



Application Note #6

Ham Radio Station Monitor Performance and Selection

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The SMT Station Monitor and SMT-Pro Station Monitor are ideal for monitoring the performance of the entire transmitter chain for both AM and SSB operations. Selecting which SMT Station monitor depends on your measurements needs. For basic monitoring of high power RF (QRO) only, than the SMT Station Monitor is recommended. If you want to monitor both high power (CRO) and low power (QRP) with higher precision than the SMT-Pro is recommend. This discussion will give you some insight to help you make a more informed selection.

One of the best methods to monitor your station is by observing the demodulated RF being transmitted and or comparing the amplified RF to the un-amplified RF from the transceiver. This can be done with a trapezoid monitor and or two tone tests.

The station monitor consists of a wide band sampler, a high performance demodulator, a variable base band output and an oscilloscope trigger output, A linear RF amplifier generally amplifies an RF signal from .5 – 5 Watts by 30dB or more to about 500-1,500 Watts. Its performance and modulation can be characterized using a spectrum analyzer (expensive) or a low cost oscilloscope using a trapezoid display.

This is done by sampling the amplifier's output by using an RF sensor such as a sampler or coupler. This sensor is connected to the oscilloscope's vertical (Y) input.

The input of the amplifier is driven by a transceiver which usually outputs less than 100W. Its output drives the input to the amplifier and also a wide band demodulator which extracts the baseband from the modulated RF.

It is this baseband that is connected to the oscilloscope's horizontal (X) input. This display yields a trapezoid pattern. This pattern compares the transceiver's output to the amplifiers output. If the amplifier is linear without any distortion and not overdriven, the trapezoid pattern will be a linear undistorted triangular waveform see Fig1. To rely on such a measurement, the demodulator and signal samplers must be linear and free of distortion.

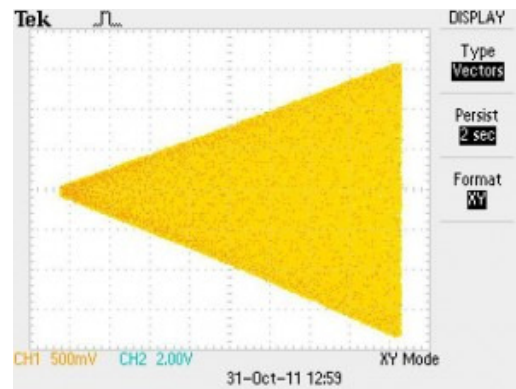


Fig. 1 Trapezoid test pattern

Most passive wide band demodulators employ an envelope detector. This detector is an electronic circuit that takes a high-frequency signal as input and provides an output which is the "envelope" of the original signal. Generally a diode rectifies the incoming signal, allowing current flow in only one direction.

Most practical envelope detectors use either half-wave or full-wave rectification of the signal to convert the AC audio input into a pulsed DC signals. Filtering is then used to smooth the final result. This filtering is rarely perfect and some “ripple” is likely to remain on the envelope follower output, particularly for low frequencies. More filtering gives a smoother result, but decreases the responsiveness; thus, real-world designs must be optimized for the application.

Low level detection

Another undesirable artifact is non-linearity of the detected baseband. This is caused by the diode’s conduction voltage drop ranging from .2 volt to .8 volt depending on the diode type and current. The diode does not linearly detect in this diminished conduction region. For high level RF envelopes this small region usually represents only a small percentage of the envelope and can be ignored.

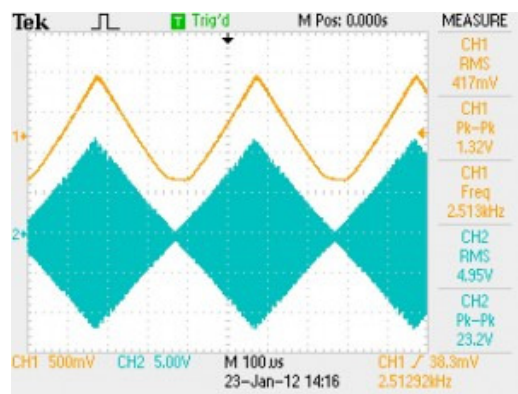


Fig. 2 Demodulator clipping no bias

See Fig 2. However, in low level RF envelopes encountered with QRP operation, this region represents a considerable portion of the modulation envelope. As a result, the baseband will exhibit significant non-linearity near the

Unique diode bias circuit

One way to mitigate this undesirable phenomena is to bias the diode such that it is conducting throughout the 100% modulation envelope. The SMT-Pro Station Monitor incorporates such a bias currents source. See Fig 3. This provides exceptional baseband linearity over a wide input range for precise transmitter amplifier linearity measurements.

