FAULT LOCATING

OUTSIDE PLANT

1. GENERAL

1.01 This addendum supplements Section 644-104-090. Place this addendum ahead of page 1 of this section.

1.02 This addendum is issued to assist cable repair technicians in locating and correcting transmission and inductive interference problems. It consists of three major parts:

(a) SECTION 4. BASIC THEORY

This section contains general information about the nature of transmission and inductive interference.

(b) SECTION 5. PROCEDURAL FLOWCHARTS - CABLE REPAIR

This section details step-by-step methods for finding and solving transmission and interference problems for cable repair technicians.

(c) SECTION 6. DIAGNOSTIC SAMPLE PROBLEMS

This section offers a case study approach to solving some specific noise problems.

Two appendices contain additional material:

- Appendix A presents sample calculations of db values.
- Appendix B shows the circuit setup used for making noise measurements.

1.03 The flowcharts (Figures 5-12) have been developed for use with the test sets listed in Part 3. These test sets or their equivalent and the flowcharts should be available to the cable repair technician.

2. PRECAUTIONS

2.01 Although not listed in the flowcharts, safety procedures and precautions shall be observed at all times.

3. TEST SETS

3.01 Test sets required by the cable repair force for fault locating transmission and inductive interference faults are listed below:

- 1013B (or equivalent)

(Section 106-020-113) This handset has dial capability for communication in outside plant.

- Wilcom T136BSB (or equivalent)

(Section 100-102-904WT) This circuit test set is capable of measuring transmission and noise on subscriber loops. This test set requires the 1013B handset as its communication link

- Wilcom T139 (or equivalent)

(Wilcom T139 Instruction Manual) This circuit termination set is a balanced switchable termination and is used in conjunction with the T136BSB circuit test set. The Wilcom T279 is an equivalent circuit termination set with an additional feature which is not used in this practice.

(•)Wilcom T304 (or equivalent)

(Wilcom T304 Instruction Manual) This cable shield splice continuity tester is capable of detecting defects in the bonding and grounding of cable shields. The Wilcom T304 is used most effectively on buried cable plant in addition to aerial and underground cable plant.

4. BASIC THEORY

4.01 This section of the guide contains general information about the causes and solutions of inductive interference problems. It covers noise parameters and the units used to measure them, the design of basic power systems, the theory behind shielding and grounding, and the functions of loop aids and ring isolators (equipment used to solve noise problems).

4.02 All physical trouble, e.g. short, ground, cross, leakage, capacitive unbalance, must be cleared using standard procedures prior to attempting to locate transmission or inductive interference problems.

A. Noise Parameters

4.03 Circuit noise:

Circuit noise or noise metallic, is the noise measured between the tip and ring conductor of a circuit. This is the noise the customer hears.

4.04 Power influence:

Power influence is the noise between ground and the tip and ring conductors tied together, as measured by the Wilcom T136 or its equivalent. The customer does not hear the power influence; however, its magnitude will determine the magnitude of circuit noise that the customer does hear. Power influence may be decreased by improving the cable shield.

4.05 Balance:

Balance denotes how much the impedance characteristics of one conductor in a pair resemble those of the other conductor. The electrical components of longitudinal impedance of a cable pair are capacitance, resistance, and inductance. Inductance is negligible as far as power current harmonics are concerned; therefore, balance denotes how much the capacitance and resistance characteristics of one conductor of a pair resemble those of the other conductor. The more alike these conductors are, the higher the balance and, consequently, the less susceptible they are to induction. Balance may be defined as follows:

Balance = Power Influence - Circuit Noise

B. Units of Noise Measurement

4.06 *Decibel (dB)*: The balance of a cable pair is measured by a meter calibrated in decibels (dB). The decibel unit expresses the ratio of two quantities. In noise work, the quantities are usually voltages, currents, or power levels. Voltages or currents can be compared in terms of dB by the following equations.

