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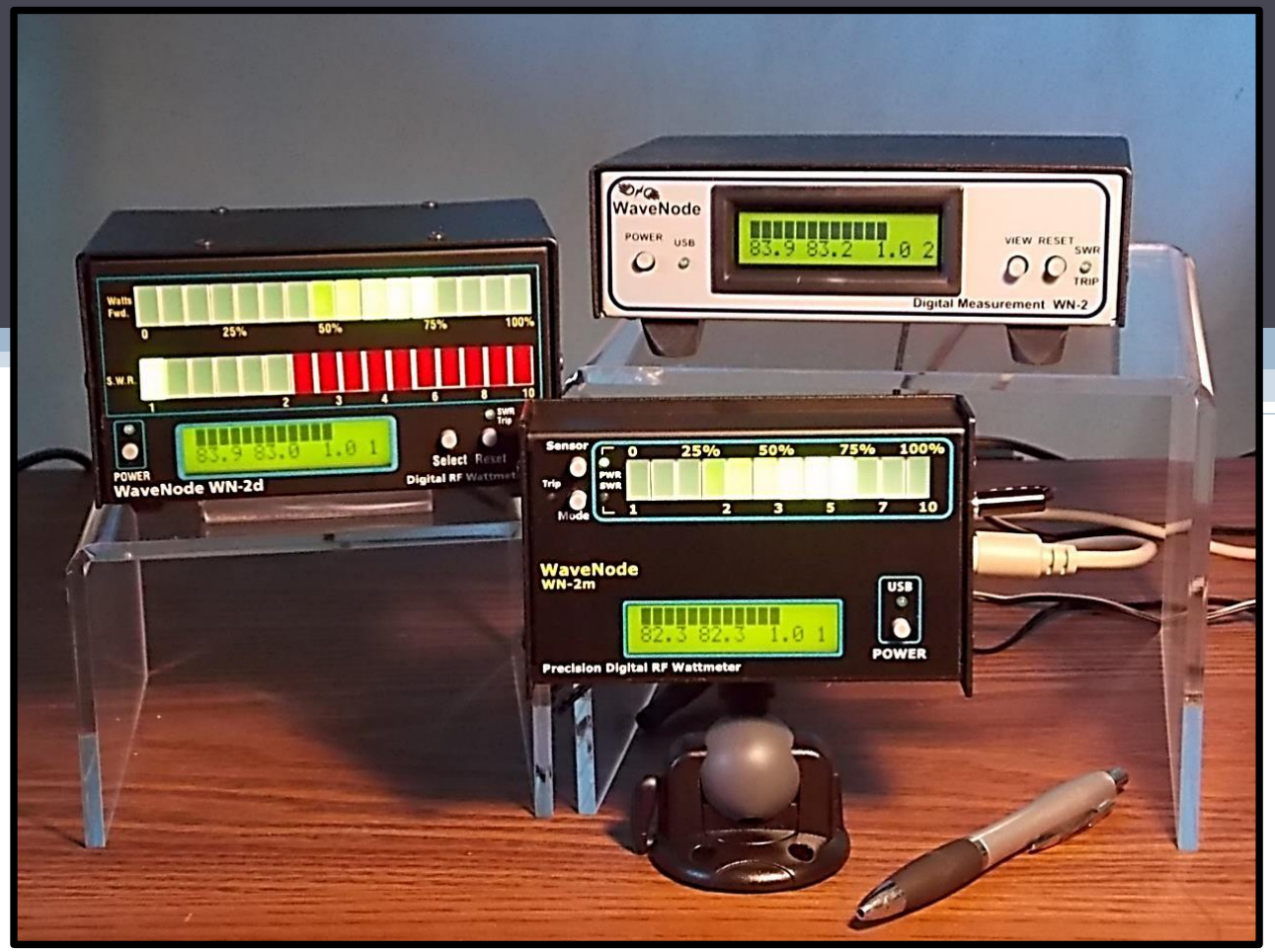
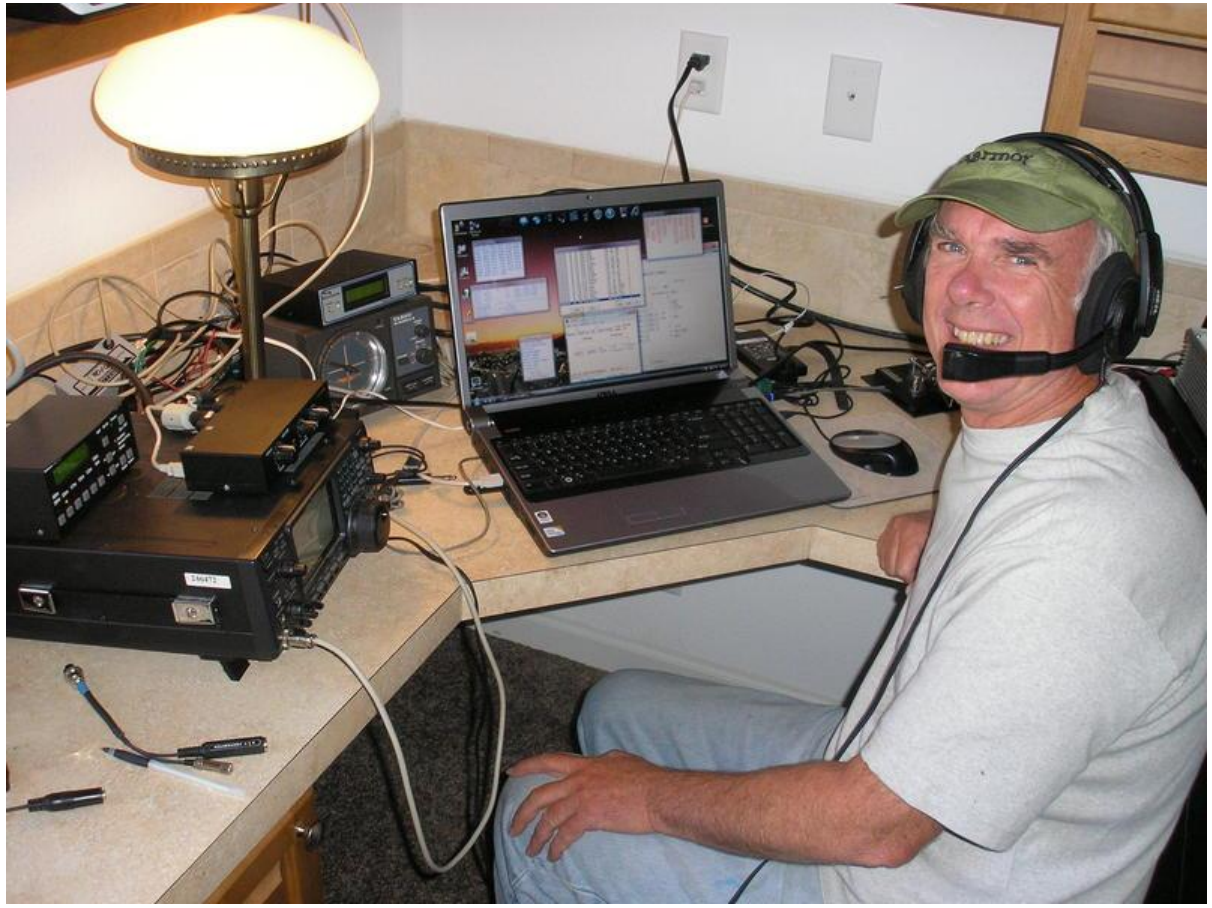


About the Presenter:

Active in Amateur Radio since 2000. Interests are primarily HF DXing and CW contesting.
Active from Humboldt County in California.
Wavenode Incorporated in 2003 to produce high-quality digital R.F. Monitoring products with a COMPLETE selection of sensors from 60 KHz to 1.3 GHz.



Wavenode Wattmeters with 4 sensor operation have synchronous detectors for each sensor.

(Provides capability that 4 separate meters cannot provide)

- SWR and power measurement happen with a single CW dit or microphone click.
- Relative gain between sensors can be made with a single CW dit.
- Generate amplifier gain plots to find 1 db and 3 db compression points.
- Noisy, intermittent or high voltage arcing are shown immediately on the display.
- Sensors for 2200 Meter thru 23cm Operation. Your instrument is never obsolete.

Sensor Selection

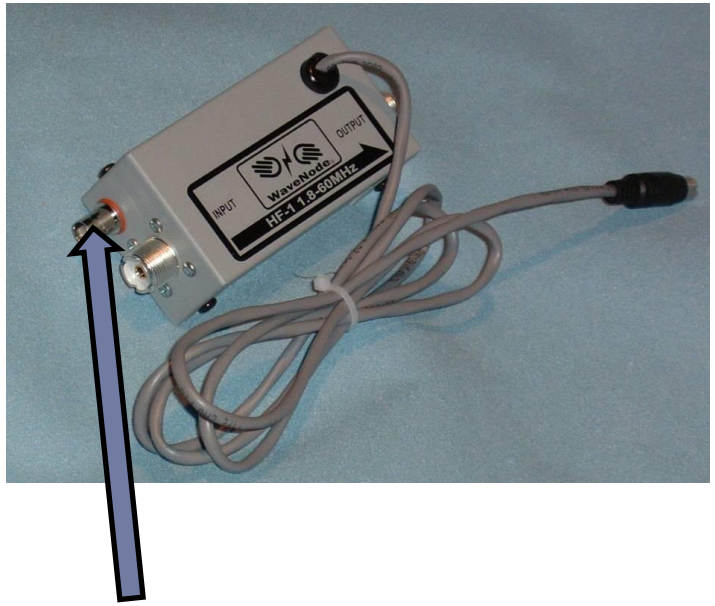
Choice of SO-239 or "N" type RF Connectors

- **HF-1: 0-2,000 Watts (1.8-60 MHz.)**
- **LP-1: 0-60 Watts (1.8 - 60 MHz.)**
- **8KW: 0- 8,000 Watts (1.8- 40 MHz.)**
- **FM-1: 0-600 Watts (20-120 MHz.)**
- **AM-1: 0-2000 Watts (500KHz-3.0 MHz.)**
- **L/M-1: 0-2000 Watts (100KHz-5 MHz)**

~~~~~~~~~~~~~~~

- **UHF-1: 0-300 Watts (120-470 MHz.)**
- **UHF-2KW: 0-2000 Watts (120-170 MHz.)**
- **UHF-220: 0-2000 Watts (200-275 MHz.)**
- **UHF-70cm: 0-2000 Watts (400-470 MHz.)**

- **SHF-2B: 0-500 Watts (900-950 MHz.)**
- **SHF-3B: 0-500 Watts (1200-1300 MHz.)**
  (33 and 23 cm Amateur bands)

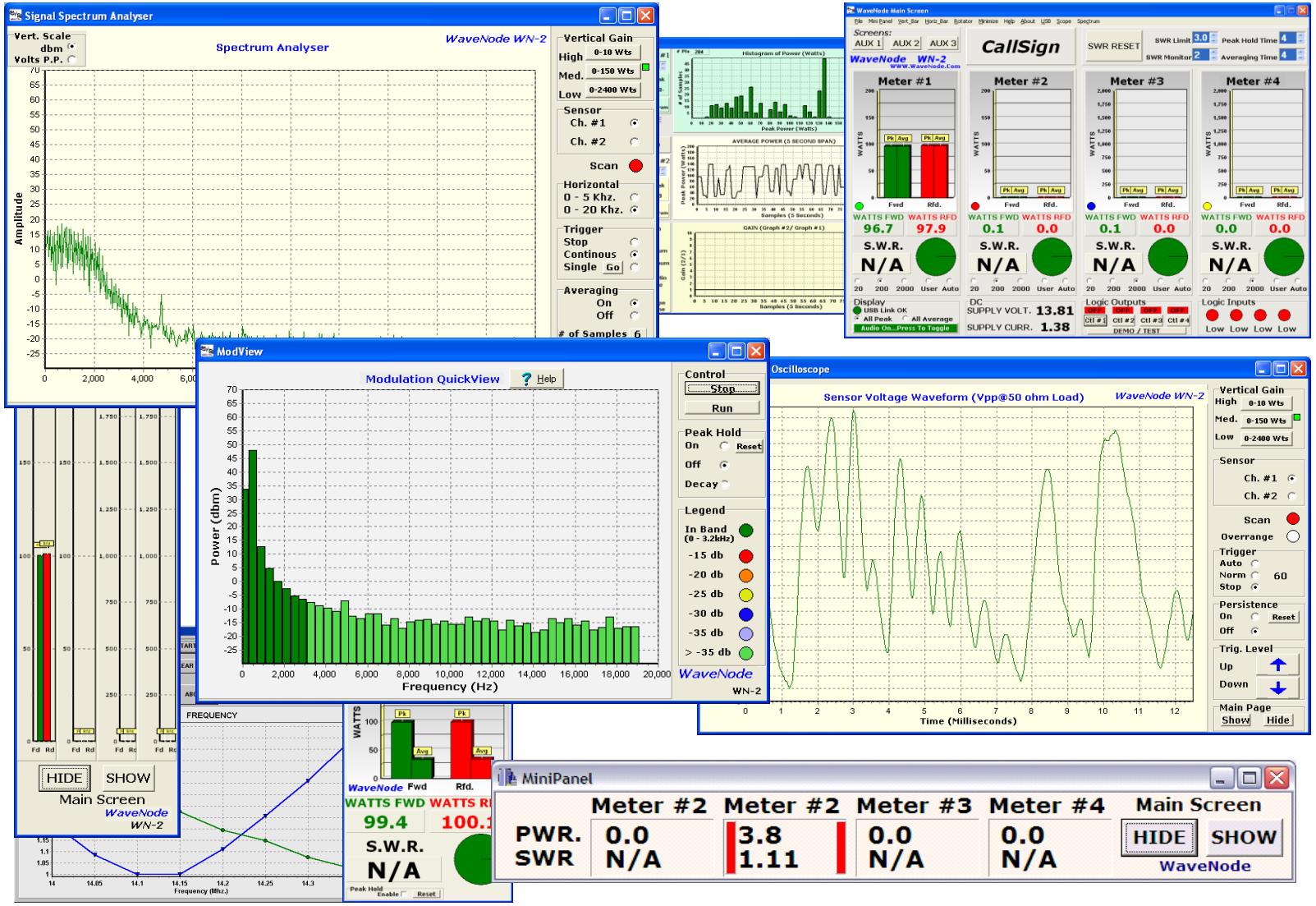


(Shown with RFView port option)

The RFView port option is available on all sensors. This option allows for IMPure feedback operation and/or direct connection to an Oscilloscope or spectrum analyzer.

https://wavenodedevelop.com/

Graphical Views Optimized for You



Basic Definition of S.W.R.

Starting with basic definition for the standing wave ratio (SWR)

$$SWR = \frac{|V_{max}|}{|V_{min}|} = \frac{|I_{max}|}{|I_{min}|}$$

When the transmission line is terminated with 50 ohms resistive:

- Vmax and Vmin are equal.
- Voltage all along the feedline is constant when measured with R.F. Voltmeter.

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All energy is reflected in an open or shorted transmission line

Simply put:

- An open termination has no Current or Power
- A shorted termination has no Voltage or Power

$$Power = V\ I * Cos\ \theta$$

(θ = phase angle between V and I in the load)

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Why Digital Watt/S.W.R. Meters?

- Peak/Average Power are easy and accurate to calculate with Math.
- Multiple remote R.F. inline sensors can show data simultaneously.
- Peak Power can be held and displayed until reset by the user. Verify power and S.W.R. with a single SSB key-click or CW “dit”.
- High-speed sampling can provide displays of flat-topping modulation and intermod products (splatter) before others complain with comments as “you’re a bit wide on my display”.
- Monitor S.W.R. and power continuously in ANY mode. No continuous tone (RTTY) is necessary. You can even operate your antenna tuner in SSB mode while in QSO.

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Transmitter/Amplifier Source Impedance

Amplifier Output impedance:

Solid State Amplifiers: typically 10-25 ohm
Tuned Output Tube amplifiers: Typically around 100- 150 ohms.

Significance of the Output Impedance:

An output impedance of 25 to 100 ohms is <2:1 SWR looking back at the source, and **90%** of reflected energy is dissipated in the final amplifier.

