# BELL SYSTEM

# 1A PROTECTIVE RELAYING TERMINAL

# CUSTOMER MANUAL

Described at the

Protective Relay Conference

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Part of the presentation of
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## PREFACE

After the Northeast power failure of November 9, 1965, the Bell System intensified its efforts to substantially improve the quality of service provided to the Power Industry. All areas of services were studied and proposed solutions were tested in both laboratory and field environments.

The 1A Protective Relaying Terminal is one of a number of developments that resulted from these studies and was developed to improve the reliability of protective relaying systems which utilize leased telephone facilities. Because of the critical nature of protective relaying systems, the 1A Protective Relaying Terminal was designed to provide extremely reliable service through fault-associated noise and other transmission impairments.

Because reliability implies both dependability and security, it is important that both elements of reliability be treated equally since security at the expense of dependability is totally inconsistent in a modern protective relaying scheme. The 1A Protective Relaying Terminal provides excellent security and dependability by means of a three-tone signal design using enhanced signal transmission. This format, along with proper allocation of the signal spectrum and innovations in terminal design, results in a significant improvement in system reliability.

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MAJOR OBJECTIVES

- HIGH DEPENDABILITY
  Ability to signal through protector noise.
- HIGH SECURITY
  No false trips due to protector noise or transmission impairments.
- FAST RESPONSE TIME
  Back-to-back trip delivery time $\leq$ 10 ms.
- REMOTE MONITORING
  Each terminal is capable of system status determination.
- IN-SERVICE TESTING
  Each terminal is capable of testing the entire system while in service.
- RUGGED INTERFACE
  Designed to operate with high reliability in power station environment.

MANY SYSTEM CONFIGURATIONS, INCLUDING

- Two-Point Unidirectional
- Two-Point Bidirectional
- Multipoint Unidirectional } Up to
- Multipoint Bidirectional } 5 point
- Single or Dual Channel for any system configuration

SIGNAL FORMAT

*Main Signals*

| | |
|---|---|
| Guard Tone | 2430 Hz |
| LF Trip Tone | 2130 Hz |
| HF Trip Tone | 2730 Hz |

*Supervisory Signals*

| | |
|---|---|
| Circuit Assurance | 1520 Hz |
| Remote Trip | 1445 Hz |
| Remote Line Failure | 1595 Hz |

Guard tone is sent continuously except during trip. Trip signal consists of enhanced LF and HF tones and the absence of guard tone.

INTERCONNECTION BETWEEN TERMINALS

The system requires specially conditioned 4-wire private line telephone facilities between terminals.

INPUT POWER REQUIREMENTS

The terminal operates from Power Company station battery.

40-54 Vdc $\leq$ 75 watts input power
100-145 Vdc $\leq$ 75 watts input power

Station battery may be either positive ground, negative ground, or ungrounded.

KEYING INPUT SIGNAL

48, 125, or 250 Vdc @200 mA max

OUTPUT

Mechanical Relay Contact (2A) or Solid State (SS) Relay (30A)

SS Relay has provision for interposing power company contact logic in operate path.

ENVIRONMENT

Temperature Range: —22° to +140° F
Recommended Humidity Range: 20% to 95%

PHYSICAL CHARACTERISTICS

Dimensions in inches:
Transceiver Mounting: 19W, 7H, 16D
Interface Mounting: 19W, 7H, 16D

The transmitter and receiver mount in the transceiver mounting unit. The five interface modules mount in the interface mounting unit.

Both the transceiver and the interface mounting unit mount in a standard 19-inch relay rack or cabinet.

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## 1. GENERAL

### SCOPE AND PURPOSE OF THIS BOOKLET

**1.01** This booklet describes the Bell System 1A protective relaying (PR) terminal designed for power industry use. The basic PR ***terminal*** consists of a main and a supervisory transmitter, a main and a supervisory receiver, and an interface unit. Two or more PR terminals interconnected over specially conditioned 4-wire telephone company (Telco) private line facilities constitute a 1A PR ***system.*** The supervisory transmitter and receiver provide for testing and constant monitoring of the system.

### PURPOSE OF THE 1A PROTECTIVE RELAYING SYSTEM

**1.02** The PR system is designed to reliably transmit and receive trip signals for the purpose of actuating circuit breakers during fault conditions. The system operates continuously and unattended.

**1.03** The PR system transmits a trip signal from a power company fault detector via specially conditioned telephone facilities to a remote power company facility (Fig. 1). The signal is first processed by the transmitter into suitable signals for transmission and then applied to the telephone line. At the remote end, the signal is processed by the receiver and its output is delivered to power company logic circuitry and then to power company circuit breakers, or directly to power company circuit breakers. The back-to-back elapsed time from receipt of a fault signal by the PR transmitter to a trip signal output from the PR receiver (but excluding transmission delays in the Telco private line facilities) is less than 10 milliseconds.

### RELIABILITY

**1.04** When a ground fault occurs on a power company phase wire, very high ground currents are present in the vicinity of the power company facility. The resulting ground potential rise causes carbon block and/or gas tube protector operation in the Telco plant. This produces a noisy environment at the very instant when the PR system is required to function. The PR system is designed to operate reliably under such adverse conditions. Reliability as used herein is defined as follows:

- Dependability: Always deliver a valid trip
- Security: Never deliver a false trip.

Dependability is enhanced by:

- Enhanced signal transmission
- Use of tones in the 2- to 3-kHz range
- Use of a specially conditioned channel.

Security is enhanced by:

- Three-signal design
- High-level detection.

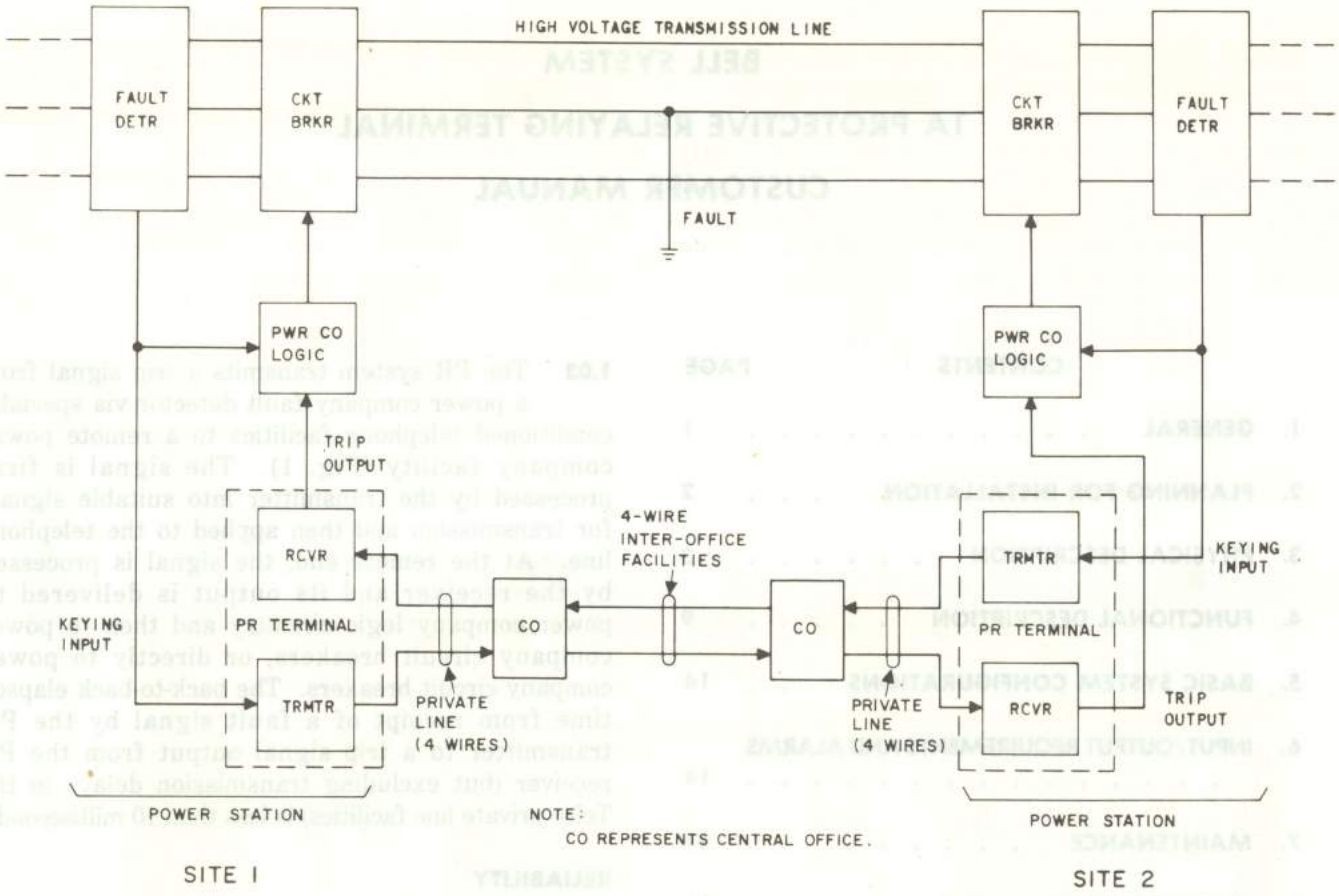



**Fig. 1—Typical Bidirectional Protective Relaying Arrangement**

## REDUNDANCY—DUAL ROUTING

**1.05** Where extreme dependability or security is required, two separate PR systems may be operated in parallel using the same or diverse routing. The inputs are operated in parallel, while the outputs may be operated either in parallel (ORed) for added dependability, or in series (ANDed) for added security. A special receiver is required for dual routing, and must be specified at the time of initial installation.

## 2. PLANNING FOR INSTALLATION

**2.01** Careful consideration in planning the overall installation with the Telco prior to actual installation is of prime importance. Consideration should be given in the planning stage to possible future requirements, appropriateness of installation location, and convenience for maintenance.

**2.02** The PR terminal may be mounted in a commercially available standard 19-inch relay rack of a height suitable to accomodate the complete terminal. The terminal may also be installed in a cabinet designed to accomodate standard 19-inch relay rack units. For simplifying the wiring to the station battery and circuit breakers, the power company may wish to use its own rack or cabinet. Rack mounting is preferred to cabinet mounting, due to better heat dissipation.

**2.03** In installations where a number of transceivers and interface mounting units must be installed, two or more racks or cabinets may be desirable, so that all apparatus when mounted will be within easy reach and view of power company personnel.

**2.04** Placing the PR terminal in service and performing certain test activities require voice communication between all sites within the

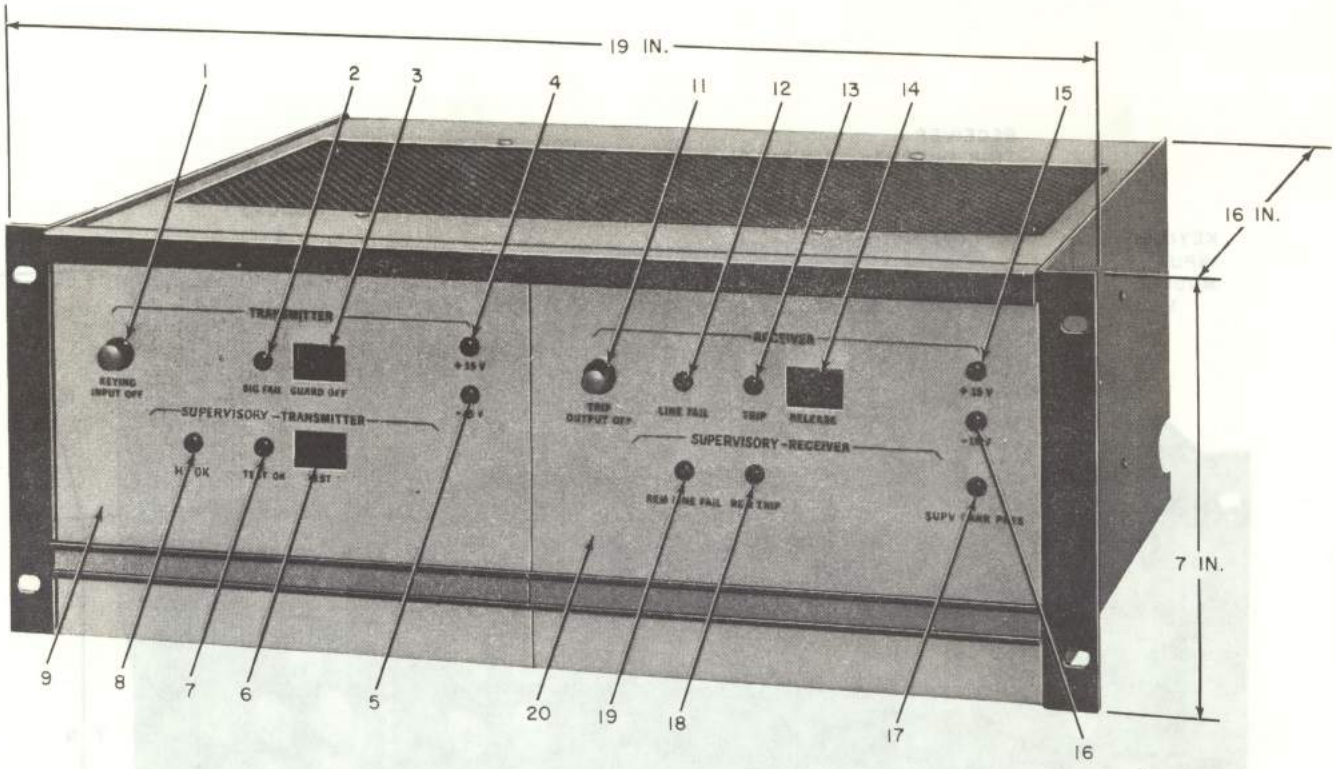
system, and also require close coordination between the power company and the telephone company.

**2.05** The PR terminal is designed to operate within a temperature range of −22 to +140°F and within a relative humidity range of 20 to 95 percent. To ensure trouble-free operation, installation sites chosen should conform to these design criteria.

## 3. PHYSICAL DESCRIPTION

### MAIN AND SUPERVISORY TRANSMITTER AND RECEIVER

**3.01** The PR terminal is modular in design so that various equipment arrangements may be implemented. A typical transmitter and receiver mounting arrangement, together with overall dimensions, controls, and indicators, is shown in Fig. 2.