(a) For voltages:

$$dB = 20 \log 10 \left| \frac{V\,2}{V\,1} \right|$$

(b) For currents:

$$dB = 20 \log 10 \left| \frac{I\,2}{I\,1} \right|$$

These equations relate the voltage, V 2 , or the current, I 2 , to some other voltage, V 1 , or current, I 1 , respectively. The value in dB can be positive or negative. If V 2 is less than V 1 , the dB value will be negative. The same applis to current and power ratios. Power levels, however, are compared in terms of dB by the following equation.

(c) For power levels:

$$dB = 10 \log 10 \left| \frac{P\,2}{P\,1} \right|$$

For examples using these equations, see Appendix 1.

4.07 It is not necessary for the cable repair technician to fully understand dB in mathematical terms to effectively work with noise levels - what is satisfactory, what is slightly noise, and what constitutes a severe noise problem.

4.08 *dBm*: Power levels are generally of greatest interest in telephone work. For this reason, a standard reference power level (dBm) has been established. This reference level is one milliwatt (or 10 -3 watts) of 1000-Hz power dissipated in a 600-ohm resistor. Substituting this into our dB equation, with dBm replacing dB to designate our reference of P 1 = 10 -3 watts, we have:

$$dBm = 10 \log 10 \left| \frac{P\,2}{10^{-3}} \right|$$

where P 2 is in watts.

4.09 *dBrn*: Noise powers are almost always less than one milliwatt. This means that the dBrn values would normally be negative. Since it is desirable to express all noise powers as positive quantities, a new unit of measurement, dBrn, has been defined as follows:

0 dBm = 90 dBrn

The "r n" stands for "reference noise" power. This reference noise power is a quantity of noise which has a negligible effect on the transmission of speech.

4.10 *dBrnc*: the physical characteristics of the telephone receiver and the human ear cause some frequencies of noise to appear louder and more disturbing than others, even though the noise signals of the different frequencies have the same power level.

4.11 A weighting curve which expresses this difference in disturbing effective relative to the disturbing effect of a 1000-Hz signal of the same power level has been developed to show the response of the telephone receiver and the average human ear to various frequencies in the audible range.

4.12 Measuring noise in dBrn with C-message weighting (dBrnc) takes into account the relative interfering effects of the various frequencies which make up a noise signal and, therefore, is a more accurate measurement of the noise the telephone user actually hears.

C. Basic Power System

4.13 Figure 1 illustrates a three-phase, Y-fed, multi-grounded neutral power distribution system. This is the configuration of most power distribution systems in the United States.

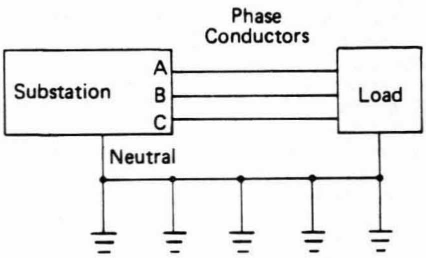


Figure 1: A Power Distribution System

4.14 Assume that this distribution system furnished power to only three customers, each with an identical electrical load connected to phase A, B, and C, respectively. If each customer places the same load on the line at the same time, the power system load will be balanced, and currents of equal magnitude will flow through phases A, B, and C.

4.15 For unequal loads, however, these currents will be somewhat different in magnitude. The geometric sum of these currents must return to the substation (I R) via the neutral wire and the earth. As a general rule, 40 percent of the current returns through the neutral wire and 60 percent returns through the earth, as shown in Figure 2.

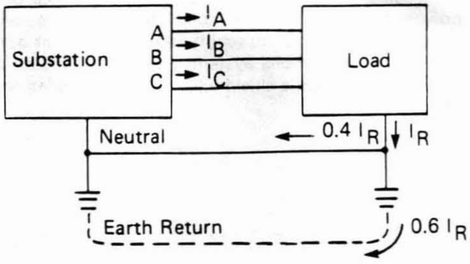


Figure 2: Current Return Paths

4.16 Alternating current flowing through a wire sets up a magnetic field which alternates with the frequency of the current. For three-phase power lines, each of the phase currents produces a magnetic field and the returning currents produce opposing magnetic fields.

