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RF Power output limit using oscilloscope method

An [i] oscilloscope method to measure the *Canada Advanced Qualification* PEP power limit for radio amateurs.

Limits [ii] shown are for Canadian amateurs, from RBR-4 regulations.

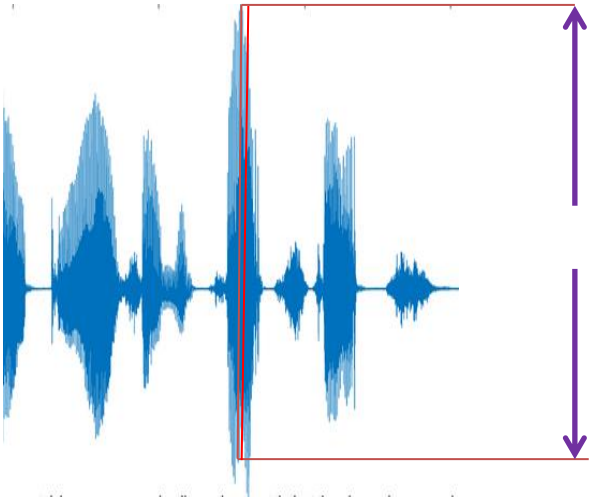
Definitions: [iii]

Peak to Peak = PTP= full excursion of voltage swing of one cycle

Peak = ½ of PTP swing

*Note: Average (of sinusoid cycles, repeated continuously) = .707 * Peak. Seldom used in power measurements but has uses when using the DC power final stage input power method of power measurement. Example in another note by author.*

Example shown on a typical oscilloscope, speech time domain waveform at output of amp, across a matched dummy load resistance R ohms (Important !...no reactance, load matched to amp)



V = largest volts swing at any instant. Scope best method. Normally one or two cycles only. With scope, apply cursors to show the narrow peak and read voltage in this area. This is PTP voltage. ½ is Peak voltage

Peak Envelope Power = (V^2 / 2)/R

For R = 50 ohms, and applying limit of 2250 Watts PEP

2250 = (V/2)^2 / R
(V/2)^2 = 2250 * R
V/2 = sqrt(2025*50) = 335 volts peak
V = 670 V peak to peak

Therefore the **highest limit instant waveform voltage on scope would be 335 volts**, if peak display function is used, or 670 volts if peak to peak display function is used. Anything over this would be exceeding the limit.

Average power of SSB is typically max 30% of the PEP. (Normally 10 to 20%) The amplifier [iv] would typically be rated as 30% of 2250 as continuous power = 675 watts

PEP vs. Average Power[v]

PEP is equal to steady carrier power, or radiotelegraph dot or dash average power, in a properly-formed CW transmission. PEP is also equal to average power in a steady FM, FSK, or RTTY transmission.

Although average power is the same as PEP for complex modulation forms, such as FSK, the peak envelope power bears no particular ratio or mathematical relationship to longer-term average power in distorted envelopes, such as a CW waveform with power overshoot, or with amplitude modulated waveforms, such as SSB or AM voice transmissions. Typical average power of a SSB voice transmission, for example, is 10-20% of PEP. The percentage of longer term average power to PEP increases with processing, and commonly reaches ~50% with extreme speech processing.

1) Example For CW (in this case, 750 watts average or carrier power)

750 watt limit (average in this case) = (Vptp/2)^2 / R over all cycles as they are the same.

V ptp/2 = sqrt (750 * 50) = 193 peak volts limit on a 50 ohm resistive load. Use peak volts function of scope.

V peak to peak = 193*2 = 386 volts limit peak to peak, using peak to peak function of scope.

Thus, oscilloscope **peak to peak reading is 386 volts limit** , across a 50 ohm load.

A note [vi] on "Peak Hold" detector instruments

It is possible to design and implement an RF voltmeter that

- responds to very short bursts of RF; and
- holds that response long enough to read the display device.

A common circuit is a simple half wave detector with enhanced charge and decay times. To be effective for PEP measurement of SSB telephony, it needs to charge the accumulator capacitor in 30ms or so of RF burst, and have a decay time of some seconds so that the meter can be read.

