatability is a critical tuner characteristic that affects the reliability of measurement data. In order to guarantee a high level of repeatability, precision mechanics and motors within the tuner are used to return the probe to its pre-calibrated positions with s-parameter vector differences of –40 to –50dB or better (see specific tuner model pages 6 through 8 for typical repeatability graphs).

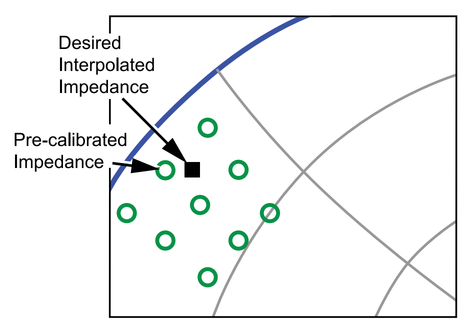




Tuning Accuracy and Interpolation

During pre-calibration, the tuner's s-parameters are recorded at a user-definable number (normally between 300-3000) of X and Y positions giving an even distribution over the Smith Chart. However, an arbitrary load impedance that falls between pre-calibrated states might be required. To achieve a high level of accuracy, a two-dimensional algorithm is used to interpolate between the closest pre-calibrated impedances in order to determine the new physical X and Y positions of the desired interpolated impedance. Interpolation increases the number of tunable impedances well beyond the initial pre-calibration range.

Given a sufficiently dense pre-calibration look-up table, a tuner's repeatability (ability to return to pre-calibrated states) and accuracy (ability to interpolate between pre-calibrated states) offer similar performances.



Patented LXI™-Certified Embedded Tuner Controller

(U.S. Patent No. 8,823,392)

All Maury slide-screw automated impedance tuners are equipped with a patented embedded LXI™-certified controller (U.S. Patent No. 8,823,392) with onboard microprocessor and memory. After pre-calibration, the lookup table is copied onto the tuner's embedded flash memory storage, as are any s-parameter files of passive components that will be used with the tuner (adapters, cables, fixtures, probes, attenuators…). The tuner's onboard microprocessor will use the lookup table and component s-parameter blocks to calculate the probe positions required to present an arbitrary load impedance taking into account (de-embedding) all adapter/fixture losses between the tuner and DUT, and all back-side losses between the tuner and the measurement instrument, as well as possible non-50Ω terminations.

An integrated web interface allows for easy point-and-click tuning.

Direct ASCII commands can be sent through raw TCP/IP interface over Ethernet or USB and used with any socket programming language or through any Telnet client program in any operating system. Commands include direct impedance tuning, reference-plane shifting, VSWR testing and more.

Parameter	Value
Manufacturer	Maury Microwave Corporation
Instrument Model	MT982-EL30
Serial Number	5270
Firmware Revision	3.4-1.24
Description	Maury MT982-EL30 - 5270
LXI Extended Features	LXI Core Functions
LXI Version	1.4
mDNS-Hostname	169.254.6.77, MT982-EL30-5270.local
IP Address	169.254.6.77
MAC Address	fc:6c:31:00:00:e6
Device Address	TCPIP0::169.254.6.77::5025::SOCKET
Telnet Address	telnet://169.254.6.77:5024

Parameter	Currently in use
VXI-11 Discovery	On
mDNS Discovery	On
DHCP	On
Auto-IP	On
Network-Hostname	MT982-EL30-5270.local
IP Address	169.254.6.77
Netmask	255.0.0.0
Gateway	0.0.0.0
Dynamic DNS Updates	On
Manual DNS	Off
Domain	Belkin
Primary DNS	10.10.1.17
Secondary DNS	10.10.1.19
Description	Maury MT982-EL30 - 5270
Web Password	hidden

