TROUBLE LOCATION METHODS USING VOICE-FREQUENCY SWEEP TEST SETS ON TRUNK CABLE PAIRS

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1. GENERAL

1.01 This section is issued to discuss the theory and techniques of trouble location with voice-frequency sweep test sets as applied to exchange area trunk cable pairs. The term "fault" has been commonly applied to opens, grounds, shorts and crosses. The term "trouble" as used here concerns primarily those irregularities which affect transmission.

1.02 The general theory of trouble location using sweep test sets is discussed in Section 330-450-100. The application to trunk cable pairs is somewhat different from the application to subscriber cable pairs:

(a) Trunk cable pairs are readily accessible at both ends, while subscriber cable pairs are not.

(b) The required precision of design is generally greater for trunks than for loops.

(c) A greater variety of loading plans may exist in trunks.

(d) Loading coils may be spaced on a capacity equivalent basis in trunks, resulting in slightly different sweep patterns.

(e) The possibilities of irregularities in trunks are somewhat different than in loops.

(f) Loading sections are usually arranged and built out as needed to provide more precise end sections and spacing.

(g) Trunk cable pairs can be readily cleared of terminal equipment at the main frame on both ends.

The application of voice-frequency sweep tests to trunk cable pairs is, therefore, discussed specifically in this section, while the application to subscriber loops is covered in Section 330-450-102.

1.03 It is necessary to have available a voice-frequency sweep test set meeting the general transmission requirements listed in Section 330-450-100. In addition, the following items are helpful:

Western Electric Artificial Cable Kit (1A ACK) or equivalent

Decade Capacitor — 3 decade, 1.0-1.5% accuracy, .001-1.110 μf range, W.E. 7A, G.R. 1419A or similar

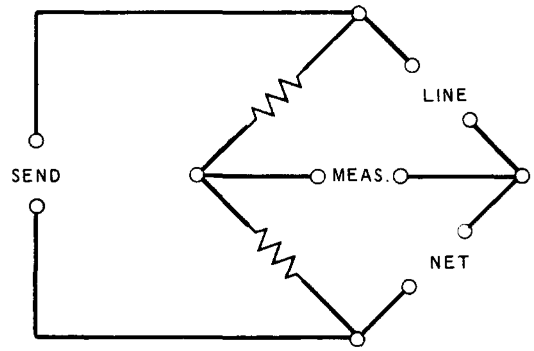
Assorted Capacitors — 5%, 400 VDCW, Tubular, W.E. type C or radio types

Loading Coils — 22 mh and 44 mh (if needed and not provided in cable kit)

Patch Cords — 3-wire, terminated in banana plugs, as required for use of cable kit.

The loading coils should be terminated in clips on one side and in banana plugs on the other.

1.04 If the sweep test set does not contain a built-in hybrid, a simple one may be constructed locally of a pair of resistors, some terminals and a small box as shown in Fig. 1. This arrangement has a flat transhybrid loss across the voiceband, making the correction easy to apply. It may be assembled with 600-ohm resistors if desired, but exchange trunks are designed nominally to be 900 ohms, and 900-ohm test equipment should be used.



MATERIAL REQUIRED
2 – 145A RESISTORS - 900 Ω
4 PR. – BANANA JACKS
1 BOX – 2" x 4" x 4"
MISC. WIRE

Fig. 1 – Resistance Hybrid for Return Loss Measurements

1.05 It is desirable to obtain, in advance of the tests, any cable layouts or job order sketches showing the structural details of the pairs to be tested. It may be desirable to make a sketch of the pairs in trouble, showing lengths, gauge, type, loading points, etc. In testing non-loaded pairs, it may be of interest to note loading points, bridged taps, splices, etc, for other pairs in the same sheath. The loop resistance and shunt capacitance should be noted for each type of cable making up the facility.

