

PROTECTIVE RELAYING CHANNEL

DESCRIPTION

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1. GENERAL

1.01 This section provides information on the protective relaying (PR) channel, which is a voice grade private line channel specifically designed for power industry audio tone protective relaying applications. *If this channel is not to be used for audio tone PR applications, do not use the channel design specified in this section; instead, use the design specified in Section 880-420-100A.*

1.02 This section is reissued to include a discussion of:

- (a) The optional 8 dB PR channel
- (b) SARTS and SMAS test access points
- (c) Impulse noise as a transmission parameter in the PR channel.

1.03 PR is the art of protecting a power system during a fault condition. The power system fault may be due to any number of causes, such as lightning striking a high-voltage transmission line, or insulation problems in a piece of power system equipment, such as a generator or transformer. The term "protective relaying" is derived simply from the name of the major items in a PR system, namely the various fault sensing relays (protective

relays), which detect abnormal conditions for parameters such as voltage, current, or temperature. The relays can be simple or complex devices, but all operate to provide a relay contact closure that acts as a control. This control is used to operate circuit breakers remotely and thus protect the power system by fault isolation.

1.04 In general, the term "protective relaying" implies the total arrangement of all relaying devices needed to protect the total customer-owned power system. However, in this section, the term "protective relaying" will refer to the protection of high-voltage transmission line sections. For all practical applications, this is the only area of protective relaying in which telephone company communication channels are used. The PR channel as used in this section is the voice-frequency channel used to transmit tone signals from one point to another.

1.05 Below are terms and definitions that may help clarify the explanation of the PR channel. Figure 1 gives an example of the terms below:

(a) **Guard tone:** A single-frequency tone applied at one PR terminal, transmitted over the PR channel, and received at the distant PR terminal to indicate circuit continuity, to inhibit false operation of the protective relaying equipment at the receiving end, or both.

(b) **Enhanced trip signal:** A trip signal of short duration (about 70 ms) may be transmitted at a much higher level than the guard signal. This signal operates relay circuitry in the receiver to activate circuit breakers to remove the high-voltage line from service. By transmitting at a higher power level, the signal-to-noise (S/N) ratio is improved.

(c) **Trip hold signal:** A trip signal that is transmitted after the enhanced trip signal.

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The trip hold signal will be transmitted as long as the fault condition exists or until the terminal is reset.

1.06 When power transmission lines experience a fault, regardless of the cause, a PR terminal will receive an alerting signal (Fig. 1) from the power company fault-detecting equipment. It is the function of the PR channel (which is terminated at both ends by a PR terminal such as the Western Electric 1A PR terminal) to transmit this trip signal to a distant location. At the distant location the trip signal may be employed by the power company to de-energize the defective power transmission line(s).

1.07 This channel is intended to provide improved **reliability** for PR systems during the power fault interval, exceeding that which can be obtained from other voice bandwidth private line channels. "Reliability," as used in this section, means both dependability and security. Dependability is the degree of assurance of delivering valid trip

signals, and security is the degree of assurance of avoiding delivery of false trip signals.

1.08 One of the unique problems inherent in providing communication service to power stations is the severe noise signals that are frequently introduced into cable facilities during power faults. This noise is often responsible for inhibiting the reception of valid trip signals during the most critical interval. Thus the degree of dependability can be reduced by noise generated during fault intervals. This noise is also responsible for causing undesired trip signals when the fault involves other power facilities, thereby reducing the security of the channel.

1.09 The improved dependability of this channel is the result of a basic improvement in the S/N ratio of the received trip signal. This improvement is accomplished by the following means:

