Peak Envelope Power (PEP)

By Larry E. Gugle K4RFE, RF Design, Manufacture, Test & Service Engineer (Retired)

This document is written concerning the workings of any RF Power Amplifier device and is applicable to:

1. A Transmitter RF Power Amplifier (RFPA) Stage.

2. A Transceiver RF Power Amplifier (RFPA) Stage.

3. A External RF Power Amplifier (RFPA) connected in-line after a Transmitter or Transceiver.

    a. The examples and equations used in this document are for.

        i. Electron (Vacuum) Tube Devices;

            1. Triode

            2. Tetrode

            3. Pentode

        ii. Solid-State Semiconductor Devices;

            1. Bipolar Junction Transistor (BJT)

            2. Junction Field Effect Transistor (JFET)

            3. Insulated Gate Field Effect Transistor (IGFET) also referred to as a Metal Oxide Semiconductor Field Effect Transistor (MOSFET).

A RFPA is normally rated by either 'Input' Peak Envelope Power (PEP) or 'Output' Peak Envelope Power (PEP).

The definition of Peak Envelope Power (PEP) by the Collins Radio Corporation is;

"Peak Envelope Power (PEP) is defined as the Root-Mean-Square (RMS) power developed at the crest of the modulation envelope".

(SSBSC-AM Invented by John R. Carson of AT&T; applied for U.S. Patent Dec. 1, 1915)

When either a **Single-Tone Test Signal** input or a **Two-Equal-Tone Test Signal** input is used, the following equations approximate the relationships for Class AB (AB1 and AB2) or Class B operation and there associated Peak Envelope Power (PEP), and Average power (AVG) meter readings.

The approximate equations given below are for a **Single-Tone** and a **Two-Equal Tone** condition, which are the most common test situations.

Definition of Symbols:

i_{pm} = Peak of the plate current pulse — the plate current pulse is not sinusoidal.

e_p = Peak value of plate swing, assumed to be sinusoidal when plate tank "Q" is sufficiently high.

π = 3.14

E_b = d-c plate voltage

Single-Tone:

DC Plate Current

$$I_b = \frac{i_{pm}}{\pi} \qquad (1)$$

Plate Input Watts

$$P_{in} = \frac{i_{pm} E_b}{\pi} \qquad (2)$$

Average Output Watts and PEP

$$P_o = \frac{i_{pm} e_p}{4} \qquad (3)$$

Plate Efficiency

$$\eta_p = \frac{\pi e_p}{4 E_b} \qquad (4)$$

Two-Equal Tones:

DC Plate Current
$$I_b = \frac{2\, i_{pm}}{\pi^2} \qquad (5)$$

Plate Input Watts
$$P_{in} = \frac{2\, i_{pm} E_b}{\pi^2} \qquad (6)$$

Average Output Watts
$$P_o = \frac{i_{pm} e_p}{8} \qquad (7)$$

PEP Watts
$$P_o = \frac{i_{pm} e_p}{4} \qquad (8)$$

Plate Efficiency
$$\eta_p = \left(\frac{\pi}{4}\right)^2 \frac{e_p}{E_b} \qquad (9)$$

The following examples demonstrate '*two*' important relationships of a **Single-Tone Signal** and a **Two-Equal Tone Signal** amplified by a system.

1. The amplifier is set up for a **Single-Tone Signal** and a Point "A" on the operating line is established below (**Figure 1**). A definite PEP output is developed under this condition.

2. By assuming a perfect amplifier, wherein the input signal wave shape is exactly reproduced in the output load, *these grid wave shapes can be used to demonstrate the relationship of PEP to Average Power*.
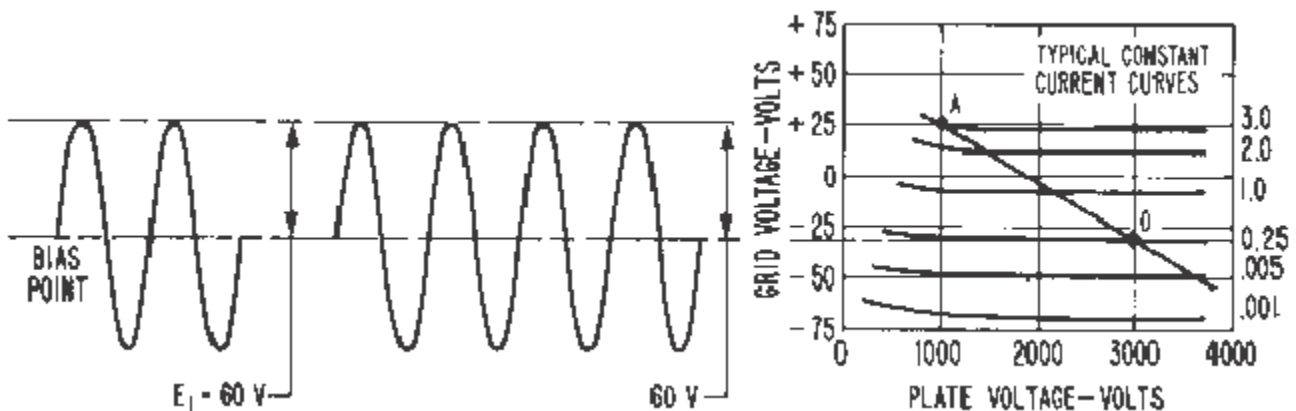

Figure 1. Single-tone condition.