This discussion focuses on the trapezoid test technique. The RF sampler or RF coupler and demodulator performance can impact the quality of the test

Note the clipping at low modulation levels (upper trace) especially evident during the modulation trough. This phenomenon is caused by the inherent lack of the detector level bias current.

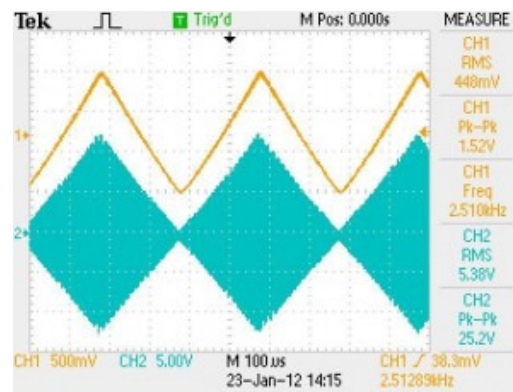


Fig. 3 Modulation envelope with bias

See Fig. 3 Note the demodulated product (upper waveform) clearly shows the improvement at the trough modulation level resulting from the addition of the detector level bias current option.

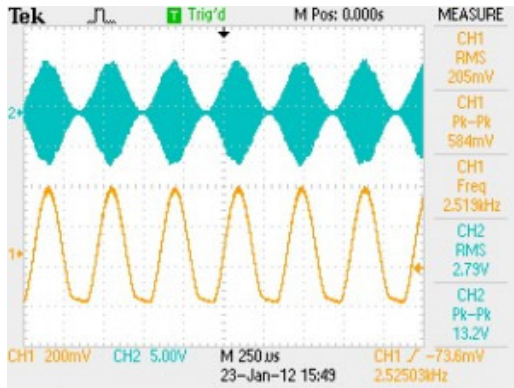


Fig. 4 Demodulated sine wave without bias

Fig. 4 Note the RF envelope (top waveform), detected product (bottom waveform) without bias current option. This is caused by the intrinsic lack of detector bias current at the modulation trough.

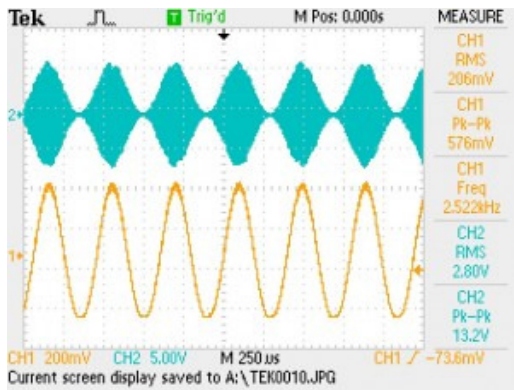


Fig. 5 Sine wave modulation with bias

Fig. 5 Note the lack of clipping at low modulation levels is especially evident during the modulation trough. This is the result of adding low level detector bias current available on the SMT-Pro option.

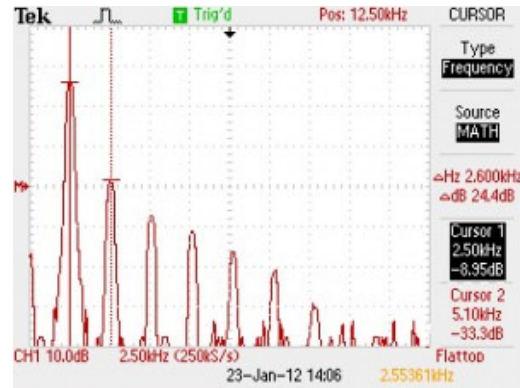


Fig. 6 THD without bias

Fig. 6 Note the significant harmonic distortion (-24.4 db) levels resulting from modulation through clipping without the detector bias option. This is especially noticeable at low power level such QRP operation. At higher levels this effect is significantly reduced.