- Selective placement of gain and loss devices

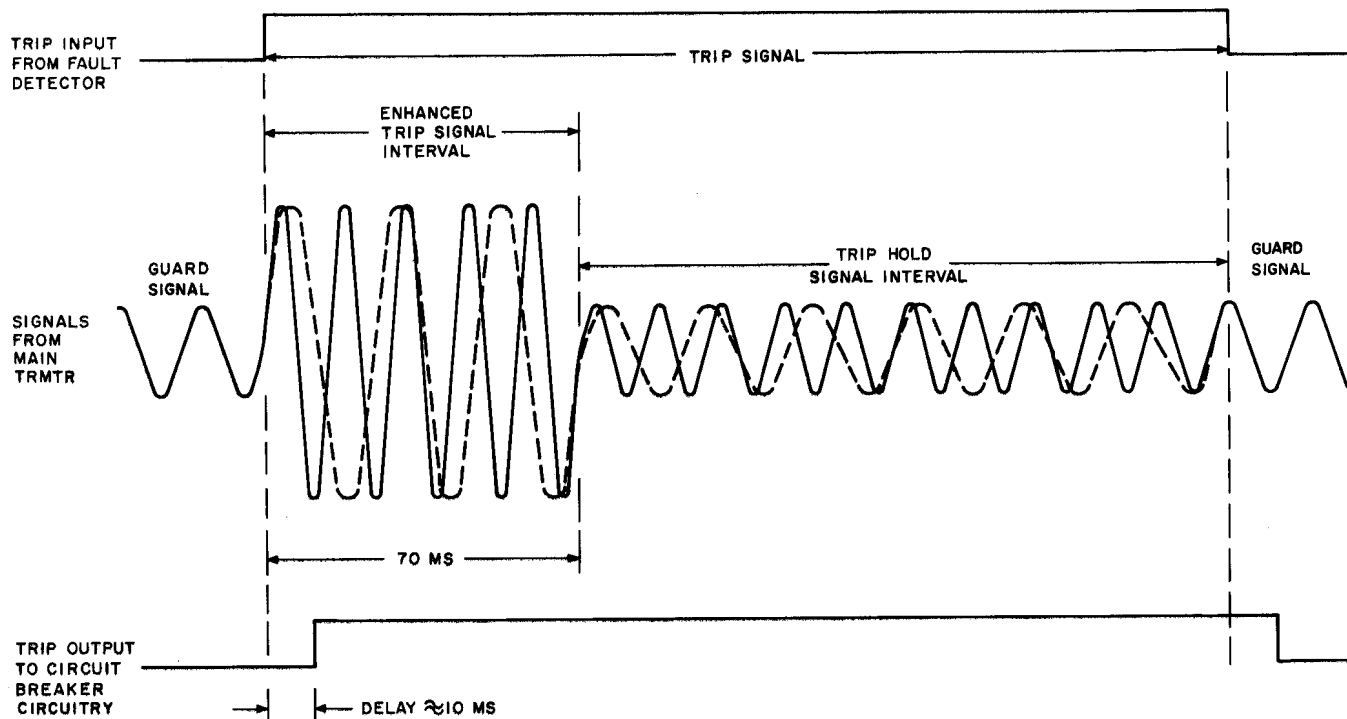


Fig. 1—Example of Signal Format for PR Channel

- Selection of cable facilities with improved resistance balance
- Transmission of an enhanced trip signal.

1.10 The standard net loss of the PR channel is 16.0 dB. An optional channel with 8.0 dB net loss will be provided upon customer request subject to the conditions described in 3.02. For channels having either the standard or optional net loss, any necessary gain or loss devices are installed at locations that insure a true improvement in the S/N ratio. For example, receiving amplifiers are not located at power stations since they would amplify undesirable noise generated in the cable from the central office to the power station as well as the incoming signal. This would degrade the S/N ratio and therefore should be avoided.

1.11 *It is essential that the PR channel be terminated in power station locations using arrangements of 44V4 or equivalent equipment (see Fig. 2 and 3). Channel terminating arrangements with such devices as Data Auxiliary Sets (828-type or 829-type), 150A Channel Service Units, 31B Voice Couplers, or Metallic Facility Terminal (MFT) equipment must not be employed.*

1.12 The conversion of longitudinal noise voltage to metallic noise voltage is directly dependent on the resistance balance of the cable pairs serving the power stations. Therefore, to minimize metallic noise voltage, cable facilities with better than average resistance balance will be employed. The resistance unbalance of the local portion of a PR channel must be 1 percent or less.