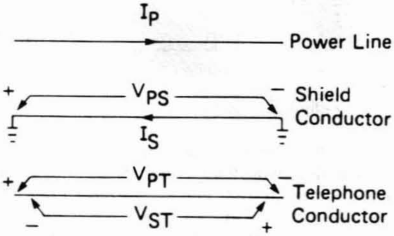
4.17 The residual current, which is the sum of the phase currents and the neutral current, has a magnetic field which is not cancelled. the resultant magnetic field will induce a voltage in any conductor in its vicinity. Thus, a telephone conductor near a power system will experience an induced longitudinal voltage whose magnitude depends upon the distance to the power lines, the length of cable exposed, and the current and balance of the power system.

4.18 There is always some unbalance in three-phase distribution systems. In a properly planned and constructed power system, the residual current is usually 60 Hz. However, if, for example, a transformer is overexcited, the residual current will also contain exceptionally large harmonic components (whole number multiples of 60 Hz). the largest harmonics are generally the odd triples (180 Hz, 540 Hz, etc.). Very little intelligible sound is carried at very low frequencies; since there is so much 60 Hz near a power line, the phone set has been designed to reject the low frequencies. Thus, it is the harmonics that lie within the voice band that produce audible noise.

D. Shielding and Grounding

4.19 If another conductor is placed near the power line parallel to the telephone conductor and is grounded at both ends, it will help shield the telephone conductor from interference. Shielding and grounding make up the first line of defense against external influences to the telephone system.

4.20 Figure 3 shows a telephone conductor with a shield conductor, both under the influence of a power line. The shield conductor may be any conductor with a ground return path (grounded at both ends). In the telephone system, the metallic sheath of the cable serves as a shield when properly bonded and grounded.



Figrue 3: Telephone and shield conductors Under Influence of Power Line

4.21 The residual power line current (I P) generates logitudinal voltages on the shield conductor and the telephone conductor. These are designated V PS and V PT , respectively. These voltages are of such polarity that they both would cause a current flow in their respective conductors opposite to the current in the power line if the current were free to flow. The current, I S , is free to flow in the shield because of its ground return path. Since we are studying the effect of the shield on longitudinal voltages in the telephone conductor. The current, I S, will also induce a voltage, V ST , on the telephone conductor. Since I P and I S flow in opposite directions, the voltages they will induce on the telephone conductor will be opposite in polarity and will, therefore, partially cancel each other. Because of this cancellation, the net longitudinal voltage induced on the telephone conductor will be much less with the shield than without it.

4.22 The cancellation of induced voltages on the telephone conductor is due to the voltage, V ST , which is induced by the current flow in the shield conductor. In most cases, increasing the current flow in the shield conductor will increase the cancellation effect and reduce the net induced voltage on the telephone conductor. to keep this shield current as great as possible, the shield must be continuous at all points and properly grounded through low resistance bonds. If good shielding techniques are applied, all areas of the inductive noise problem will be improved.

E. Loop Aids

4.23 Importance of Loop Current Measurement:

There is more to transmission improvement than fixing noise problems. For the customer, the ability to hear and be heard is just as important. But before either noise or hearing problems become a concern, the customer must first be connected with the called party. This is established by the loop current.

4.24 In general, the relays in the CO require a minimum of 20 MA to operate reliably. A customer line with very low loop current often has an interesting trouble history characterized by comments such as "no dial tone (NDT)," "can't break dial tone (CBDT)," "get wrong numbers (GWN)," or "bell rings after answer (BRAA)." A low loop current condition is usually the result of a circuit exceeding the typical design limit of 1300 ohms or the long route designs, e.g., Resistance Zone (RZ) 18 (1800 ohms) and RZ28 (2800 ohms). All circuits designed to exceed 1300 ohms require range extension equipment to aid the C.O. battery.

4.25 Importance of Circuit Loss Measurement:

Circuit loss measurements indicate how well the customer can hear or be heard. For proper service, a line should not exceed 8.5 dB of loss to the milliwatt termination. A customer with a higher loss may have a trouble history characterized by comments such as "can't hear (CH) - can't be heard (CBH)" or "can't hear on Direct Distance Dialing (CH on DDD)."