LEGEND

TRANSMITTER

1 — KEYING INPUT OFF INDICATOR LAMP
2 — SIGNAL FAIL INDICATOR LAMP
3 — GUARD OFF SWITCH
4 — +15 VOLT INDICATOR LAMP
5 — −15 VOLT INDICATOR LAMP
6 — TEST SWITCH
7 — TEST OK INDICATOR LAMP
8 — HIGH FREQUENCY OK INDICATOR LAMP
9 — TRANSMITTER CONTROL PANEL

RECEIVER

11 — TRIP OUTPUT OFF INDICATOR LAMP
12 — LINE FAIL INDICATOR LAMP
13 — TRIP INDICATOR LAMP
14 — RELEASE SWITCH
15 — +15 VOLT INDICATOR LAMP
16 — −15 VOLT INDICATOR LAMP
17 — SUPERVISORY CARRIER PRESENT INDICATOR LAMP
18 — REMOTE TRIP INDICATOR LAMP
19 — REMOTE LINE FAIL INDICATOR LAMP
20 — RECEIVER CONTROL PANEL

**Fig. 2—Main and Supervisory Transmitter and Receiver**

**3.02** The housing for the transmitter/receiver is the transceiver mounting unit. The front door of the transceiver mounting unit, which mounts the control panels, is hinged at the bottom and held in the closed position by magnetic latches. The mounting unit may be opened by pulling outward on the top of the door. Terminal strips are provided on the back of the mounting unit to provide interconnecting within the terminal and to the power company equipment.

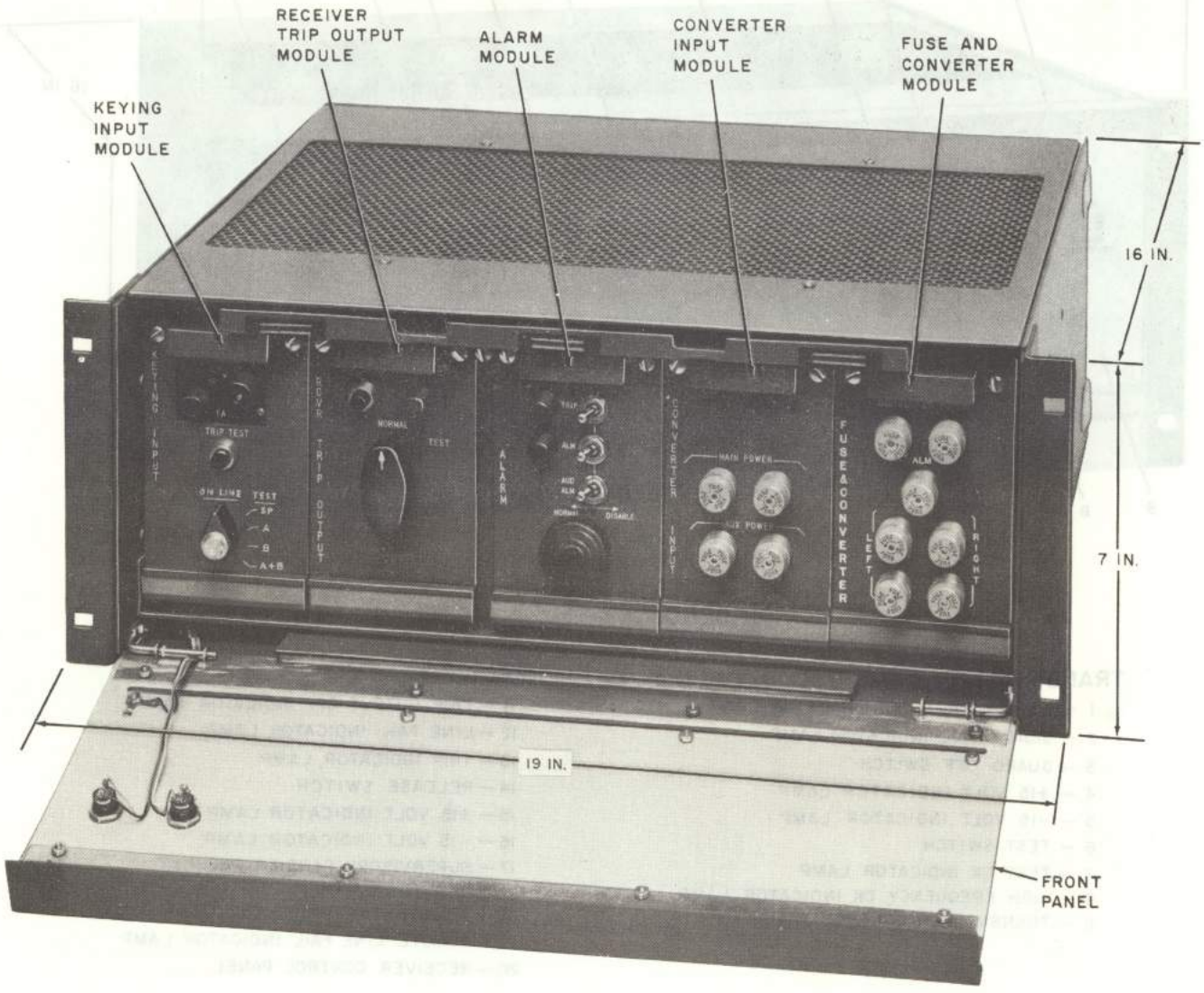



**Fig. 3—Interface Mounting Unit With Modules**

## INTERFACE MOUNTING UNIT

**3.03** Up to five interface modules are housed in the interface mounting unit. A typical interface mounting arrangement is shown in Fig. 3. Each module has its own terminal strips for connecting to other units and to power company equipment.

**3.04** Controls and indicators on the individual modules are shown in Fig. 4 through 8. Two indicators, SYSTEM ALARM and ALARM DISABLE, are located on the front panel of the interface unit. Controls and indicators and their functions are given in Table A. The front panel of the interface mounting unit is hinged at the bottom and held in the closed position by magnetic latches. The mounting unit may be opened by pulling outward on the top of the panel.

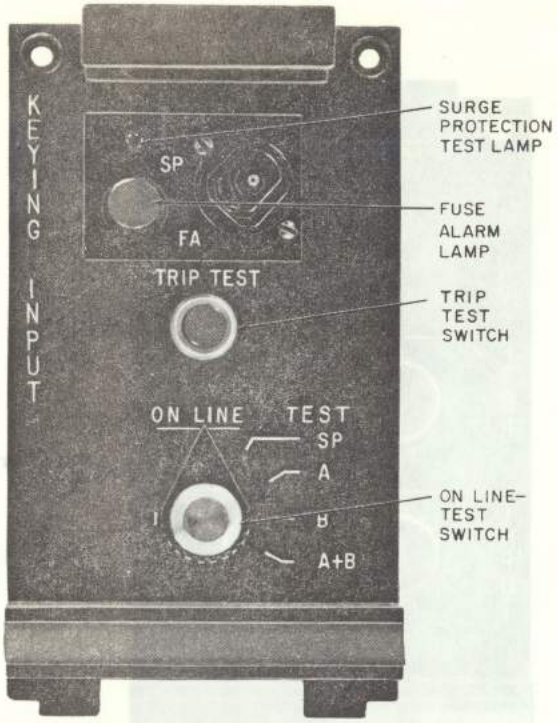



**Fig. 4—Keying Input Module**

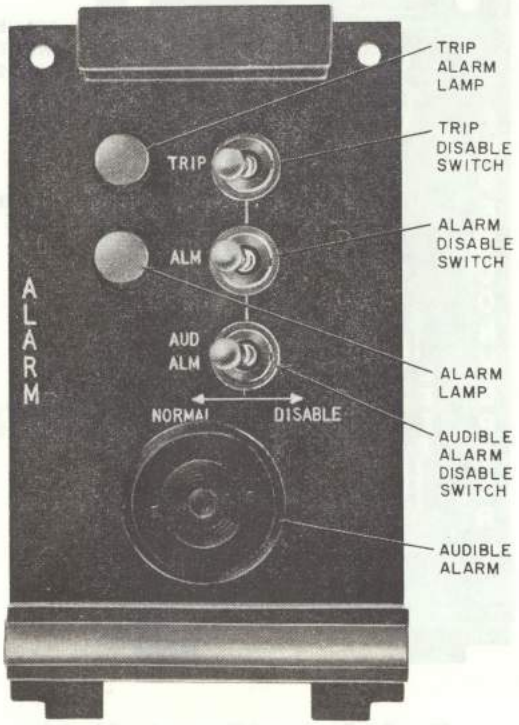



**Fig. 5—Alarm Module**

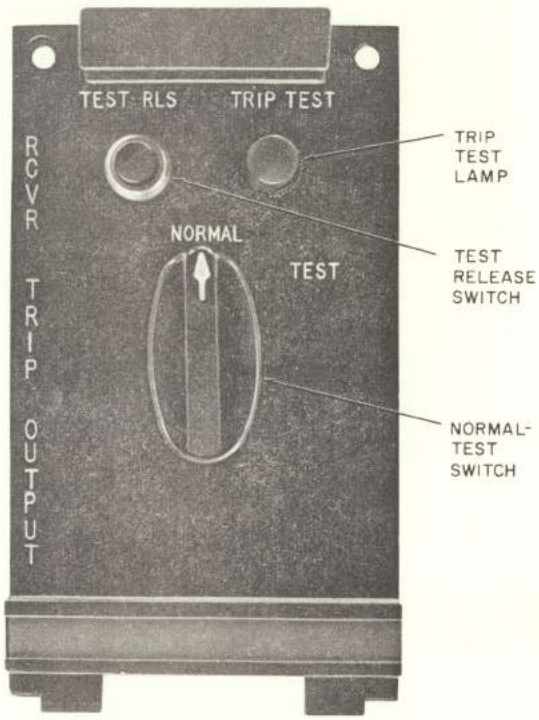



**Fig. 6—Receiver Trip Output Module**

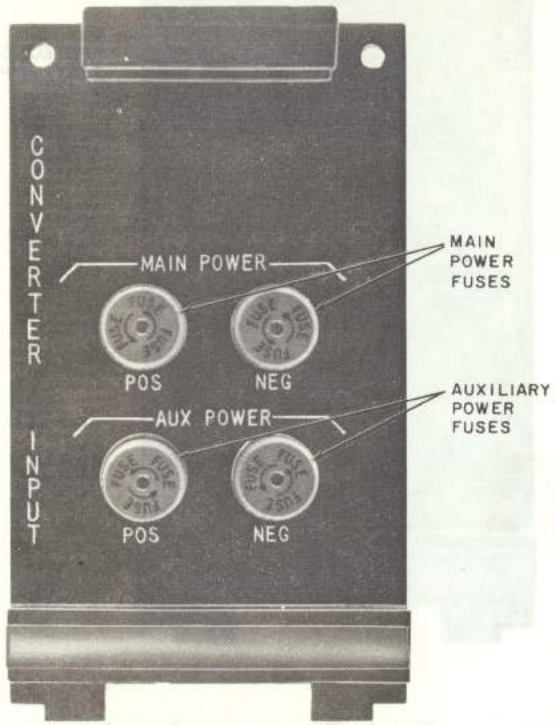



**Fig. 7—Converter Input Module**

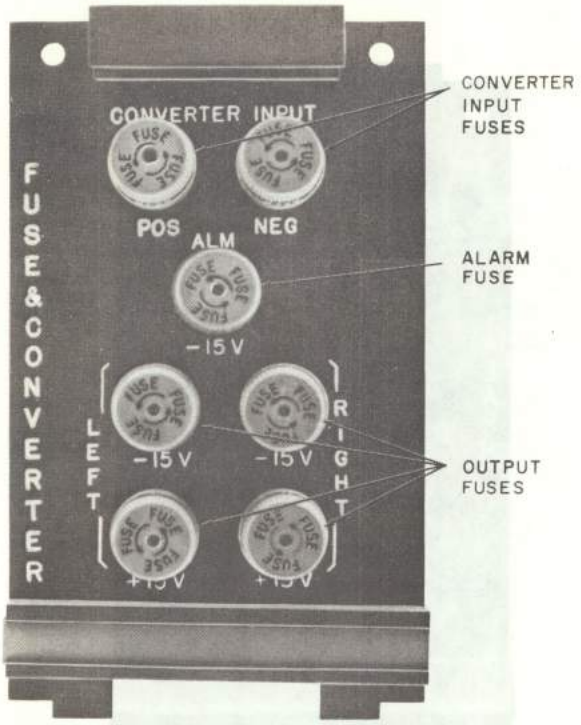



**Fig. 8—Fuse and Converter Module**

TABLE A

CONTROLS AND INDICATORS AND THEIR FUNCTION (FIGURES 2 THROUGH 8)

| CONTROL OR INDICATOR | FUNCTION |
|---|---|
| *TRANSMITTER* | |
| KEYING INPUT OFF Lamp | Indicates ON LINE-TEST switch on keying input module is in TEST position |
| SIG FAIL Lamp | Indicates failure of transmitted output signal |
| GUARD OFF Switch | Disables guard signal for test purposes |
| +15V Lamp | Indicates transmitter +15V is normal |
| −15V Lamp | Indicates transmitter −15V is normal |
| TEST Switch | Initiates in-service test |
| HF OK Lamp | Indicates high-frequency test is satisfactory |
| TEST OK Lamp | Indicates high-frequency and low-frequency tests are satisfactory |
| *RECEIVER* | |
| TRIP OUTPUT OFF Lamp | Indicates NORMAL-TEST switch on trip output module is in TEST position |
| LINE FAIL Lamp | Indicates loss of received signal |
| TRIP Lamp | Indicates trip signal has been received |
| RELEASE Switch | Releases trip indicating circuit |
| +15V Lamp | Indicates receiver +15V is normal |
| −15V Lamp | Indicates receiver −15V is normal |
| SUPV CARR PRES Lamp | Indicates supervisory system signal continuity |
| REM TRIP Lamp | Indicates trip signal has been received at remote site |
| REM LINE FAIL Lamp | Indicates line failure at remote site |
| CHAN SELECT Switch (Not Illustrated) | Provides for channel A, channel B, or dual-channel operation (dual-channel systems only) |

TABLE A (CONT)

CONTROLS AND INDICATORS AND THEIR FUNCTION (FIGURES 2 THROUGH 8)

| CONTROL OR INDICATOR | FUNCTION |
|---|---|
| *KEYING INPUT MODULE* | |
| SP Lamp | Surge protection test lamp |
| FA Lamp | Indicates defective keying input surge protection fuse |
| TRIP TEST Switch | Initiates out-of-service trip test |
| ON LINE-TEST Switch | Removes transmitter from service for out-of-service tests |
| *RECEIVER TRIP OUTPUT MODULE* | |
| NORMAL—TEST Switch | Removes receiver from service for out-of-service tests |
| TRIP TEST Lamp | Provides indication of received trip for out-of-service test |
| TEST RLS Switch | Releases TRIP TEST lamp, which locks up during test when solid-state relay is used |
| *ALARM MODULE* | |
| TRIP Lamp | Provides visual alarm that trip signal has been received at the local or a remote site |
| ALM Lamp | Provides visual alarm that any alarmable condition exists at the local or a remote site |
| Audible Alarm | Provides audible alarm that a trip signal has been received or an alarmable condition exists |
| TRIP DISABLE Switch | Disables TRIP lamp |
| ALM DISABLE Switch | Disables ALM lamp |
| AUD ALM DISABLE Switch | Disables Audible Alarm |
| *INTERFACE UNIT FRONT PANEL* | |
| SYSTEM ALARM Lamp | Provides visual alarm that a TRIP or ALM indication on the alarm module exists |
| ALARM DISABLE Lamp | Provides visual alarm that an alarm on alarm module has been disabled |

## 4. FUNCTIONAL DESCRIPTION

### GENERAL

**4.01** The primary function of the PR terminal (Fig. 9) is to deliver a reliable trip signal. The terminal is designed so that a trip signal may be sent from any point to any other point within a symmetrical system. In addition, two supervisory functions — "monitor" and "test" — are provided. Each terminal can monitor and test all other terminals within the system when used in a symmetrical arrangement. The receiving terminal(s) of a unidirectional system can be tested only from the transmitting site.