1.13 The employment of enhanced trip signals to improve the S/N ratio may result in adjacent channel interference. To minimize this interference, restrictions on signal levels, duration of signals, and frequency of occurrence are placed on the use of enhanced trip signals. The transmitted inband signal power, averaged over any 3-second interval, must not exceed 0 dBm. The short-term power limitation sets the maximum power at +16 dBm (rms), but it should be noted that signal peaks that exceed a +12 dBm sine wave may experience clipping. Because of the possible interference to adjacent lines, the number of enhanced trip signals that may be transmitted for testing 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 over the PR channel will depend on the number of power fault occurrences and hence cannot be defined.

1.14 On the other hand, the use of enhanced trip signals increases dependability, which results in the prompt de-energization of the power line that has the fault condition. This minimizes the period during which interfering noise from power line faults can be introduced into the telephone cable plant. Therefore, the net effect on adjacent channels from the employment of enhanced trip signals is beneficial.

2. TYPES OF ARRANGEMENTS

2.01 The PR channel can be used in several different system arrangements, depending on application requirements. Basically, there are two circuits: either one-way, using two wires; or 2-way, using four wires. The one-way, 2-wire system can only transmit in one direction. This system would be similar to one-half of the 4-wire PR system shown in Fig. 2.

2.02 Each circuit can be used in 2-point or multipoint configurations. The 2-point circuit shown in Fig. 2 and 3 consists of two direct transmission paths, whereas the multipoint circuit in Fig. 4 is slightly more complex. (Figure 3 shows the equalization employed at the terminal location on a 2-point circuit. Similar equalization arrangements may be provided for multipoint circuits). The local portion of the PR channel is not limited to 4-wire in multipoint operation. At each location, a pair exists for each transmitter and each receiver. The number of receivers depends on the number of distant locations—one receiver for each distant location. For example, each location in a 3-point symmetrical system would have two receivers and three pairs of wires. An example of this multipoint system is shown in Fig. 4.

2.03 Variations and combinations of the 2-point and multipoint circuits may be arranged where necessary to satisfy requirements. The channel may be nonsymmetrical where transmission is in only one direction between certain points.

2.04 Switched Maintenance Access Systems (SMAS) provide access for testing PR channels at central office locations either locally or by the Switched Access Remote Testing System (SARTS). Fig. 2 and 4 show the central office locations for

the minimum number of access points required to take full advantage of the trouble sectionalization capability of SARTS. SMAS access is not applicable to customer premises—see following information. Additional SMAS information is available in Sections 667-302-102, 667-302-103, 667-302-200, and 667-303-102.



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.*

3. TRANSMISSION PARAMETERS

3.01 The facility parameters covered in this part represent the minimum limits to which the PR channel must be maintained. The limits specified are somewhat different in certain areas from the usual voice grade private line transmission specifications. The differences are due to the particular requirements for the PR systems. Table A provides a summary of the transmission parameters that are covered in more detail in the following paragraphs.

3.02 ♦The engineered standard net loss of the PR channel is 16.0 dB at 1000 Hz. As an option, however, a PR channel having an engineered net loss of 8.0 dB at 1000 Hz will be provided upon customer request subject to the availability of suitable local facilities. Accordingly, the 8.0 dB channel will be provided only if 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 the standard or optional net loss channel, a loss variation of ± 1 dB is permitted at the time of initial installation. Short-term (meaning a few seconds or less) loss variations may be caused by dynamic regulation of carrier system amplifiers and some maintenance activities. This variation in the channel loss should not exceed ± 3 dB. Long-term (meaning periods of days, weeks, or even longer) loss variations are primarily caused by temperature changes affecting local plant, component aging, and amplifier drift. Long-term loss variations should not exceed ± 4 dB.♦