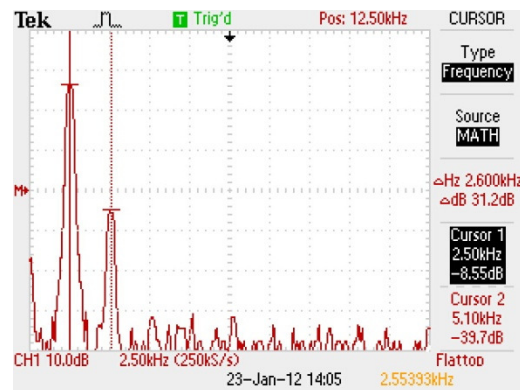


Fig. 7 THD with bias

Fig. 7 Note the significantly reduced harmonic distortion levels as a result of eliminating modulation through clipping with the detector bias option. This is especially noticeable at low power level such QRP operation. At higher levels this effect is significantly reduced. The second harmonic distortion is down -31.2 dB. At higher modulation levels of > 5watts, second order harmonic distortion is -45 dB. All other modulation products are virtually eliminated.

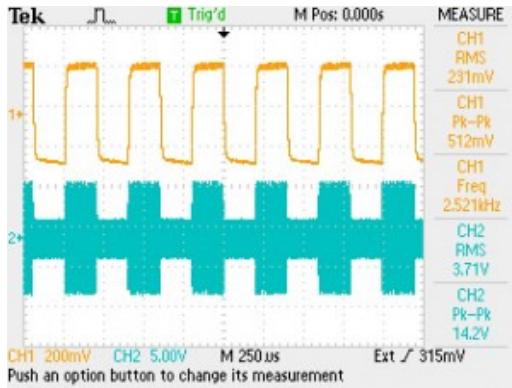


Fig. 8 Pulse response

Fig. 8 This graph shows the modulated RF envelope (lower trace) along with the demodulated signal (upper trace). Note that the transition times easily meet the bandwidth specifications (10-30,000 Hz) there is no spurious distortion ringing, overshoot present.

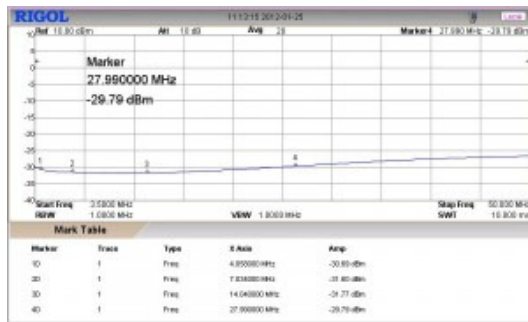


Fig. 9 Sampler bandwidth

Fig. 9 The nominal sampler output equals -30dB of the RF being sampled. This is a power ratio reduction of 1000:1. This also equals a voltage ratio reduction of 31.623. Decibels state a power ratio, not an amount. They tell how many times more (positive dB) or less (negative dB) a signal is but not how much more or less in absolute terms.

Decibels are logarithmic, not linear. For example, 20 dB is not twice the power ratio of 10 dB. Use this equation to find decibels: $A = 10 \cdot \log_{10} (P2/P1)$ (dB) where P1 is the

power being measured, and P1 is the reference to which P2 is being compared. To convert from decibel measure back to power ratio: $P2/P1 = 10^{(A/10)}$. Voltage is more easily measured than power, making it generally more convenient to use: $A = 20 \cdot \log_{10}(V2/V1)$. Where A=voltage ratio. The equation for obtaining voltage ratio from dB is $V2/V1 = 10^{(A/20)}$. Thus, to obtain the equivalent voltage (Peak, P-P, or RMS) for -30dB multiply the sampled voltage times 31.63. For example if the RMS voltage at the sampler = 5 volts, then the actual RF RMS voltage at the sampler input would be $5 \times 31.63 = 158.15$. The power ($P = E^2/R$) would be 500.2 Watts.

Fig. 10 The wideband graph of the sampler output is shown here. While the nominal sampler output equals is -30dB of the RF being sampled.