4.26 If a repairperson tests this line by calling the testboard, it will sound like a good circuit. However, when the customer calls across town or long distance, the additional loss on the far-end loop might make it sound like a poor circuit. Since what is heard by calling the test board can be deceiving, the loss measurement must be used to evaluate the line. Loops with losses greater than 8.5 dB can be corrected by repair, redesign, or the addition of voice frequency amplifiers, whichever is determined to be appropriate.

4.27 Why Cables are Loaded:

A capacitor is two conductive plates separated by an insulator. A cable pair may be thought of as two very narrow, very long plates separated by an insulating material; as a result, telephone cable pairs are highly capacitive. Since this causes inefficient use of voice power, the cable pair must be modified to transmit voice power very far. This is done by adding inductance periodically to offset the capacitance. This process is called loading; it improves the efficiency of a cable pair by improving the power factor and the frequency response.

4.28 Because some inefficiency can be tolerated for short distances, customers close to the CO are served by nonloaded cable pairs. Loaded pairs serve customers with loops beyond 15,000 feet (or 18,000 feet depending on the plant design rules used).

4.29 The H88 loading scheme requires that load coils be placed 6,000 feet apart along the pair. The first load point out of the CO will be 3,000 feet out so that customer lines will be spaced correctly through the CO section. Load spacing is critical, particularly in the first four sections from the CO, because loop aids (such as repeaters and range extenders with gain) are designed to work on properly loaded cable pairs. Missing or improperly spaced load coils will degrade the transmission quality of the cable pair.

4.30 Two other situations will prevent loaded pairs from working porperly: a customer line or bridged tap located between two load points. All customers on a loaded pair must be located in the end section, the portion of the cable beyond the last load coil. Bridged tap may be used in an end section, too, as long as the total cable length past the last load coil does not exceed 12,000 feet or less than 3,000 feet.

4.31 Several problems may arise if these requirements are not met:

- poor frequency response may prevent Touch-Tone telephone digits from registering correctly,
- the customer may have trouble hearing, or
- there may be transmission distoration.

4.32 To detect bridged tap or a customer line in a loaded cable, measure and compare the loop current and circuit loss. If the loop current seems correct for the distance from the CO but the loss is high, this suggests one of the following:

- the customer line is being fed between loads,
- there is bridged tap in the loaded sections, or
- for nonloaded cable, there is more than 6,000 feet of bridged tap.

F. Ringer Isolators

4.33 If the tip and ring could be perfectly balanced, no noise would be heard on the telephone line. The design of CO equipment, cable, and station equipment minimizes the differences in tip and ring, but perfect balance is never found. Perhaps the biggest single source of unbalance in multiparty lines is more ringers to ground on one side of the line than on the other. This is especially difficult to control because every disconnection or addition to the line changes the balance. The answer is to have no ringers to ground. This can be accomplished with ringer isolators.

4.34 A ringer isolator is a switch between the ringer and ground which is normally open. It monitors the tip and ring looking for the negative superimposed battery current which accompanies the ringing signal. Whenever ringing is present, the ringer is connected to ground. At all other times, the ringer is not grounded; therefore, it cannot unbalance the line during a phone call. Using ringer isolators on all parties of a multiparty line can improve the balance by as much as 15dB.

G. Guidelines

4.35 The Guidelines for Transmission and Noise in the Wisconsin Telephone Company are the values shown in Table A.

4.36 Each transmission and noise measurement has a value range which can be categorized as *Satisfactory*, *Marginal* or *Unsatisfactory*. The measurement value ranges are shown in Table A.

(a) *Satisfactory* - Provides acceptable service and should not result in a trouble report.

(b) *Marginal* - May provide a poor level of service that boarders the unacceptable area. The circuit possibly is not out of service, but will almost certainly cause a trouble report due to customer dissatisfaction. Corrective action should be taken to improve the level to satisfactory.

(c) *Unsatisfactory* - Provides unacceptable service. If a circuit is considered to be out of service. Corrective action must be taken to restore service.