3.03 Attenuation distortion is the difference in the response of a channel at any two

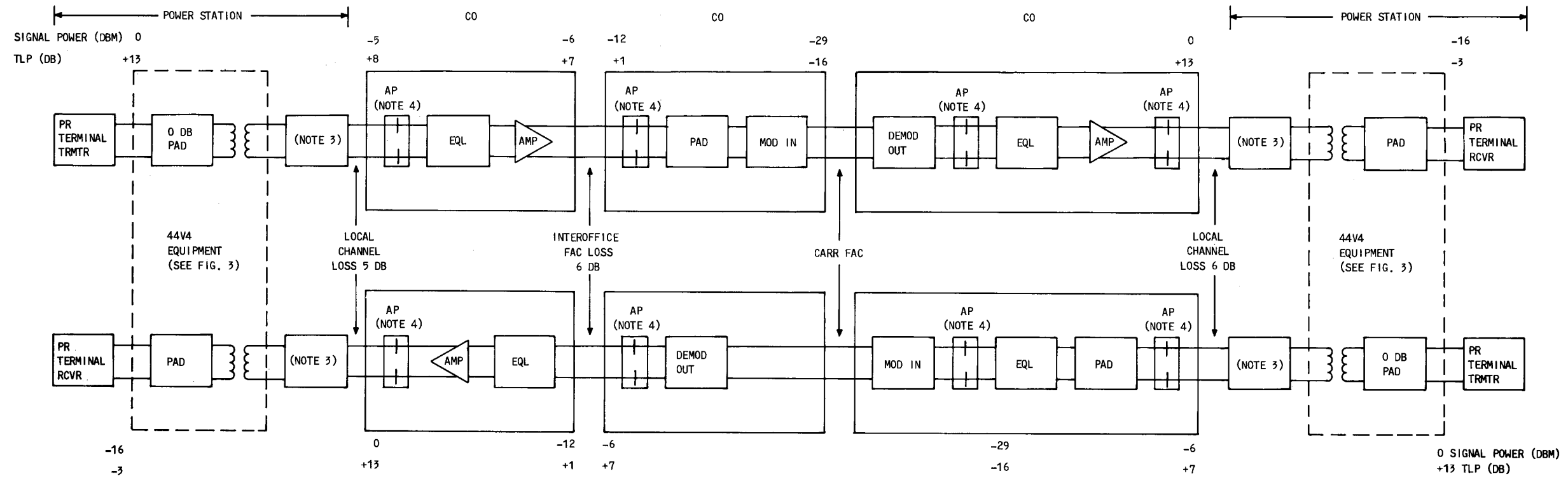
frequencies. It is specified by placing a limit on the maximum loss at any frequency in a specified band of frequencies with respect to the loss of a 1000-Hz reference frequency. The loss may vary from -2 to +6 dB compared with the loss at 1000 Hz in the frequency band between 300 and 3000 Hz. For the frequency band between 500 and 2800 Hz, the loss may vary from -1 to +3 dB compared with the loss at 1000 Hz.

3.04 Envelope delay distortion is an indirect measure of nonlinearity of the phase characteristics of a circuit. An indirect measure is used because of the difficulty of measuring phase directly. The measured envelope delay distortion for a circuit is the maximum envelope delay minus the minimum envelope delay within the frequency band of interest. ♦For this channel, the envelope delay distortion must be less than 2000 μ s over the frequency band between 800 and 2600 Hz.♦

3.05 Message circuit noise is the noise on a channel in the absence of a signal. The measurement of this noise is called C-message noise because it is passed through a C-message weighting network before being measured at the receiving end. Limits for C-message noise at the receiving end are given in Table A.

3.06 The C-message noise described above is not necessarily the noise experienced when a signal is present. Quantizing noise in digital carrier systems and the effect of companders in both analog and digital systems result in signal-dependent noise. Because this noise depends on the presence of a signal, it is impossible to approximate the S/N ratio from the received level and C-message noise measurements alone. For long-haul analog systems that are noncompandored, the received level and C-message noise measurement give a good approximation of the S/N ratio.

