Homebrew HF SWR/Power Meter

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NAØTC - 285 TechConnect Radio Club
http://www.naøtc.org/
Theory

• Standing Waves

Dynamic Demo: http://www.walter-fendt.de/ph14e/stwaverefl.htm
SWR accuracy is only as good as the power measurement accuracy (both Forward & Reflected)
Theory

• How should RF Power be measured?
  1. RF voltmeter connected at the output of the transmitter
Theory

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  1. RF voltmeter connected at the output of the transmitter

No!

  1. Voltage reading is dependent upon load impedance at the point of measurement
     • Power meters on Ameritron Power Amplifiers
  2. To determine power, we need independent measurements of voltage and current
Theory

• How should RF Power be measured?
  1. RF voltmeter connected at the output of the transmitter
  2. Use a TRUE POWER meter that can measure both current and voltage of both the forward and reflected waves
RF Power Meter Components

*Meter can be:
- Analog or digital
- Current or voltage
- 0-100 uA typical (non-powered)
SWR/Power Meter - Digital

Sensor

RF IN

Directional Coupler

Envelope Detectors

RF OUT

Forward

Reflected

Digital Processor

Digital Display

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Alpha 4520 Digital Power/SWR Meter
SWR/Power Meter - Digital

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RF IN

RF OUT

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SWR/Power Meter - Digital

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My Digital Power Meter

Resolution:
100W/40000 uV = 0.025 W/uV
Digital Power/SWR Meters

What is the main difference?

Alpha 4520
Digital Power/SWR Meters

Cost!

$30 up

~$0-50

Alpha 4520

$800

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Digital Power/SWR Meters

Accuracy varies from ~5% to ?

• Power reading accuracy is very dependent on Sensor calibration accuracy (both Forward & Reflected)

Accuracy: 5-10% achievable

Accuracy Spec = <5%

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Ultimate Limit on Accuracy?

- **Sensor Calibration!**
  - Initial CAL accuracy
    - Volts out vs Power In
    - SWR is a calculation, *not a measurement*
  - Volts out vs Frequency
  - Traceable to NIST?
  - Drift with time
    - Load impedance drift with heating (1-3 KW???)
- Having a digital readout:
  - Doesn’t improve accuracy
  - Improves resolution
  - May improve repeatability
- Having a digital processor does allow for better calibration of sensor characteristics
• Accuracy:
  • Same specs as Alpha 4520
    • 5% maximum
    • 3% (typical)
  • NIST traceable factory calibration
  • What does this mean?
  • eHam rating: 5.0/5 (121 reviews)
  • $435
Directional Coupler

• Only couples power flowing in one direction
• Only couples a small sample of the power flowing in the desired direction

Green = desired coupling
Red = undesired coupling

• **Coupling factor** represents the primary property of a directional coupler
  • To reduce 100 w to 100 mw => Coupling factor = -30 dB
• **Directivity** is the measure of how well a coupler isolates two opposite-travelling (forward and reverse) signals
  • *Creates region of uncertainty around all measurements*
• Bird 43: Directivity >30 dB

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Dual Directional Coupler

- RF IN
- X
- Forward Coupler
- RF OUT

Green = desired coupling
Red = undesired coupling

Forward

Reflected

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Common Directional Couplers

Coupled Transmission Line Coupler

Bird 43
Common Directional Couplers

Tandem Match Coupler

Bruene Bridge*

*Most common type found in commercial amateur transmitters
Common Directional Couplers

Tandem Match Coupler

Bruene Bridge*

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How do we get Voltage & Current?
Common Directional Couplers

Tandem Match Coupler

Bruene Bridge*
Common Directional Couplers

Tandem Match Coupler

Bruene Bridge*

Null adjustment
Common Sensors

• Tandem Match Coupler
  • This coupler has some nice features:
    • Simplicity, excellent directivity
    • Scalable to other power levels, and
    • 50-Ω load impedances on all ports
  • Covering 1.8-30 MHz requires careful transformer design
  • Input VSWR can degrade rapidly as frequency drops below 7 MHz

• Bruene Bridge
  • Requires comparatively little space
  • Most commonly used design by Ham equipment manufacturers
  • Primary challenges with this design:
    1. Parasitic lead inductance associated with C2
    2. High values for C2
    3. Excessive secondary wire length on T1, and
    4. Impedance control in the bifilar secondary winding
  • The lead inductance and C2 result in a series resonance that progressively deteriorates bridge balance as the frequency is raised
Fig 19—Schematic diagram of the high-power directional coupler. D1 and D2 are germanium diodes (1N34 or equiv). R1 and R2 are 47 or 51-Ω, ⅛-W resistors. C1 and C2 have 500-V ratings. The secondary windings of T1 and T2 each consist of 40 turns of #26 to #30 enameled wire on T-68-2 powdered-iron toroid cores. If the coupler is built into an existing antenna tuner, the primary of T1 can be part of the tuner coaxial output line. The remotely located meters (M1 and M2) are connected to the coupler box at J1 and J2 via P1 and P2.
At 100 watts, $I_{\text{FWD\hspace{0.1cm}OUT}}$ (into a short) > 6 mA
At 100 watts, $V_{\text{FWD\hspace{0.1cm}OUT}}$ (into an open) > 2.0 vdc

Any small signal diode will work
(Germaniums are best for QRP)

SWR Sensor (from 2010 ARRL Antenna Handbook)

Shield on coax used as a Faraday shield (grounded on one end only)
Tandem Match Coupler

Caution: Germanium diodes don’t like heat
Tandem Match Coupler Using Balun Core

DX Zone.com “Digital QRP SWR/ Power Meter” by KD1JV

Compensation Diodes
(I don’t recommend)
Processor/Display

DX Zone.com "Digital QRP SWR/ Power Meter" by KD1JV

• http://kd1jv.qrpradio.com/
• http://www.dxzone.com/cgi-bin/dir/jump2.cgi?ID=18048

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“Whitman’s Sampler” tin
Common Envelope Detector

Diodes:
- Type not critical
- Germanium best for QRP
- Matched is desirable, but not required
Diode Options

Silicon:
  • 1N3600 => $V_D \sim 0.7$ volt

Germanium:
  • 1N34, 1N60, 1N270 => $V_D \sim 0.3$ volt
No matching attempted

Diode type dependent

VDC

Watts

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Isolated Meter Circuit

Forward

Diode

+X VDC

1 uF

780X

+V_{IN}

100K

0.01 uF

Forward OUT

Reflected

Diode

LM324 or equivalent

Reflected OUT

Source

~ 300 ohm

2 vdc

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A SIMPLE SWR METER FOR QRP (1 WATT) LEVELS

Not required

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Performance – Power Measurement

Homebrew (Tandem Match)

Bird (Coupled Line/Digital)

Pride (Breune)

Diode type dependent
Performance – SWR Measurement

25 ohm Load @ $P_F = 60$ watts

1.8 MHz 14 MHz 28 MHz

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