Edit Configuration

3.5mm & 7mm LXI™-Certified Multi-Harmonic Automated Tuners

Available Models

<table>
<tr><th rowspan="3">Model</th><th rowspan="3">Frequency Range (GHz) [1]</th><th colspan="6">Matching Range</th><th rowspan="3">Power Capability [2]</th><th rowspan="3">Vector Repeatability (Min)</th><th rowspan="3">Insertion Loss [3] (Max)</th><th rowspan="3">Connectors [4]</th></tr>
<tr><th colspan="2">Single Frequency Tuning (Minimum)</th><th colspan="2">Two Frequency Tuning</th><th colspan="2">Three Frequency Tuning</th></tr>
<tr><th>Fmin</th><th>Fmax</th><th>Fmin</th><th>Fmax</th><th>Fmin</th><th>Fmax</th></tr>
<tr><td>XT981ML01</td><td>0.65 – 8.0</td><td rowspan="4">100:1</td><td rowspan="4">40:1</td><td rowspan="4">10:1–100:1</td><td rowspan="4">10:1–100:1</td><td colspan="2" rowspan="2">N/A</td><td>250 W CW
2.5 kW PEP</td><td>–50 dB</td><td>0.3 dB</td><td rowspan="3">7mm</td></tr>
<tr><td>XT982ML01</td><td>0.8 – 18.0</td><td rowspan="2">50 W CW
0.5 kW PEP</td><td rowspan="3">–40 dB</td><td>0.6 dB</td></tr>
<tr><td>XT982ML03</td><td>0.8 – 18.0</td><td>10:1–100:1</td><td>10:1–100:1</td><td>1.0 dB</td></tr>
<tr><td>XT983ML01</td><td>2.0 – 26.5</td><td colspan="2">N/A</td><td>25 W CW
250 kW PEP</td><td>0.8 dB</td><td>3.5mm
(male/female)</td></tr>
</table>

[1] Including fundamental and harmonic frequencies.
[2] Power rated at maximum VSWR.
[3] With probes fully retracted.
[4] Precision 7mm per Maury data sheet 5E-060; Precision 3.5mm per Maury data sheet 5E-062

Accessories Provided

Each tuner is provided with one (1) MT1020F power supply, one (1) USB cable, one (1) Ethernet cable, one (1) USB to Ethernet adapter, and one (1) operating manual.

Recommended Accessories

8799A1 or 2698C2 Torque Wrench

Recommended for tightening all 3.5mm, 2.92mm, 2.4mm & 1.85mm or 7mm precision connectors to the proper in. lbs without over-torquing the connection.

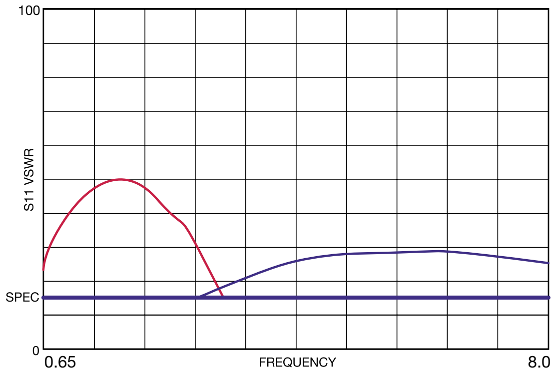
A028D 7mm Connector Gage Kit

Recommended for checking the critical interface dimensions of precision 7mm connectors. Dial indicator style. Thread-on connector.

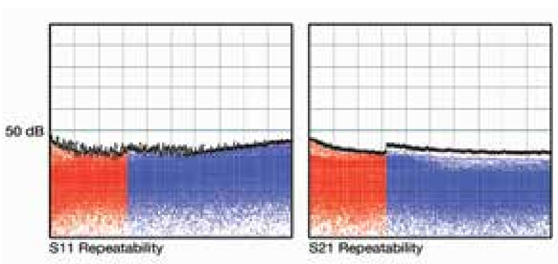
A050A 2.92mm/3.5mm Digital Connector Gage Kit

Recommended for checking the critical interface dimensions of precision 2.92mm & 3.5mm connectors. Digital indicator style.

Exemplary Performance Data for Model XT981ML01 Multi-Harmonic Automated Tuners



VSWR versus Frequency for XT981ML01 Multi-Harmonic Automated Tuners (probe response for individual probes).



Repeatability for XT981ML01 Multi-Harmonic automated tuners (repeatability response for individual probes).