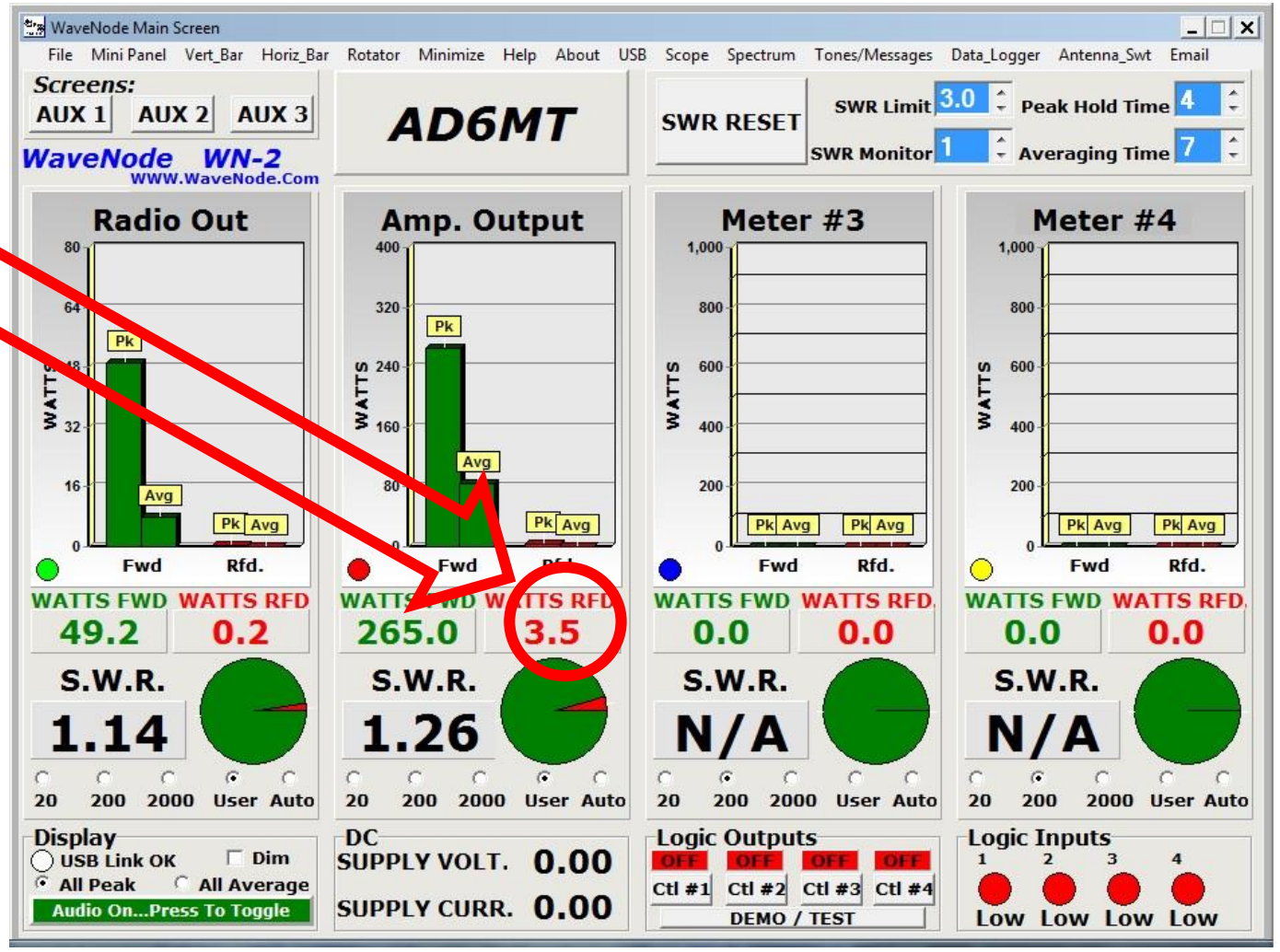
Why is S.W.R. important?

That “Reflected” power has to be dissipated somewhere. It is being dissipated in the amplifier output amplifier (either tubes, FETs, or Transistors).

An S.W. R. of 2:1 is the typical safe operating margin in a solid state radio or amplifier. It is designed for that, and even so, if your amplifier is operating at 1000 watts, then:

100 excess watts

Is dissipated in the final amplifier stage as heat. Heat is the biggest factor on tube and semiconductor lifetime.



Why does S.W.R. Matter ?

(Further discussion of why?)

- A transmission line (ideal line) sends all energy to the terminating end (the antenna) **only** when terminated in it's characteristic impedance (typically 50 ohms).

- Termination in other than 50 ohms results in power being reflected back to the R.F. source (your radio or amplifier) and being dissipated there as heat. This is why manufacturers "throttle back" the power output when high S.W.R. is detected, typically > 2:1.

- High SWR can present a high voltage at the transmitter final amplifier and cause primary breakdown in finals. Solid state amplifiers are especially vulnerable.

- High SWR causes excessive line losses due to dielectric losses (E-Field) and IR losses (high current nodes in the line).

Why Continuous S.W.R. monitoring?

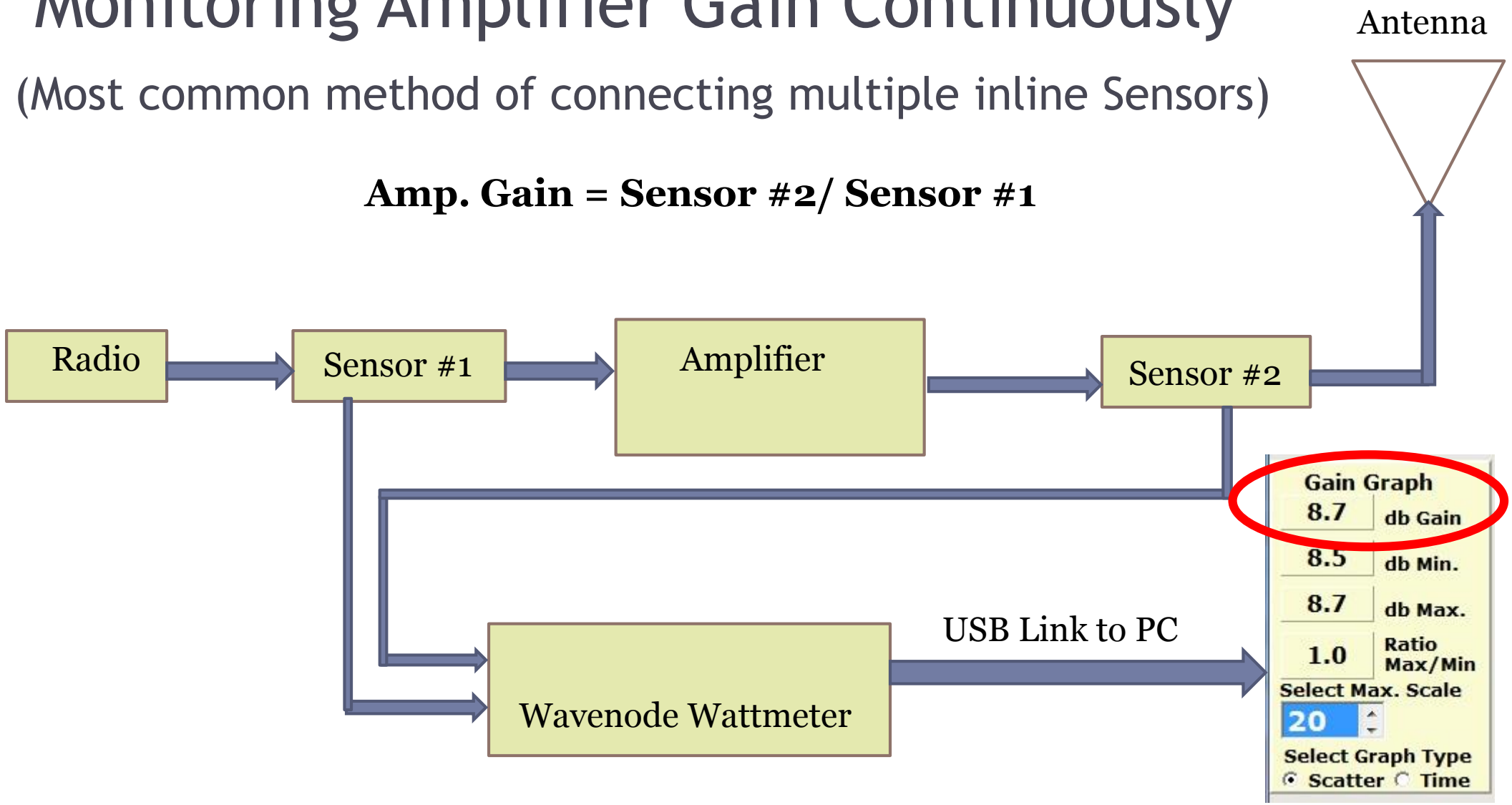
(as opposed to checking once in a while with an antenna analyzer)

- Antenna analyzers are great, but not a substitute for continuous SWR monitoring in day to day usage.
- Feedlines, baluns and R.F. connectors get wet, dirty or have dielectric breakdowns. Spurious/intermittent SWR values can be easily spotted on the digital wattmeter display and indicate a problem that analog meters will not show.
- Solid-state amps usually consist of several push-pull amplifiers summed together. A failure of one “brick” may go un-noticed for days or even years. A digital wattmeter can show a loss of amplifier gain quickly while operating.

Monitoring Amplifier Gain Continuously

(Most common method of connecting multiple inline Sensors)

Amp. Gain = Sensor #2/ Sensor #1



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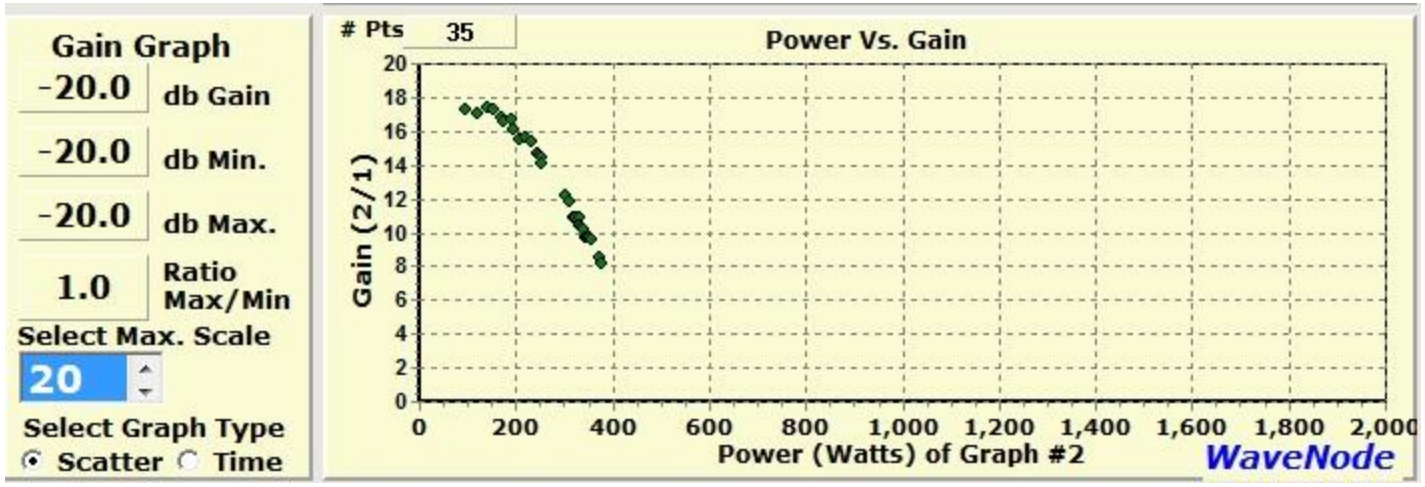
Can I Make a Graph of Gain vs. Output Level?

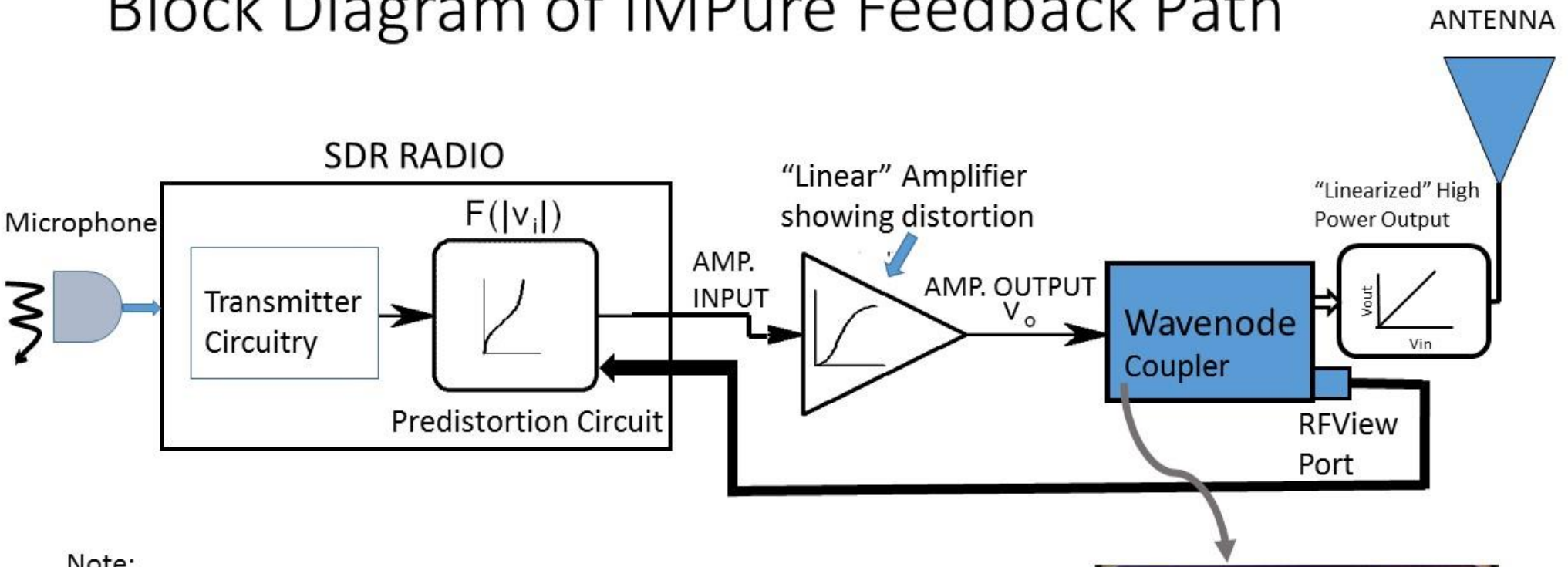
What can I conclude from the poor gain graph shown below?

- The graph was made with a small solid-state amplifier using the setup on the previous slide.
- The gain is reduced from 15 to 6 db as the power output varies from 80 to 400 watts.
- This amplifier should not operate at more than 200 watts if we don't want to exceed 1 db compression point.
- The 3 db compression point is about 350 watts. Best not to exceed this.



How is RFView port option involved in Distortion Reduction?

Block Diagram of IMPure Feedback Path



Note:

1. No particular amplifier is specified. Any amplifier can be "Linearized".
2. There are no tables or coefficients to be input. The Predistortion circuit circuit "learns" the amplifier non-linearity characteristics by monitoring the RFView port signal.

Wavenode WN-2 Wattmeter

IMPure Documentation

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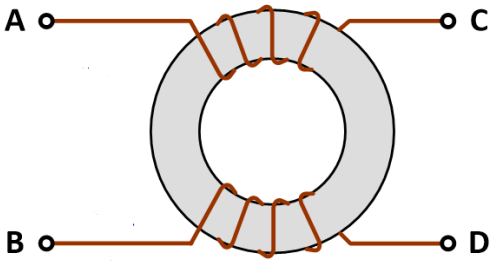
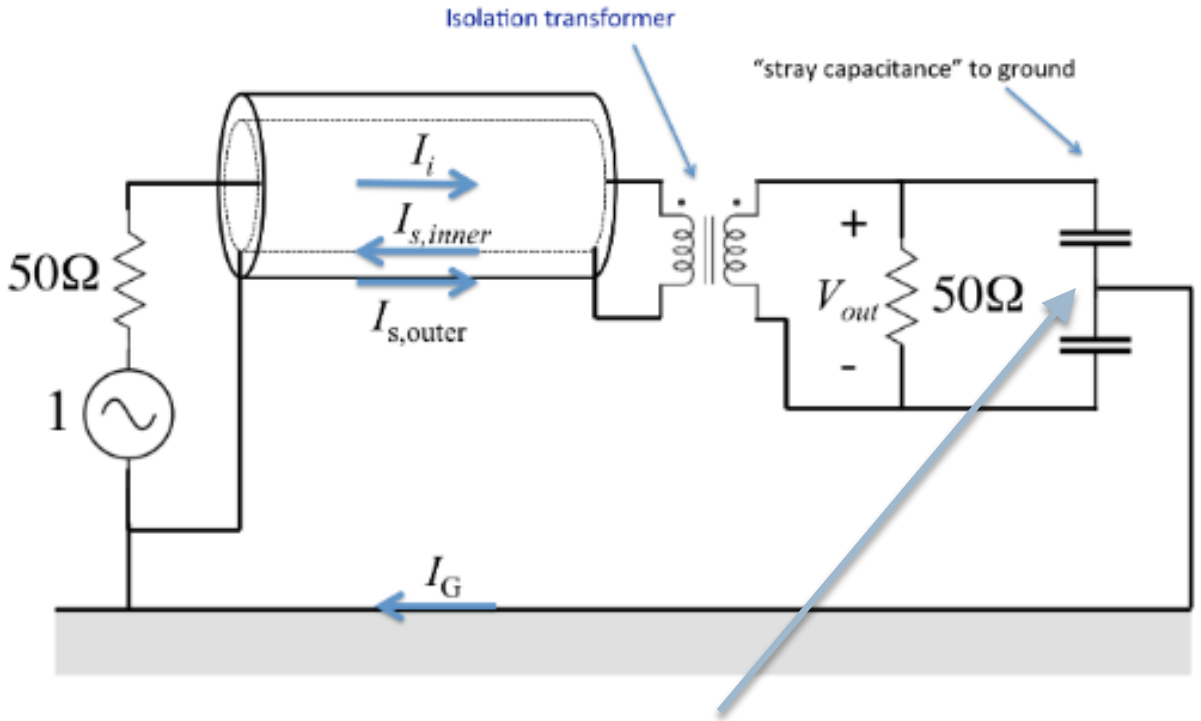
Let's Talk about Common-Mode Chokes



Purpose: To force the R.F. currents on the coax center conductor and inner braid to be equal amplitude and 180 degrees out of phase.

Ideally, no R.F. current will flow on the outside surface of the braid.

Why does an Antenna have common mode current and how does the Choke prevent it?



Stray antenna capacitance to ground causes current to ground (the common mode current). We need to put a high impedance in this path. The common mode choke does this.

The isolation transformer provides a high impedance to the current Ig due to capacitance to ground. This forces the coax inner conductor and inner braid currents to be equal.

! LESS NOISE PICKUP ON THE COAX WHEN LISTENING !

