# PROTECTIVE RELAYING CHANNEL

# TRANSMISSION SPECIFICATIONS AND CONSIDERATIONS

CONTENTS PAGE



## 1. GENERAL

1.01 This section describes the protective relaying (PR) channel, which is a voice grade private line channel specifically designed for power industry audio tone PR applications. The PR channel provides improved reliability for PR systems during power fault intervals over that obtainable from other available voice bandwidth channels. ***If this channel will not be used for audio tone PR applications, do not use the channel design specified in this section; instead, use the design specified in Section***

*880-420-100.* The PR channel provides improved dependability by:

(a) Allowing the application of enhanced tone signals

(b) Requiring selection of cable facilities with better than average resistance balance.

(c) Placing any gain or loss devices only at central office locations and not at the power station sites.

**1.02** This section is reissued

(a) To include a discussion of Frequency Division Multiplexing

(b) To change the standard reference frequency of PR channels from 1000 Hz to 1004 Hz to agree with ***Bell System Technical Reference PUB 41011*** [1].

Revision arrows are used to emphasize the more significant changes.

**1.03** This section is limited to the terminal interface criteria and transmission facility parameter limits for the protective relaying channel (Technical Reference PUB 41011) [1]. Considerations related to a typical protective relaying system using this channel with the 1A Protective Relaying System are covered in associated Section 851-201-100. However, the protective relaying channel may be used with any PR terminal that meets the interface specifications described in Part 4.

**1.04** Section 876-310-100 contains engineering recommendations concerning electrical protection of wire plant communications facilities serving power stations.

**1.05** The standard net loss of the PR channel is 16 dB. As an option, however, a PR channel having a net loss of 8 dB is available upon request subject to the stipulation that the loss of the normally available local loop in the receive leg (including loop loss from the serving central office, high voltage protection transformer loss, circuit terminating transformer loss) does not exceed 8.0 dB. For either channel, it is necessary that any gain or loss devices or bridging be provided at central office locations and not at the power stations. The arrangement ensures a true improvement in the signal-to-noise ratio. Amplifiers located at power stations will amplify locally generated noise as well as the received signal—a condition that would degrade the signal-to-noise ratio. One of the unique problems inherent in providing communication service to power stations is the severe noise introduced into cable facilities during power faults. This noise is responsible for inhibiting the reception of valid protective relaying trip signals by operating the receiver squelch of a protective relaying terminal during the most critical interval. Thus, dependability (the ability to receive a valid trip signal) can be compromised by noise generated during fault intervals. However, staged fault tests have confirmed that a short burst of enhanced (high level) tones (permissible on the protective relaying channel) can be successfully transmitted to a distant receiver over the channel during the fault interval in spite of this noise. The restrictions on enhanced signal levels, format, and frequency of signal occurrence permissible on the protective relaying channel are described in this section beginning at Part 4.

ours are 8db net loss

**1.06** The conversion of common mode (longitudinal) noise voltage to transverse (metallic) noise voltage depends directly on the resistance balance of the cable pairs serving the power station. Therefore, to minimize metallic noise voltage, cable facilities should be selected with better than average resistance balance. Accordingly, a requirement of 1 percent or less resistance unbalance is specified for the local channel portion of the protective relaying channel. Resistance balance tests for the local channel portion of the PR channel are described in Sections 310-540-500 and 638-600-102.

## 2. TYPES OF ARRANGEMENTS PROVIDED

### A. General

**2.01** The basic protective relaying channel is a 2-way, 4-wire channel and may be ordered in a 2-point or multipoint configuration.

**2.02** The 2-way, 4-wire channel may be part of a unidirectional (nonsymmetrical) control system, or it may be a full bidirectional (symmetrical or nonsymmetrical) control system. The term "symmetrical" as used in this section applies to a complete system that can perform the same control and supervisory functions from any point in the system to any other point in the same system. A "nonsymmetrical" system, conversely, lacks some control or supervisory function between two or more system points that are provided between other points in the same system.

2.03 Figure 1 is a simplified block diagram of a standard 16 dB, 2-point, bidirectional, symmetrical channel layout that includes typical signal power levels at associated TLPs. The optional 8 dB channel would be provided by reducing the 10 dB and 11 dB pads in the receive legs to 2 dB and 3 dB, respectively, thereby increasing each received signal power from -16 dBm to -8 dBm. Refer to Section 851-201-100 for other typical examples of channel application to the 1A PR System in 2-point or multipoint, unidirectional (nonsymmetrical) or bidirectional (symmetrical or nonsymmetrical) control systems.

**B. Station Termination and Transmission Facility Selection**

2.04 The terminal end of the PR channel facility at the power station generally requires insertion of a transformer (44V4 arrangement or equivalent) in both the transmitting and receiving lines (see Fig. 2). This arrangement provides cable equalization and voltage limitation. The only exception to the placing of the transformer is the situation in which a special protection high voltage isolation transformer is in use and a 1:1 terminating transformer would be called for. In this case, the 1:1 terminating transformer should be left out. A 0 dB pad is inserted into the transmitting end. The pad value for the receiving end is selected to provide a receiving level of -16 dBm in the case of the standard channel or -8 dBm in the case of the optional channel.

2.05 The arrangement of 44V4 or equivalent equipment required at each PR terminal (Fig. 2) is determined by the type of cable facility selected for the local channel. Amplifiers are prohibited at the terminal site (the power station) due to noise (see 1.05). Therefore, when gain is required, the amplifiers must be placed at the central office as shown in Fig. 1.