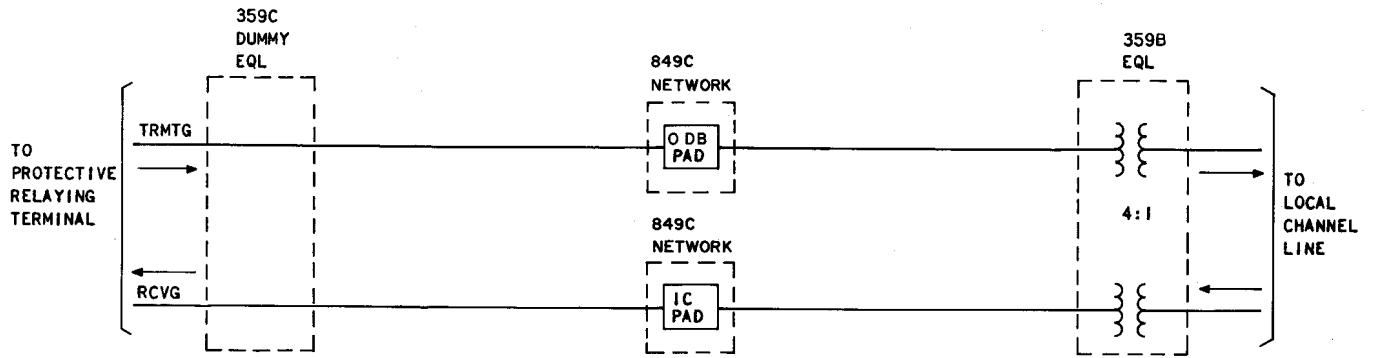
3.07 C-notched noise is a measurement of the amount of noise on a channel when a signal is present. In making this measurement, a single-frequency holding tone is applied at 0 dBm at the transmitting end of the PR channel to simulate a signal. This tone operates companders and other signal-dependent devices. At the receiving end, the tone is removed by a narrow band elimination filter (notch filter), and the noise is then measured through a C-message filter. The ratio of the received 1000-Hz power to the C-notched noise is a good approximation of the S/N ratio.



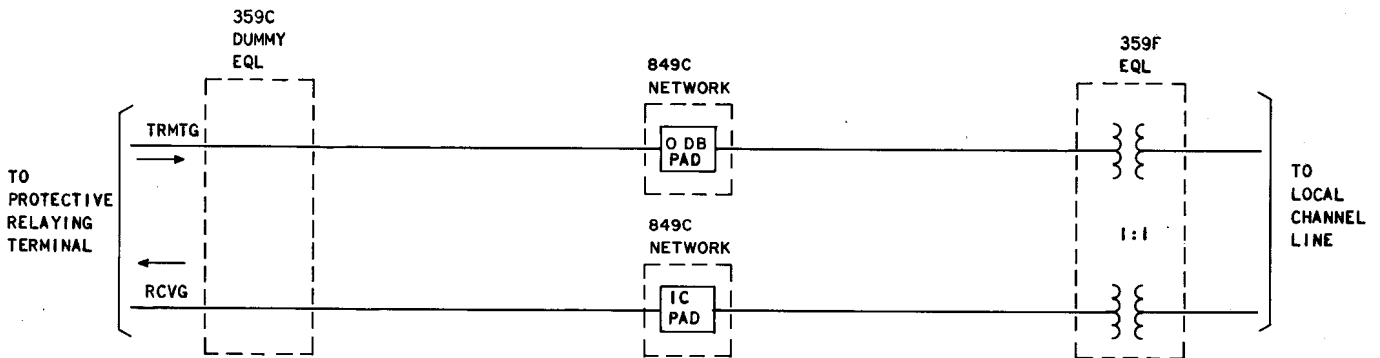
NOTES:

1. 2-POINT, 2-WIRE LAYOUT IS SAME AS ONE HALF OF THIS LAYOUT.
2. THE 16-DB LOSS FROM PR TERMINAL TRANSMITTER TO PR TERMINAL RECEIVER IS MADE UP OF FACILITY LOSS, TRANSFORMER LOSS, EQUALIZATION LOSS IN 44V4 EQUIPMENT, AND PAD LOSS.
3. TWO TYPES OF INTERFACES ARE POSSIBLE AT THIS POINT. THEY ARE: AN ISOLATION TRANSFORMER OR A NEUTRALIZING TRANSFORMER. THEY MAY BE MOUNTED IN A HIGH VOLTAGE INTERFACE UNIT WHICH IS PART OF THE INTEGRATED PROTECTION SYSTEM. BOTH INTERFACES ARE OPTIONAL; THEREFORE IN SOME CASES ONLY A DIRECT PATH MAY EXIST.
4. SMAS ACCESS POINTS - REFER TO SECTION 667-302-102, 667-302-103, 667-302-200 AND 667-303-102 FOR ACCESS CODES, ORIENTATION CODES AND OTHER INFORMATION. THESE ACCESS POINTS MUST BE FLAGGED AS SPECIAL AT TIME OF INSTALLATION. REFER TO BSPTS FOR FLAGGING TECHNIQUE. SEE 2.04.