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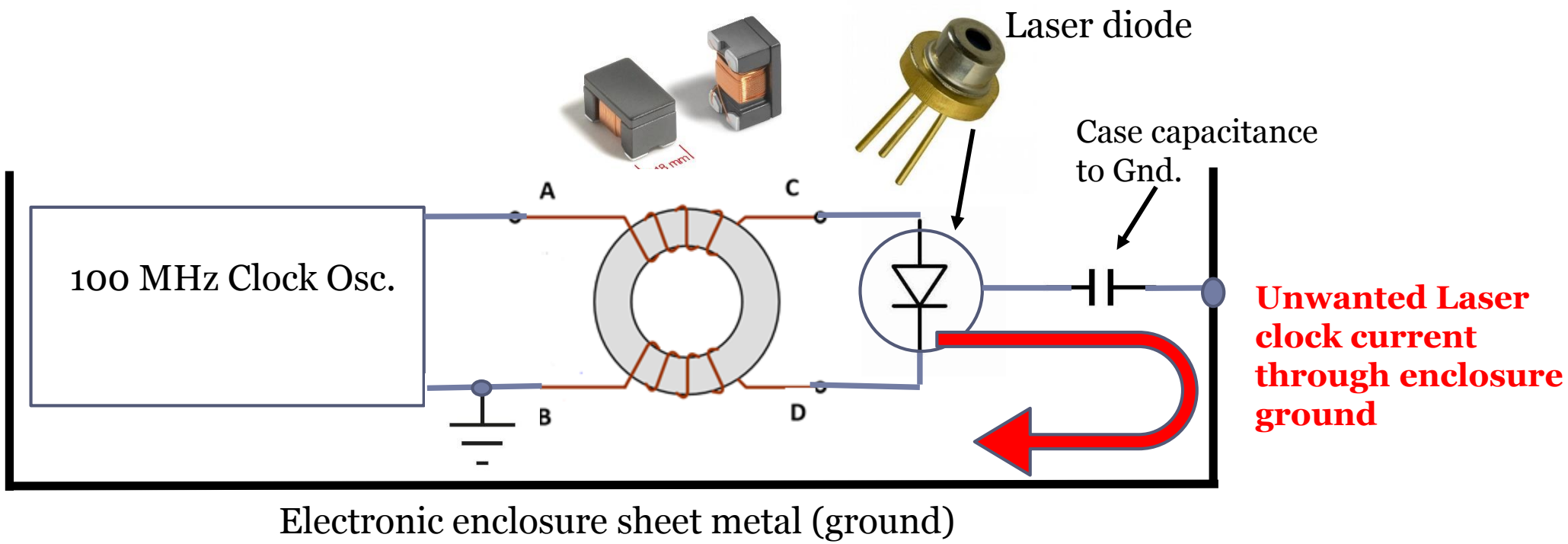
Analogous stray current to ground causing R.F.I.



Clocking currents getting into enclosure sheet metal makes F.C.C. tough to pass.
Adding the common-mode choke can reduce stray current in the sheet metal by > 20 db.
This can mean passing FCC emissions test, or NOT.

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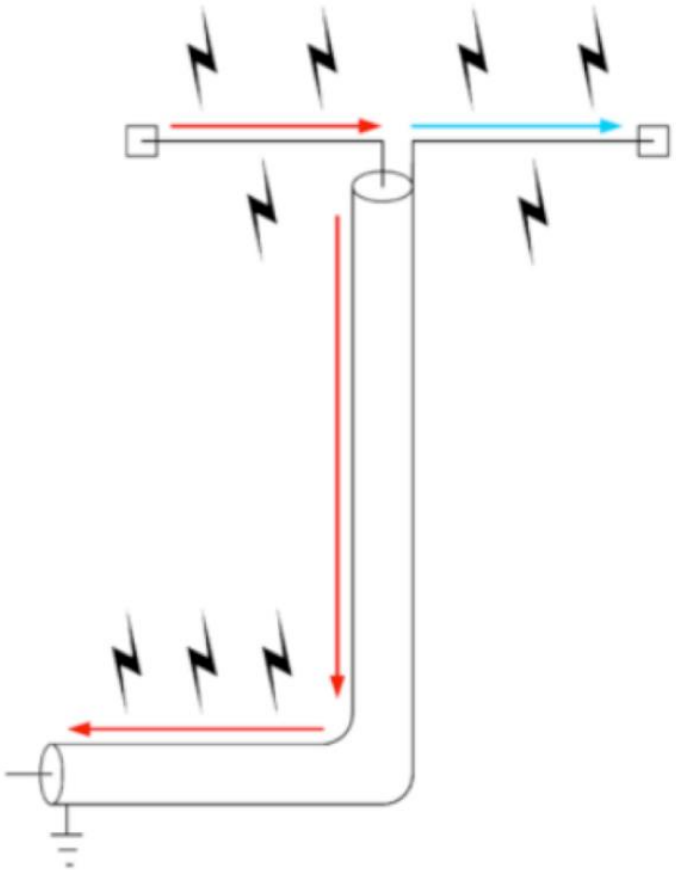
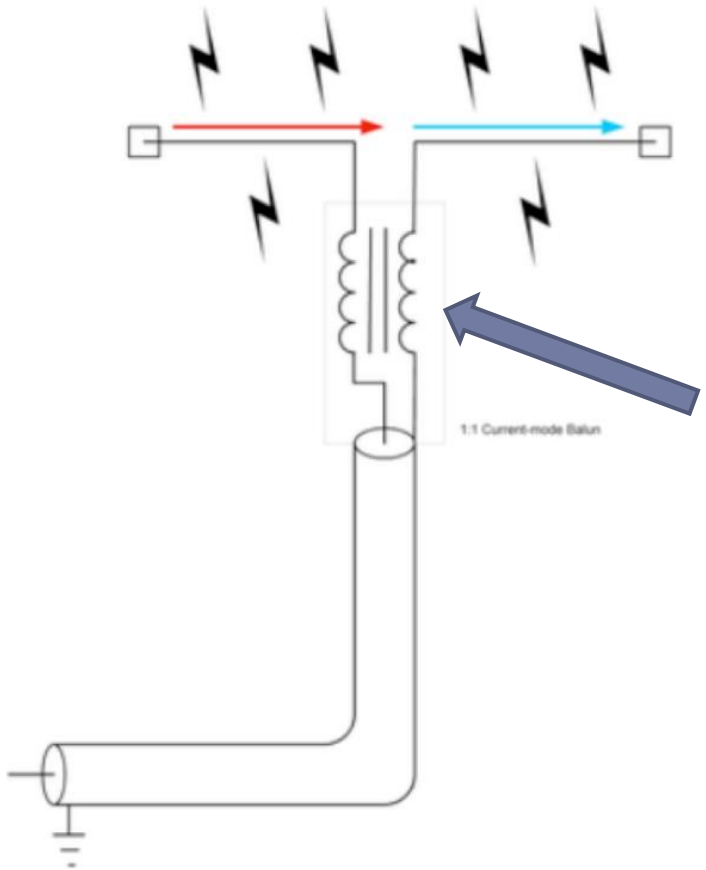
Does SWR Cause R.F. in the Shack Equipment Grounds?





YES…. If the R.F. Flows on the *OUTSIDE* of the Coax shield. S.W.R. does not necessarily cause R.F. in the shack, but R.F. on the shack grounds can be a symptom of high S.W.R.

We use a balun at the antenna feedpoint to force the current on the coax inner conductor and shield to be equal and opposite in phase (180 degrees).

Therefore, no current flows on the outer surface of the coax shield (and no hot microphone or key).

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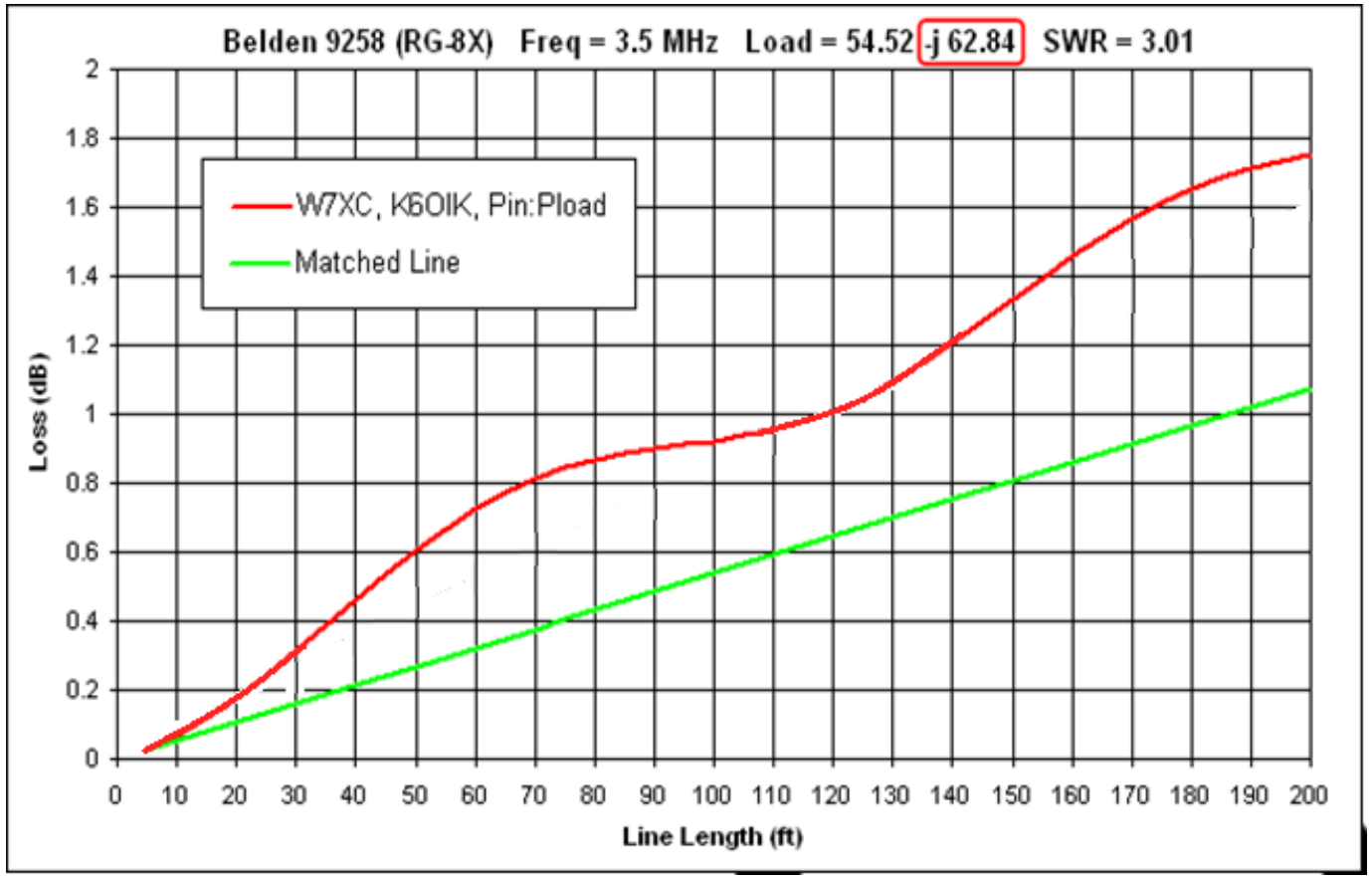
Additional Coax loss due to S.W.R.



- Green Line: Loss due to Coax with S.W.R. = 1:1.
- Red Line: Loss with S.W.R. =3:1.
- Note Loss is ~ 2X in the feedline due to S.W.R. present.

https://ac6la.com/swrloss.html

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A very comprehensive coax line loss calculator that spells out loss due to S.W.R.

Line Loss Calculator:

Note: Set Line Length 100 here to use the ERP Calc. Put actual line length in the ERP Calc.

Parameters:			Results:	
Line Type:	Belden 9258 RG-8X ▾	Matched Loss:	1.087	dB
Line Length:	100 (•) Feet ( ) Meters	SWR Loss:	0.536	dB
Frequency:	14 MHz	Total Loss:	1.622	dB
Load SWR:	3 :1	Power Out:	68.828	Watts
Power In:	100 Watts	Power Loss:	31	%
	Calculate before using ERP Calc.			

https://kv5r.com/ham-radio/coax-loss-calculator/

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N-type or SO-239/PL259?

Any measurement device generates a loss and some impedance discontinuity in the line.

N-type vs. PL259/SO-239 and frequency of usage.

- SO-239 is adequate for <150 MHz (S11 between -30 and -18 db).
- N is a better choice for >150 MHz (reliable S11 better than -27 db).

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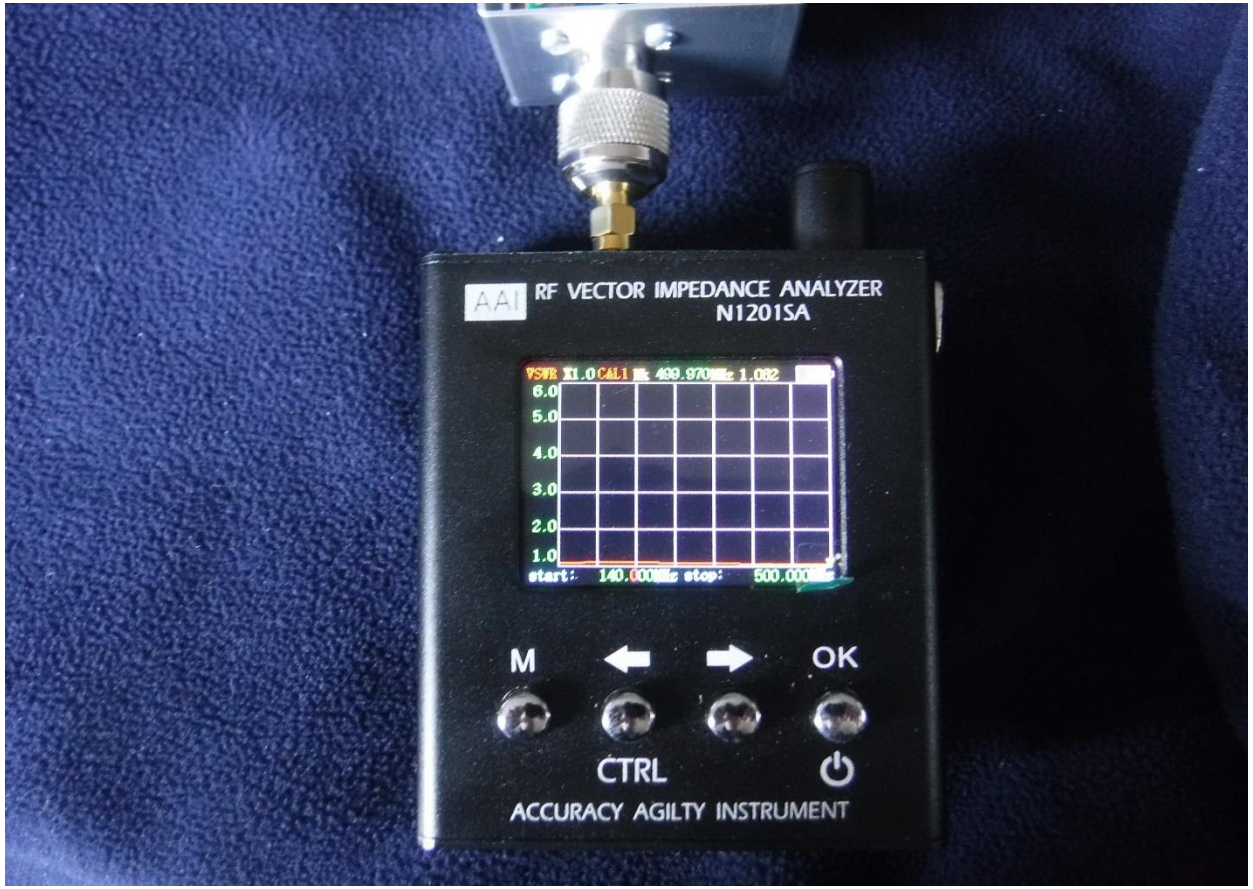
S11 with Vector Impedance analyzer

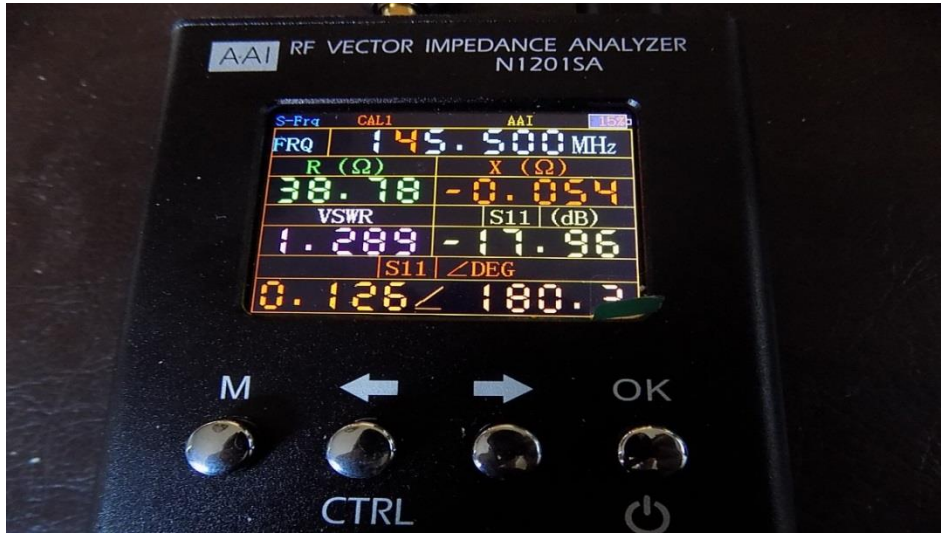
(Reflection coefficient)



Vector Impedance Analyzer. This little unit operates 137 MHz to 2.7 GHz. Cost is ~$100.

S11 of Wavenode UHF-1 Sensor at 445 MHz. S11 of -34 db.

Observed S.W.R. Results with SO-239 Connectors on UHF-1 sensor at 145 and 450 MHz.



Test Setup and Results:

- S11 of -18db at 145 MHz. (SWR= 1.29:1)(1.6% loss).
- S11 of -13.2db at 450 MHz. (SWR=1.56:1)(5% Loss).

Observed S.W.R. Results with N-type Connectors on UHF-1 sensor on 145 and 450 MHz.

Test Setup and Results:

- S11 of -28db at 145 MHz. (SWR= 1.08:1) (<0.2% loss).