TABLE A
GUIDELINES FOR NOISE MITIGATION

Category	Circuit Noise (Noise Metallic)	Power Influence (Noise to Ground)	Circuit Balance (PI-CN)	Station Current	Suggested Action to be Taken
Satisfactory	<20 dBrnc	<80 dBrnc	>60 dB	>23 ma	None
Marginal	>20 dBrnc <30 dBrnc	>80 dBrnc <90 dBrnc	>50 dBrnc <60 dBrnc	>20 ma <23 ma	Note 1
Unsatisfactory	>30 dBnrc	>90 dBrnc <95 dBrnc	<50 dB	>20 ma	Note 2
		>95 dBrnc			Note 3

Reference - > More < Less

Note 1 - Refer to supervisor for review and possible noise mitigation.
Note 2 - If noise cannot be corrected locally have condition reported to ICEP Entineer for assistance and mitigation. Send speed letter to Manager Network Planning and Engineering - ICEP with completed N1 and N2 forms attached. Explain corrective action taken.
Note 3 - Have condition reported to IDEP Engineer for assistance and mitigation. Send speed letter to Manager Network Planning and Engineering - ICEP with completed M-137 and N2 forms attached.
Note 4 - Station current measurement with a T 136 test set having a DC resistance of 430 ohms.

* This measurement to be made with a T136 test set having a DC resistance of 430 ohms.

† A possibility exists that a marginal or unsatisfactory balance will occur when noise and power influence are in the satisfactory range. When this happens, the balance should be considered satisfactory if noise is less than 20 and power influence is less than 70. If noise is more than 20, balance is not considered satisfactory and corrective action should be taken.

5. PROCEDURAL FLOWCHARTS - CABLE REPAIR

5.01 Fault locating and correction procedures for transmission problems are shown in Fig. 5 and Fig. 6.

5.02 Fault locating and correction procedures for inductive interference problems are shown in Fig. 7 through 12.

6. DIAGNOSTIC SAMPLE PROBLEMS

6.01 This section offers a case study approach to solving some specific noise problems.

6.02 Case 1

Problem - There is a sudden rash of trouble reports in a confined area.

Solution - A number of things could cause this situation. This discussion addresses the problem of blown capacitor bank fuses.

Figure 13 illustrates a typical arrangement of a capacitor bank. Note that the capacitors are rectangular in contrast to transformers which are cylindrical. The fuses in this figure are in the closed position; the capacitor bank is in service.

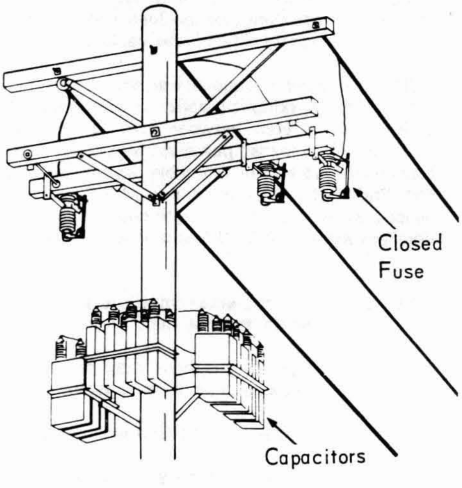


Figure 13

Figure 14 illustrates the arrangements when all fuses are open; this capacitor bank is out of service. This, also, is a normal arrangement. This situation occurs when the capacitor bank is needed only for a peak power load season (such as summer air conditioning); for the rest of the year, the bank may not be needed.

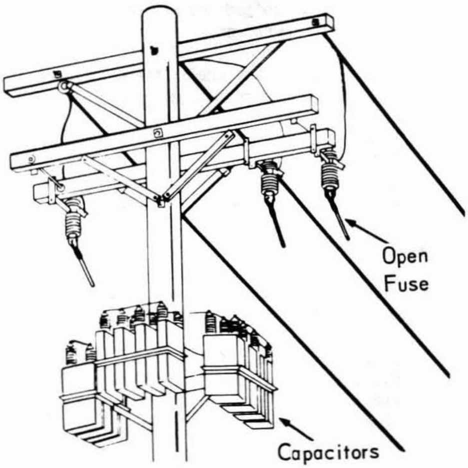


Figure 14

Figure 15 illustrates the problem which can cause a large increase in the noise heard on a telephone line. When only one or two fuses are closed, the power line is extremely unbalanced.