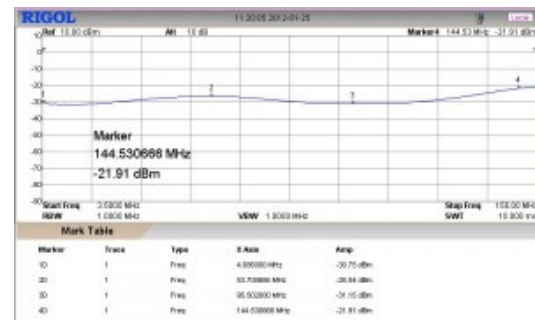


Fig. 10 2-150 MHZ bandwidth

Here at 4MHz it is -30.75dB, and 21.91 dB at 144.53 MHz Again, the equation for obtaining voltage ratio from dB is $V2/V1 = 10^{(A/20)}$. Thus, -21 dB equals a voltage-ratio of 11.22 and the power ratio equals 125.89. To obtain the equivalent voltage (Peak, P-P, or RMS) for -21 dB, multiply the sampled voltage times 11.22. For example, if the RMS voltage at the sampler = 5 volts, then the actual RF RMS voltage at the

sampler input would be $5 \times 11.22 = 56.1$. The power ($P = E^2/R$) would be 62.9 Watts.

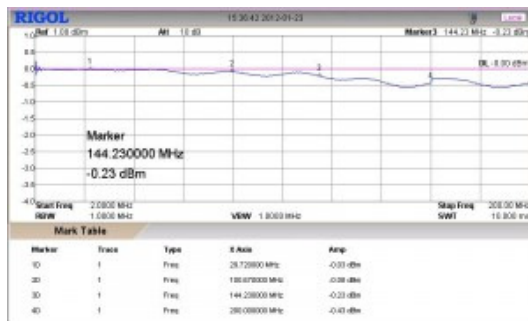


Fig 11 Insertion loss with bias

Fig. 11 Station monitor insertion loss without detector bias current option is show here. The insertion loss (-.03dB at HF frequencies) is barely measurable. This is the current consumed by the detector only (a few micro amps). For practical purposes this loss can be ignored since it equals a power ratio of 1.00693:1, so again, virtually all the power passing through the sampler is delivered to the load.

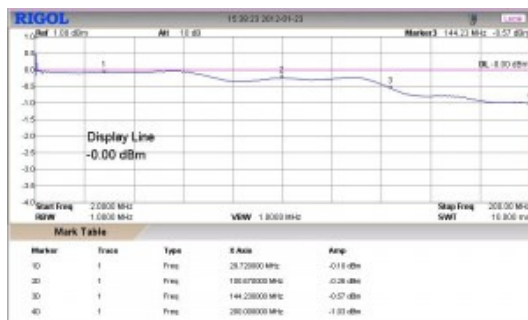


Fig. 12 Insertion loss with bias

Fig. 12 Station monitor insertion loss with detector bias current option is show here. The insertion loss (-.25dB at HF and 1dB at 200MHz) is barely measurable. This is the current consumed by the detector and its biasing current supply (a few micro amps). For practical purposes this loss can be ignored since it equals a power ratio of 1.059:1. Here, virtually all the

power passing through the sampler is delivered to the load.

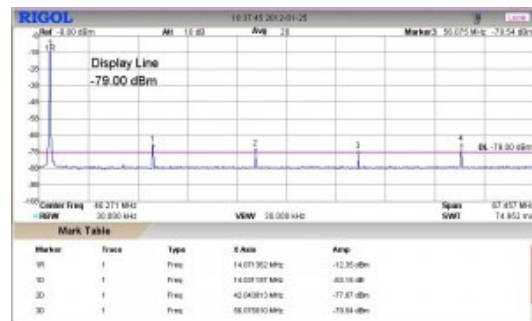


Fig. 13 Spurious emissions

Fig. 13 The graph of spurious emission of a typical linear amplifier (Ameritron AL811H) passing through the SMT & SMT-Pro station monitor. Note, the worst case harmonic spurious emission is -63.15 dB from the fundamental frequency of 14MHz. This is the residual spurious emission of the AL811H amplifier. Remarkably, when not overdriven, the AL811H despite its ancient design, exhibits excellent spurious emission characteristics. The additional spurious emissions contributed by the station monitor measurements were negligible. It should be noted that the power of these spurious emission are at least 100 times (20dB) better than the minimum allowed by the FCC: *§97.307 Emission standards (d) For transmitters installed after January 1, 2003, the mean power of any spurious emission from a station transmitter or external RF amplifier transmitting on a frequency below 30 MHz must be at least 43 dB below the mean power of the fundamental emission.*

Most, if not, all of the foregoing oscilloscope measurements can be made with an inexpensive 30MHz oscilloscope. By using appropriate accessories and techniques, the ham radio operator can maximize the RF transmitted signal performance.