- S11 of -31db at 450 MHz. (SWR=1.05:1) (<0.1% loss).

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More About Power/SWR Meters…

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How to read the Watt/SWR Meter Specification:

(The sensor(s) is the heart of your meter. A wattmeter is an instrument and we should understand it's capabilities and limitations)

- Insertion Loss:
  Measured in db or %. Should be < 1% or 0.05 db.
- Frequency Range:
  The range where directivity and accuracy are within acceptable limits.
- Power Capability (intermittent or continuous):
  Can the sensor sustain continuous power operation? Is there an engineering margin implied?
- S11 (reflected power due to impedance mismatch):
  -20 db is 1% reflected power. Poor S11 also limits the sensor minimum detectable SWR.
- Directivity:
  Ability of sensor to discern between forward and reflected power. Expressed in db. 25 db is very adequate and allows a minimum SWR measurement of 1.04:1.
- Balance:
  Not commonly given, but is related to Directivity and typically applies to H.F. bridge sensors.

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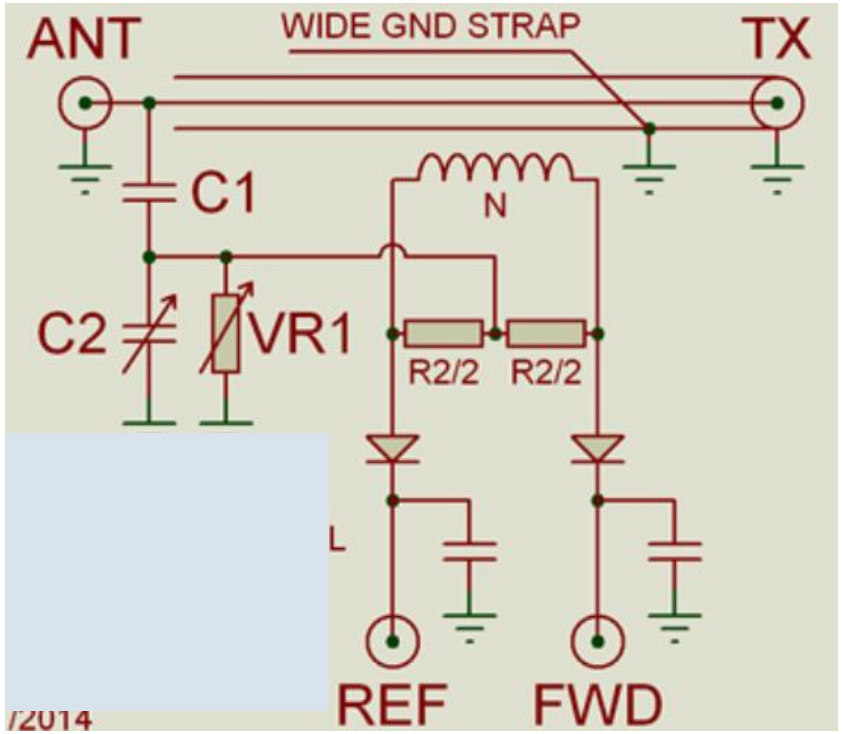
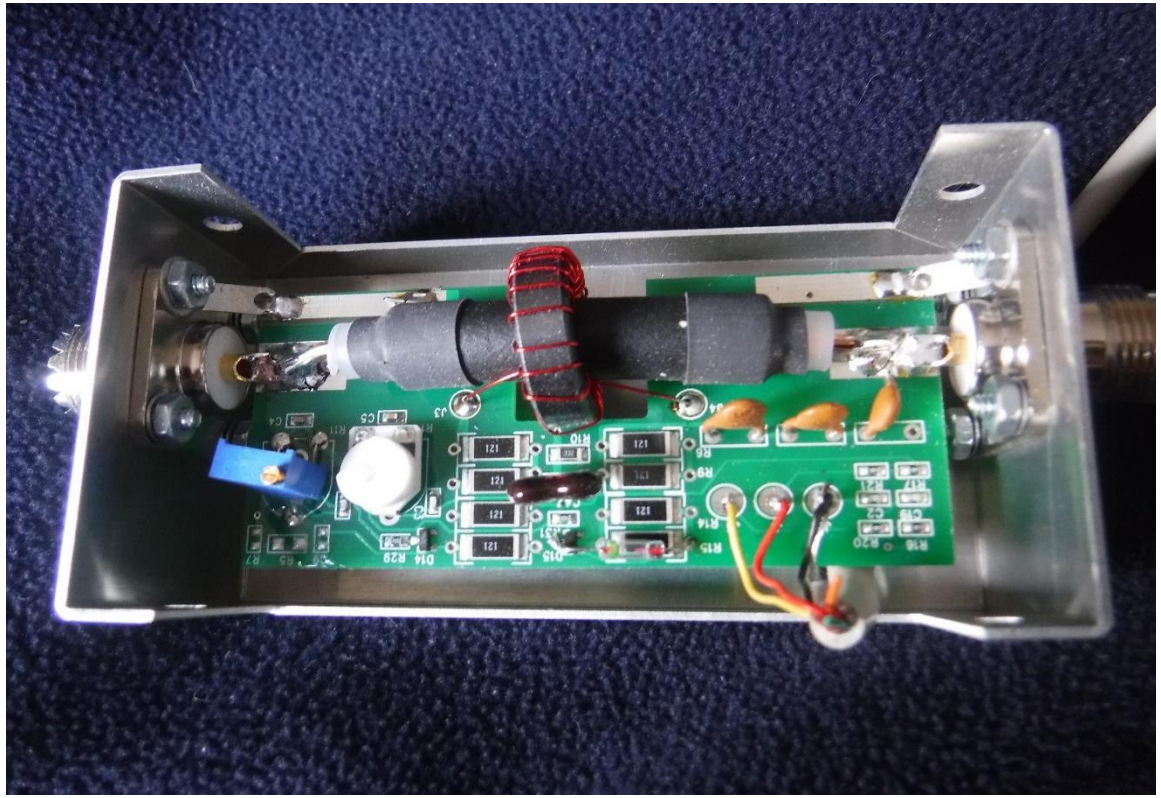
How Do H.F. inline couplers work?



Simplified Bridge Circuit

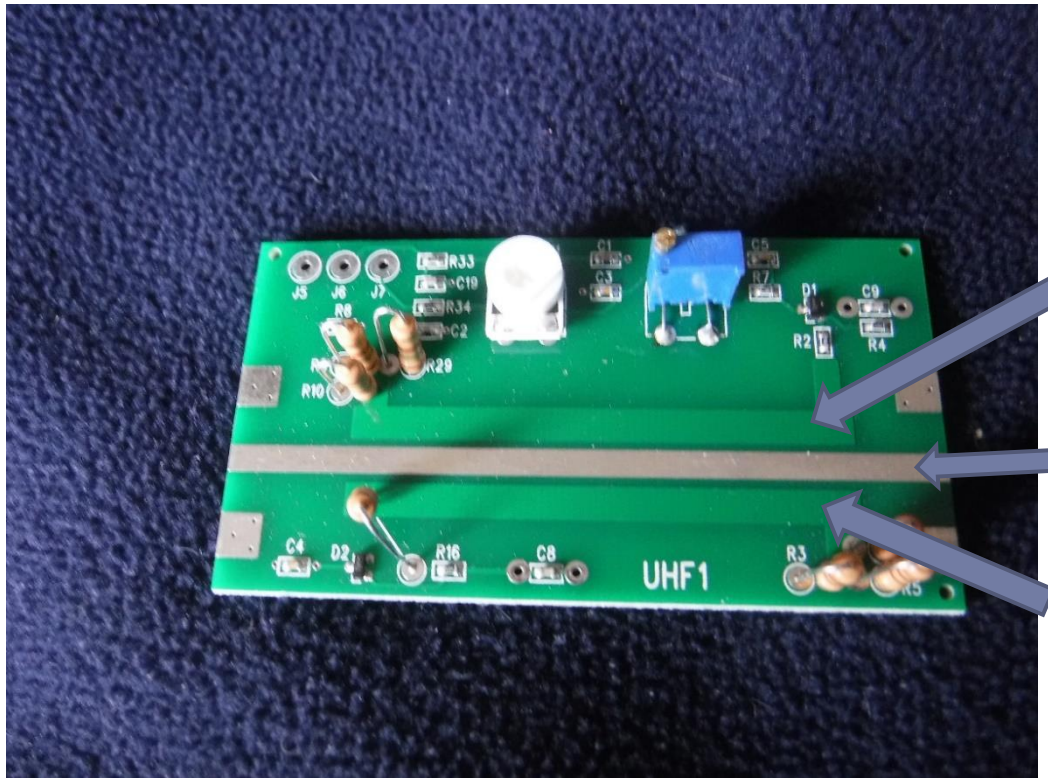


Internal view of Wavenode HF-1 Sensor

- **The toroid <u>current</u> transformer senses the line current.**
- **C1, C2 divider senses the line voltage.**

How UHF and SHF Stripline Couplers Work

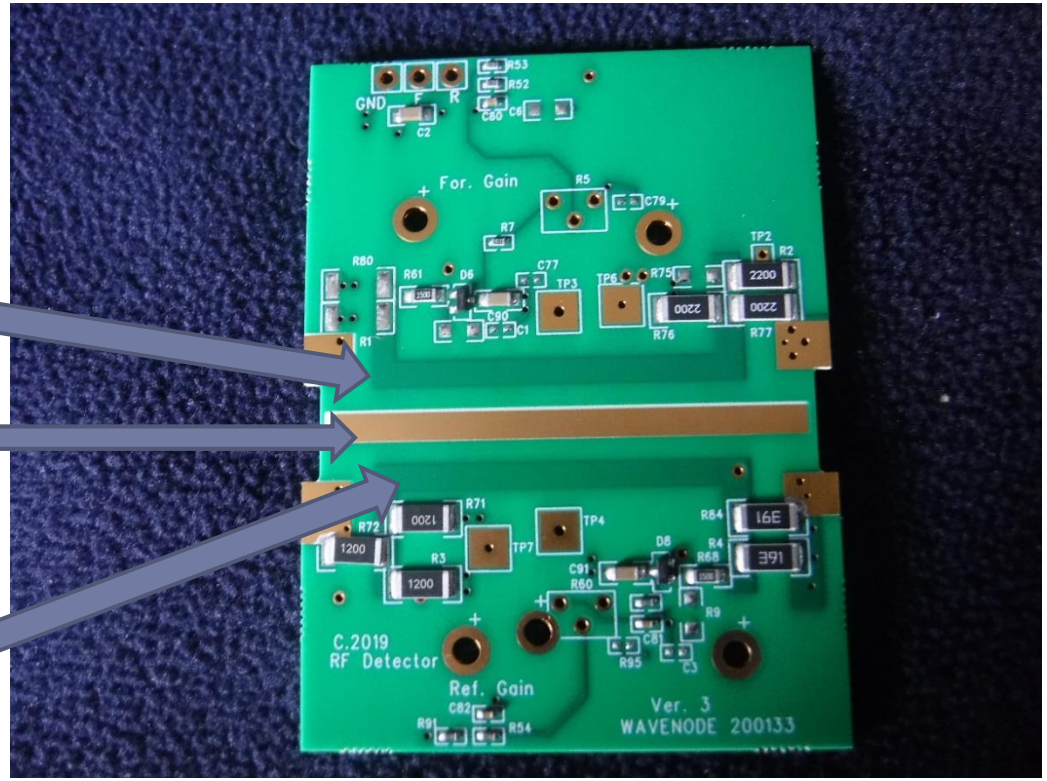
VHF and UHF sensing PC boards removed for clarity.



Forward Pwr. Sensor

RF Line

Reflected pwr. Sensor strip



Wavenode UHF-1 Sensor for 120-510 MHz .
Dual Stripline with -23 db coupling.

SHF-3B Sensor for 33 and 23 cm (0-500 Watt).
Dual stripline with -25 db coupling on Rogers 4003C PTFE material.

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The Question: Where does the Inline sensor go?

An SWR Inline Sensor measures the impedance of the line AT THE POINT WHERE IT IS INSERTED and compares it to the desired 50 ohm impedance. It cannot actually measure the voltage maxima and minima at every point in the line.

For this reason, there are two ideal places to put the sensor in the line:

1. At the transceiver (or Amplifier Output) since this is the equipment we wish to protect.
2. At the antenna feedpoint since this is a true measurement of the antenna without the effects of the feedline and it's dependence on length. Most often, this is not practical.
3. If using an external antenna tuner, put the sensor Before the tuner if using one sensor. This allows you to observe that the tuner is doing it's job.

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Exploring Digital Meters in More Detail.

How they Work.
Understanding Wattmeter Specifications.

(Section 2)

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Where Do We Place the Inline Sensor??

$$\Gamma = \frac{V_r}{V_f}.$$

Definition of Reflection Coefficient

$$\Gamma = \frac{Z_L - Z_O}{Z_L + Z_O}$$

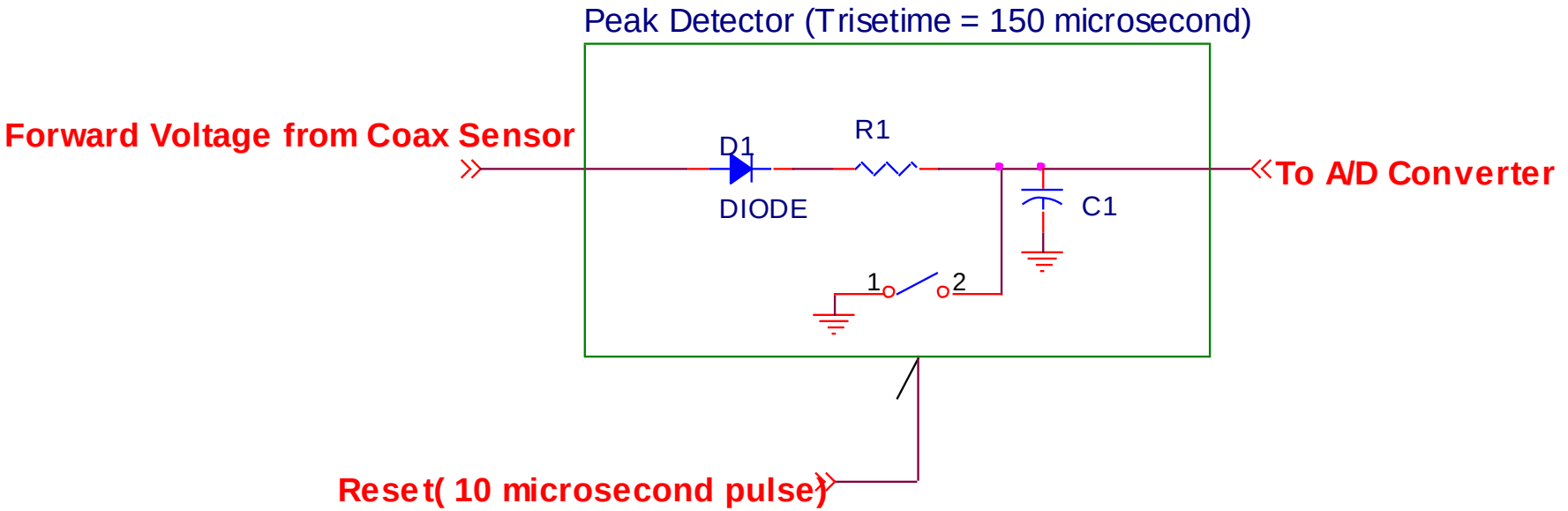
Note: Γ Is Independent of coax line length or position along the coax.

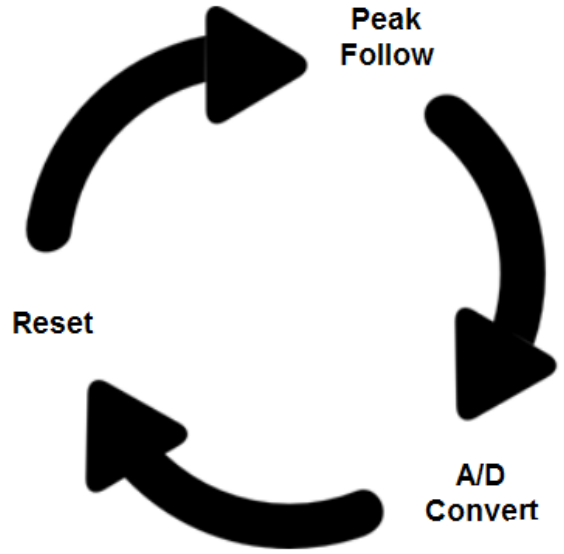
$$\mathrm{VSWR} = \frac{|V_{\max}|}{|V_{\min}|} = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

The VSWR only depends on the *amplitude* of the of the reflection coefficient Γ, so the measured SWR will be constant at any point on the coax length.