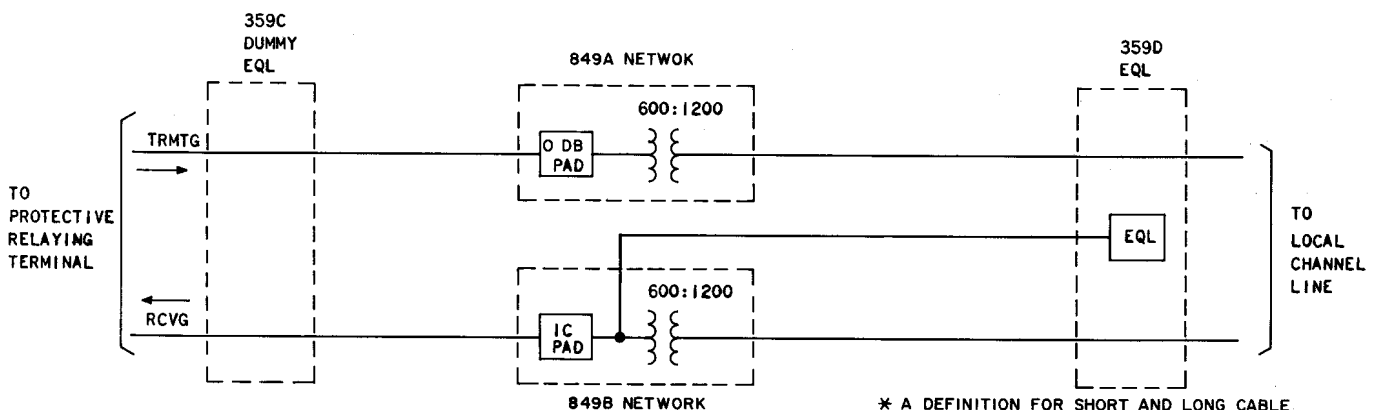
Fig. 2—Typical 2-Point, 4-Wire Layout for Standard 16 dB PR Channel



A. FOR LONG NONLOADED CABLE *



B. FOR SHORT NONLOADED CABLE *



C. FOR LOADED CABLE *

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

Fig. 3—44V4 Equipment Arrangement

SECTION 310-540-100

The limit of S/N ratio is 24 dB. ♦For a standard 16 dB channel, assuming the transmitted signal power of a 1000-Hz test signal is 0 dBm and the received signal power is -16 dBm (74 dBrnC), the C-notched noise will be at least 24 dB less (50 dBrnC or less) at the receiver. For an 8.0 dB channel, if the transmitted signal power of a 1000 Hz test signal is 0 dBm and the received signal power is -8 dBm (82 dBrnC), the C-notched noise will be at least 24 dB less (58 dBrnC or less) at the receiver.

3.08 Impulse noise is characterized by large peaks or impulses in the total noise waveform. It is 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.♦

3.09 Single-frequency (SF) interference is defined as the presence of spurious or interfering tones with a received signal. It can usually be detected by a simple listening test. The human ear can detect an interfering tone if its level is within 3 dB of the desired signal. A listening test in the presence of the desired signal is required to detect spurious tones generated as a result of the signal. For such interfering tone, an alternate method may be used employing the C-notched noise measurement technique. A listening test made after the suppression of the holding tone will reveal the presence of any tones. In either case, a signal should be applied to the circuit to condition compandors to their normal operating point. If the presence of SF interference is detected by the listening test, further tests using a frequency selective voltmeter, or equivalent, are usually necessary to determine the frequency and level of the interfering tone. SF interfering tone appearing on the PR channel should be less than the limits given in Table A.

3.10 Most long-haul carrier systems operate in a single sideband suppressed carrier mode. Because the carrier is not transmitted and must be reinserted at the receiving end, there may be a slight difference in frequency between the modulating and demodulating carriers. The resulting frequency shift contributes a constant change at all frequencies in the voiceband. The frequency shift limit for the overall channel is ± 5 Hz, although it is very unusual for this limit to be approached.