2.06 ***It is essential that the PR channel be terminated in power station locations using arrangements of 44V4 or equivalent equipment (see Fig. 1 and 2). Channel terminating arrangements with such devices as Data Auxiliary Set (828-type or 829-type), 150A Channel Service Units, 31B Voice Couplers, or Metallic Facility Terminal (MFT) equipment must not be employed.***

these ↑ are loopback devices

**3. PHYSICAL INTERFACE**

**A. Physical Limits of Channel**

3.01 The physical interface between the PR channel facilities and the PR terminal equipment will usually be a terminal block arranged for convenient connection of the required number of pairs of conductors to the PR terminal (one transmitting pair and one or more receiving pairs). The terminal block is provided by the telephone company for installation in a space provided by the customer power company. The space provided must be in a suitable location to permit maintenance testing of the channel circuit when the PR terminal is disconnected.

3.02 The local channel portion of the PR channel facility must be included for consideration in the overall wire facility communications services provided to the power station for electrical protection. These communications services are usually provided via the pairs of one or more cables serving the power station. The cable shield and pairs are given coordinated protection at all points on the cable. The exact arrangement depends on the nature of the power station, the magnitude of possible fault currents, and the types of services provided on the pairs. PR using tone signaling is one of the designated services; therefore, PR channel layout effort must be coordinated with the Protection Engineer.

**4. INTERFACE ELECTRICAL CRITERIA**

4.01 The transmission parameters for the PR channel are covered in this part. The channel is designed for ac transmission only; therefore there is no provision for dc signals from any PR terminal equipment used. The following requirements are necessary to ensure proper functioning of the telephone network, the PR channel, and the terminal equipment.

**TERMINAL IMPEDANCE AND BALANCE**

4.02 The nominal source and load impedance of the PR terminal equipment connected to this channel should be 600 ohms ±10 percent and resistive over the 300- to 3000-Hz band. The terminal equipment should be longitudinally balanced to minimize noise generation. Test equipment used for installation and maintenance should be 600 ohms resistive to assure that transmitted and received power is as specified.

## POWER REQUIREMENT FOR INBAND SIGNALS (300 to 3995 Hz)

4.03 The signals applied by the terminal at the interface to the PR channel must meet the following limits to protect other services on adjacent channels of the same transmission facility.

### A. Nonenhanced Signals

4.04 Signals that are employed continuously are defined as nonenhanced signals and must meet all the following requirements. Appendix 1 contains an example of the computation of the requirements for nonenhanced multiple-frequency signals.

#### Three-second Average Limitation

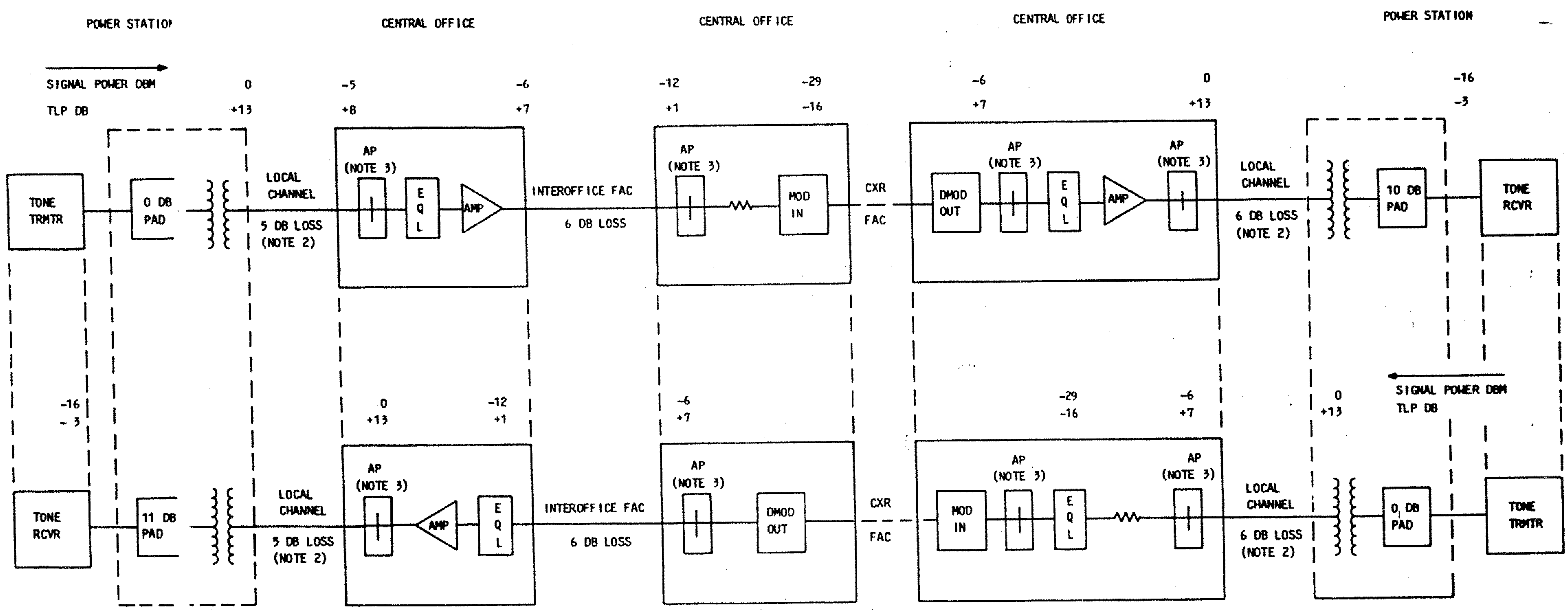
4.05 The transmitted inband signal power averaged over any 3-second interval must not exceed 0 dBm. This requirement must be met at all times.