XT981
ML01

U.S. Patent No. 8,823,392
International Patents Pending

Specifications

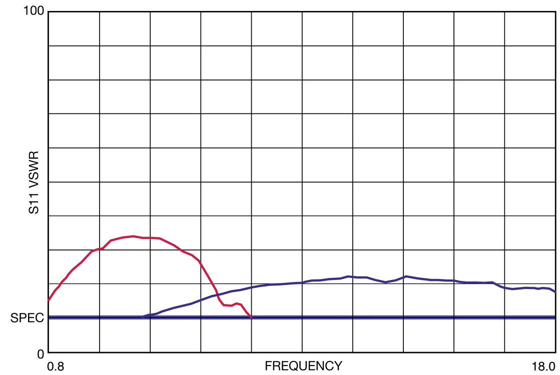
Frequency Range -- 0.65 to 8.0 GHz [1]
VSWR Matching Range
- Single Frequency Tuning (Fmin) -- 100:1
- Single Frequency Tuning (Fmax) -- 40:1
- Two Frequency Tuning (Fmin) -- 10:1–100:1
- Two Frequency Tuning (Fmax) -- 10:1–100:1

Power Capability -- 250 W CW; 2.5 kW PEP [2]
Vector Repeatability (Min) -- –50 dB
Insertion Loss (Max) -- 0.3 dB [3]
Connectors -- 7mm [4]

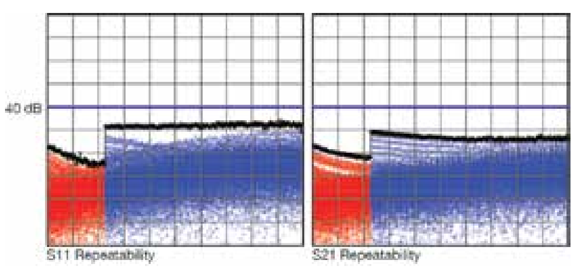
[1] Including fundamental and harmonic frequencies.
[2] Power rated at maximum VSWR.
[3] With probes fully retracted.
[4] Precision 7mm per Maury data sheet 5E-060.

Note: exemplary tuner, actual tuner may differ in size.

Exemplary Performance Data for Model XT982ML01 Multi-Harmonic Automated Tuners



VSWR versus Frequency for XT982ML01 Multi-Harmonic Automated Tuners (probe response for individual probes).



Repeatability for XT982ML01 Multi-Harmonic automated tuners (repeatability response for individual probes).

XT982
ML01

U.S. Patent No. 8,823,392
International Patents Pending

Specifications

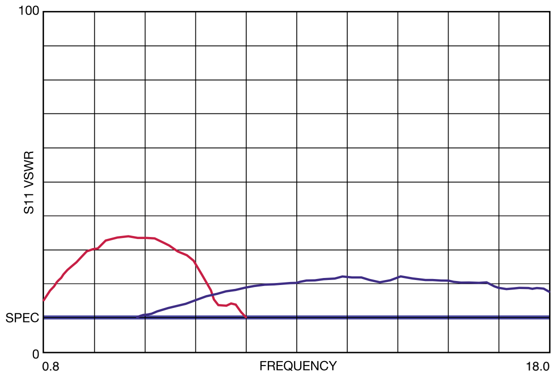
Frequency Range -- 0.8 to 18.0 GHz [1]
VSWR Matching Range
- Single Frequency Tuning (Fmin) -- 100:1
- Single Frequency Tuning (Fmax) -- 40:1
- Two Frequency Tuning (Fmin) -- 10:1–100:1
- Two Frequency Tuning (Fmax) -- 10:1–100:1

Power Capability -- 50 W CW; 0.5 kW PEP [2]
Vector Repeatability (Min) -- –40 dB
Insertion Loss (Max) -- 0.6 dB [3]
Connectors -- 7mm [4]

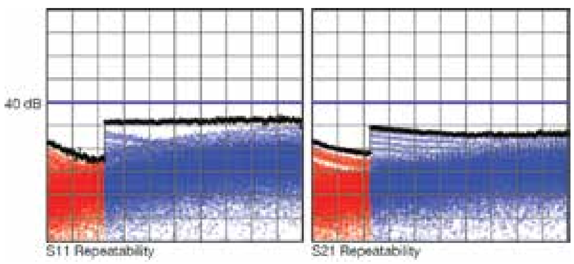
[1] Including fundamental and harmonic frequencies.
[2] Power rated at maximum VSWR.
[3] With probes fully retracted.
[4] Precision 7mm per Maury data sheet 5E-060.