***Note:*** A system is referred to as "symmetrical" when each site in the system is equipped to transmit to, and receive from, every other site in the system.

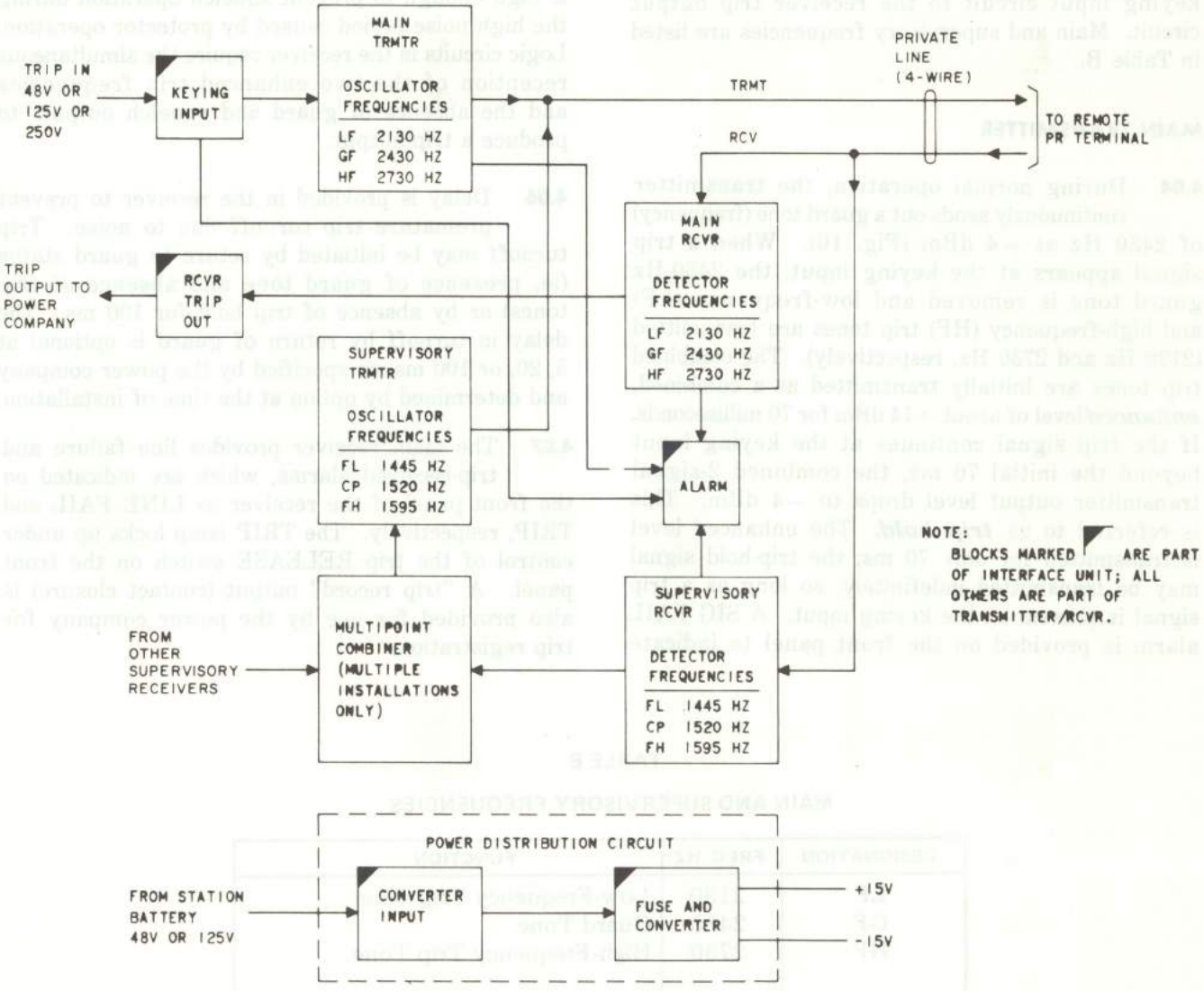



**Fig. 9—Block Diagram of Basic 1A Protective Relaying Terminal**

**4.02** In addition to the local TRIP and LINE FAIL indications, the supervisory circuit continuously provides indications of the status of the remainder of the system. The indications are ***remote trip, remote line failure,*** and ***supervisory carrier present.*** Signals to provide these indications share the private line channel of the main system.

**4.03** Testing of trip signal transmission may be performed on an in-service basis. If a valid trip signal occurs during an in-service test, the test is aborted and the trip signal is sent to the remote terminal. An out-of-service test is also provided which tests the overall trip transmission capability of the system from the transmitter keying input circuit to the receiver trip output circuit. Main and supervisory frequencies are listed in Table B.

## MAIN TRANSMITTER

**4.04** During normal operation, the transmitter continuously sends out a guard tone (frequency) of 2430 Hz at −4 dBm (Fig. 10). When a trip signal appears at the keying input, the 2430-Hz guard tone is removed and low-frequency (LF) and high-frequency (HF) trip tones are transmitted (2130 Hz and 2730 Hz, respectively). The combined trip tones are initially transmitted at a combined, ***enhanced*** level of about +14 dBm for 70 milliseconds. If the trip signal continues at the keying input beyond the initial 70 ms, the combined 2-signal transmitter output level drops to −4 dBm. This is referred to as ***trip hold.*** The enhanced level is transmitted for only 70 ms; the trip-hold signal may be transmitted indefinitely, so long as a trip signal is present at the keying input. A SIG FAIL alarm is provided on the front panel to indicate failure to transmit trip or guard frequencies. A "trip record" output (contact closure) is also provided for use by the power company for trip registration.

## MAIN RECEIVER

**4.05** Detectors in the main receiver respond to the guard frequency, the two trip frequencies at the enhanced level, and the two trip frequencies at the trip-hold level. A squelch circuit is also provided in the receiver to prevent a false trip output from the receiver, which might occur during extremely high noise conditions such as that caused by failure of a telephone company multiplex transmission system. However, the squelch threshold is high enough to prevent squelch operation during the high noise period caused by protector operation. Logic circuits in the receiver require the simultaneous reception of the two enhanced trip frequencies and the absence of guard and squelch outputs to produce a trip output.

**4.06** Delay is provided in the receiver to prevent premature trip turnoff due to noise. Trip turnoff may be initiated by return to guard status (ie, presence of guard tone and absence of trip tones) or by absence of trip hold for 100 ms. The delay in turnoff by return of guard is optional at 5, 20, or 100 ms, as specified by the power company and determined by option at the time of installation.

**4.07** The main receiver provides line failure and trip-received alarms, which are indicated on the front panel of the receiver as LINE FAIL and TRIP, respectively. The TRIP lamp locks up under control of the trip RELEASE switch on the front panel. A "trip record" output (contact closure) is also provided for use by the power company for trip registration.

TABLE B

MAIN AND SUPERVISORY FREQUENCIES

| DESIGNATION | FREQ, HZ | FUNCTION |
|---|---|---|
| LF | 2130 | Low-Frequency Trip Tone |
| GF | 2430 | Guard Tone |
| HF | 2730 | High-Frequency Trip Tone |
| FL | 1445 | Remote Trip Tone |
| CP | 1520 | Supervisory Carrier Present Tone |
| FH | 1595 | Remote Line Fail, Test Tone |

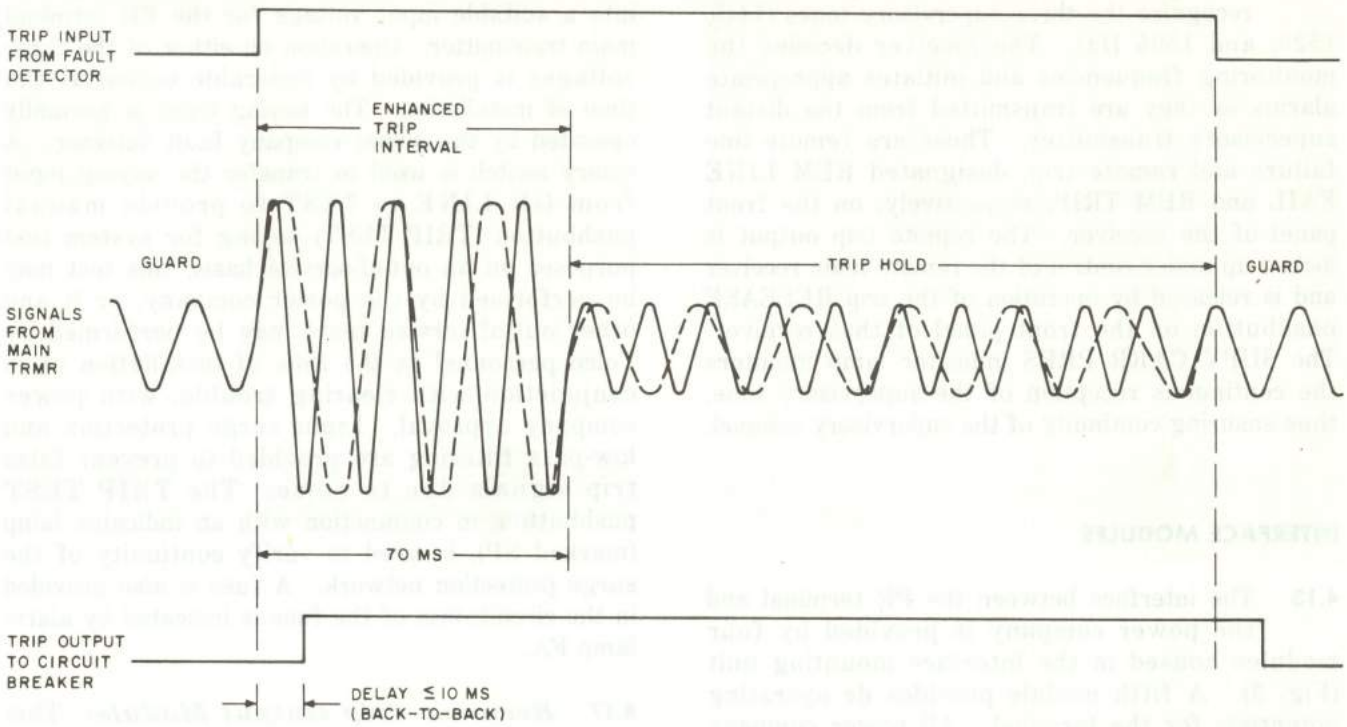



**Fig. 10—Trip Signal Format**

**4.08** When a dual-routed system is desired, two transmitters and two receivers per channel are required. One of the receivers, specially designed for dual-routed systems, contains provisions for combining the received signals on an AND or OR basis and is provided by installer option. Front panel controls for each transmitter and receiver are as described for the single-routed system, except for the addition of a channel selector switch located on one of the two receivers. The channel selector switch permits overriding the dual-routed control by selecting an output from either receiver.

## SUPERVISORY TRANSMITTER

**4.09** The supervisory transmitter is provided to transmit the signals for the monitor and test functions previously mentioned.

**4.10** The monitoring function requires that one of two supervisory tones, either 1445 Hz or 1595 Hz, be transmitted to the other PR terminals to indicate remote trip or remote line failure. A third tone, 1520 Hz, is transmitted continuously in the absence of the other two tones to provide circuit assurance of the supervisory transmission channel. This tone is recognized as supervisory carrier present (SUPV CARR PRES) on the front panel of the remote receiver. These three tones are generated by a sinusoidal oscillator in the supervisory transmitter (Table B). Only one tone is produced at a given time, as controlled by two keying control signals. The oscillator output also provides a clock signal for the logic circuitry in the supervisory transmitter and receiver.

**4.11** The supervisory transmitter provides a test tone and logic for the in-service test feature of the supervisory system. The front-panel TEST pushbutton is used to initiate the test. Sequential operation of lamps HF OK and TEST OK provide visual indication of completion of the test. See 6.08 and 6.09 for further details.

## SUPERVISORY RECEIVER

**4.12** The supervisory receiver is provided to recognize the three supervisory tones (1445, 1520, and 1595 Hz). The receiver decodes the monitoring frequencies and initiates appropriate alarms as they are transmitted from the distant supervisory transmitter. These are remote line failure and remote trip, designated REM LINE FAIL and REM TRIP, respectively, on the front panel of the receiver. The remote trip output is locked up under control of the remote main receiver and is released by operation of the trip RELEASE pushbutton on the front panel of that receiver. The SUPV CARR PRES indicator lamp monitors the continuous reception of the supervisory tone, thus ensuring continuity of the supervisory channel.

## INTERFACE MODULES

**4.13** The interface between the PR terminal and the power company is provided by four modules housed in the interface mounting unit (Fig. 3). A fifth module provides dc operating potentials for the terminal. All power company interface inputs and outputs are designed to meet the 2.5-kV surge withstand capability (SWC) test as proposed by the IEEE.