#### Instantaneous Signal Power Limitation

4.06 The instantaneous signal power must not exceed +13 dBm (3.46 volts peak across 600 ohms).

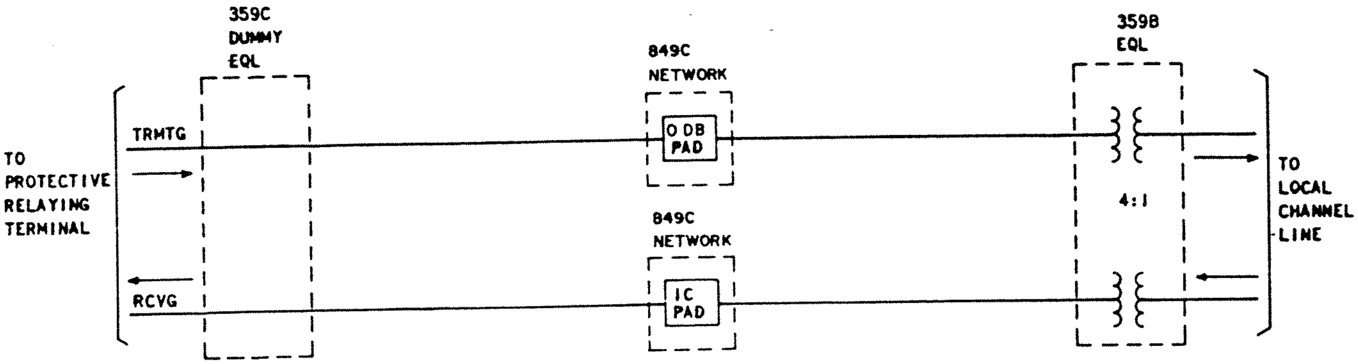
#### Weighted RMS Voltage Limitation

4.07 The voltage applied to a cable pair must not exceed the limits given below (4.08 and 4.09) to prevent interference into adjacent cable pairs.

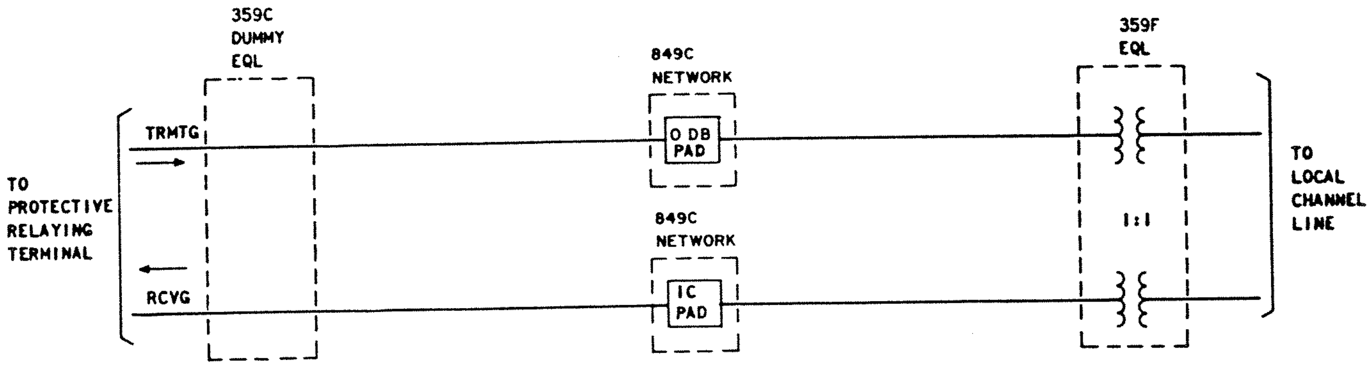



NOTES:
1. FACIL :Y LOSSES SHOWN ARE FOR ILLUSTRATIVE PURPOSES EXCEPT FOR OVERALL 16 DB LOSS.
2. INCLU :S TRANSFORMER LOSS
3. SMAS , :CESS POINTS. REFER TO SECTIONS 667-302-102, 667-302-103, 667-302-200 AND 6( '-303-102 FOR ACCESS CODES, ORIENTATION CODES AND OTHER INFORMATION. THESE ACCES: POINTS MUST BE FLAGGED AS SPECIAL AT THE TIME OF INSTALLATION. REFER TO BSPS F )R FLAGGING TECHNIQUE. SEE 7.01.

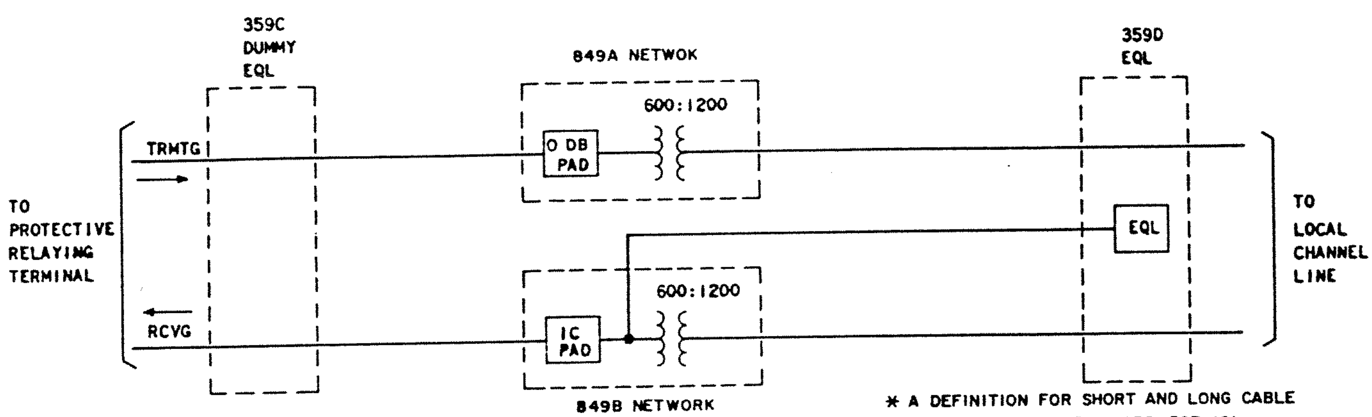
**Fig. 1—Typical 2-Point 4-Wire Layout for Standard 16 dB Protective Relaying Channel**