Peak Detection

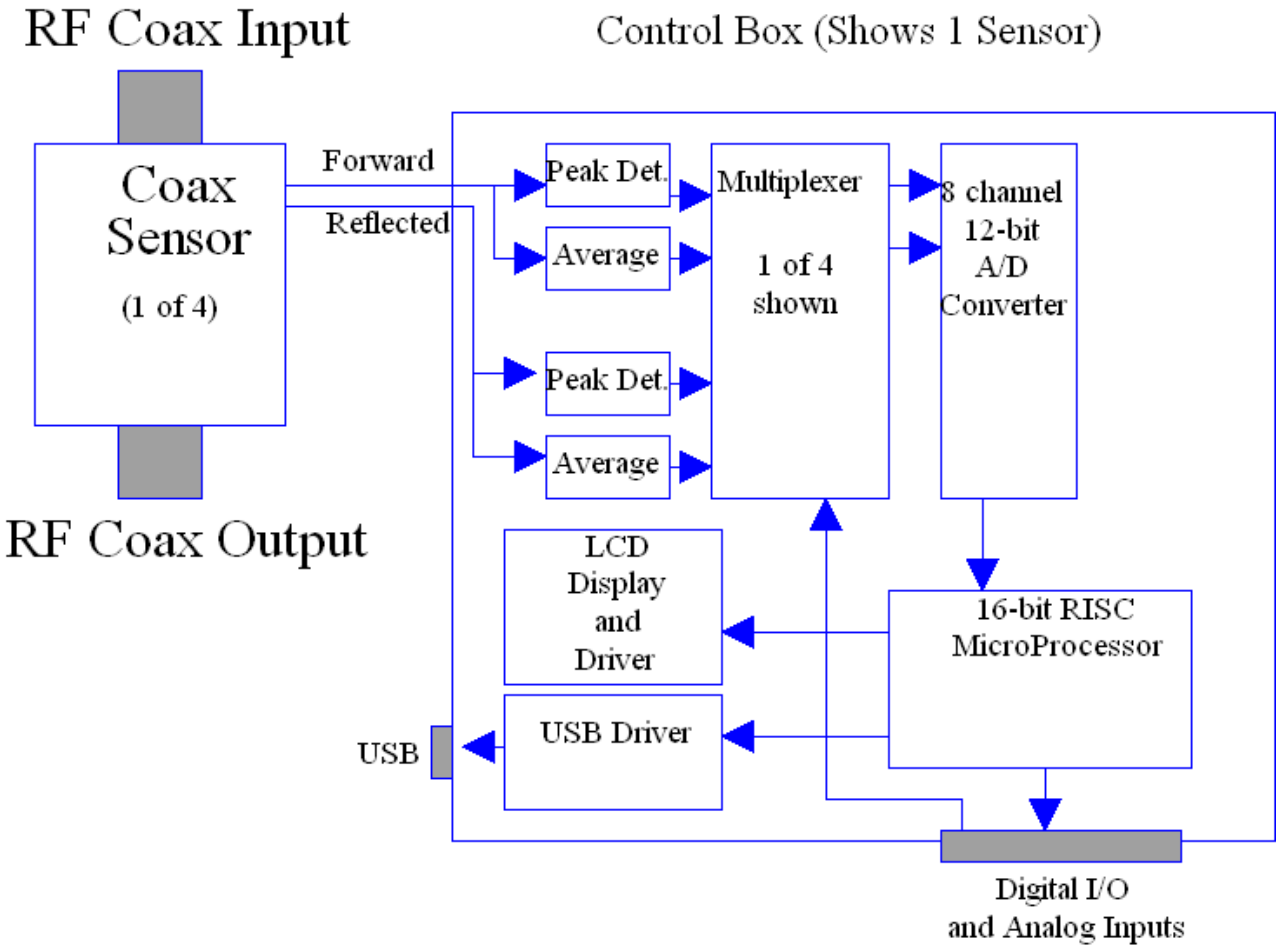
- Peak capture, A/D convert, reset 20 times per second. This happens simultaneously on forward and reflected power on all four sensors.
- Each sample is independent of the previous sample.
- Independent, sequential samples allow synchronous detection.





•Simplified schematic of Synchronous Peak Detector.

Synchronous Detection of Inline Sensors



- The gain (or loss) of an amplifier or antenna tuner must be measured synchronously, that is, at the same moment in time. This is especially true for amplitude-varying signals as SSB or CW. Therefore, the amplifier input and output sensors must measure the power (both forward and reflected) *at the same time*.

- To measure SWR with varying signal amplitude, both the forward and reflected voltages must be measured at the same instant in time, not one after the other. Therefore, dual and identical peak and average detectors for each sensor provide the best result.

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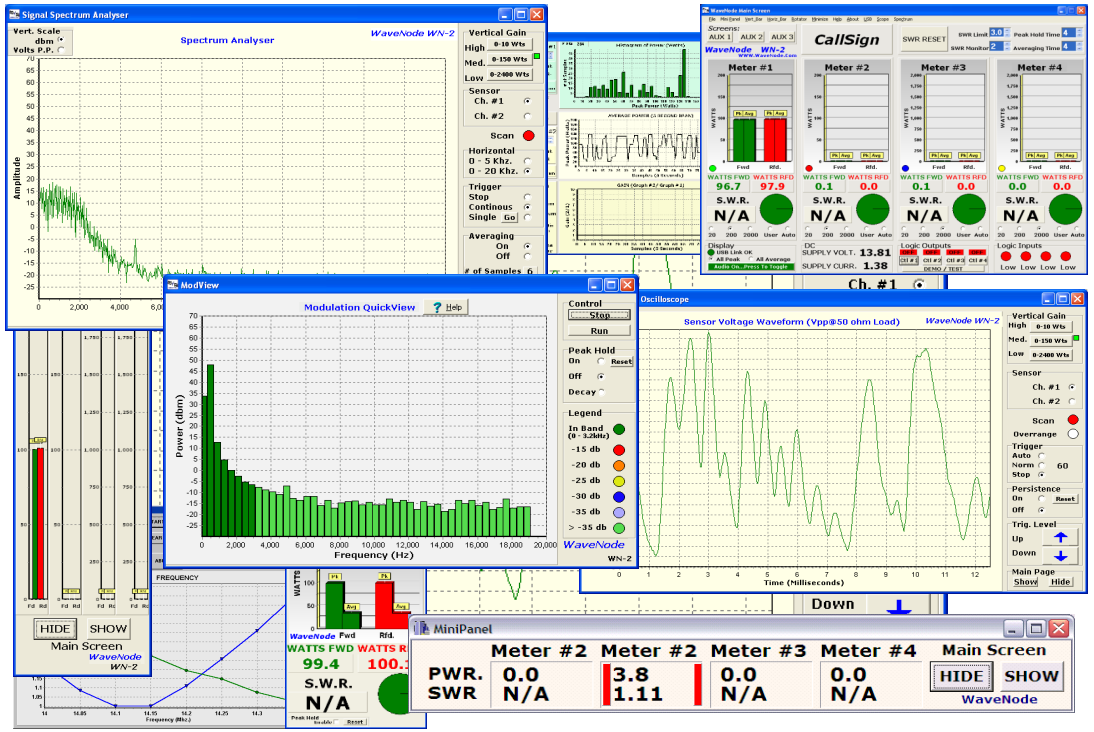
Expanded Discussion Wavenode Capabilities

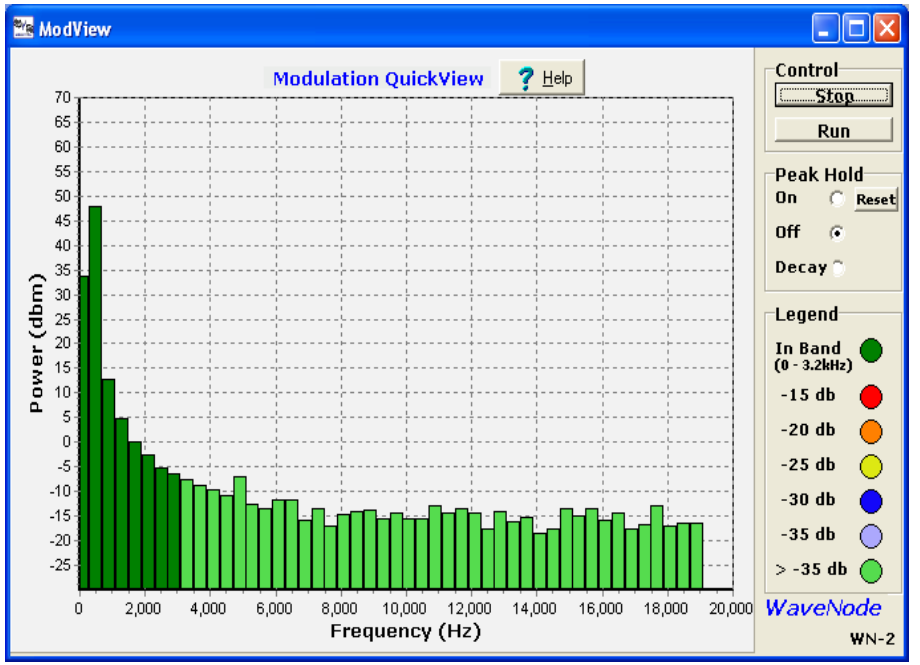
(Section 3)

What Else can We Do with the Measured Power Samples?

1. Sample the R.F. envelope and digitize the modulation envelope to provide a Modulation Oscilloscope and Spectrum Analyzer. The sampling must be done before the peak detectors.
2. We can compare two sensors to generate amplifier gain and compression curves.
3. We can monitor both input and output of an antenna tuner to measure loss and functionality.



Typical Screen Views with Wavenode Software



A Modview Screenshot with SSB

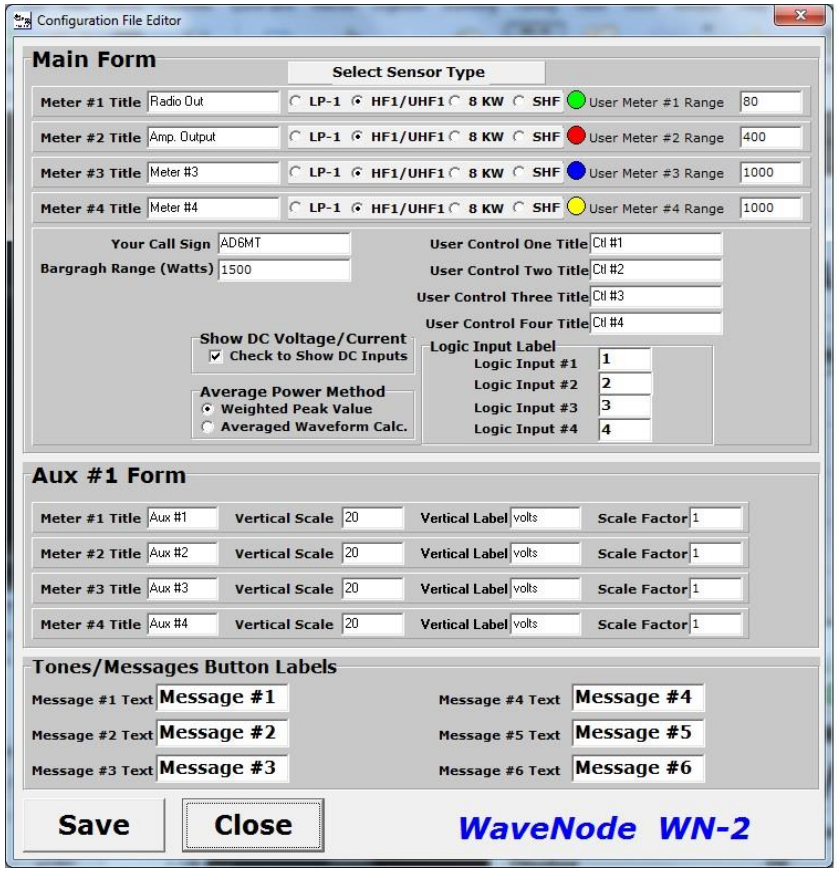
Can I Easily Install this Wattmeter and Use It?

(I don't want to read a 47 page manual. That shows a poor user interface).

- **Wavenode was designed to be easy and intuitive. We have an aversion to products that are hard to install. Software should be easy to understand.**
- 1. Wavenode products are designed for standalone or PC connected operation.
- 2. Wavenode sensors are plug-and-go. There are no tables, calibrations or other worries. You can add sensors at any time by plugging it in and get back on the air.
- 3. Our USB driver is for all Windows OS. It is digitally signed and certified by Microsoft for Wavenode meters.
- 4. Our software is easy to understand. The manual is the "Help" item on our menu bar. It's always there without searching elsewhere.
- 5. A good user interface doesn't happen by accident. You can explore all the features with a small "Help" button right there to tell you exactly what you are looking at. Just click and explore our screen views, you won't break it.

What parameters can I configure? Is it flexible?

- Wavenode meters have a configuration menu to label meters, set bargraph ranges, SWR trip levels, etc. You configure your software and meter the way you need. Change menu items as your station changes



The SWR limit that will trip the SWR level is determined by the screen view above. The “Monitor” determines which sensor (1->4) is being monitored for excess SWR.

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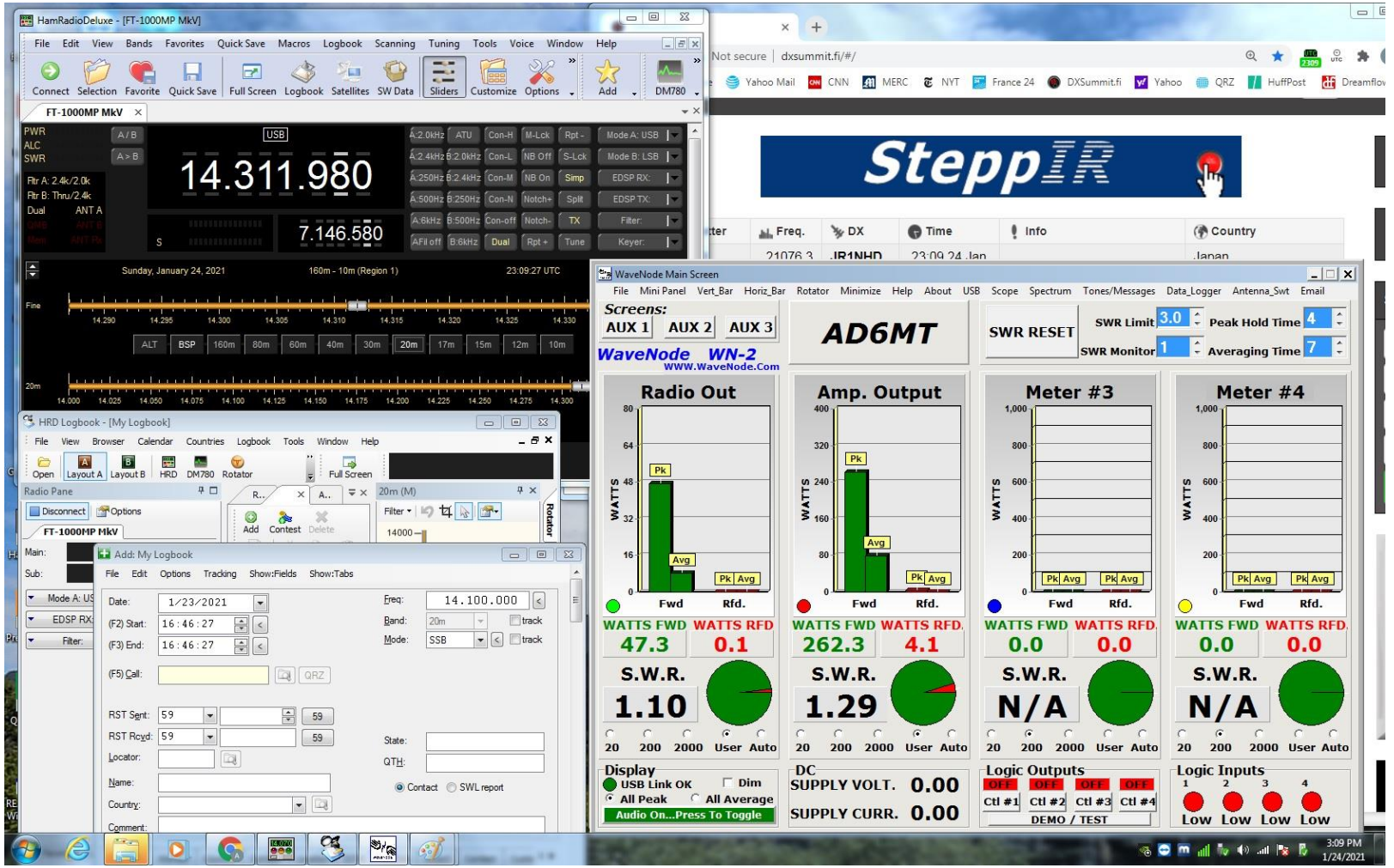
My PC Monitor is already Overflowing-no more room

My Monitor(s) look like this::

- DX skimmers
- Logging software.
- Radio Interface
- SDR Operation
- Rotator Controls

- Where can I put that Wattmeter software?