**4.14** ***Converter Input Module:*** This module provides protection from surges on the station battery input. The unregulated dc input may be either 48 volts or 125 volts, positive ground, negative ground, or ungrounded. Appropriate options at the time of installation provide the voltage choices. When used on 125 volts, options on the converter input module provide for positive ground, negative ground, or ungrounded operation. Both input leads of the converter input module are fuse-protected. Output voltages from this module provide the input to the dc-to-dc converter, the keying input module, and the trip output module.

**4.15** ***Fuse and Converter Module:*** This module consists of a dc-to-dc converter and a fuse panel. It changes the station battery input into +15 volts and −15 volts to provide the operating potentials for the various units in the PR terminal. All leads into and out of the dc-to-dc converter, except ground leads, are fuse-protected.

**4.16** ***Keying Input Module:*** This module accepts a keying signal from the power company of 48 volts, 125 volts, or 250 volts and changes it into a suitable input voltage for the PR terminal main transmitter. Operation on either of the three voltages is provided by orderable option at the time of installation. The keying input is normally operated by the power company fault detector. A rotary switch is used to transfer the keying input from ON LINE to TEST to provide manual pushbutton (TRIP TEST) keying for system test purposes on an out-of-service basis; this test may be performed by the power company, or it and other out-of-service tests may be performed by Telco personnel at the time of installation or in conjunction with clearing trouble, with power company approval. Input surge protection and low-pass filtering are provided to prevent false trip signals due to noise. The TRIP TEST pushbutton, in conjunction with an indicator lamp (marked SP), is used to verify continuity of the surge protection network. A fuse is also provided in the circuit; loss of the fuse is indicated by alarm lamp FA.

**4.17** ***Receiver Trip Output Module:*** This module receives the main receiver trip output signal and delivers an appropriate trip signal to the power company. The output may be either a relay contact closure or the output of a solid-state relay, as selected by the power company before installation. A NORMAL-TEST switch on the front of the module permits the trip output to be removed from the power company circuit breaker and operate the TRIP TEST indicator lamp instead, to provide for manual system testing of trip reception. With the solid-state relay option, the TRIP TEST lamp is locked up under control of the TEST RELEASE pushbutton switch.

> ***Note:*** The solid-state relay is a transistor-like device having a noncontinuous current carrying capacity of 30 amperes, as opposed to the electro-mechanical relay which has a 2-ampere current carrying capacity.

**4.18** ***Alarm Module:*** This module provides two alarm lamps and an audible alarm to give indications of a received trip and other alarmable conditions. Switches are provided to disable each of the alarms. When any alarm is disabled by operation of a switch, an ALARM DISABLE lamp lights on the front panel of the interface unit.

## IN-SERVICE TESTING

**4.19** Two in-service tests are provided:

- Trip-tone transmission and detection capability
- Remote line fail.

These tests are discussed in the following paragraphs.

**4.20** ***Trip-tone Transmission and Detection Capability:*** This test is accomplished by sending the trip tones one at a time ***with*** guard tone present (Fig. 11). A frequency shift in the supervisory tones is also sent to inform the supervisory control logic that a test is in progress. Enhanced levels and normal levels of each of the individual trip tones are sent sequentially.

**4.21** After the test is initiated by pushing and releasing the TEST pushbutton on the front panel of the supervisory transmitter, an appropriate response from the remote station is received, depending on system configuration.

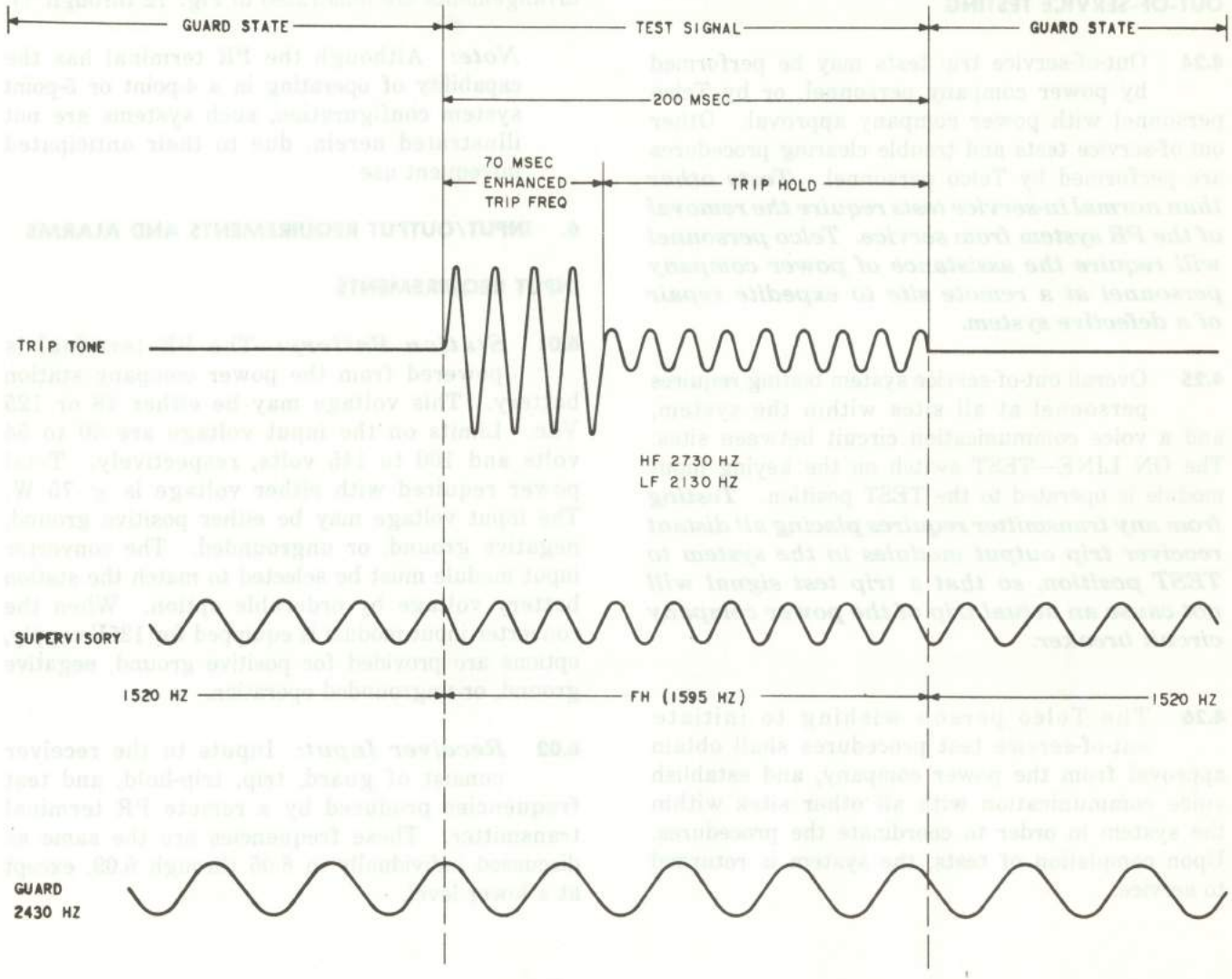



**Fig. 11—Test Signal Format**

**4.22** A timer in the supervisory transmitter returns the terminal to normal after a 2-second test interval. The 2-stage test (HF OK and TEST OK) is designed to aid in locating trouble within the system. Further information on in-service testing is presented in Part 8.

**4.23** ***Remote Line Fail:*** This test verifies the operation of line failure detection at the remote terminal(s), and provides a REM LINE FAIL indication at the local supervisory receiver. The test is initiated by operating the GUARD OFF switch on the local transmitter. This will result in a transmitter SIG FAIL indication (indicating that the local transmitter is inhibited), followed by the REM LINE FAIL indication verifying that the remote end has registered a line failure.

### OUT-OF-SERVICE TESTING

**4.24** Out-of-service trip tests may be performed by power company personnel, or by Telco personnel with power company approval. Other out-of-service tests and trouble clearing procedures are performed by Telco personnel. ***Tests other than normal in-service tests require the removal of the PR system from service. Telco personnel will require the assistance of power company personnel at a remote site to expedite repair of a defective system.***

**4.25** Overall out-of-service system testing requires personnel at all sites within the system, and a voice communication circuit between sites. The ON LINE—TEST switch on the keying input module is operated to the TEST position. ***Testing from any transmitter requires placing all distant receiver trip output modules in the system to TEST position, so that a trip test signal will not cause an actual trip of the power company circuit breaker.***

**4.26** The Telco person wishing to initiate out-of-service test procedures shall obtain approval from the power company, and establish voice communication with all other sites within the system in order to coordinate the procedures. Upon completion of tests, the system is returned to service.

### MULTIPOINT COMBINER

**4.27** In symmetrical multipoint systems, one transmitter and two or more (maximum of four) receivers are located at each site. The multipoint combiner is used to combine the multiple signals from the supervisory receivers and present common inputs to the supervisory transmitter. The combiner is provided in multipoint systems only (Fig. 9).

## 5. BASIC SYSTEM CONFIGURATIONS

**5.01** The PR terminal may be connected in any one of several different symmetrical system configurations, as well as many nonsymmetrical (unidirectional) configurations. Various symmetrical system arrangements and three typical unidirectional arrangements are illustrated in Fig. 12 through 17.

> ***Note:*** Although the PR terminal has the capability of operating in a 4-point or 5-point system configuration, such systems are not illustrated herein, due to their anticipated infrequent use.

## 6. INPUT/OUTPUT REQUIREMENTS AND ALARMS

### INPUT REQUIREMENTS

**6.01** ***Station Battery:*** The PR terminal is powered from the power company station battery. This voltage may be either 48 or 125 Vdc. Limits on the input voltage are 40 to 54 volts and 100 to 145 volts, respectively. Total power required with either voltage is $\leq$ 75 W. The input voltage may be either positive ground, negative ground, or ungrounded. The converter input module must be selected to match the station battery voltage by orderable option. When the converter input module is equipped for 125V supply, options are provided for positive ground, negative ground, or ungrounded operation.

**6.02** ***Receiver Input:*** Inputs to the receiver consist of guard, trip, trip-hold, and test frequencies produced by a remote PR terminal transmitter. These frequencies are the same as discussed individually in 6.05 through 6.09, except at a lower level.

**6.03** ***Keying Input:*** A fault as detected by the power company fault detector produces a keying input signal of either 48, 125, or 250 volts at ≤ 200 mA dc. This keying signal is applied to the keying input module of the interface unit. The keying input module is equipped to accept any one of the three input voltages when initially ordered from the factory.

## OUTPUT REQUIREMENTS

**6.04** The outputs of the PR terminal consist of guard, trip, trip-hold, test frequencies, and a dc trip signal, plus various alarms, and contact closures for trip recording. These signals are discussed individually in the following paragraphs.

### Transmitter Output

**6.05** ***Guard:*** This frequency is produced continuously while the system is in operation and not in the trip or trip-hold mode. The guard frequency is a single 2430-Hz tone transmitted at a level of −4 dBm. The guard tone serves to assure circuit continuity in the idle state.

**6.06** ***Enhanced Trip:*** The trip signal is transmitted by the PR terminal in response to a keying input signal from the power company or by operation of the TRIP TEST switch during out-of-service testing. The trip signal is composed of a low frequency (2130 Hz) and a high frequency (2730 Hz) in the absence of the guard frequency. Enhanced trip is transmitted for a timed 70-ms interval at a combined level of about +14 dBm.

**6.07** ***Trip Hold:*** At the end of the timed (enhanced trip) interval, if the keying input is still present, the combined trip signal is reduced to a level of −4 dBm. Trip hold may be transmitted indefinitely, so long as the keying input signal remains.

**6.08** ***HF Test:*** This signal is one of two test signals used for in-service testing of the PR terminal. The HF test signal is composed of HF (2730 Hz) and GF (2430 Hz) signals from the main transmitter and 1595 Hz from the supervisory transmitter. The HF (2730 Hz) frequency is transmitted for a timed 70 ms at the enhanced level (about +11 dBm), and then reduced to the trip- hold level (−7 dBm) for an additional 130 ms. Successful transmission of and response from the HF test causes the HF OK lamp to light and initiates the LF test.

**6.09** ***LF Test:*** This signal is the second test signal used for in-service testing. The LF test signal is composed of LF (2130 Hz) and GF (2430 Hz) signals from the main transmitter and 1595 Hz from the supervisory transmitter; it can only be generated after completion of the HF test. As in the case of the HF test, these signals are transmitted for a timed 70 ms at the enhanced level, and then at the reduced level for an additional 130 ms. Successful transmission of and response from the LF test causes the TEST OK lamp to light.