A. FOR LONG NONLOADED CABLE*




B. FOR SHORT NONLOADED CABLE*




* A DEFINITION FOR SHORT AND LONG CABLE CAN BE FOUND IN BSP 852-307-101.

C. FOR LOADED CABLE*

Fig. 2—44V4 Equipment Arrangement

**4.08** ***Single-Frequency Signal Limitation:*** Signals consisting solely of a single frequency must not exceed mathematically the limits given in Fig. 2. This restriction is expressed as follows [1] [3]:

$$E(f) \leqslant \frac{10^{5.3}}{f^{1.65}} \quad \text{or}$$

$$20 \log_{10} E(f) \leqslant 106 - 33 \log_{10} f$$

$$300 \text{ Hz} \leqslant f \leqslant 3995 \text{ Hz}$$

where f = frequency in Hz

E(f) = rms voltage at frequency f

Converting from voltage to power in dBm at any f:

Power (dBm 600 ohms)

$$\leqslant 10 \log_{10} \left[ \frac{E(f)^2}{600} \times \frac{1000}{1} \right]$$

$$\leqslant 10 \log_{10} \frac{1000}{600} + 10 \log_{10} E(f)^2$$

$$\leqslant 10 \log_{10} 1.667 + 20 \log_{10} E(f)$$

$$\leqslant 2.2 + 20 \log_{10} E(f)$$

$$\leqslant 2.2 + 106 - 33 \log_{10} f$$

$\leq 108.2 - 33 \log_{10} f$
for $300 \text{ Hz} \leq f \leq 3995 \text{ Hz}$

Therefore the voltage or power limitation for any single frequency within the 300- to 3995-Hz range based on the original expression or its conversion defines the line drawn on the graph (Fig. 3) as the upper limit.

**4.09** ***Multiple-Frequency Signal Limitation:*** The signal level restriction of 4.08 applies to a signal composed solely of a single-frequency tone. That restriction does not permit two or more tones to be applied simultaneously to the PR channel at the maximum value permitted for each individual tone. If the signal contains multiple tones, the individual frequency components must be weighted, and then the root-sum-squares (rss) of these weighted rms voltages taken to determine if the signal is acceptable. Weighting is performed by referencing all signal components to a chosen reference frequency. Each component rms voltage is multiplied by a weighting factor that is calculated by dividing the maximum permitted rms voltage at the reference frequency by the maximum permitted rms voltage at the signal component frequency. The root-sum-square (rss) of all the weighted signal components must be less than the maximum permitted rms voltage at the reference frequency. This procedure can be expressed mathematically as follows [1] [2]:

$$\sqrt{\Sigma_i \left[ W(f_i)\, E(f_i) \right]^2} \leqslant E_r(f_r)$$

$$300 \text{ Hz} \leqslant f_i \leqslant 3995 \text{ Hz}$$

Where $E(f_i)$ = rms voltage of the signal component at frequency $f_i$

$W(f_i)$ = weighting factor for frequency $f_i$

$$= E_r(f_r)/E_r(f_i) = \left[ \frac{f_i}{f_r} \right]^{1.65}$$

$E_r(f_r)$ = rms voltage restriction for the chosen reference frequency $f_r$

$$= 10^{5.3}/f_r^{1.65}$$

$E_r(f_i)$ = rms voltage restriction for frequency $f_i$

$$= 10^{5.3}/f_i^{1.65}$$

If 1000 Hz is chosen as the reference frequency, then inband signals can be expressed as:

$$\sqrt{\Sigma_i \left[W(f_i)\, E(f_i)\right]^2} \leq 10^{0.35} \text{ volts} \cong 2.24 \text{ volts}$$

$$\text{Where } W(f_i) = \left[\frac{f_i}{1000}\right]^{1.65} \quad 300 \text{ Hz} \leq f_i \leq 3995 \text{ Hz}$$

and $f_i$ is the numerical value of the frequency in Hz (see single-frequency limit of 2.24 volts for 1000 Hz on Fig. 3).

### B. Enhanced Signals

4.10 Trip signals sent from a PR terminal may exceed the requirements for rms voltages specified in 4.07 through 4.09 and the instantaneous signal power limitation given in 4.06. Signals that exceed those limits are defined as enhanced signals. Appendix 1 contains an example of computation for enhanced signals. Trip signals (enhanced signals) must meet ***all*** the following requirements.

#### Three-second Average Limitation

4.11 The transmitted inband signal power for enhanced signals, averaged over any 3-second interval, must not exceed 0 dBm. This requirement is the same as for nonenhanced signals (4.05) and must be met at all times.

#### Short-Term Power Limitation

4.12 The transmitted inband signal power for enhanced trip signals must not exceed +16 dBm (rms). This requirement must be met at all times. Signal peaks that exceed a +12 dBm sine wave may be subject to clipping.