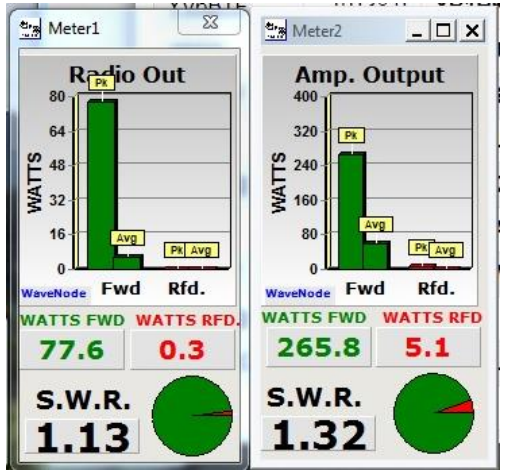
- (see next page for ideas)



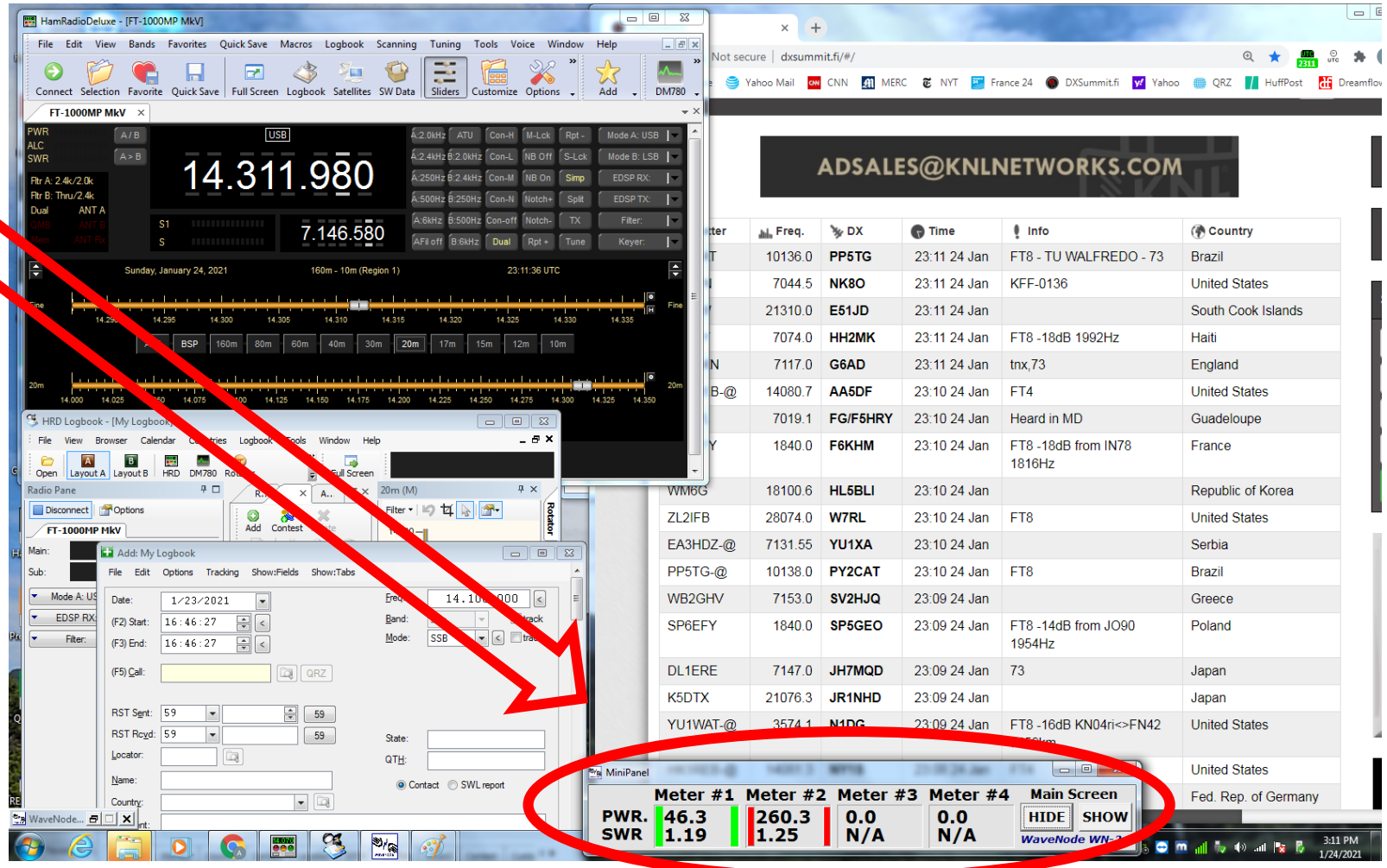
Get Power and SWR data with minimal Screen Clutter.

Your Wavenode software can fit here:
(The Minipanel screenview)

OR: Here is another option:



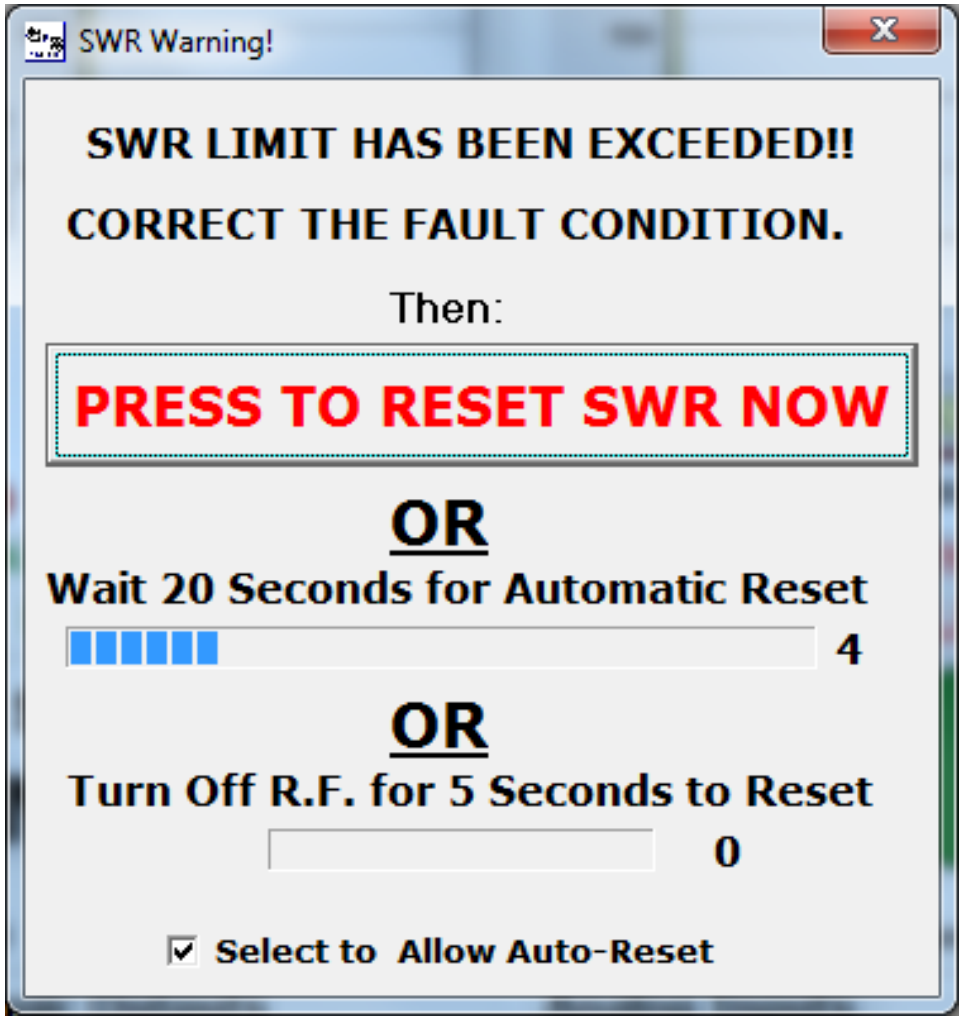
Single Meters show what you need most



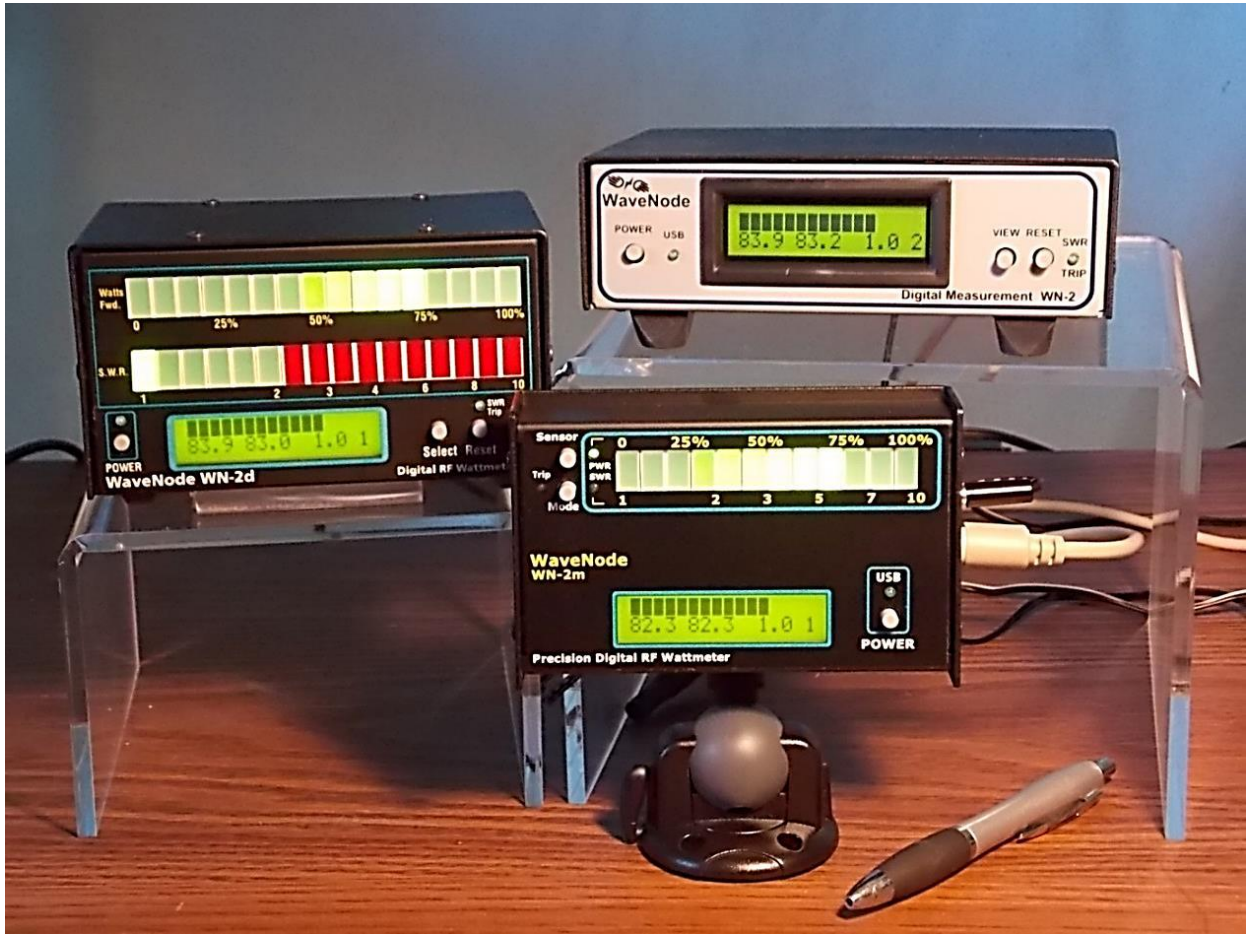
New features and Software Updates are always on our Website

- Wavenode models WN-2 and WN-2d have an SWR trip relay for the user. This is typically used to interrupt the amplifier keying line between transceiver and amplifier.
- The Smart Reset feature (March 2021) allows the relay to automatically reset when excessive SWR has energized the relay and deactivated the amplifier. This automatic reset occurs when:
-
- 1. The R.F. signal has been turned off for 5 seconds.
- Or:
- 2. 20 seconds after the high SWR event.

- You can also instantly reset the SWR relay by pushing the Reset button on the hardware or the "**PRESS TO RESET SWR NOW**" as on previous versions of software.

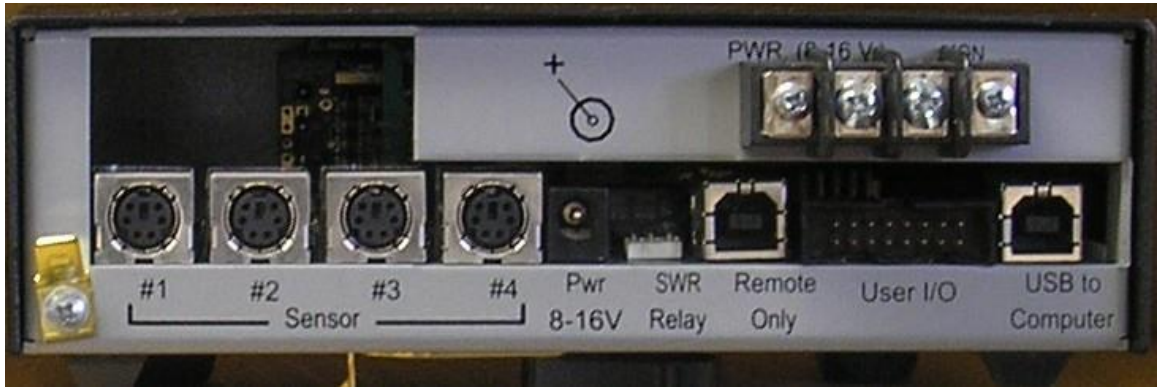


Shameless Product Promotion…Wavenode Digital Wattmeters since 2004



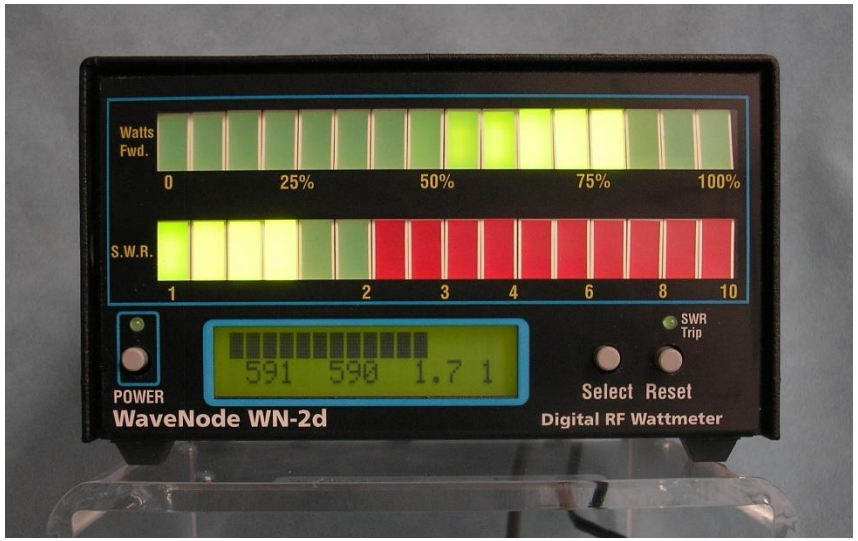
WaveNode WN-2 (4 R.F. Sensor Input)

- Front View with RF present showing bargraph and Peak, Average and SWR



- Rear View showing coax inline sensor inputs
- Other connections for power input, SWR relay connector, User I/O and USB port

WaveNode WN-2d (4 Sensor Inputs)

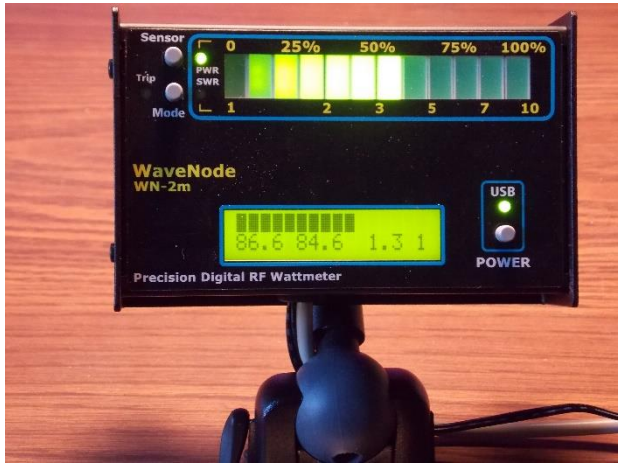


- Front View with Peak power and S.W.R. LED Bargraphs. Top bargraph displays peak power. The scale is user selectable for each of the four thruline sensors installed.
- Bottom bargraph shows SWR on 1:1 -> 10:1 scale.

- Rear View with Sensor Inputs, Auxiliary inputs, and USB Interface.