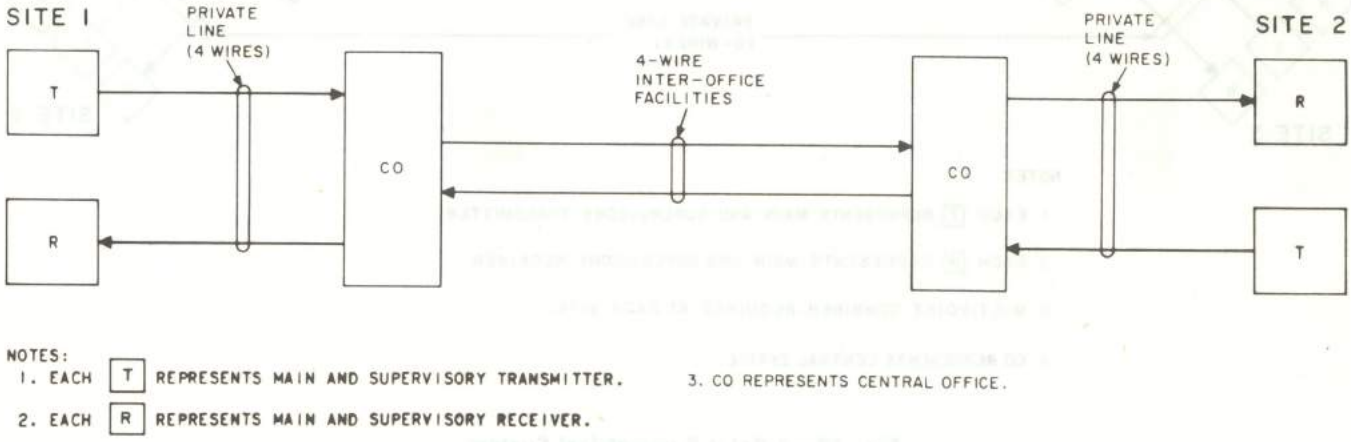
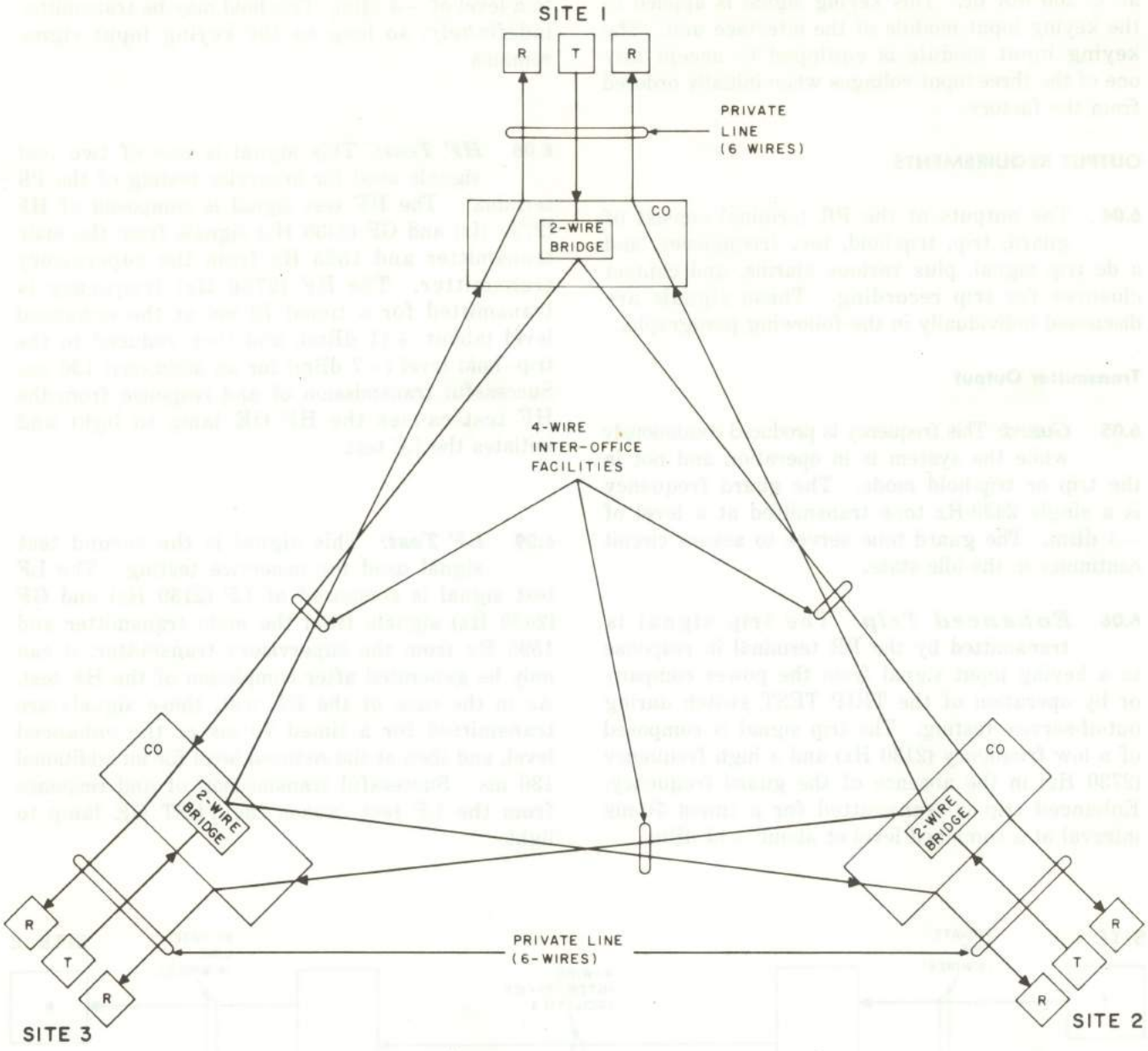



**Fig. 12—2-Point Symmetrical System**




NOTES:

1. EACH [T] REPRESENTS MAIN AND SUPERVISORY TRANSMITTER.
2. EACH [R] REPRESENTS MAIN AND SUPERVISORY RECEIVER.
3. MULTIPOINT COMBINER REQUIRED AT EACH SITE.
4. CO REPRESENTS CENTRAL OFFICE.

**Fig. 13—3-Point Symmetrical System**

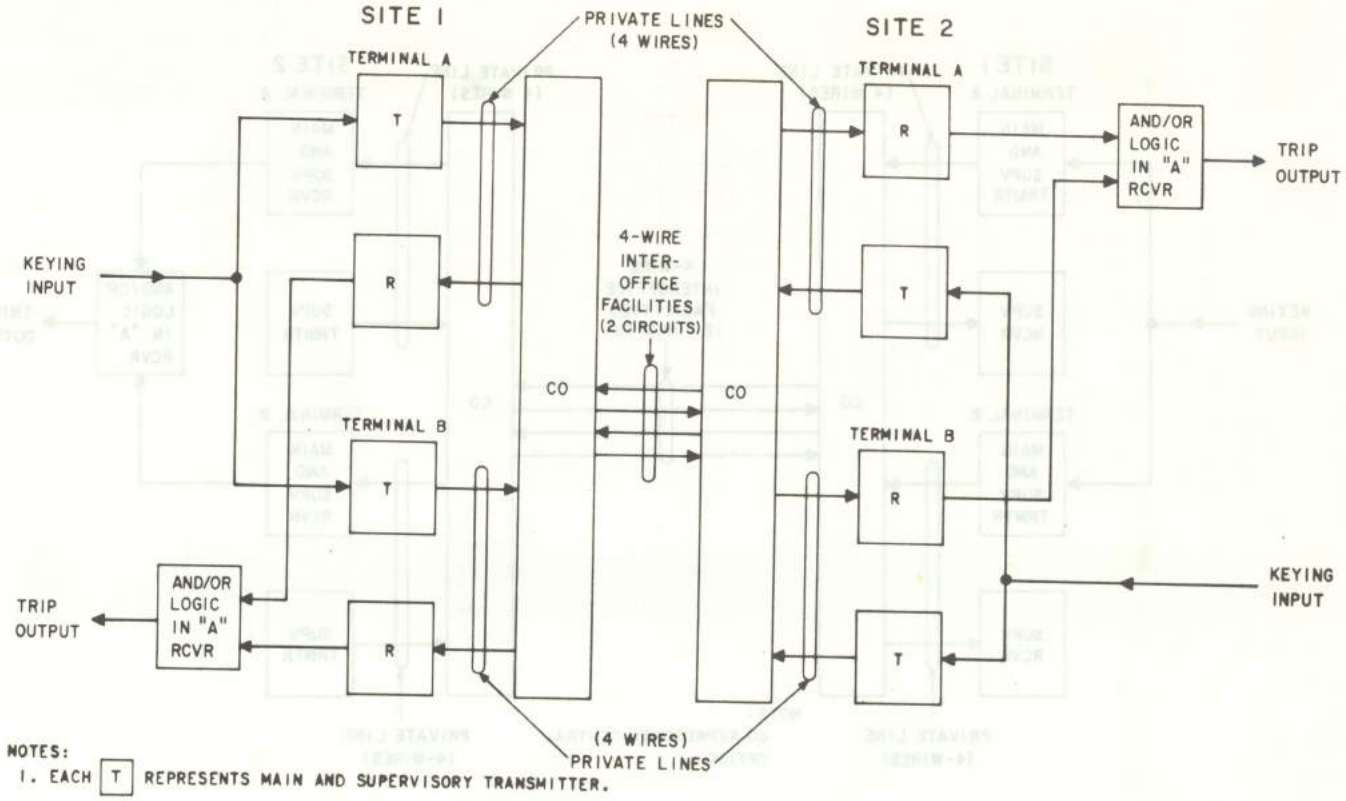



**Fig. 14—2-Point Dual-Channel Symmetrical System**

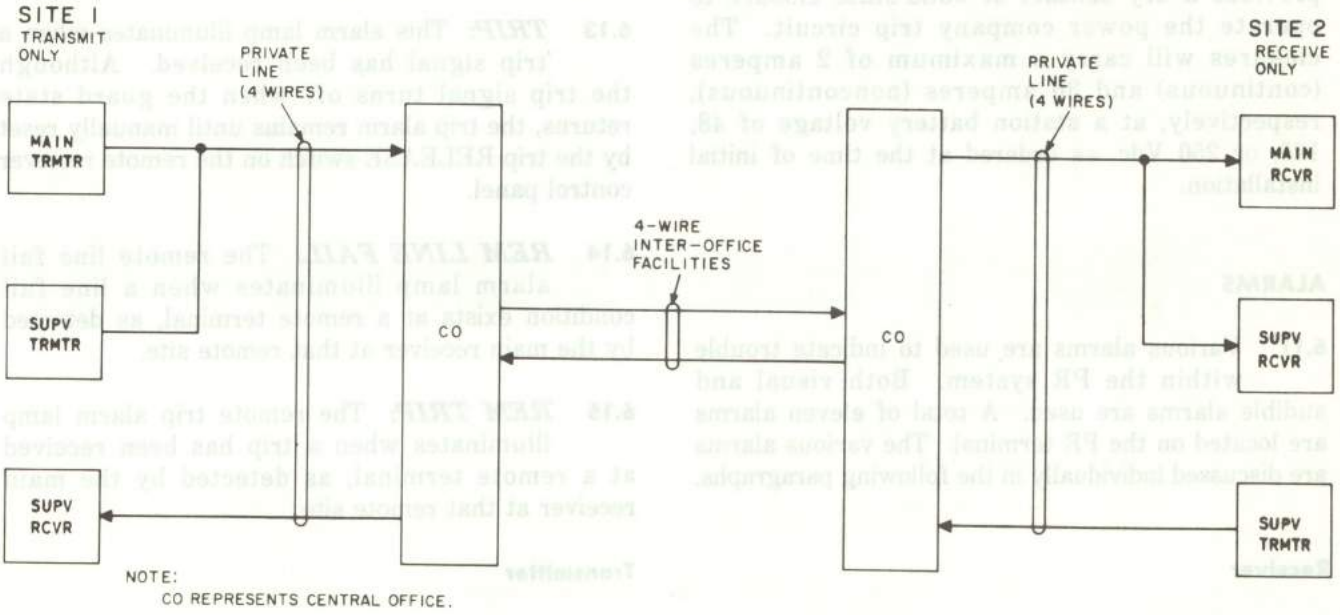



**Fig. 15—2-Point Single-Channel Unidirectional System**

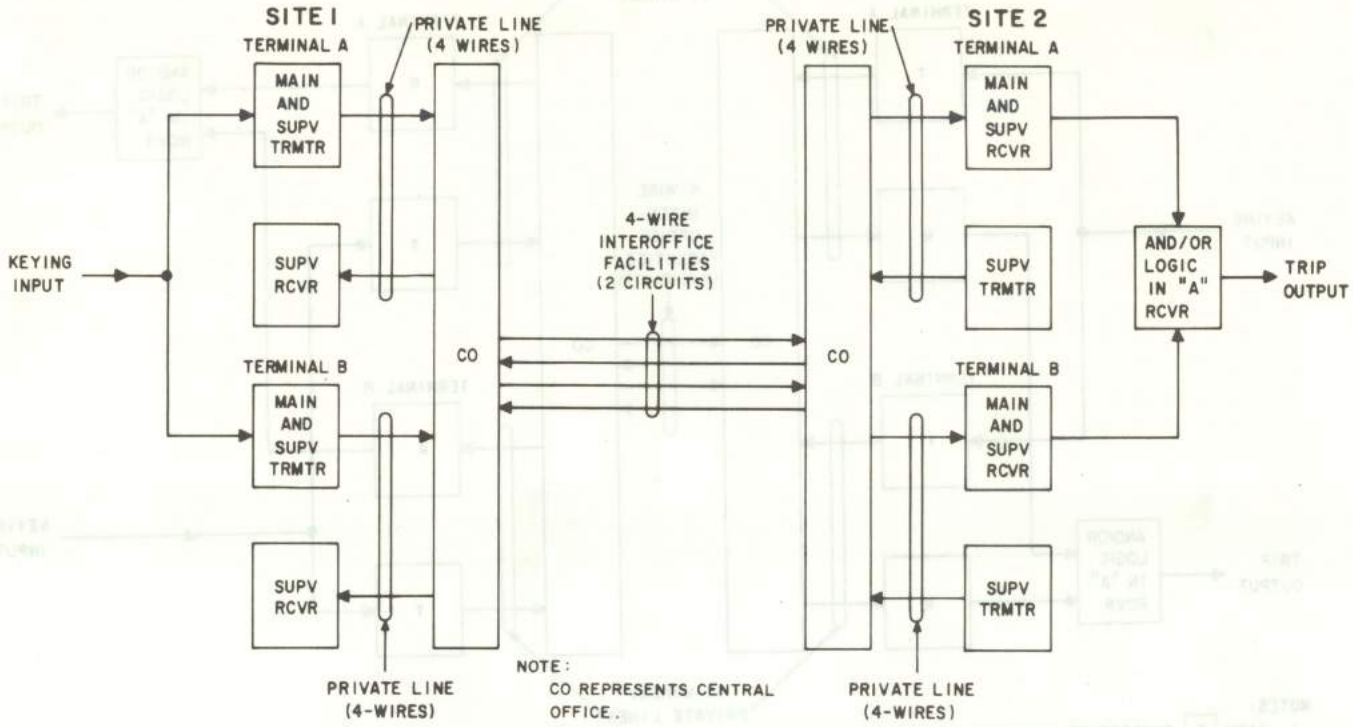



**Fig. 16—2-Point Dual-Channel Undirectional System**

#### Trip Output Module Output

**6.10** After a valid trip signal has been detected by the receiver, the trip output module provides a dry contact or solid-state closure to operate the power company trip circuit. The closures will carry a maximum of 2 amperes (continuous) and 30 amperes (noncontinuous), respectively, at a station battery voltage of 48, 125, or 250 Vdc, as ordered at the time of initial installation.

### ALARMS

**6.11** Various alarms are used to indicate trouble within the PR system. Both visual and audible alarms are used. A total of eleven alarms are located on the PR terminal. The various alarms are discussed individually in the following paragraphs.

#### Receiver

**6.12** ***LINE FAIL:*** This alarm lamp is illuminated when noise on the telephone line is abnormally high. This alarm is also activated when both guard and trip frequencies are simultaneously absent. Due to the fast-operate time of the receiver, it is generally possible to receive a trip signal in spite of intermittent line failure indication.

**6.13** ***TRIP:*** This alarm lamp illuminates when a trip signal has been received. Although the trip signal turns off when the guard state returns, the trip alarm remains until manually reset by the trip RELEASE switch on the remote receiver control panel.

