COMPUTATIONAL EXAMPLES
MULTIPLE FREQUENCY SIGNAL
ENHANCED TRIP SIGNALS

1. COMPUTATION EXAMPLE—MULTIPLE FREQUENCY SIGNAL

1.01 A transmitter used for protective relay purposes employs the following signals on a continuous basis:

FREQUENCY	VOLTAGE (RMS)
*2700 Hz	*0.5 volt
*3000 Hz	*0.4 volt

*See 4.09 in Section 851-201-101.

(Note early indication of trouble for each frequency in Fig. 3 of Section 851-201-101.)

$$\text{Power (2700 Hz)} = (0.5)^2/600 \times 10^3 = 0.417 \text{ mw}$$

$$\text{Power (3000 Hz)} = (0.4)^2/600 \times 10^3 = 0.267 \text{ mw}$$

$$\text{Power (Total)} = 0.417 \text{ mw} + 0.267 \text{ mw} = 0.684 \text{ mw}$$

1.02 The total power transmitted meets the requirement that inband power must not exceed 0 dBm (1 mw) averaged over any 3-second interval and also meets the instantaneous signal power limitation limiting the signal power to +13 dBm (3.46 volts peak across 600 ohms).

1.03 Using 1000 Hz as the reference frequency, the weighted signal voltage is calculated as follows:

FREQUENCY	WEIGHTING FACTOR*	X	rms VOLTAGE	=	WEIGHTED VOLTAGE
2700	$\left[\frac{2700}{1000}\right]^{1.65} = 5.15$	X	0.5	=	2.57
3000	$\left[\frac{3000}{1000}\right]^{1.65} = 6.13$	X	0.4	=	2.45

$$\text{Equivalent voltage} = \sqrt{(2.57)^2 + (2.45)^2}$$

$$= 3.55 \text{ volts (equivalent 1000-Hz voltage)}$$

*See 4.09 in Section 851-201-101.

1.04 Since 3.55 volts (equivalent 1000-Hz voltage) exceeds the 2.24-volt limit for a 1000-Hz signal, the signaling frequency and/or level needs to be modified before this equipment can be connected to telephone company facilities.

2. COMPUTATION EXAMPLE—ENHANCED TRIP SIGNALS

2.01 A protective relaying terminal transmitter normally transmits a supervisory tone of 2200 Hz at a power level of -10 dBm. During a power fault, the supervisory tone is removed and enhanced 2000- and 2400-Hz signals are transmitted at +10 dBm each. After a 50-millisecond interval, the level of each tone is reduced to a -10 dBm level until the fault is cleared. After the fault is cleared, the normal supervisory tone of 2200 Hz is transmitted at a power level of -10 dBm.

2.02 A single-frequency signal of 2200 Hz at a power level of -10 dBm must meet both the 3-second average limitation of 0 dBm and the single-frequency voltage limitation. The supervisory signal does meet the 3-second average limitation (ie, -10 dBm is less than 0 dBm). The single-frequency limitation for 2200 Hz is:

$$\text{Power (dBm 600 ohms)} \leq 108.2 - 33 \log_{10} f$$

$$\text{Power (dBm 600 ohms)} \leq 108.2 - 33 \log_{10} (2200)$$

$$\text{Power (dBm 600 ohms)} \leq -2.1 \text{ dBm}$$

Thus, since -10 dBm is less than -2.1 dBm, the supervisory signal meets the single-frequency voltage limitation.

2.03 The composite power of the enhanced 2000- and 2400-Hz signal is the sum of two +10 dBm signals and is equal to +13 dBm. This meets the short-term power criterion of +16 dBm given in 4.12 of 851-201-101. The maximum energy permitted in any 3-second interval is equal to 1 milliwatt (0 dBm) × 3 seconds = 3 mw-seconds. The energy in the enhanced signal is equal to (10 mw + 10 mw) × 0.05 second = 1 mw-second.

The energy in the 2.95-second interval prior to the advent of the enhanced trip signals is equal to 0.1 mw (-10 dBm) × 2.95 seconds = 0.295 mw-second.

Total energy = 1.0 mw-second + 0.295 mw-second = 1.29 mw-seconds.

The energy in the 2.95-second interval after the advent of the enhanced trip signal is equal to 0.1 mw (-10 dBm) + 0.1 mw (-10 dBm) × 2.95 seconds = 0.2 mw × 2.95 seconds = 0.59 mw-second.

Total energy = 1.0 mw-second + 0.59 mw-second = 1.59 mw-second.

The total energy in any 3-second interval is less than 3 mw-seconds and hence meets requirements.

Because each of the two trips tones of 2000 and 2400 Hz could be transmitted at a power level of -10 dBm (0.245 volt across 600 ohms) for a considerable amount of time, this arrangement must be checked for long-term suitability.

2.04 Using 1000 Hz as the reference frequency the weighted signal voltage is calculated as follows:

FREQUENCY	WEIGHTING FACTOR*	X	rms VOLTAGE	=	WEIGHTED VOLTAGE
2000 Hz	$\left[\frac{2000}{1000}\right]^{1.65} = 3.14$	X	0.245	=	0.769
2400 Hz	$\left[\frac{2400}{1000}\right]^{1.65} = 4.24$	X	0.245	=	1.04

$$\text{Equivalent voltage} = \sqrt{(0.769)^2 + (1.04)^2}$$

$$= 1.29 \text{ volts (equivalent 1000-Hz voltage)}$$

*See 4.09 in Section 851-201-101.

Since 1.29 volts does not exceed the allowable 2.24-volt limit for a 1000-Hz signal, the use of 2000- and 2400-Hz tones at -10 dBm power level is permissible.