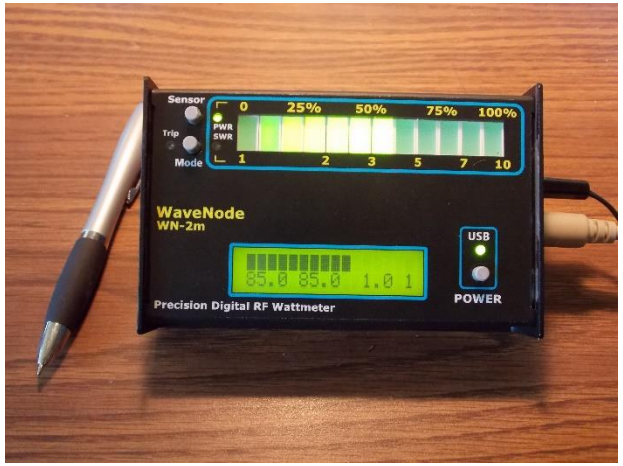
WaveNode WN-2m (2 sensors)

Various mounting options



On Optional Pedestal

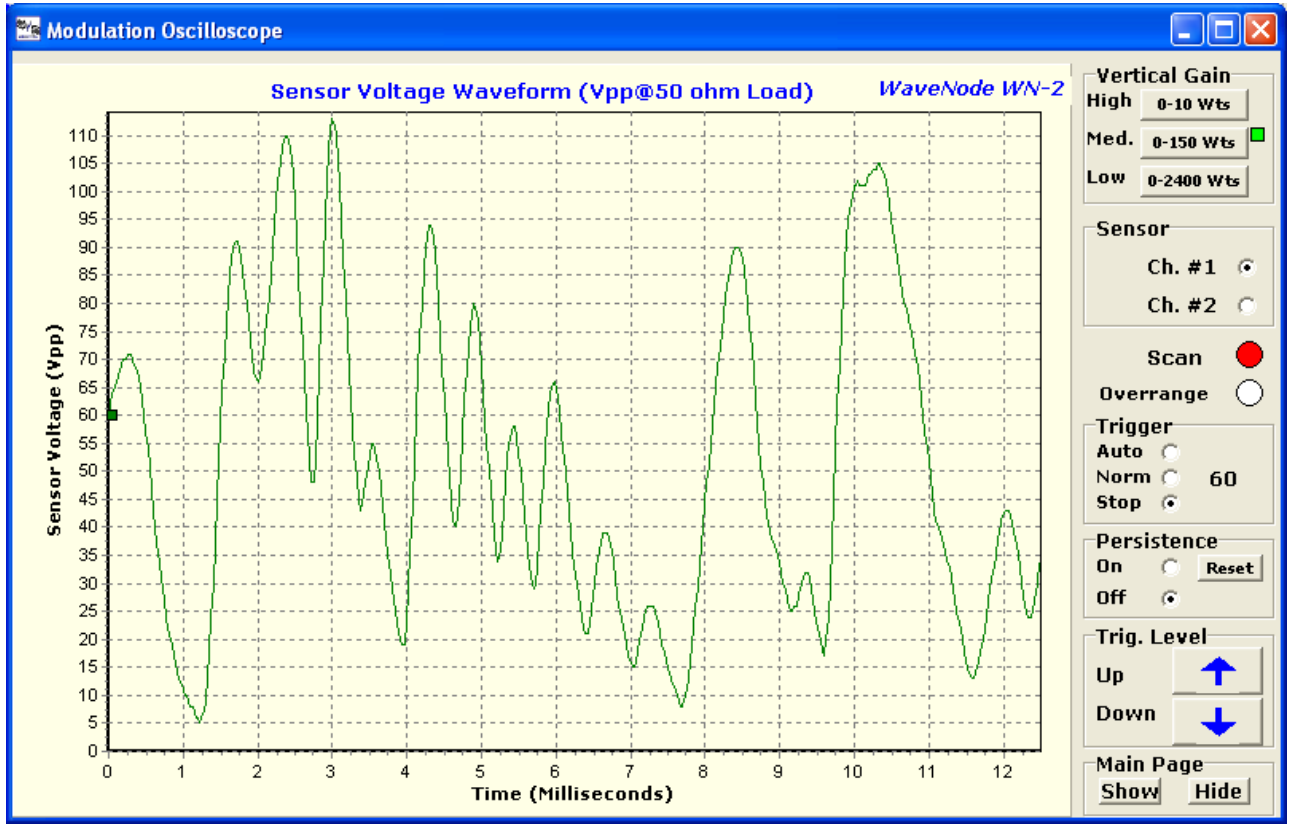
Tilted Viewing angle…Internal Connectors



Tilted Viewing angle..External Connectors

Showing Internal Connectors, Top or Bottom Cable Exit

Modulation Scope

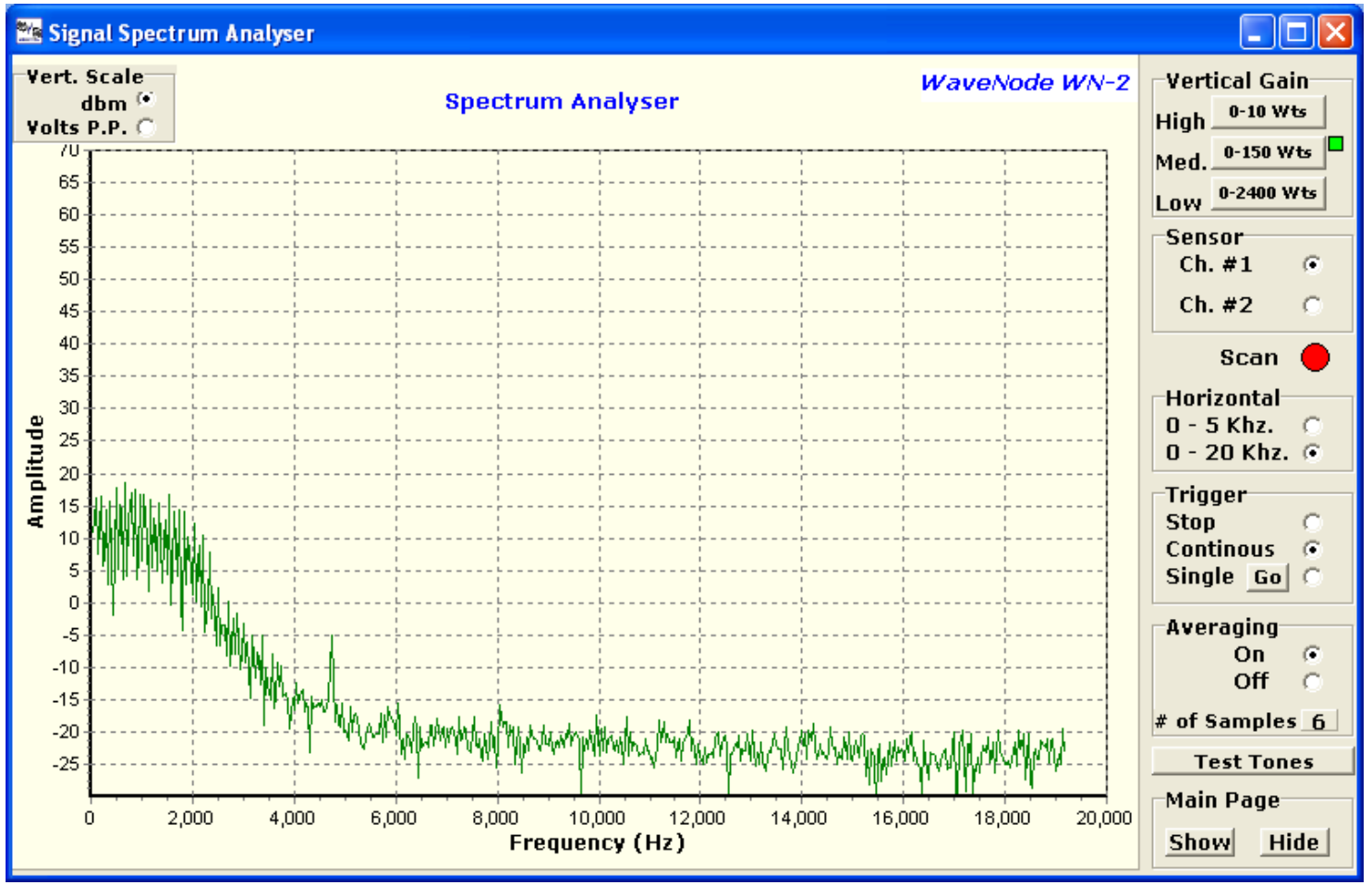


Modulation pattern on SSB.

- Scope shows actual RF Voltage at the coax in Volts Peak-Peak.
- The scope hardware/software is in the WN-2. Your soundcard is NOT used.

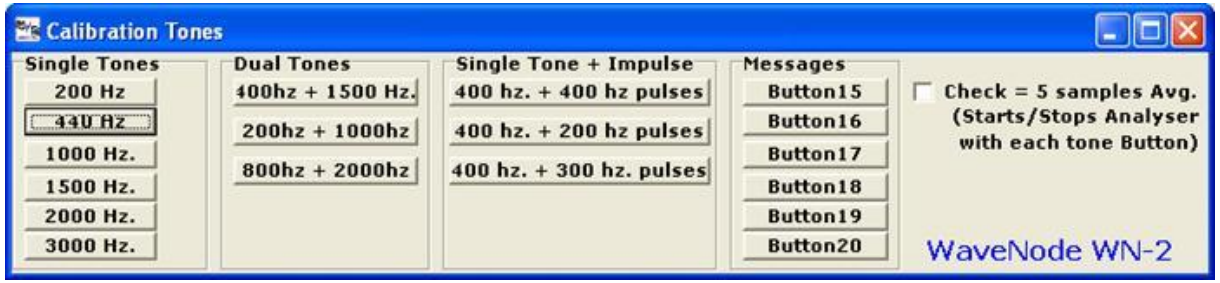
WaveNode

Spectrum Analyzer

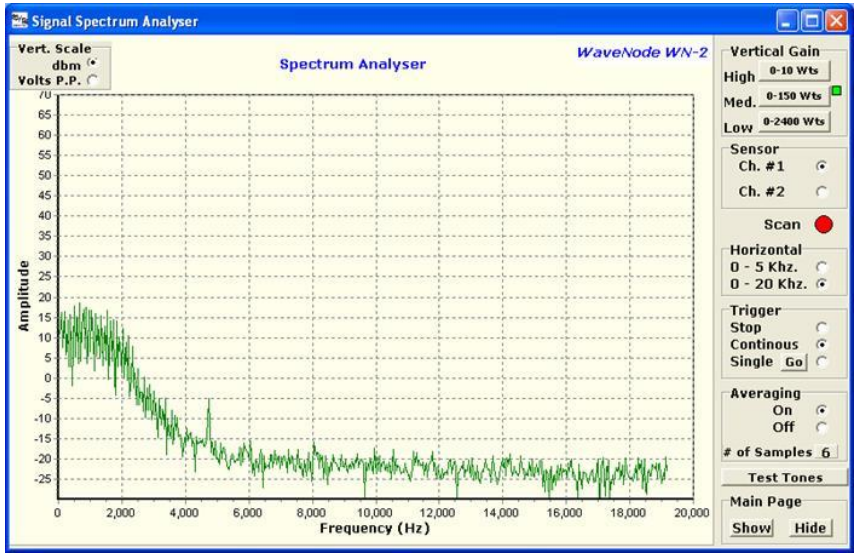


- The Spectrum Analyzer provides DC to 20 KHz modulation analysis.
- Has the features found in a laboratory Instrument for sound/distortion analysis.

Test Tones Menu



- Pressing the button activates the tone for 3 seconds, and the results can be viewed on the Spectrum Analyzer or Oscilloscope.
- Perfect for observing Linear Amplifier output without the use of a function generator.



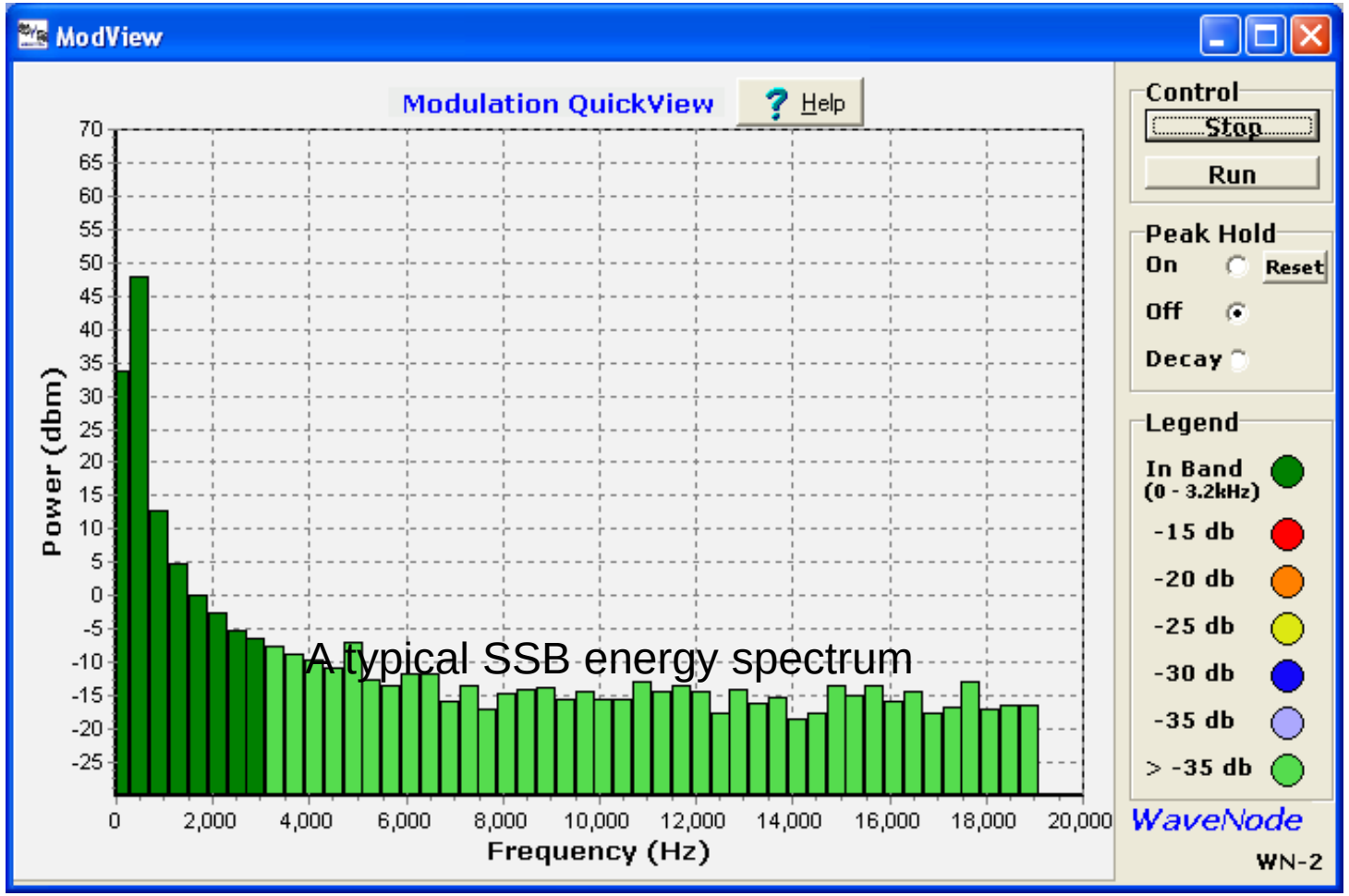
Question: Why pulse+sine Modulation?

Answer: The pulse energy spreads audio energy from 0-20Khz into the input, and allows observation of the transmitter bandwidth immediately with the Spectrum Analyser.

Pulse + Sine function Input

QuickView Modulation Spectrum

- For realtime, continuous monitoring
- Fast ,continuous viewing of IM and Splatter components into adjacent frequencies.
- The energy is divided into 400Hz segments and compared to DC -3 KHz energy.

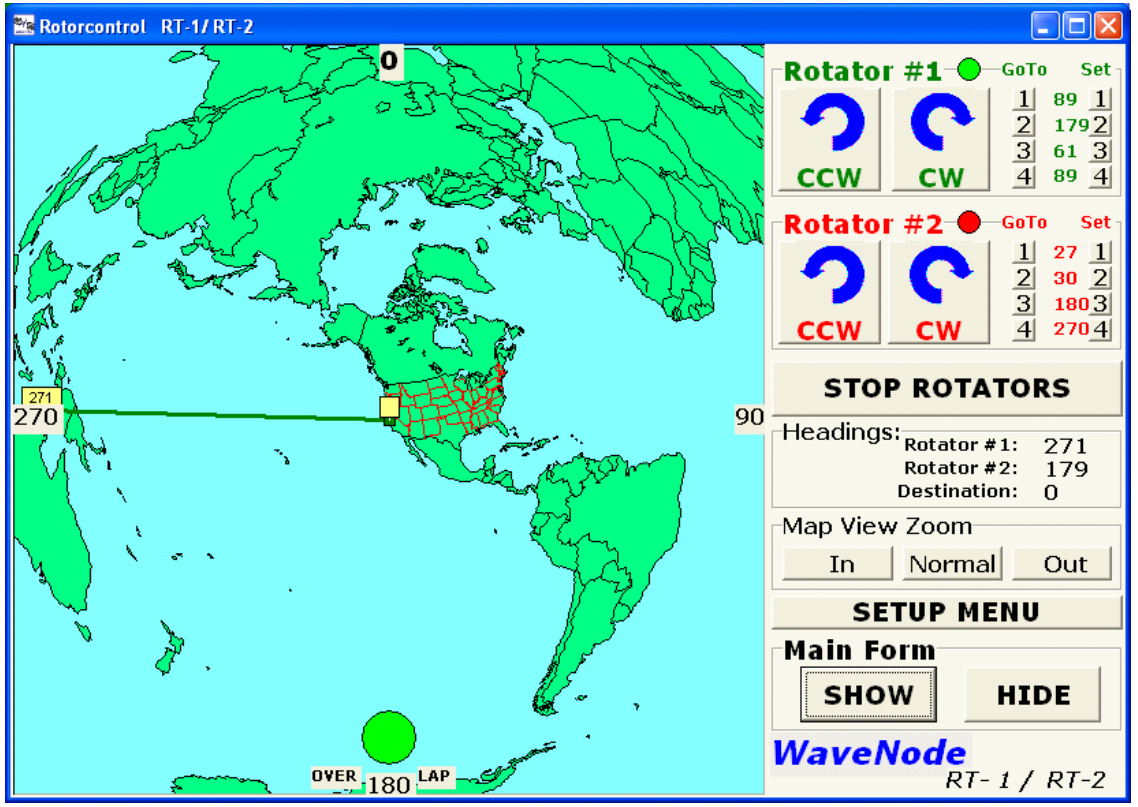


WaveNode

Now with Email/Text fault notification for high SWR or low R.F. power output.

- Text/Email fault notification for remote base station or repeater usage.
- Generate an email or Text when monitoring high/low batterie voltage, RF power too low, or high SWR events

Optional Yaesu Rotator Control



- Single/ Dual Rotator Control and View.
- Map View Customized to your QTH.
- No Alignment or additional software necessary.
- Click on Map to Send your Rotator to a new Position.