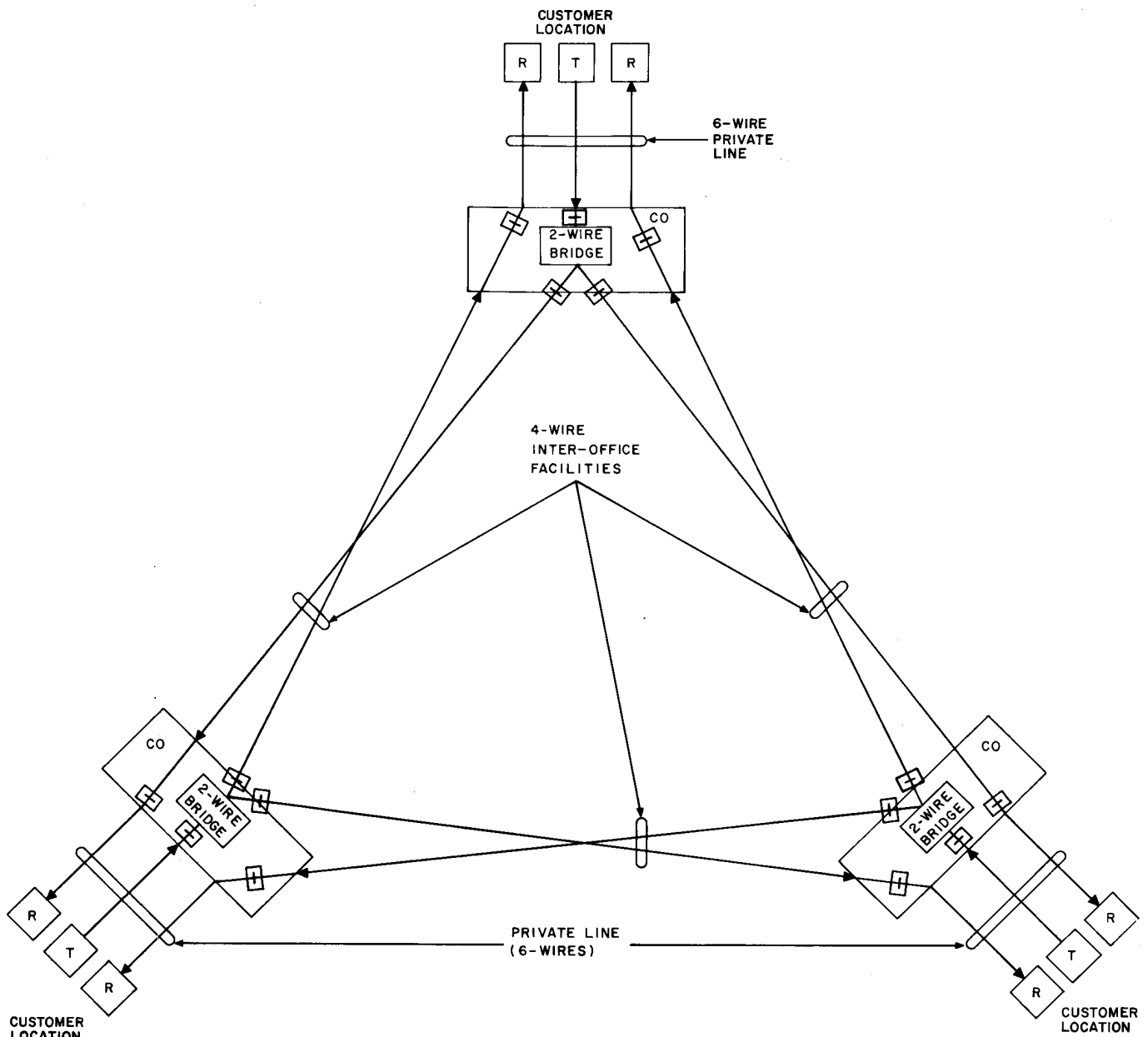
3.11 During power fault conditions, longitudinal voltages of large magnitude may be induced in the local channels serving power stations. When terminated by a well-balanced, protected repeat coil, the conversion from longitudinal to metallic voltage depends primarily on the resistance of the cable facility serving the power station. The resistance unbalance of the local channel cable pairs provided for PR channels must be 1 percent or less.