Single-Tone Signal

$$P_{avg} = \frac{E_{I(rms)}^2}{R_L} = \frac{\left(\frac{60}{\sqrt{2}}\right)^2}{R_L} = \frac{1800}{R_L} \ W \qquad (10)$$

$$PEP = \frac{E_{I(rms)}^2}{R_L} = \frac{\left(\frac{60}{\sqrt{2}}\right)^2}{R_L} = \frac{1800}{R_L} \ W \qquad (11)$$

$$Therefore, \ PEP = P_{avg} \qquad (12)$$

3. To drive the amplifier to the same PEP output with a two-equal tone Signal, the drive signal voltage for each tone must be 1/nth (n = number of tones) the amplitude of the single tone signal. For a **Two-Equal Tone Signal** *the two frequencies (f1 and f2) are equal in amplitude but slightly different in frequency.* As a result, when they are exactly in phase, the two crest voltages add directly to produce the crest of the two-tone envelope. When the two frequencies are exactly out of phase, then the cusp of the two-tone envelope results (**Figure 2**). *Note that the voltage amplitude at the crest of the resultant two-equal tone envelope is equal to that of the single-tone envelope and therefore the tube is driven to the same point "A" on the operating line in each case.* If the tube is driven to the same peak anode current and the same peak anode voltage swing by different exciting signals, then the Peak Envelope Power Output for both signals is the same.
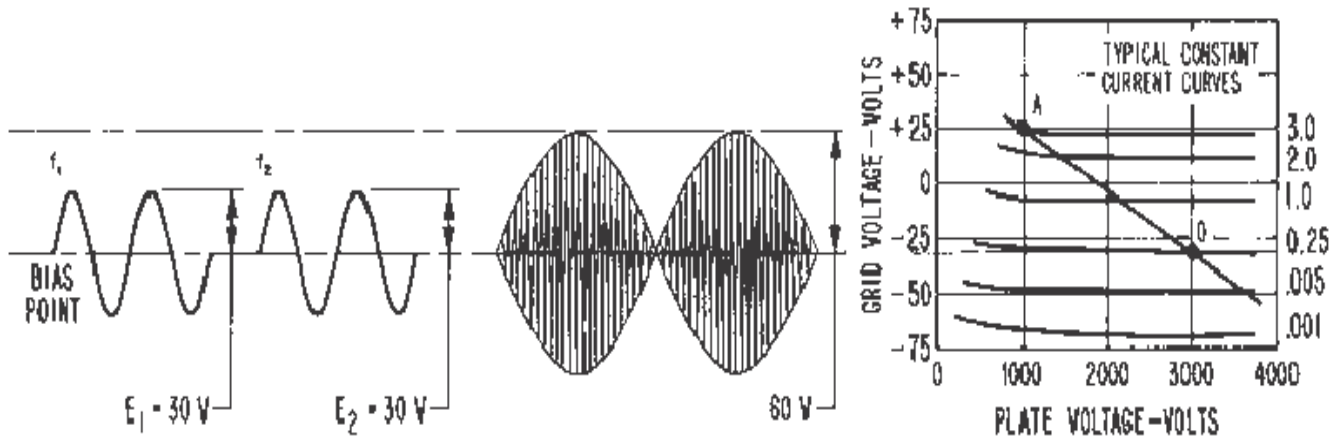

Figure 2. Two-Equal tone condition.

Two-Equal Tone Signal

$$P_{avg} = P_{1\,avg} + P_{2\,avg} \tag{13}$$

$$= \frac{(E_{1(rms)})^2}{R_L} + \frac{(E_{2(rms)})^2}{R_L}$$

$$= \frac{\left(\frac{30}{\sqrt{2}}\right)^2}{R_L} + \frac{\left(\frac{30}{\sqrt{2}}\right)^2}{R_L}$$

$$= \frac{450}{R_L} + \frac{450}{R_L} = \frac{900}{R_L} \ W$$

$$PEP = \frac{(E_{1rms} + E_{2rms})^2}{R_L} \tag{14}$$

$$= \frac{\left(\frac{30}{\sqrt{2}} + \frac{30}{\sqrt{2}}\right)^2}{R_L}$$

$$= \frac{\left(\frac{60}{\sqrt{2}}\right)^2}{R_L} = \frac{1800}{R_L} \ W$$

$$\text{Therefore, } PEP = 2 \times P_{avg} \tag{15}$$