**6.14** ***REM LINE FAIL:*** The remote line fail alarm lamp illuminates when a line fail condition exists at a remote terminal, as detected by the main receiver at that remote site.

**6.15** ***REM TRIP:*** The remote trip alarm lamp illuminates when a trip has been received at a remote terminal, as detected by the main receiver at that remote site.

#### Transmitter

**6.16** ***SIG FAIL:*** The signal fail alarm lamp illuminates when none of the transmitter signals (LF, GF, HF) are present.

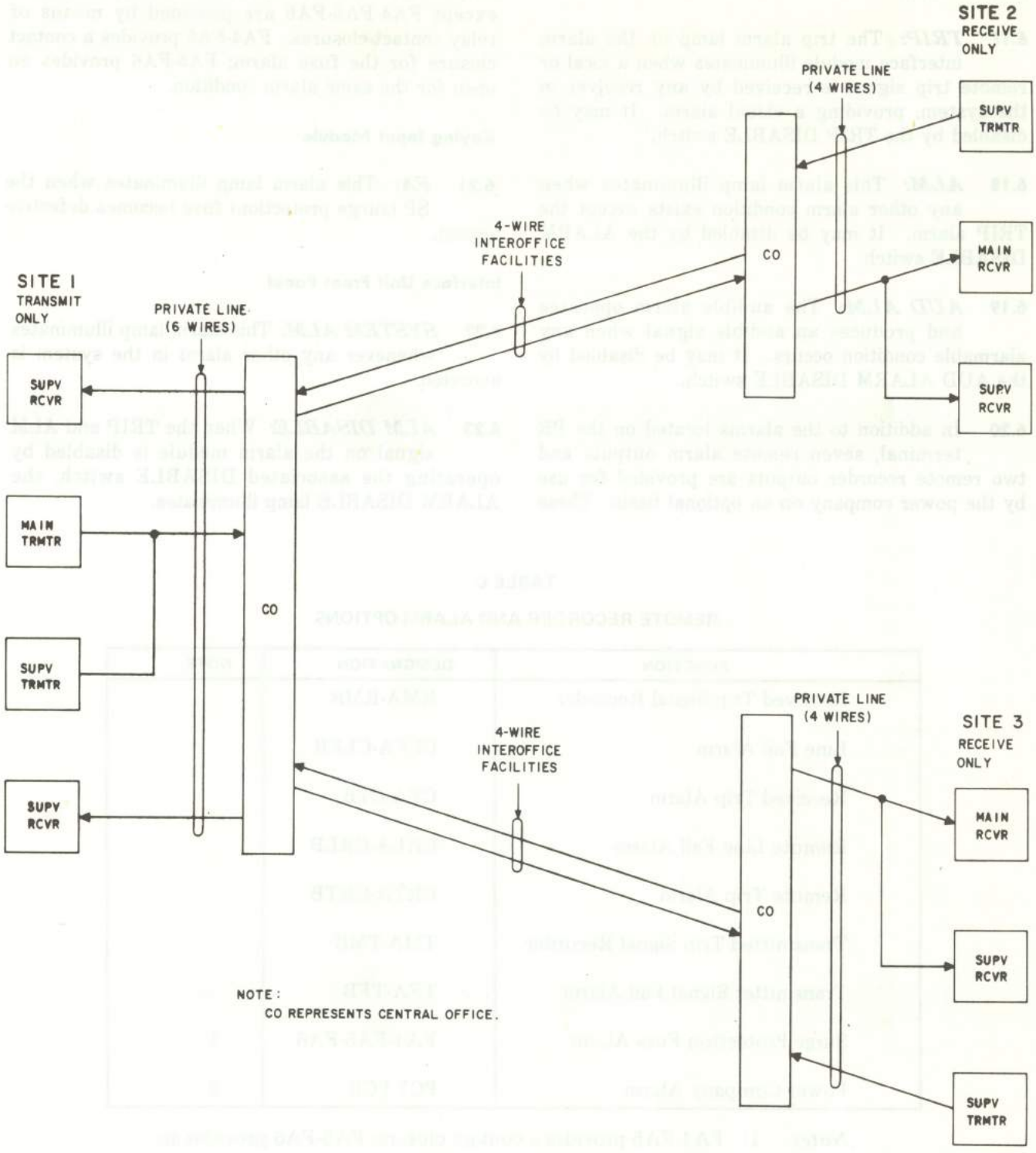



**Fig. 17—Unidirectional Transmitter With Two Receivers**

**Alarm Module**

**6.17** ***TRIP:*** The trip alarm lamp on the alarm interface module illuminates when a local or remote trip signal is received by any receiver in the system, providing a visual alarm. It may be disabled by the TRIP DISABLE switch.

**6.18** ***ALM:*** This alarm lamp illuminates when any other alarm condition exists except the TRIP alarm. It may be disabled by the ALARM DISABLE switch.

**6.19** ***AUD ALM:*** The audible alarm operates and produces an audible signal when any alarmable condition occurs. It may be disabled by the AUD ALARM DISABLE switch.

**6.20** In addition to the alarms located on the PR terminal, seven remote alarm outputs and two remote recorder outputs are provided for use by the power company on an optional basis. These outputs are listed in Table C. All of the indications except FA4-FA5-FA6 are provided by means of relay contact closures. FA4-FA5 provides a contact closure for the fuse alarm; FA5-FA6 provides an open for the same alarm condition.

**Keying Input Module**

**6.21** ***FA:*** This alarm lamp illuminates when the SP (surge protection) fuse becomes defective (open).

**Interface Unit Front Panel**

**6.22** ***SYSTEM ALM:*** This alarm lamp illuminates whenever any other alarm in the system is actuated.

**6.23** ***ALM DISABLE:*** When the TRIP and ALM signal on the alarm module is disabled by operating the associated DISABLE switch, the ALARM DISABLE lamp illuminates.

TABLE C

REMOTE RECORDER AND ALARM OPTIONS

| FUNCTION | DESIGNATION | NOTE |
|---|---|---|
| Received Trip Signal Recorder | RMA-RMB | |
| Line Fail Alarm | CLFA-CLFB | |
| Received Trip Alarm | CTA-CTB | |
| Remote Line Fail Alarm | CRLA-CRLB | |
| Remote Trip Alarm | CRTA-CRTB | |
| Transmitted Trip Signal Recorder | TMA-TMB | |
| Transmitter Signal Fail Alarm | TFA-TFB | |
| Surge Protection Fuse Alarm | FA4-FA5-FA6 | 1 |
| Power Company Alarm | PCT-PCR | 2 |

*Notes:*
1. FA4-FA5 provides a contact closure; FA5-FA6 provides an open contact for the SP fuse alarm.
2. Provides system alarm, trip, and remote trip alarm.
3. Leads for all of the above remote alarms are subject to induced high-voltage transients; No. 20 AWG KS-19165-L1 wire (or equivalent) shall be used for these leads.

## 7. MAINTENANCE

**7.01** Power company maintenance shall be limited to the in-service tests and the out-of-service trip test and surge protection test described in Parts 8 and 9, respectively, and the replacement of fuses and incandescent lamps. For maintenance beyond this scope, call Telco repair service.

**7.02** For convenience in maintenance, spare fuses and incandescent lamps should be kept at each PR terminal site. Telco repair service should supply spares as needed. Field replaceable fuses and lamps required for the terminal are listed in Tables D and E, respectively.

## 8. IN-SERVICE TESTS

**8.01** This part describes in-service test procedures for the PR terminal and system. The tests herein are made without access to components internal to the circuit packs and modules of the terminal; the tests use built-in alarms and indicators.

**8.02** The tests are presented in step-procedure format. If a particular test should fail, refer to the correspondingly numbered step in Part 10 (TROUBLESHOOTING).

**8.03** No routine tests are specified to be performed by Telco. The power company may wish to perform in-service tests on a routine basis; such tests may be performed as deemed necessary, but should not exceed seven tests per week because of possible interference on adjacent telephone channels.

TABLE D

FIELD REPLACEABLE FUSES

| FUSE LABEL | LOCATION (MODULE) | FUSE TYPE AND RATING |
|---|---|---|
| *48V STATION BATTERY* | | |
| MAIN POWER | | |
| POS | Converter Input | Bussman GBA, 5A |
| NEG | Converter Input | Bussman GBA, 5A |
| POS | Fuse & Converter | Bussman GBA, 3A |
| NEG | Fuse & Converter | Bussman GBA, 3A |
| *125V STATION BATTERY* | | |
| MAIN POWER | | |
| POS | Converter Input | Bussman GBA, 3A |
| NEG | Converter Input | Bussman GBA, 3A |
| POS | Fuse & Converter | Bussman GBA, 1.5A |
| NEG | Fuse & Converter | Bussman GBA, 1.5A |
| *48V OR 125V STATION BATTERY* | | |
| AUX POWER | | |
| POS | Converter Input | Bussman GBA, 1.5A |
| NEG | Converter Input | Bussman GBA, 1.5A |
| ALM | Fuse & Converter | Bussman GBA, 3A |
| LEFT −15 | Fuse & Converter | Bussman GBA, 3A |
| LEFT +15 | Fuse & Converter | Bussman GBA, 3A |
| RIGHT −15 | Fuse & Converter | Bussman GBA, 3A |
| RIGHT +15 | Fuse & Converter | Bussman GBA, 3A |
| FA | Keying Input | WECo 70E, 180mA |

TABLE E

FIELD REPLACEABLE INCANDESCENT LAMPS

| LAMP | LOCATION | TYPE |
|---|---|---|
| TRIP OUTPUT OFF | Rcvr Control Panel | General Electric or Dialco 382 |
| TRIP | Alarm Module | |
| ALM | Alarm Module | |
| SYSTEM ALARM | Interface Control Panel | |
| ALARM DISABLE | Interface Control Panel | |
| KEYING INPUT OFF | Trmtr Control Panel | |
| FA | Keying Input Module | GE or Dialco 394 |
| TRIP TEST | Rcvr Trip Output Module | Dialco 507-6022-1437-600 |

**8.04** ***Verify System Normal—All Systems:*** This test applies to all terminals of all types of systems (unidirectional, bidirectional, multipoint, single channel, and dual channel). This test verifies that the dc potentials are present at the terminal and that supervisory carrier is present.

**8.05** ***Procedure:***

| STEP | PROCEDURE |
|---|---|
| 1 | Observe that ***only*** +15V and −15V lamps on transmitter(s) are lighted. |
| 2 | Observe that ***only*** +15V, −15V, and SUPV CARR PRES lamps on receiver(s) are lighted. |

**8.06** ***Remote Line Fail Test—All Transmit Terminals:***

**8.07** ***Procedure:***

| STEP | PROCEDURE |
|---|---|
| 3 | Operate the GUARD OFF switch on transmitter for about three seconds. Observe that after a delay of about one second, the REM LINE FAIL lamp on receiver lights. Observe that REM LINE FAIL lamp extinguishes one to three seconds after GUARD OFF switch is released. |

**8.08** ***Trip Test—All Transmit Terminals:*** This test automatically tests the capability of all links of the system to transmit and detect the enhanced trip and the trip hold signals in two stages. Transmission of the high-frequency trip tone (2730 Hz) is tested first, followed by transmission of the low-frequency trip tone (2130 Hz). If the high-frequency test is unsuccessful, the low-frequency test is not attempted by the transmitter.

**8.09** ***Procedure:***

| STEP | PROCEDURE |
|---|---|
| 4 | Operate and hold TEST switch on transmitter. Observe that HF OK and TEST OK lamps light immediately when TEST switch is operated. |
| 5 | Release TEST switch. Observe that HF OK and TEST OK lamps extinguish momentarily. Observe that HF OK lamp lights in about 0.5 second, is extinguished, and is followed by TEST OK lamp which lights for about one second.<br><br>***Note:*** Time intervals are not critical and vary by type of system. |

## 9. OUT-OF-SERVICE TESTS

**9.01** This part describes the out-of-service test procedures for the PR terminal and system that may be performed by the power company. It is assumed that the in-service tests described in Part 8 have been satisfactorily completed prior to performing these tests.

**9.02** The out-of-service trip test requires personnel at all sites within the system and voice communication between all sites.

***WARNING: Be certain that all receiver trip output modules in the system are in TEST position before trip signals are transmitted.***

**9.03** ***Procedure:***

| STEP | PROCEDURE |
|---|---|
| 6 | At the receiving site(s), operate the NORMAL—TEST switch on the trip output module to TEST position. |
| 7 | At the transmitting site, operate the ON LINE—TEST switch on the keying input module to TEST A position (TEST A+B for a dual-channel system). |
| 8 | At the transmitting site, operate the TRIP TEST switch on the keying input module for about five seconds. |
| 9 | At the receiving site(s), observe that the TRIP lamp on the receiver lights and remains lighted. Observe that the TRIP TEST lamp on the trip output module lights for about five seconds if the trip output module uses a dry contact (2-ampere) relay. If the trip output module uses a 30-ampere solid-state relay, observe that the TRIP TEST lamp lights and remains lighted.<br><br>***Note:*** If the wiring option providing power company logic in series with the solid-state relay operating circuit is used, the TRIP TEST lamp may not light during this test. |
| 10 | Momentarily operate the RELEASE switch(es) on the receiver(s) to extinguish the TRIP lamp(s). Extinguish the TRIP TEST lamp(s), if lighted, by momentarily operating the TEST RLS switch(es) on the receiver trip output module(s). |

| STEP | PROCEDURE |
|---|---|
| 11 | Restore the system to service as follows:<br>(1) At the transmitting site, operate the ON LINE—TEST switch to ON LINE position.<br>(2) At the receiving site(s), operate the NORMAL—TEST switch(es) to NORMAL position. |

**9.04** ***Surge Protection Test—All Transmit Terminals:*** This test provides for verification of the surge protection circuitry in the keying input module associated with the transmitter(s) of single- or dual-channel systems.

***Note:*** This test requires the system to be out of service, but no attendant is required at the receive terminal(s).

**9.05** ***Procedure:***

| STEP | PROCEDURE |
|---|---|
| 12 | Operate ON LINE—TEST switch on keying input module to TEST SP. Operate and release TRIP TEST switch on keying input module several times. Observe that SP lamp flashes each time TRIP TEST switch is operated, but does not light steadily if TRIP TEST switch is held operated. |
| 13 | After test is completed, operate ON LINE—TEST switch on keying input module to ON LINE. |

## 10. TROUBLESHOOTING

**10.01** This part provides guidance in isolating trouble which has appeared in performing the tests described in Part 8. Any trouble found in performing the tests described in Part 9 must be referred to Telco repair service.