Good implementations require an active circuit, it they require power to operate.

Poor implementations are usually marked by longer charge times, and some ham grade instruments with a PEP switch are so poor as to be unusable for PEP measurement on SSB telephony. Circuits that do not require power are unlikely to work well at all.

The advantage of this type of instrument is that it is active all the time, and captures significant bursts of RF, often more effectively than a CRO (Cathode ray oscilloscope, or analog scope SIC) , and the output can be used to activate an alarm if desired. A properly working implementation is very effective in monitoring PEP output of an SSB transmitter under speech modulation.[vii]

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[i] Even using an oscilloscope is tricky. Probes at RF can be inaccurate. A 10X probe is usually used but at RF frequencies the probe capacitance may affect the reading. A DSO (digital storage scope) may miss a peak event in waveform capture. An analog scope may not show a peak waveform even. A 5% accuracy limit is reasonable as a general rule but better accuracy would require more rigorous technique.

[ii] *Canada Power limits, from RBR-4*
10. Restrictions on Capacity and Power Output
The transmitting power of an amplifier installed at an amateur station shall not be capable of exceeding by more than 3 dB the transmitting power limits described in this section.

10.1 Amateur Radio Operator Certificate with Basic Qualification
The holder of an Amateur Radio Operator Certificate with Basic Qualification is limited to a maximum transmitting power of:
(a) where expressed as direct-current input power, 250 W to the anode or collector circuit of the transmitter stage that supplies radio frequency energy to the antenna; or
(b) where expressed as radio frequency output power measured across an impedance-matched load,
(i) 560 W peak envelope power for transmitters that produce any type of single sideband emission, or
(ii) 190 W carrier power for transmitters that produce any other type of emission.

10.2 Amateur Radio Operator Certificate with Advanced Qualification
The holder of an Amateur Radio Operator Certificate with Advanced Qualification is limited to a maximum transmitting power of:
(a) where expressed as direct-current input power, 1,000 W to the anode or collector circuit of the transmitter stage that supplies radio frequency energy to the antenna; or
(b) where expressed as radio frequency output power measured across an impedance-matched load,
Standards for the Operation of Radio Stations in the Amateur Radio Service RBR-4
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(i) 2,250 W peak envelope power for transmitters that produce any type of single sideband emission, or
(ii) 750 W carrier power for transmitters that produce any other type of emission.

[iii] *PEP for FCC and Canada*: ***Peak envelope power*** *(PEP) is the root mean square (rms) value of a single RF cycle at the crest of the modulation. This is an FCC definition.(* Also Canada SIC*) PEP is normally considered the occasional or continuously repeating crest of the modulation envelope under normal operating conditions (Wikipedia)*

The ITU Radio Regulations define the terms Peak Envelope Power, Mean Power and Carrier Power with regard to a radio transmitter. The terms are defined as: (Owenduffy.net)

> *Peak Envelope Power 'pX' (s1.157) means the average power supplied to the antenna transmission line by a transmitter during one radiofrequency cycle at the crest of the modulation envelope taken under normal operating conditions.*
>
> *Carrier Power 'pZ' (s1.159) means the average power supplied to the antenna transmission line by a transmitter during one radio frequency cycle taken under the condition of no modulation.*

[iv] What does the amplifier advertised power capability mean ? Manufacturers want to advertise a large , but verifiable number. Normally, but not always, this is peak power. Many manufacturers do not explain this well, or at all. How this applies to duty cycle is also a question. Carrier use means long on times. This should be evaluated before selecting an amplifier for RF use. A 1 KW peak power amplifier for SSB may not be suited to 1 KW continuous power, and in fact, likely is not.

[v] *From Wikipedia*

[vi] *Reprinted from Owenduffy.net. Very good power article.*

[vii] The author has used an active circuit for peak power indication with MFJ style crossed needle output indicators for years. Typically they are calibrated with scope and dummy load method. They are useful approximate indicators.