#### Frequency of Occurrence of Enhanced Signal Transmission

4.13 Transmission of enhanced trip signals may result in observable crosstalk on adjacent channels. Because of this possible interference, the number of enhanced signals for ***test*** purposes is limited to seven occurrences per week. An occurrence is defined as an enhanced signal transmission within a 3-second interval. The number of actual trip signal transmissions on the PR channel will depend on the number of power fault occurrences and is therefore undefined.

## POWER LIMITS FOR OUT-OF-BAND SIGNALS

4.14 The signal applied by the PR terminal equipment to the telephone company interface located on customer premises must meet the following limits in order to protect other services:

#### Above the Voiceband

| Frequency Band | Max Power in dBm |
|---|---|
| 3995 to 4005 Hz | -18 |
| 4 to 10 kHz | -16 |
| 10 to 25 kHz | -24 |
| 25 to 40 kHz | -36 |
| above 40 kHz | -50 |

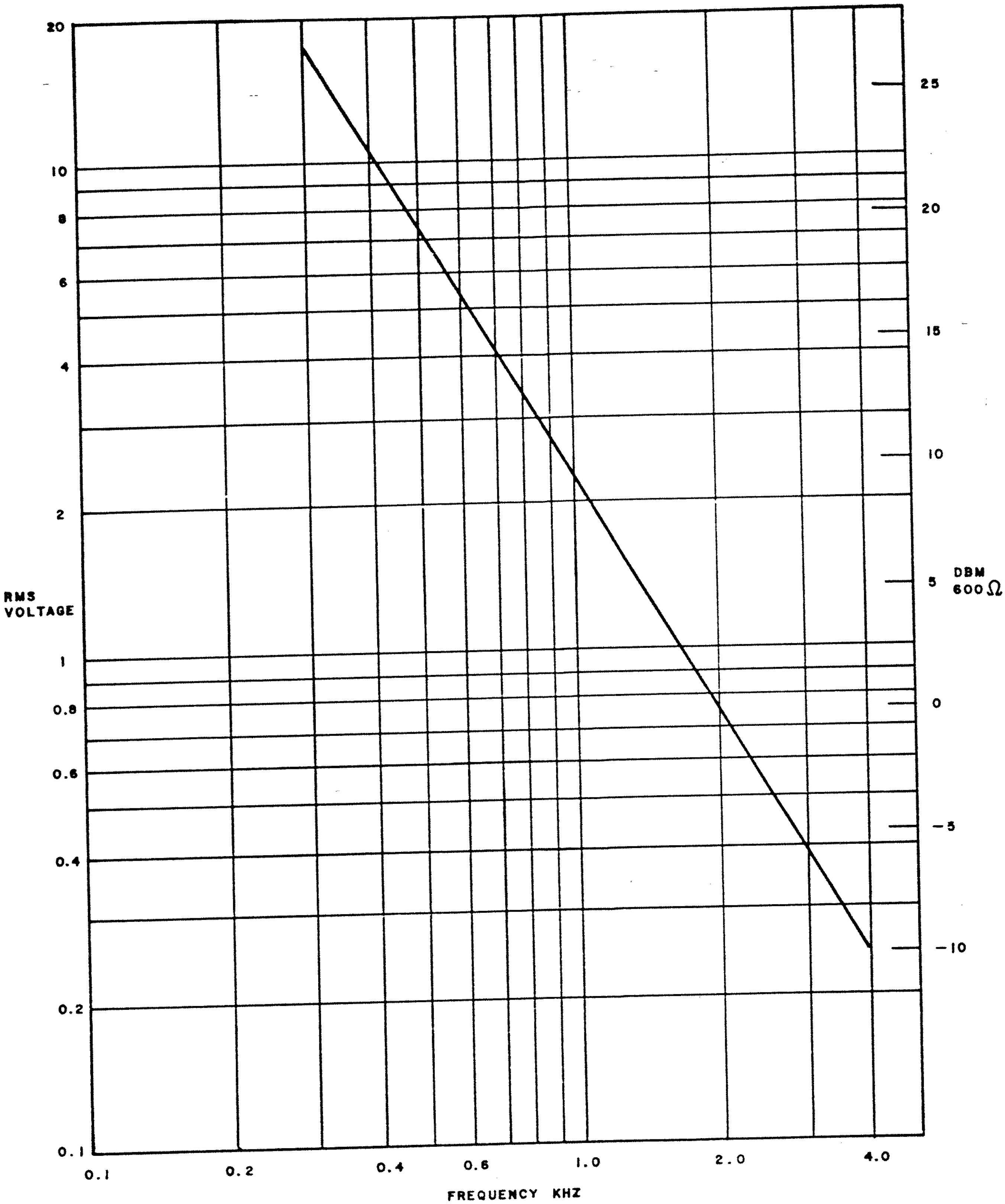



Fig. 3—Single Frequency Signal Limitation

#### Below the Voiceband

The PR channel is not represented as being capable of carrying signals below 300 Hz. Where extraneous signals below 300 Hz are applied, the rms currents and voltages (including harmonics and spurious signals) at the interface shall not exceed the following:

(a) Rms current per conductor as specified by the Telephone Company, but never to exceed 0.35 amperes.

(b) Magnitude of conductor to ground voltage not to exceed 70 volts peak

(c) Conductor to conductor voltage shall be such that conductor to ground voltage does not exceed 70 volts peak. For ungrounded signal source, conductor to conductor limit is the same as conductor to ground limit.