Note: exemplary tuner, actual tuner may differ in size.

Exemplary Performance Data for Model XT982ML03 Multi-Harmonic Automated Tuners



VSWR versus Frequency for XT982ML03 Multi-Harmonic Automated Tuners (probe response for individual probes).



Repeatability for XT982ML03 Multi-Harmonic automated tuners (repeatability response for individual probes).

XT982
ML03

U.S. Patent No. 8,823,392
International Patents Pending

Specifications

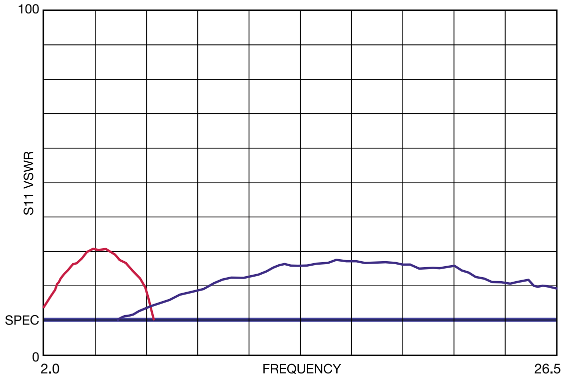
Frequency Range -- 0.8 to 18.0 GHz [1]
VSWR Matching Range
- Single Frequency Tuning (Fmin) -- 100:1
- Single Frequency Tuning (Fmax) -- 40:1
- Two Frequency Tuning (Fmin) -- 10:1–100:1
- Two Frequency Tuning (Fmax) -- 10:1–100:1
- Three Frequency Tuning (Fmin) -- 10:1–100:1
- Three Frequency Tuning (Fmax) -- 10:1–100:1

Power Capability -- 50 W CW; 0.5 kW PEP [2]
Vector Repeatability (Min) -- –40 dB
Insertion Loss (Max) -- 1.0 dB [3]
Connectors -- 7mm [4]

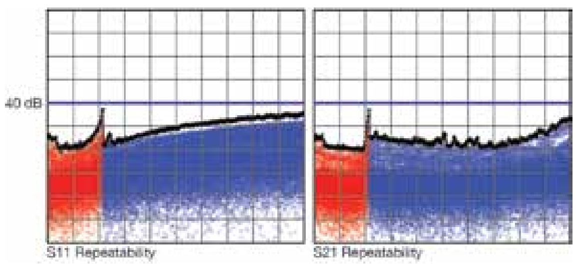
[1] Including fundamental and harmonic frequencies.
[2] Power rated at maximum VSWR.
[3] With probes fully retracted.
[4] Precision 7mm per Maury data sheet 5E-060.

Note: exemplary tuner, actual tuner may differ in size.

Exemplary Performance Data for Model XT983ML01 Multi-Harmonic Automated Tuners



VSWR versus Frequency for XT983ML01 Multi-Harmonic Automated Tuners (probe response for individual probes).



Repeatability for XT983ML01 Multi-Harmonic automated tuners (repeatability response for individual probes).

XT983
ML01

U.S. Patent No. 8,823,392
International Patents Pending

Specifications

Frequency Range -- 2.0 to 26.5 GHz [1]
VSWR Matching Range
- Single Frequency Tuning (Fmin) -- 100:1
- Single Frequency Tuning (Fmax) -- 40:1
- Two Frequency Tuning (Fmin) -- 10:1–100:1
- Two Frequency Tuning (Fmax) -- 10:1–100:1

Power Capability -- 25 W CW; 250 kW PEP [2]
Vector Repeatability (Min) -- –40 dB
Insertion Loss (Max) -- 0.8 dB [3]
Connectors -- 3.5mm [4]

[1] Including fundamental and harmonic frequencies.
[2] Power rated at maximum VSWR.
[3] With probes fully retracted.
[4] Precision 3.5mm per Maury data sheet 5E-062.