**10.02** When a trouble has occurred in performing the test procedures, refer to the corresponding step number in this part to begin trouble isolation. When the trouble appears to be cleared, return to the step in the test procedures where the trouble was encountered, and repeat that and subsequent tests.

**10.03** Since troubleshooting steps cover more detail than the steps in the test procedures, it is necessary in some cases to use several troubleshooting steps to cover one test step. In such cases, the troubleshooting steps are numbered with the same basic number as the test step number, ***plus*** a letter suffix to the basic number. For example: The troubleshooting procedure corresponding to test Step 3 has two parts, identified as 3a and 3b.

**10.04** The troubleshooting chart lists the control or indicator, the ***correct*** condition of the control or indicator for that step, and the probable cause of the trouble if the correct condition is not met.

## TROUBLESHOOTING CHART

| STEP | CONTROL OR INDICATOR | NORMAL CONDITION | PROBABLE CAUSE AND/OR CORRECTIVE ACTION |
|---|---|---|---|
| 1 | +15V lamp<br>−15V lamp | lighted<br>lighted | A. If one or more, but not all, lamps are extinguished, check for defective fuse(s) in fuse and converter module. |
| 2 | +15V lamp<br>−15V lamp<br>SUPV CARR PRES lamp<br>All other lamps | lighted<br>lighted<br><br>lighted<br>extinguished | B. If all lamps are extinguished, check for defective fuse(s) in converter input module. |
| | | | C. Check station battery input voltage. |
| | | | D. If SIG FAIL lamp on transmitter is lighted, refer problem to Telco. |
| | | | E. If TRIP lamp on receiver is lighted, operate RELEASE switch on receiver to extinguish lamp. |
| | | | F. IF REM TRIP lamp is lighted, operate RELEASE switch on associated distant receiver to extinguish lamp. |
| | | | G. If SUPV CARR PRES lamp is extinguished and LINE FAIL lamp is also extinguished, trouble in local supervisory receiver or in associated distant supervisory transmitter is indicated. Refer problem to Telco. |
| | | | H. If REM LINE FAIL lamp is lighted, perform the same procedure *at distant receiver* (as described in G) for LINE FAIL at local receiver. |
| 3a | REM LINE FAIL lamp | lighted | A. Refer problem to Telco. |
| 3b | LINE FAIL lamp at distant rcvr. | lights when local GUARD OFF switch is operated | B. Refer problem to Telco. |
| 4 | HF OK and TEST OK lamps | Both lamps lighted immediately | Refer problem to Telco. |
| 5 | HF OK and TEST OK lamps | Both extinguished, followed by HF OK lighting, followed by TEST OK lighting | If both lamps fail to light, failure of high-frequency trip tone test is indicated. Transmitter will not initiate low-frequency trip tone test if HF test fails. If HF OK lamp lights but TEST OK lamp fails to light, failure of LF tone test is indicated. Refer problem to Telco. |

## NOTES

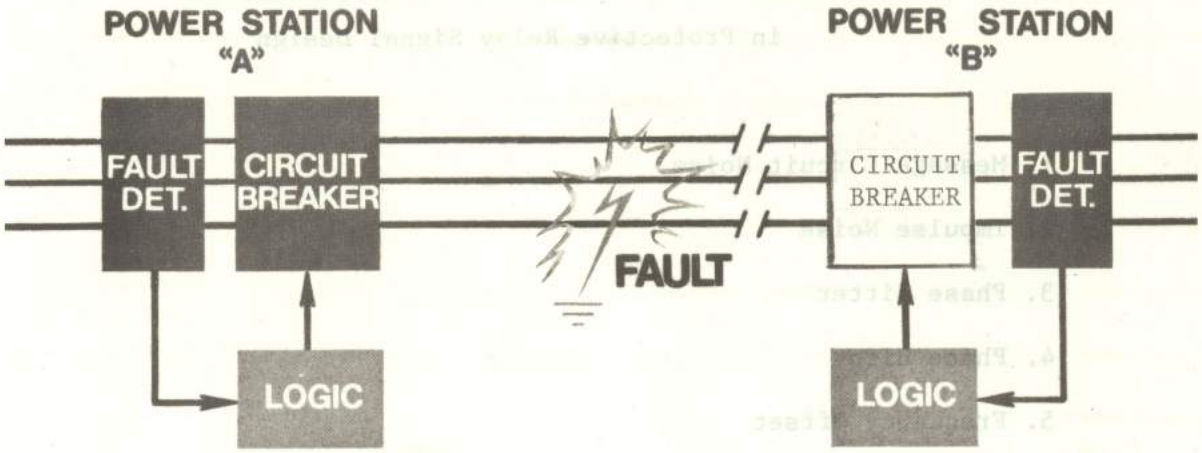



Figure 1

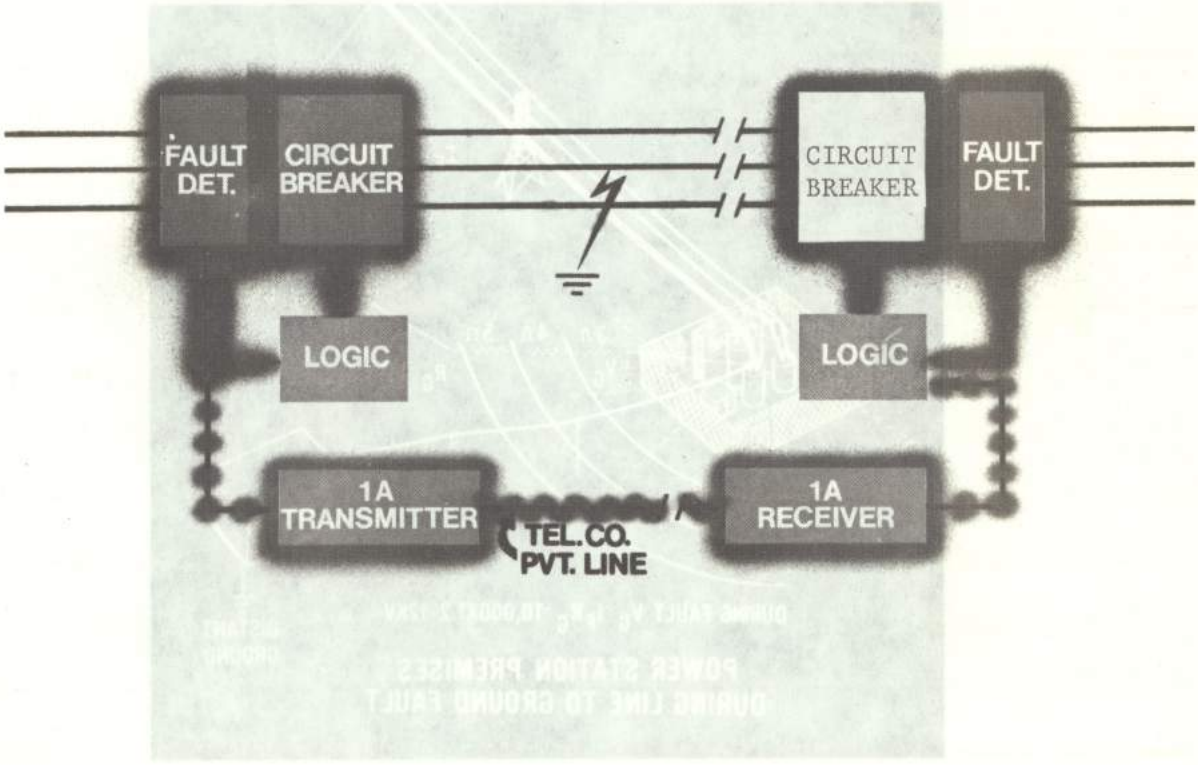



Figure 2

Transmission Impairments to be Considered
in Protective Relay Signal Design

1. Message Circuit Noise
2. Impulse Noise
3. Phase Jitter
4. Phase Hits
5. Frequency Offset
6. Spurious Tones
7. Gain Hits and Drop-Outs
8. Nonlinear Distortion
9. Channel Amplitude and Delay Distortion
10. Combinations of Above