(d) Total weighted rms voltage in band from 50 to 300 Hz not to exceed 100 volts. The procedure for determining allowable signal levels follows from that described in 4.09 and is expressed as follows:

$$\sqrt{\sum_i [W(f_i)\,E(f_i)]^2} \leq 100$$

$$50 \text{ Hz} \leq f_i \leq 300 \text{ Hz}$$

where $W(f_i) = \dfrac{f_i}{10^2}$ ; for $50 \text{ Hz} \leq f_i \leq 100 \text{ Hz}$

$W(f_i) = \dfrac{f_i^{1.65}}{10^{3.3}}$ ; for $100 \text{ Hz} \leq f_i \leq 300 \text{ Hz}$

$E(f_i)$ = rms voltage of signal component at frequency $f_i$

#### Frequency Division Multiplexing

4.15 ♦Frequency division multiplexing which combines the signals of two or more audio tone PR channels onto a single audio tone PR channel is not recommended because of the inherent increase in susceptibility to noise interference and the attendant decrease in reliability achievable. However, where such multiplexing is employed in spite of this strong recommendation, the composite signal power and weighted rms voltage for both non-enhanced and enhanced signals must not exceed the limits set forth in 4.03 through 4.14.♦

## 5. TRANSMISSION FACILITY PARAMETER LIMITS

### A. General

5.01 The PR channel may consist of both exchange and toll facilities. The important transmission parameters are described in the following paragraphs. Table A gives a summary of these requirements.

5.02 The circuit layout record (CLR) may show transmission level (TL) and/or signal power (dBm) at various circuit points. Channel lineup should be made using signal power values. Accordingly, at station terminals (Fig. 1), the test signal power is 0 dBm. If TL information only is given, the test signal power will be down 13 dB from the TL value. For example, at the input of a carrier channel (-16 TL), the test signal power should be -29 dBm.

### B. Channel Net Loss and Variations

5.03 ***Engineered net loss*** of a standard PR channel is 16 dB at ♦1004 Hz♦ (initial loss 16 dB ±1 dB). As an option, however, a PR channel having a net loss of 8.0 dB at ♦1004 Hz♦ (initial loss 8 dB ±1 dB) is available subject to conditions described in 1.05.

5.04 ***Short-term loss variations*** (meaning a few seconds or less) may result from dynamic regulation of carrier or radio system amplifiers due to the effects of switching from working to standby facilities or from the effects of certain maintenance activities. The variation in channel loss due to short-term variations should not exceed ±3 dB.

5.05 ***Long-term loss variations*** (meaning periods of days, weeks, or even longer) are primarily caused by temperature changes affecting local plant by component aging and by amplifier drift. These variations (corrected during periodic routine maintenance) must not exceed ±4 dB.

## TABLE A

## TRANSMISSION FACILITY PARAMETER LIMITS

1. Engineered Loss: Standard Channel — 16.0 dB @ 1004 Hz
Optional Channel (subject to the stipulation that the total loss in local loop of receive leg does not exceed 8.0 dB) — 8.0 dB @ 1004 Hz

2. Initial Loss at Installation: Standard Channel — 16.0 dB ±1 dB @ 1004 Hz
Optional Channel — 8.0 dB ±1 dB @ 1004 Hz

3. Short Term Loss Variations: Less than ±3 dB

4. Long Term Loss Variations: Less than ±4 dB

5. Attenuation Distortion (Reference 1000 Hz)

| FREQUENCY RANGE | VARIATION (dB) |
|---|---|
| 300 — 3000 Hz | −2 to +6 |
| 500 — 2800 Hz | −1 to +3 |

6. Envelope Delay Distortion: Less than 2000 microseconds over band from 800 to 2600 Hz

7. C-Notched Noise: Standard 16.0 dB Channel — Less than 50 dBrnC at receiver
Optional 8.0 dB Channel — Less than 58 dBrnC at receiver

8. C-Message Noise:

| CIRCUIT LENGTH (MILES) | NOISE AT RECEIVER 16 dB CHANNEL (dBrnC) | 8 dB CHANNEL (dBrnC) |
|---|---|---|
| 0 — 50 | 28 | 36 |
| 51 — 100 | 31 | 39 |
| 101 — 400 | 34 | 42 |
| 401 — 1000 | 38 | 46 |

9. Impulse Noise:

| THRESHOLD WITH RESPECT TO RECEIVED 1004 HZ TEST TONE POWER SENT AT 0 dBm | MAXIMUM COUNT ABOVE THRESHOLD ALLOWED IN 15 MINUTES |
|---|---|
| −6 dB | 15 |
| −2 dB | 9 |
| +2 dB | 5 |

### C. Attenuation Distortion

**5.06** Attenuation distortion limits for the PR channel are given in Table A. Attenuation distortion is defined as the difference in the frequency response of a channel at any two frequencies. Specific attenuation distortion limits are specified by placing a limit on the maximum loss at any frequency in a specified band with respect to the loss of a ▶1004-Hz◀ reference frequency. The loss at ▶1004 Hz◀ is arbitrarily designated as the reference. Differences in the reference and the loss at any other frequency in the band are measured in dB + or –. The "–"

TABLE A (Cont)

TRANSMISSION FACILITY PARAMETER LIMITS

10. Single Frequency Interference:

| CIRCUIT LENGTH (MILES) | SINGLE FREQUENCY LIMIT | |
|---|---|---|
| | 16 dB CHANNEL (dBrnC) | 8 dB CHANNEL (dBrnC) |
| 0 – 50 | 25 | 33 |
| 51 – 100 | 28 | 36 |
| 101 – 400 | 31 | 39 |
| 401 – 1000 | 35 | 43 |

11. Frequency Shift: Less than ±5 Hz

12. Local Channel Resistive Unbalance Limit: 1% or less unbalance between conductors

13. Phase Hits: No limits are specified for this channel.

14. Gain Hits: No limits are specified for this channel.

15. Dropouts: No limits are specified for this channel.

16. Propagation Time: No limits are specified for this channel.

sign means that the loss is ***less*** than that at the ▶1004-Hz◀ reference. The "+" sign means the loss is greater than that at the ▶1004-Hz◀ reference.