Note: exemplary tuner, actual tuner may differ in size.

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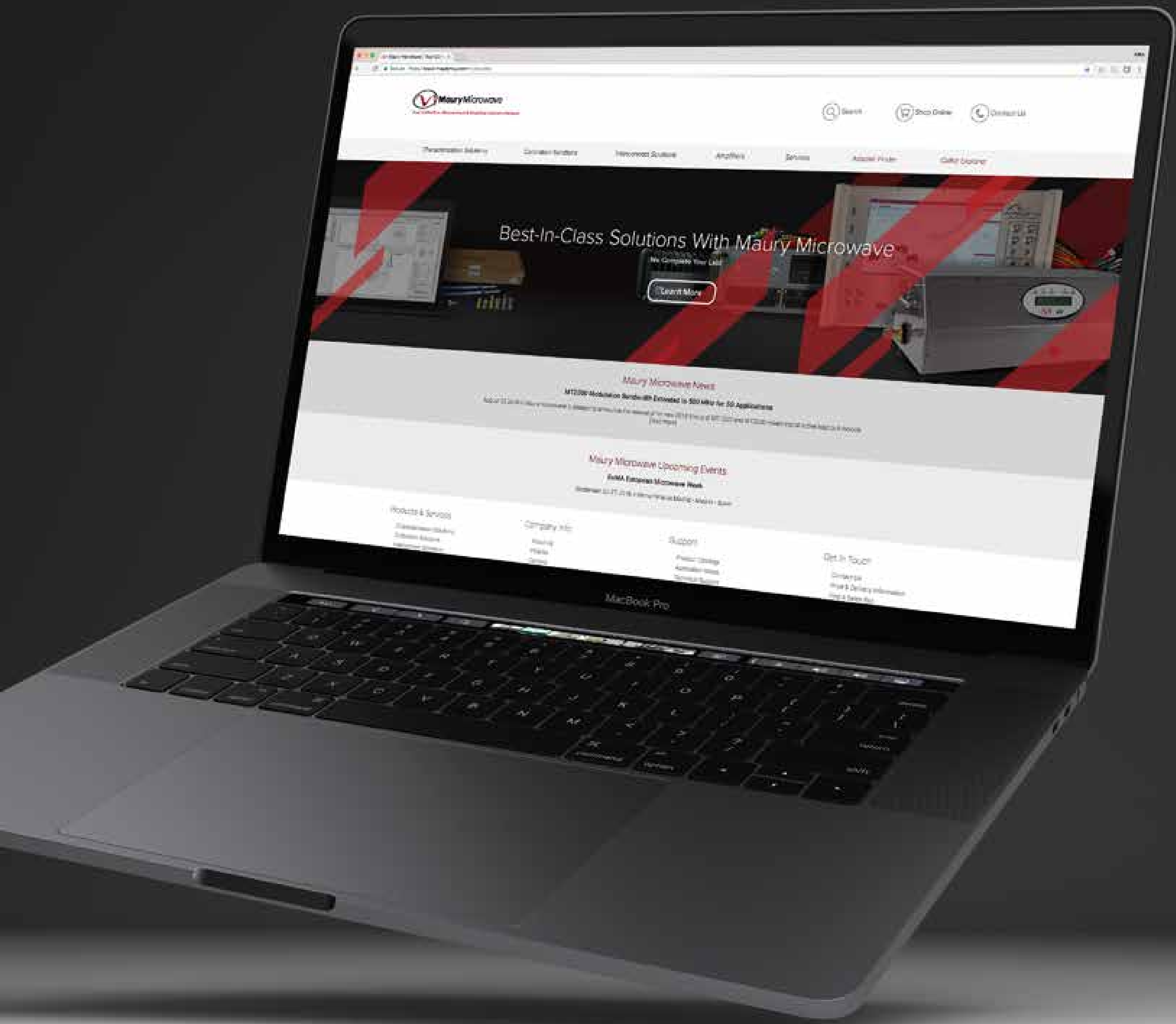
OUR PRODUCTS



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Maury Microwave

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