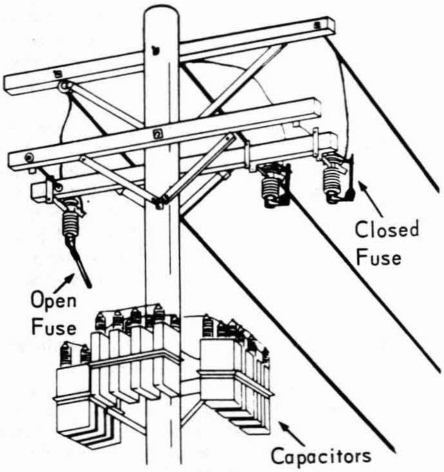


Figure 15

The capacitor bank fuses are visible from the ground and may be noted while you are driving along a road paralleling the power line. Watch for any such irregularities while traveling to the customer who reported the circuit noise problems.

Report the location of any unbalanced capacitor banks to the ICEP engineer. Once these unbalances are corrected, investigate any remaining noise problems.

6.03 Case 2

Problem - There is a chronic noise problem.

Solution - Since many chronic trouble conditions are intermittent, ordinary testing methods frequently fail to identify the problem. This is particularly true in the case of poor connections where applying test battery temporarily "seals" the poor connection and results in multiple TOK's.

The Varley test is designed to locate these intermittent poor connections; however, if the test battery is applied to the line just prior to the Varley test or if the repairperson calls the testboard on the line in question, the trouble probably will not show up on the Varley.

Use the lowest possible battery voltage for the Varley test (20V or, preferably, less). Always call the testboard on a line *other than the line in trouble* to request a Varley. Ask the test board to avoid putting any test battery on the line other than the 20V Varley. If the Varley results do not show a problem, ask the tester to open the line to you and tell the tester you will call back to restore it later.

With the line open to you, begin sectionalizing the cable with the noise measurement set and the T139 or 120H coil to determine whether the trouble is in the station wiring or in the cable facilities. With the T139 or equivalent in the circuit, record the circuit noise toward the station and toward the CO. Monitor the noise reading until the trouble appears on the line (usually within ten minutes). A substantial increase in circuit noise will indicate trouble (it usually pegs the meter). Once the trouble appears, it will remain until battery is applied to the line.

If the trouble is toward the station, it can be isolated by lifting IW's, sets, etc. If it is toward the CO, continue sectionalizing the cable to isolate the trouble.

6.04 Case 3

Problem - "Touch-Tone telephone digits fail to work," "cannot hear," or "distortion."

Description - When measured at the station, the loop current seems acceptable for the distance from the CO, but the circuit loss is quite high.

Solution - One of three things may be causing this situation:

- the customer line is being fed between load coils,
- there is bridged tap in the loaded sections of the cable, or
- for nonloaded cable, there is more than 6,000 feet of bridged tap.

If the customer line is fed between load coils or is fed by nonloaded cable, request a change to another cable pair. If not, find the bridged tap in the loaded section and remove it.

6.05 Case 4

Problem - There is a balance problem in B-buried service wire.

Solution - Measure the balance of both pairs in the B-buried wire and use the pair with the best balance. If the balance of neither pair is acceptable, the wire must be replaced.

6.06 Case 5

Problem - There is unbalance in the loop.

Solution - Use the following chart to determine the cause of the problem, then correct it.

TYPE OF UNBALANCE	WHAT TO LOOK FOR
Leak to ground (high resistance ground)	Moisture in terminals Dirty carbons Tree limbs touching open wire Wire insulation damaged by lightning
Series resistance	Cable below manufacturing standards Resistance in splices Cable damaged during construction
Capacitance unbalance	Cable below manufacturing standards Split pairs Bridged tap with one side open Side crosses to dead conductors Unbalanced ringers on party line