### D. Envelope Delay Distortion

**5.07** A finite time interval is required for transmission between the sending and receiving ends of any type of channel. The delay time, which differs for different frequencies, distorts the shape of the signal wave at the receiving end with respect to its shape at the transmitting end. Distortion of this kind, called envelope delay distortion, is measured in fractions of a second difference in arrival time between two frequencies in the signal wave envelope. The PR channel envelope delay distortion limit, which uses a reference frequency toward each of the two ends of the signal wave envelope, is given in Table A. The mathematical definition and expression of envelope delay distortion may be found in the references [3].

### E. C-Notched Noise

**5.08** The C-notched noise limits for the standard 16 dB channel and the optional 8 dB channel are given in Table A. The limit for the ratio of received power of a ▶1004-Hz◀ test signal to C-notched noise power is 24 dB. Assuming the transmitted signal power of a ▶1004-Hz◀ test signal is 0 dBm and the received power is -16 dBm (74 dBrnC), the C-notched noise will be at least 24 dB less (50 dBrnC or less) at the receiver.

**5.09** C-notched noise is a measure of the amount of noise on a channel when a signal is present. This measurement is made by applying a single-frequency holding tone to the transmitting end of the PR channel to act as a signal. This measurement is described in Section 310-540-500. This tone operates compandors [4] and other signal dependent devices. The tone is removed at the receiving end of the PR channel by a very narrow band-elimination filter (notch filter), and the noise is then measured through a C-message filter.

### F. C-Message Noise

**5.10** The C-message noise limits in Table A listed by circuit length in miles is a measure of the amount of noise on a channel in the idle condition. These readings are ***not*** valid for determining the signal-to-noise ratio of the received

'R trip signal when compandors are employed on he channel. The C-message noise measurement ;ives a good indication of the received noise when signal is being transmitted through noncompandored acilities [5].

### ;. Impulse Noise

;.11 Impulse noise is characterized by large peaks or impulses in the total noise waveform. It s measured with an instrument which responds to noise waveform excursions above a selectable power threshold using a counter having a maximum counting rate of 7 counts per second. Measurements are made through a C-message filter. A holding tone which is transmitted to activate any compandored facilities in the channel is notched out at the receiver. The impulse noise measurement for the PR channel involves counting the number of noise peaks exceeding a threshold numerically 6 dB below the received test tone power. In addition, counts are made of the number of noise peaks exceeding thresholds which are 2 dB below and 2 dB above the received test tone power. Limits for impulse noise at the receiver are given in Table A.

### H. Single-Frequency Interference

5.12 The single-frequency interfering tone must be at least 3 dB below the C-message noise requirement for each mileage category shown in Table A.

### I. Frequency Shift

5.13 Maximum frequency shift for the overall channel is ±5 Hz, although it is very unusual for this limit to be approached. Frequency shift cannot appear on VF wire plant and will seldom be a serious problem on carrier or radio facilities. Where N3 System channels connect to an L-type carrier at an N3-L junction, frequency shift may appear on every other channel of the N3 System unless the frequency control grid has been extended to the N3 terminal (see Section 855-335-108). Either the frequency-control grid should be extended and other requirements of 855-335-108 met, or a different channel on the N3 System should be chosen for the PR channel. Frequency shift will not be found on D1 and D2 channels of T-Carrier Systems. The LMX or MMX channels of L-type carrier should normally hold frequency shift well within the 5-Hz end-to-end limit.

### J. Phase Hits, Gain Hits, Dropouts

5.14 There are no limits specified for this channel.

### K. Propagation Time

5.15 There is no specified propagation time limit on the PR channel. The absolute delay times for end-to-end transmission on various combinations of voice facilities and carrier systems may be calculated from information and examples presented in Section AB27.401.2. Typical examples shown in the practices give computed delay times ranging from 0.1 millisecond for 2 miles of 22NL cable facility up to 7.8 milliseconds for a 300-mile combination of N, LMX, MWV facilities and equalizers. If a multipoint circuit is involved, the addition of the recommended absolute delay equalizers in the various branches can increase the absolute delay time considerably. The ultimate constraint, therefore, that should be of concern is the expected response time of the affected power company relays. As long as this response time is 3 cycles or greater at 60 Hz (minimum of 48 milliseconds), then end-to-end progagation time need not be a serious concern. However, the ultimate goal of the power industry is a relay response time of 1 cycle at 60 Hz or approximately 16 milliseconds. Accomplishment of that goal would then approach the constraints of propagation time on the facilities and require careful evaluation to avoid defeating such a fast response time. For example, assume that a PR terminal under consideration has a back-to-back response time of less than 10 milliseconds (typical for the 1A PR terminal). Allowable propagation time would be less than 6 milliseconds to avoid encroaching on the expected 1-cycle response time of the power relay.

### L. Local Channel Resistance Unbalance Requirement

5.16 The resistance unbalance of the local channel portion of the PR channel must be 1 percent or less. Percent resistance unbalance is defined as follows:

$$R_U = \frac{|R_T - R_R|}{R_T + R_R} \times 200$$

where $R_U$ = resistance unbalance (in percent)

$R_T$ = resistance of tip conductor

$R_R$ = resistance of ring conductor

Resistance unbalance measurements should be made only on the conductors of the local channel pair. Mutual drainage reactors should be removed from the pair during measurement because this device adds shunt resistance to the pair.