4. INITIAL LINEUP

4.01 The parameters of the PR channel described above are actually requirements that must be met for the PR channel to provide communication for protection of the customer's high-voltage lines. Some of these requirements are engineered into the channel at the time of design and layout of the circuits. Other requirements must be met by adjustments that are made by the operating personnel at the time the circuit is to be turned up for service.

4.02 For initial lineup, the measurement of certain channel parameters is necessary to assure that the channel meets the established requirements. The parameters that must be measured on initial lineup are:

- Loss (end-to-end)
- Attenuation distortion
- C-message noise
- C-notched noise
- ♦Impulse noise♦
- Resistance balance.



NOTES:

1. EACH **T** REPRESENTS TRANSMITTER.
2. EACH **R** REPRESENTS RECEIVER.
3. EACH **+** REPRESENTS A SMAS ACCESS POINTS. REFER TO SECTIONS 667-302-102, 667-302-103, 667-302-200 AND 667-303-102 FOR ACCESS CODES, ORIENTATION CODES AND OTHER INFORMATION. THESE ACCESS POINTS MUST BE FLAGGED AS **SPECIAL** AT THE TIME OF INSTALLATION. REFER TO BSPs LISTED ABOVE FOR FLAGGING TECHNIQUE. SEE 2.04.

Fig. 4—3-Point Symmetrical System

TABLE A
PROTECTIVE RELAYING CHANNEL

1. Engineered Loss: Standard Channel — 16.0 dB @ 1000 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 @ 1000 Hz

2. Initial Loss at Installation: Standard Channel — 16.0 dB ±1 dB @ 1000 Hz
Optional Channel — 8.0 dB ±1 dB @ 1000 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:

NOISE AT RECEIVER

CIRCUIT LENGTH (MILES)	16dB 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 COUNTS ABOVE THRESHOLD ALLOWED IN 15 MINUTES
-6 dB	15
-2 dB	9
+2 dB	5

TABLE A (Contd)
PROTECTIVE RELAYING CHANNEL

10. Single Frequency Interference:			
	CIRCUIT LENGTH (MILES)	SINGLE FREQUENCY LIMIT	
		16 dB CHANNEL (dBmC)	8 dB CHANNEL (dBmC)
	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			

◆Limits◆ for these parameters are given in Table A. Detailed test procedures are given in Section 310-540-500.

638-600-101

Integrated Protection System for Power Station Communications—Installation

4.03 Initial lineup of the PR channel will require the coordination of operating personnel at both the customer locations and the COs. A communication path between these locations should be established to facilitate lineup and test procedures.

638-600-102

Integrated Protection System for Power Station Communications—High Potential and Resistance Unbalance Testing

4.04 When transmission problems are suspected or when one or more of the parameter requirements listed for initial lineup is not met, further measurements may be necessary. Here again, Section 310-540-500 provides more detailed information on the measurements that need to be made. In general these measurements include the remaining parameters and requirements listed in Table A.

638-600-103

Integrated Protection System for Power Station Communications—Assignment Charts and Circuit Establishment

638-600-104

Integrated Protection System for Power Station Communications—Installation Inspection, Test and Maintenance Requirements

5. REFERENCES

5.01 The following is a list of BSPs that are related to the PR channel and may be useful reference material:

667-302-102

SMAS-4A Access Point Locations

667-302-103

SMAS-4A Access Point Assignment

201-211-101 ◆CO Terminating Unit for Integrated Protection System—Description, Installation, and Maintenance◆

667-302-200

SMAS-4A Access Point Cross Connections

310-540-500 Protective Relaying Channel—Initial Lineup and Maintenance Test Requirements

667-303-102

SMAS-5A Access Point Rules◆

638-600-100 ◆Integrated Protection System for Power Station Communications—Description and Placing

851-201-101

Protective Relaying Channel—Transmission Specifications and Considerations