Figure 3

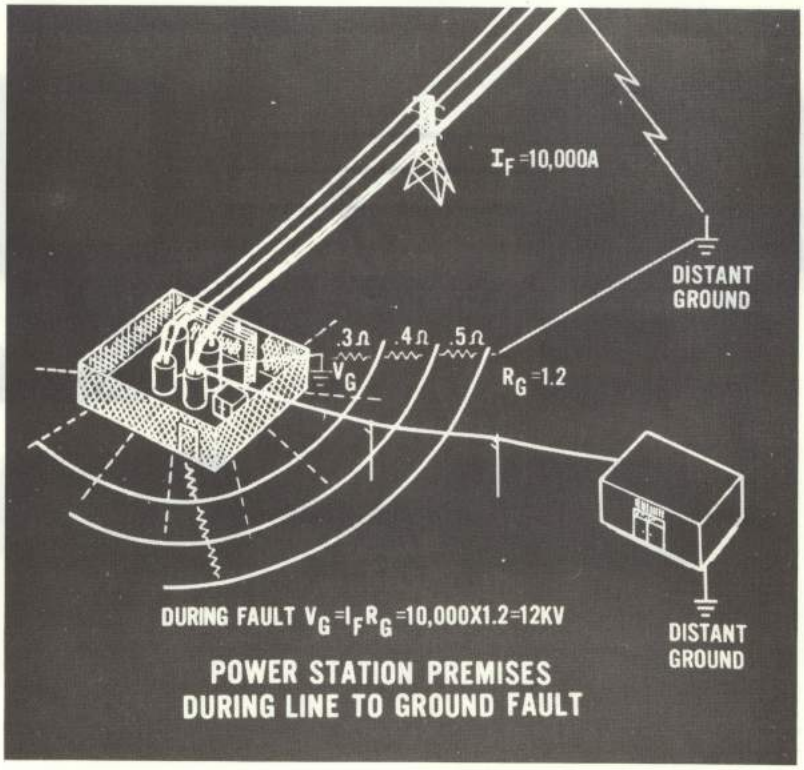



Figure 4

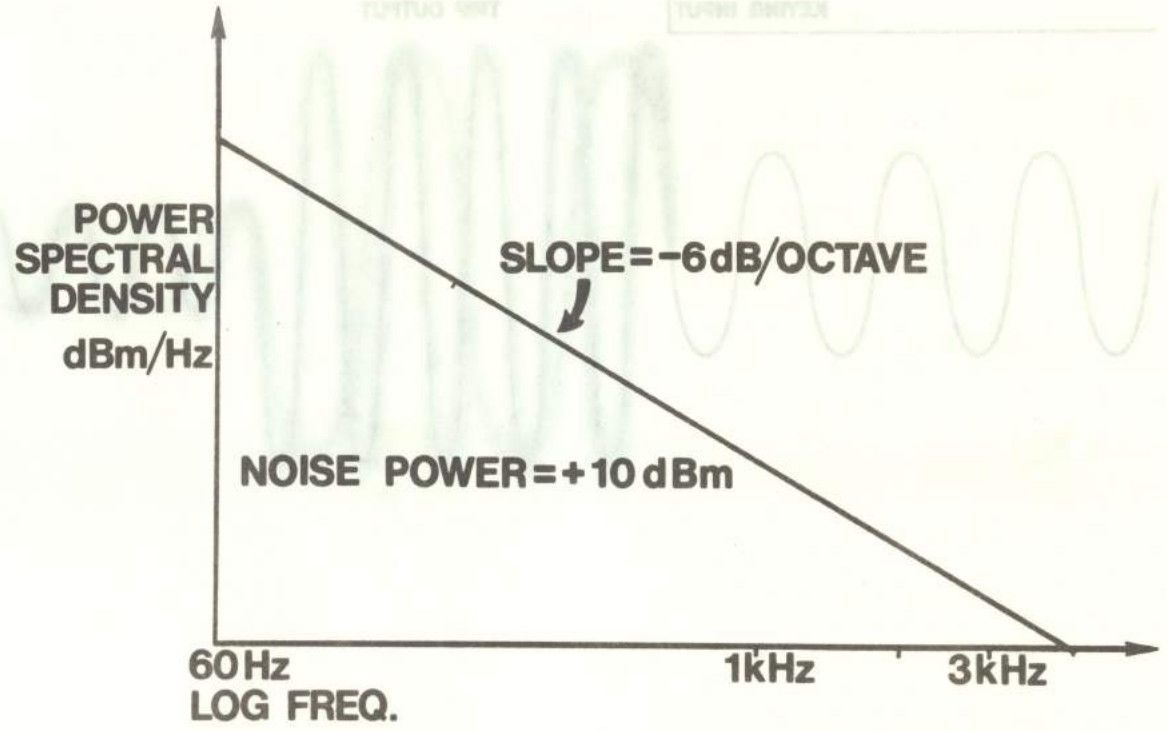



Figure 5

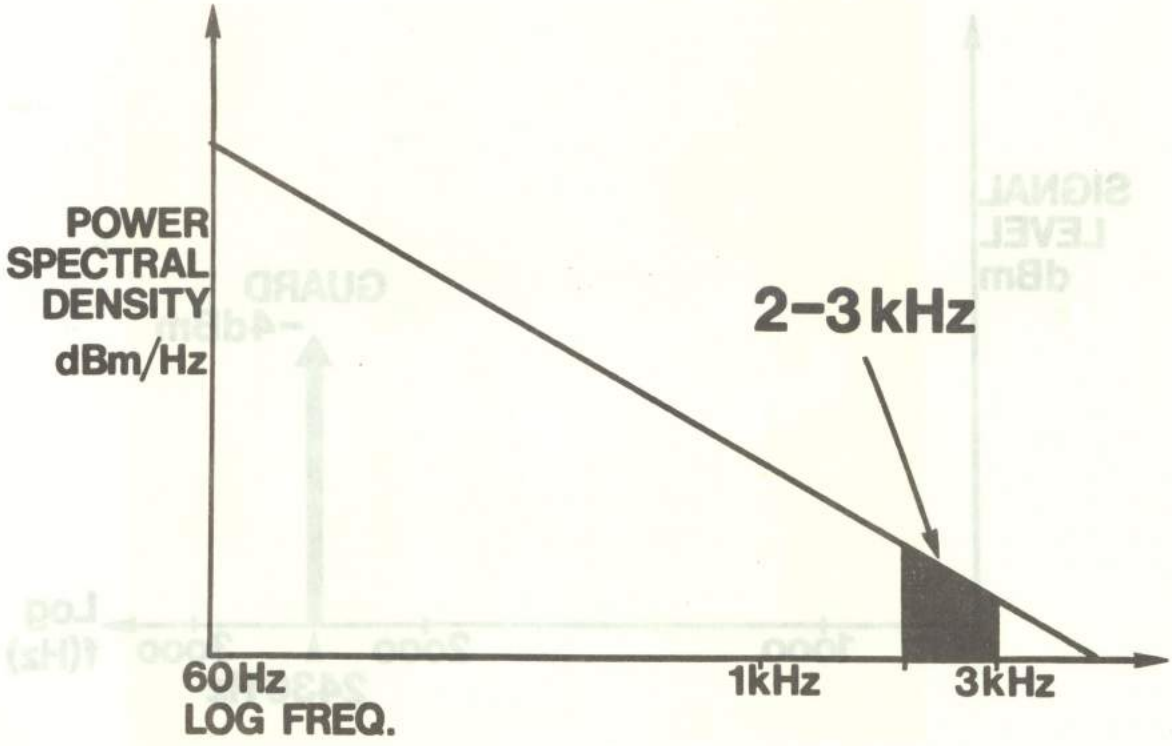



Figure 6

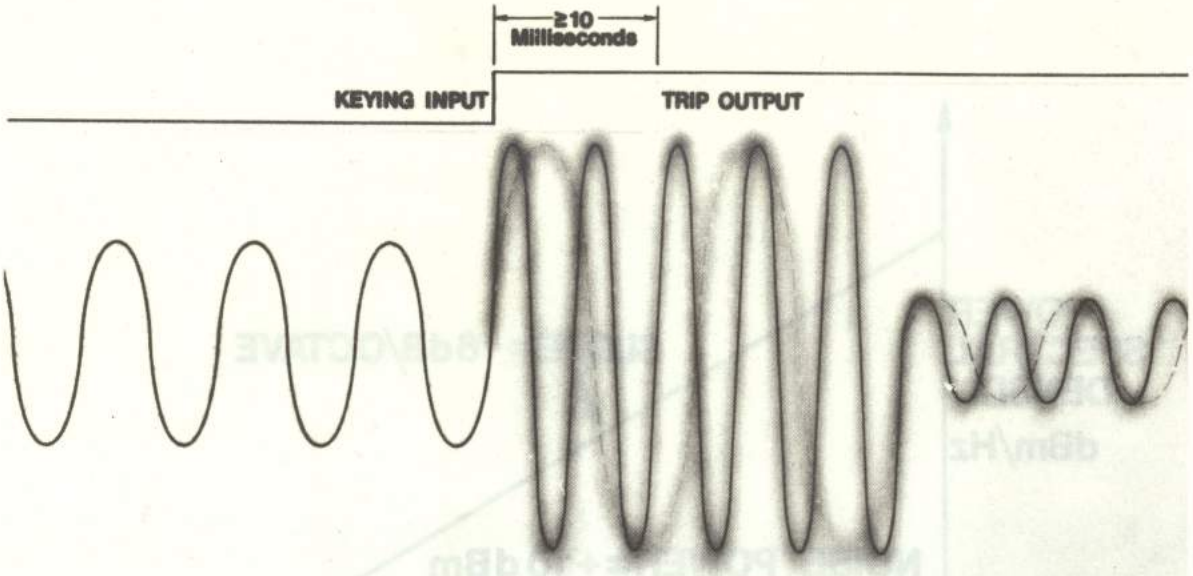



Figure 7

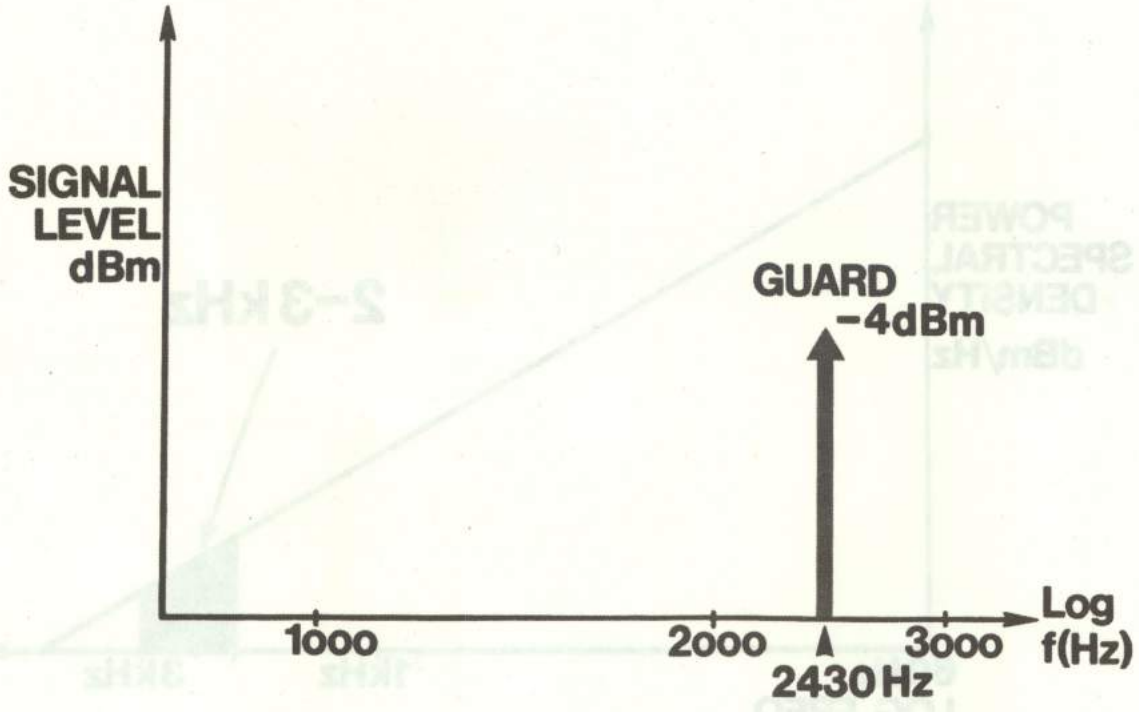



Figure 8

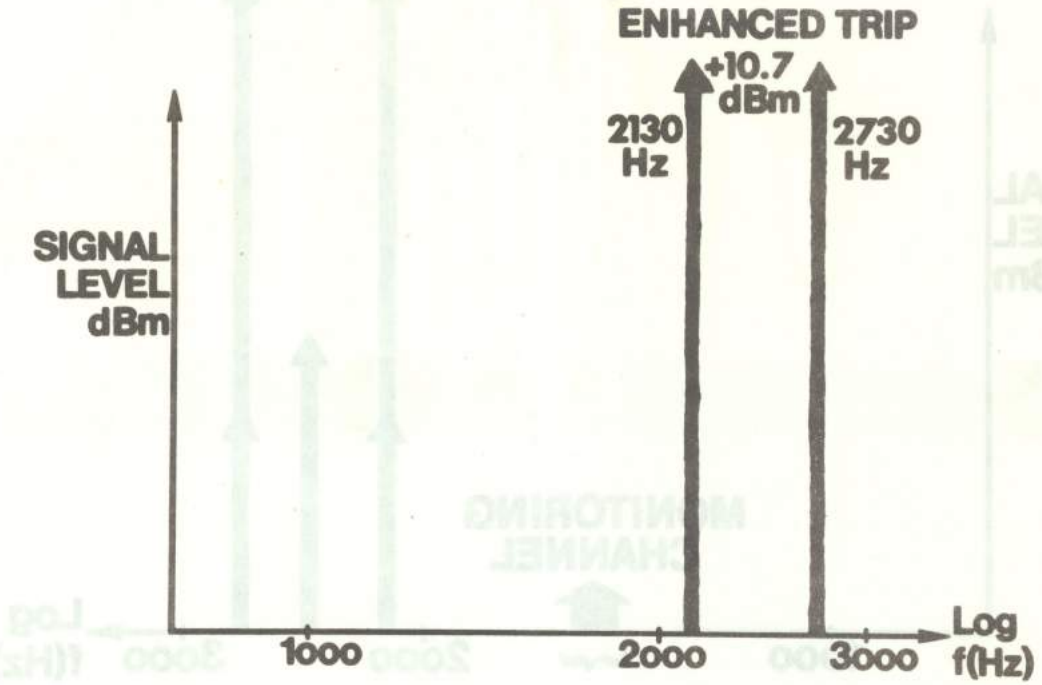



Figure 9

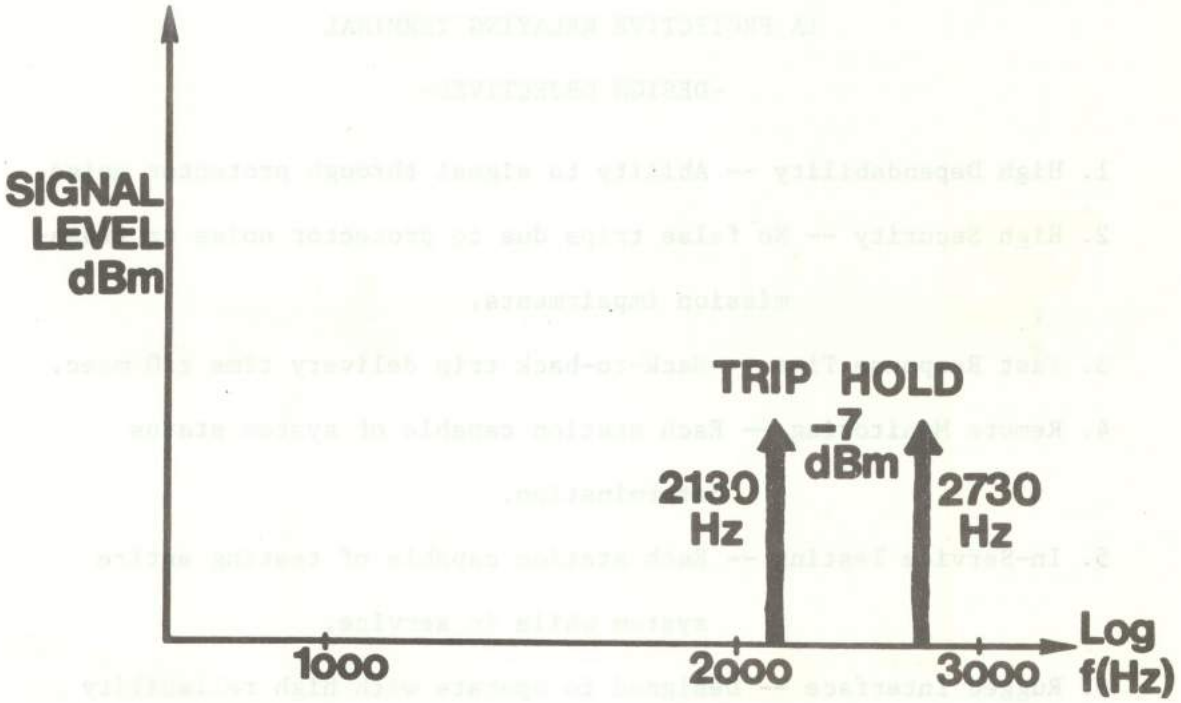



Figure 10

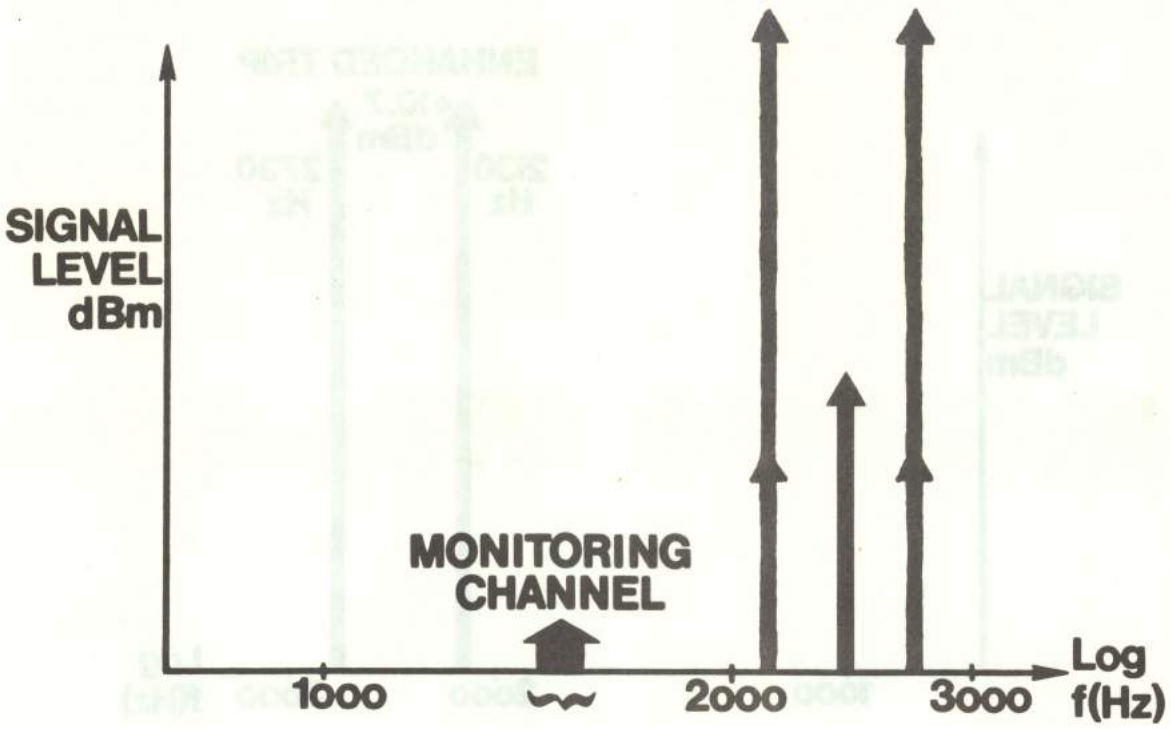



Figure 11

1A PROTECTIVE RELAYING TERMINAL

-DESIGN OBJECTIVES-

1. High Dependability -- Ability to signal through protector noise.
2. High Security -- No false trips due to protector noise or transmission impairments.
3. Fast Response Time -- Back-to-back trip delivery time z10 msec.
4. Remote Monitoring -- Each station capable of system status determination.
5. In-Service Testing -- Each station capable of testing entire system while in service.
6. Rugged Interface -- Designed to operate with high reliability in power station environment.

Figure 12