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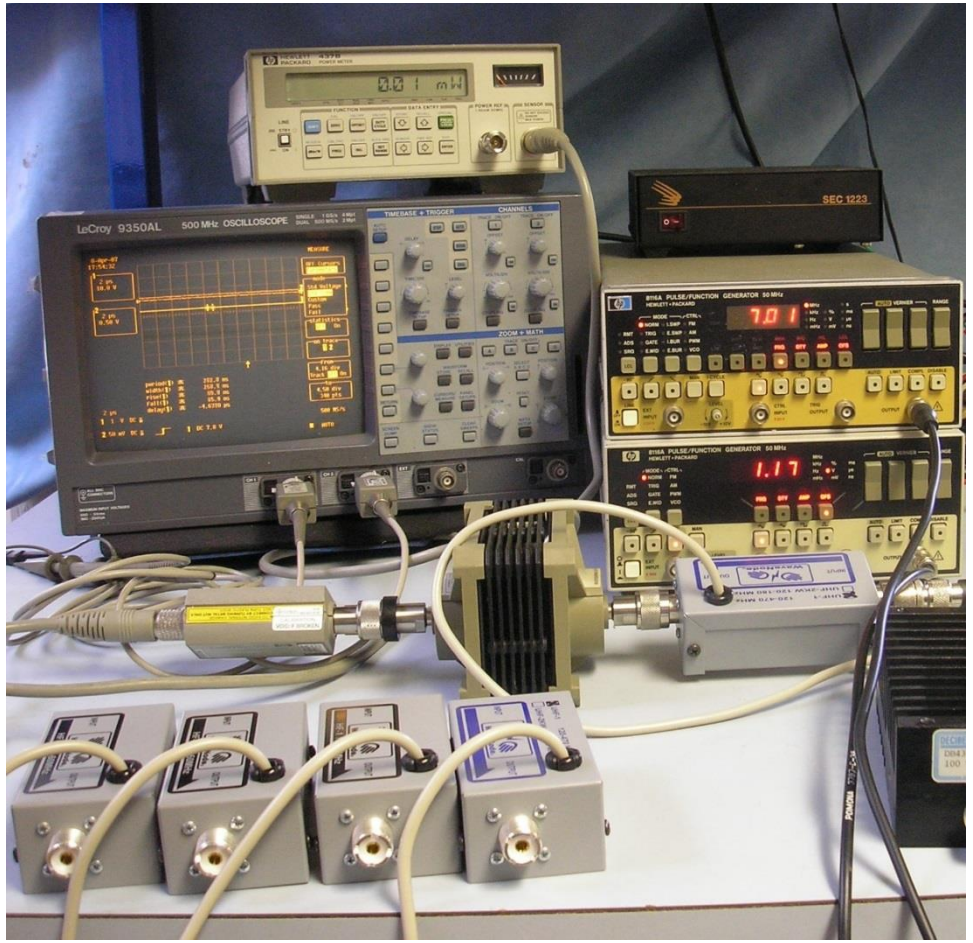
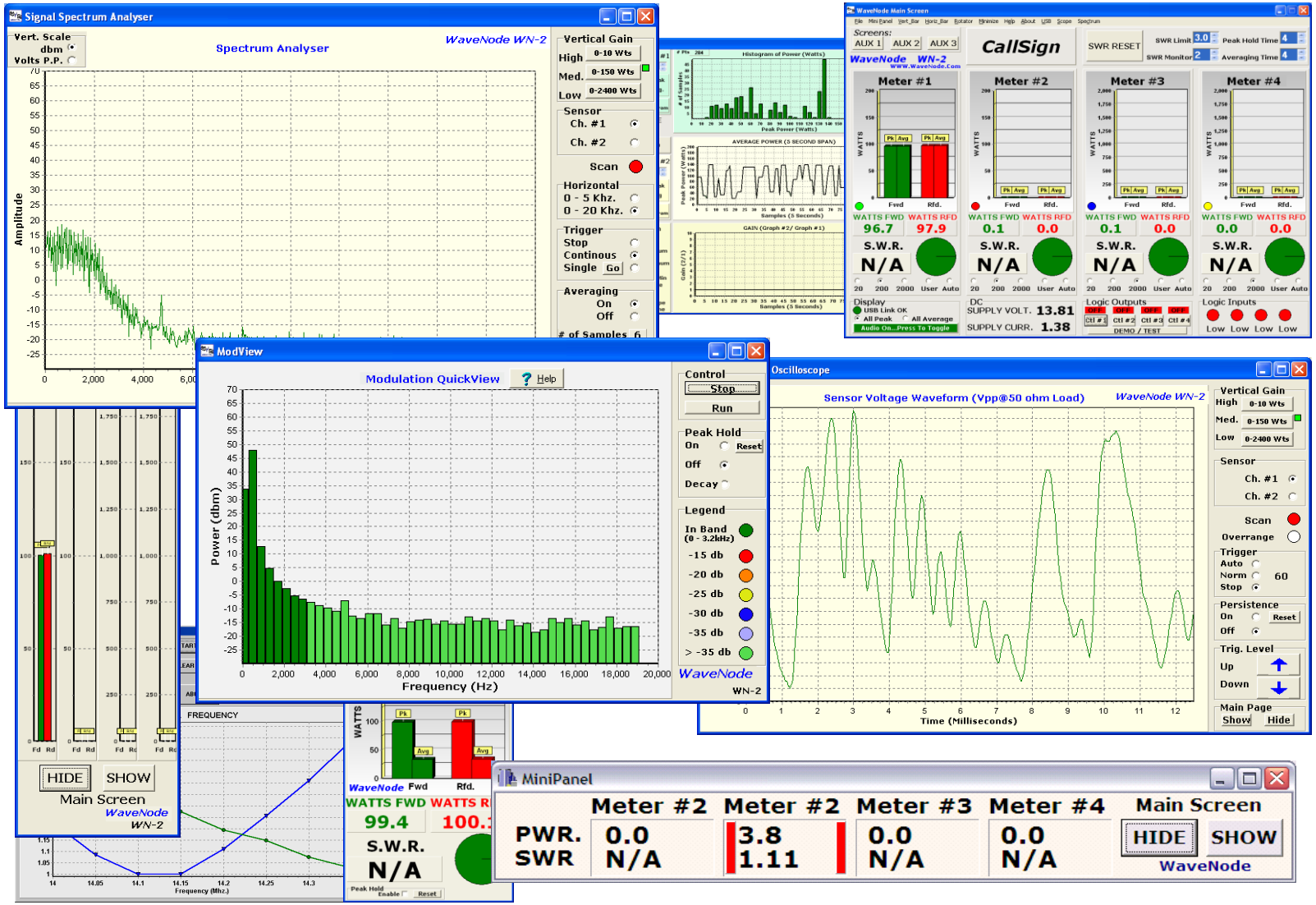
Test/Calibration

- NIST traceable Calibration with HP Model 437B power meter and matching 8482B Detector.



Graphical Views Optimized for You



WaveNode

WaveNode products provide continuous station monitoring.

- Simultaneous monitoring of RF power/SWR on two or four separate coax inline sensors. Fast peak detection provides power and SWR data with a single CW dit.
- Calculates SWR, peak and average power for display on the built-in LCD display. Bargraph displays of peak power, average power, and S.W.R.
- Direct USB computer interface on all products for Microsoft OS XP, 7, Vista, 8 and 10.. Microsoft digitally signed USB driver makes installation easy.
- 12-bit A/D converter, and precision peak/ average detection circuitry for each sensor. Digital Oscilloscope view of the modulation envelope.

WaveNode

Features (continued)

- Spectrum Analysis monitors the data content and bandwidth of the modulation speech or data stream. Monitor Intermodulation and splatter real-time as you operate.
- Additional monitoring circuitry is provided for station DC voltage/current (WN-2).
- Four digital outputs allow monitoring and control with remote PC (WN-2 and WN-2d).
- Four additional analog inputs allow real-time monitoring on the local LCD display or remotely through USB interconnect to a host PC (WN-2 and WN-2d).
- Relay provided to trigger on user selected SWR level for equipment protection (WN-2 and WN-2d only).
- All data viewing and control can be done locally or remotely via PC.

WaveNode

Talking wattmeter

Wavenode meters can voice announce either SWR or Peak Power with a single keyboard keystroke. Type either “s” or “p”.

Any of the four sensors can be announced by typing 1, 2 , 3 or 4.

A voice or tone will indicate. Type “t” or “a” to select tone or voice announcing. The tone mode will continue until “t” is typed again.

If SWR level is exceeded, a voice announcement will be made to prompt the user.

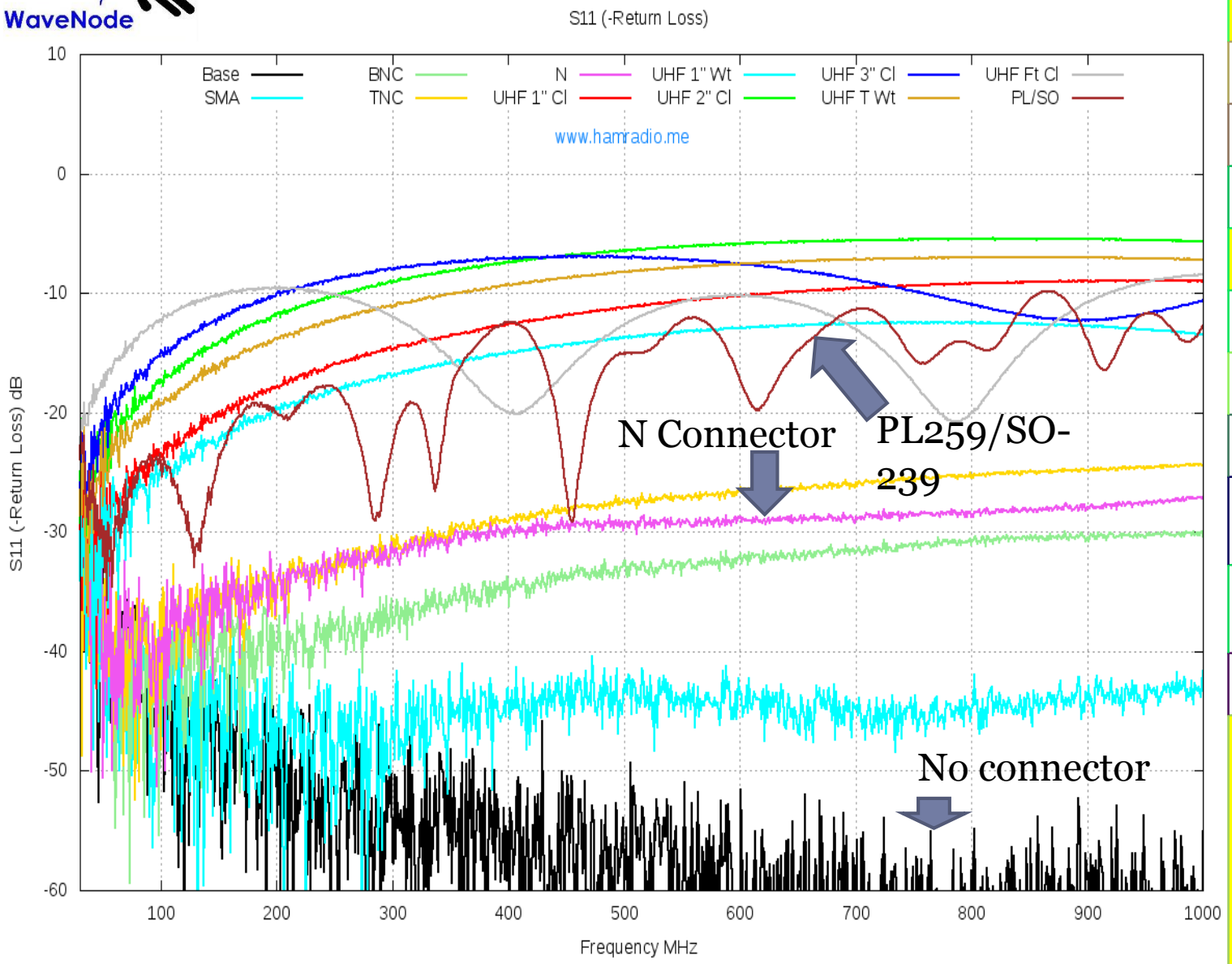
WaveNode

Review

- Expandable. Operate stand-alone or with P.C.
- Real-time R.F. Diagnostic and Monitor tools. Transmitted signal bandwidth continuous monitoring.
- Commercial, rugged construction.
- Software upgrades are always provided free of charge on our website.
- Add sensors as you need them. Just plug the new sensor in and you are ready to go.

Some Additional Information from the Web with links

Return Loss S11 for Different Types of Connectors



Item	Description
Baseline:	Direct connection of test cables using superb SMAs.
SMA:	Same as baseline plus two more SMA barrels.
BNC:	Two SMA to BNC Converters plus one BNC Barrel in between.
TNC:	Two SMA to TNC Converters plus one TNC Barrel in between.
N:	Two SMA to N Converters plus one N Barrel in between.
UHF 1″ Cl:	This is a 1″ Amphenol Model PL-258 Barrel with clear dieletric.
UHF 1″ Wt:	El cheapo 1″ SO-239 Barrel with White dielectric.
UHF 2″ Cl:	A 2″ SO-239 Barrel with Clear dielectric.
UHF 3″ Cl:	The combination of the Amphenol 1″ and the 2″ using a Male-Male joiner. It is really about 3.5″ long.
UHF T Wt:	A UHF T adapter with two SO-239 and one PL259 and White dieletric. The PL259 port was left open.
UHF Ft Cl:	A 12.5″ long SO-239 Barrel. This is the thing used to stick through walls.
PL/SO:	One SMA to N, then N to SO-239 Converter directly mated to one PL259 to TNC converter then TNC is adapted to SMA. This is the only *non-barrel* UHF configuration and presents the smallest and shortest impedance bump to the RF signal of all the UHF connections under test.

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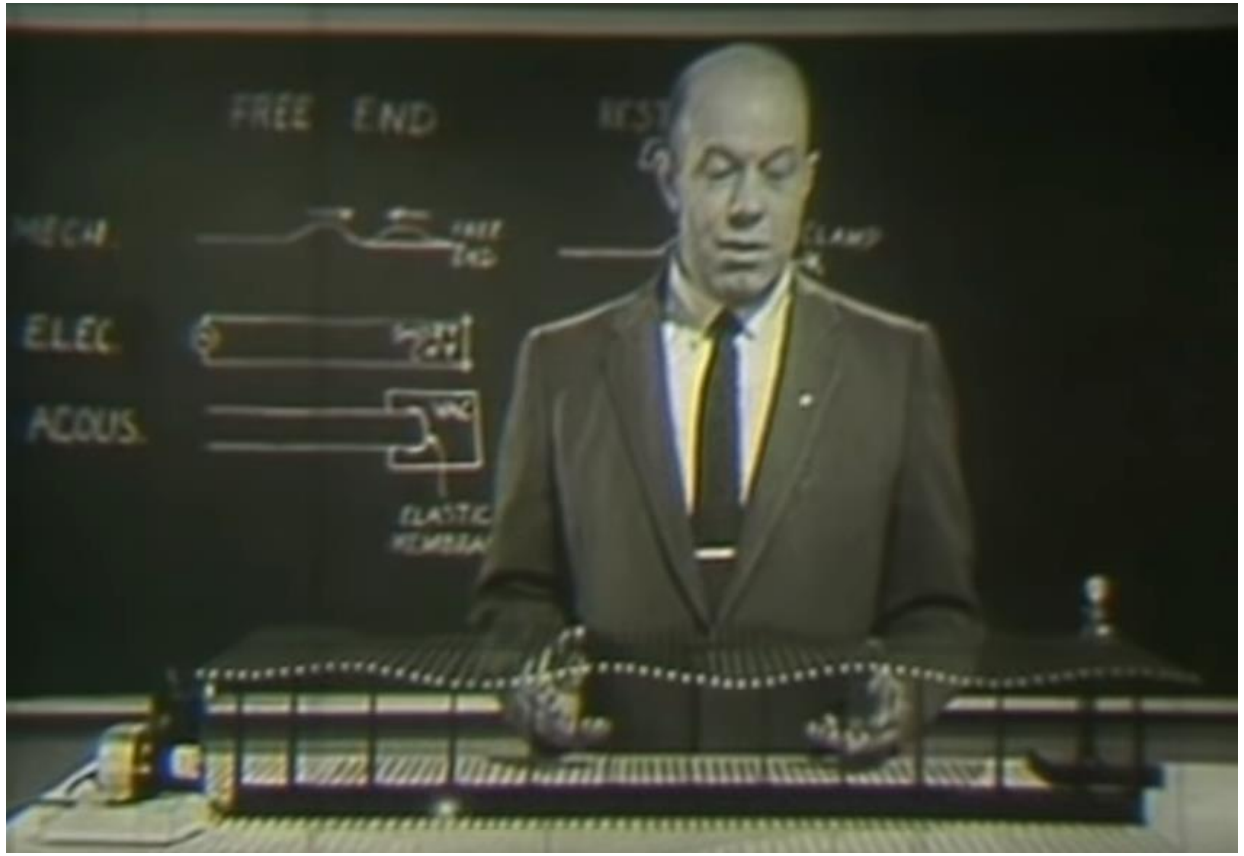
Video of S.W.R. on a Spring Model



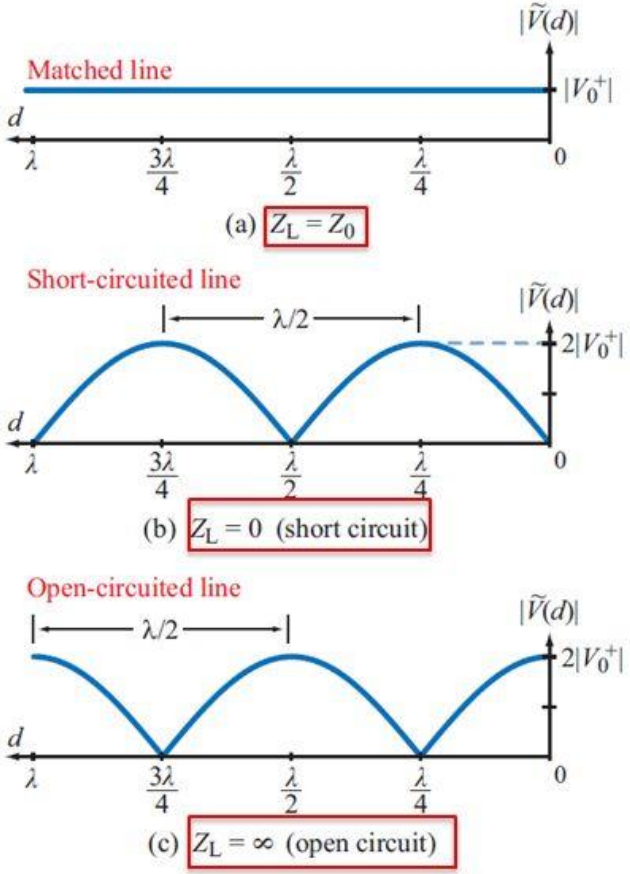
It's a classic video that every Science student has seen, but it is a good reminder.
(and now has application to our life)

https://www.youtube.com/watch?v=DovunOxlY1k

WaveNode

Standing Waves on Line that is terminated with 50 ohm, short, and open.

Standing Wave Patterns for 3 Types of Loads



With no reflected wave present, there will be no interference and no standing waves.

$\Gamma = 0$

Line termination is 50 Ohm.
Voltage is equal at the source and along the line.

$\Gamma = -1$

Shorted Line: termination voltage is 0.
Note Vmax is 2X voltage.
Maxima occur every lambda/2.

$\Gamma = 1$

Open Line: Termination current is 0.
Vmax is 2X voltage (as with shorted line).
Maxima occur every lambda/2.