## 6. SYSTEM DESIGN CONSIDERATIONS

### A. Reliability

6.01 Service outages in the telephone facilities are generally due to the following: vehicle accidents involving utility poles, storms and floods, malicious destruction, or maintenance and construction activities. Although plans exist for service restoration after interruptions as rapidly as feasible, extended delays are sometimes encountered. Efforts are continuing to shorten the duration and frequency of these outages; however, several alternatives are available when a very high degree of reliability is required as indicated in 6.02.

### B. Backup

6.02 A 100 percent backup over dual, diversified routes (when feasible) is recommended for critical PR application. Dual diversified routes will not guarantee 100 percent reliability, but experience indicates that this arrangement provides a very high degree of reliability. Avoidance routing is also possible to by-pass specific geographical locations.

### C. Bridging

6.03 As mentioned in 1.05, bridging (required in multipoint systems) should be done at the central office for optimum signal-to-noise ratio advantage. Bridging is required in the transmitting pair only at the central office; therefore, the multipoint bridging circuit described in Section 314-815-101 should be used. This resistive-type bridge provides gain, equalization, and test access, and minimizes possibility of crosstalk of enhanced tones into adjacent channels of connecting carrier facilities. Section 851-220-101 also describes the engineering considerations associated with application of the 2-wire bridging circuit for bridging up to five lines at one central office point.

## 7. MAINTENANCE CONSIDERATIONS

7.01 The tariffs generally specify that private line facilities and equipment provided by the telephone company must be released by the customer at a mutually agreeable time for preventive maintenance purposes. The critical nature of PR necessitates close cooperation between the telephone company and power company on maintenance schedules. The continuous "on-line" nature of this service requires that the affected power company dictate the more advantageous time for such maintenance (considering peak power load periods, etc). Preventive maintenance effort should be avoided during times of severe electrical, ice, or wind storms that may cause operation of the PR system at some point on the protected power block. Responsibility must never be assumed for locating trouble in customer-owned equipment.

***CAUTION: All tests on this channel must be performed on an out-of-service basis; no test shall be performed on this channel unless prior coordinated approval for circuit turn-down has been given by the authorized power utility personnel.***

## 8. REFERENCES

8.01 The following technical reference sources are identified in the text by the corresponding number shown enclosed in brackets [ ].


1. ➧***Transmission Specifications for Voice Grade Private Line Audio Tone Protective Relaying Channels,*** Bell System Transmission Engineering Technical Reference PUB. 41011, March 1978,➧ Western Electric Company, Inc., Indiana Publication Center, P.O. Box 26025, Indianapolis, Ind. 46226

2. ***Transmission Specifications for Private Line Metallic Circuits,*** (Preliminary) Bell System Transmission Engineering Technical Reference, PUB 43401, December 1971, Western Electric Company, Inc., Indiana Publication Center, P.O. Box 26025, Indianapolis, Ind. 46226.

3. ***Transmission Systems for Communications,*** Members of the Technical Staff, Bell Telephone Laboratories, Fourth Edition,

February 1970, pp 516-521. Order Form SDI-80.80 to: Western Electric Company, Inc., Indiana Publication Center, P.O. Box 26025, Indianapolis, Ind. 46226.

4. Ibid, Page 677.

5. ***Analog Parameters Affecting Voiceband Data Transmission—Description of Parameters,*** Bell System Technical Reference PUB. 41008, October 1971, and ***Transmission Parameters Affecting Voiceband Data Transmission— Measuring Techniques,*** PUB. 41009, May 1975, Western Electric Company, Inc., Indiana Publication Center, P.O. Box 26025, Indianapolis, Ind. 46226.

**8.02** The following additional Bell System Practices (several of which are referenced in the text) are closely related to the content of this section.

| SECTION | TITLE |
|---|---|
| 310-540-100 | Protective Relaying Channel Description |
| 310-540-500 | Protective Relaying Channel Initial Lineup and Maintenance Test Requirements |
| 314-410-500 | Voice Bandwidth Private Line Data Circuits Tests and Requirements |
| 314-815-100 | Voiceband Multipoint Split Bridge With Gain, Equalization and Test Access—Description |
| 638-600-100 | Integrated Protection System for Power Station Communication—Description and Placing |
| 660-807-500 | Faults—Open Wire and Cable Voltmeter and Wheatstone Bridge Testing Procedure |
| 662-300-503 | Local Test Desk—12-Type Wheatstone Bridge Tests |
| 662-400-503 | Local Test Desk—14-Type Wheatstone Bridge Tests |
| 667-302-102 | SMAS-4A Access Point Locations |
| 667-302-103 | SMAS-4A Access Point Assignment |
| 667-302-200 | SMAS-4A Access Point Cross Connections |
| 667-303-102 | SMAS-5A Access Point Rules |
| 851-201-100 | 1A Protective Relaying Terminal—System Considerations |
| 855-220-101 | Bridging Circuit for 2-Wire Multistation Private Line Networks |
| 855-335-108 | Carrier Engineering System Application N3-L Junction |
| 876-310-100 | Electrical Protection of Wire Plant Communication Facilities Serving Power Stations |
| 880-100-110 | Multiple-Route Data Circuits Propagation Time Equalization |
| 880-420-100 | Private Line Data Circuits Voice Bandwidth General Design Information |

# 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.