1.06 It is most advantageous that trouble location tests be made and troubles cleared at the time acceptance tests are completed and before trunk cable pairs are put in service. Irregularities may develop due to in-service splicing operations, or pairs may be assigned before the tests can be made. In these cases, it will ***always*** be necessary to turn down the service or patch it to another facility before beginning tests. Cable pairs with Special Service Measures (SSM) or Special Service Protection (SSP) must not be tested until they have been released and removed from service in accordance with local practices. Considerable effort can thus be avoided if troubles are located and cleared before services are assigned to the pairs.

1.07 Tests on trunk cable pairs should be made at the main frame termination of the pair. The protective devices should be removed at both ends to remove the effects of terminating equipment.

1.08 Insertion loss tests are useful in detecting the presence of irregularities in a trunk cable pair because the effect of an irregularity on frequency response is evident regardless of the length of the pair. These tests do not provide any information on the location of the irregularity, however, and they require coordinated personnel and equipment at both ends of the pairs. Impedance tests with precision terminations may be used to locate troubles, but they also require coordinated personnel and equipment at both ends of the pair. The discussion here is, therefore, confined to other types of tests which can also locate faults.

1.09 Impedance measurements can reveal considerable information about irregularities in cable pairs. Unterminated measurements may be made with little or no assistance at the far end of the cable pair. Impedance measurements with sweep test sets cannot be made with great precision, however, and they do not indicate phase angles. The effect of an irregularity on impedance is decreased as the distance between the irregularity and the point of measurement increases. Their chief advantage lies in the fact that they can be easily made with a minimum of equipment. They will detect and locate the troubles which have a serious effect on transmission.

1.10 Return loss tests tend to be more sensitive and accurate because they require matching both impedance magnitude and phase angle. They may be sensitive to minor irregularities that are not transmission affecting. The effect of an irregularity on return loss is also affected by the distance to the irregularity.

1.11 The choice of impedance measurements may be a matter of convenience. Impedance measurements may be more convenient with a dual channel set, but less convenient with a single channel set.

1.12 The greatest accuracy can be obtained with precision terminations at the distant end of the trunk. The discussion here is concerned with tests to open or short-circuit terminations, however, because the troubles can generally be located with greater speed and less effort.

1.13 Personnel involved in making tests on trunk cable pairs should be familiar with or have training in the use of the particular sweep set to be used. Local practices may be consulted where available. It will also be helpful to develop some experience through experimentation with an artificial cable kit.

2. TESTING TECHNIQUES

(A) General

2.01 Two general techniques may be used for location of troubles in trunk cable pairs. One involves the use of impedance measurements and comparisons. The other involves the use of return loss measurements and comparisons.

2.02 The shapes of impedance curves are sometimes indicative of the type of trouble and its location. Return loss curves cannot be interpreted in this manner, but they tend to be more sensitive in the identification and location of small irregularities. Both techniques are described below.

(B) Impedance Measurements

2.03 Many irregularities can be located by pair matching, i.e., the comparison of the impedance curve for the unknown pair with the impedance curve for a known pair assembled from the artificial cable kit. The artificial pair is adjusted until the two curves match. This method is very convenient when using a dual channel sweep set. When using a single channel set, it may be necessary to trace the curve for the unknown pair on the graticule with a grease pencil. The known artificial pair may then be connected in place of the unkown pair. The arrangement for a dual channel set is shown in Fig. 2.

2.04 The impedance comparison technique is adequate for the majority of trouble location problems. Various irregularities are introduced into the artificial pair until a combination is found which causes the impedance curve of the artificial pair to coincide with the impedance curve of the unknown pair. When the traces coincide, the trouble or troubles introduced in the artificial pair simulate those in the pair under test.

(C) Return Loss Measurements

2.05 Another technique involves the use of return loss measurements. Irregularities cannot be predicted from the shape of a return loss curve as is sometimes the case with impedance curves, but return loss measurements tend to be more accurate than impedance measurements. Return loss measurements are, therefore, more useful in the identification and location of small irregularities, and they may be made more conveniently with the single channel set.

2.06 When the sweep set has a built-in hybrid, the unknown pair is connected to the LINE jack, and a known pair assembled from the arti-

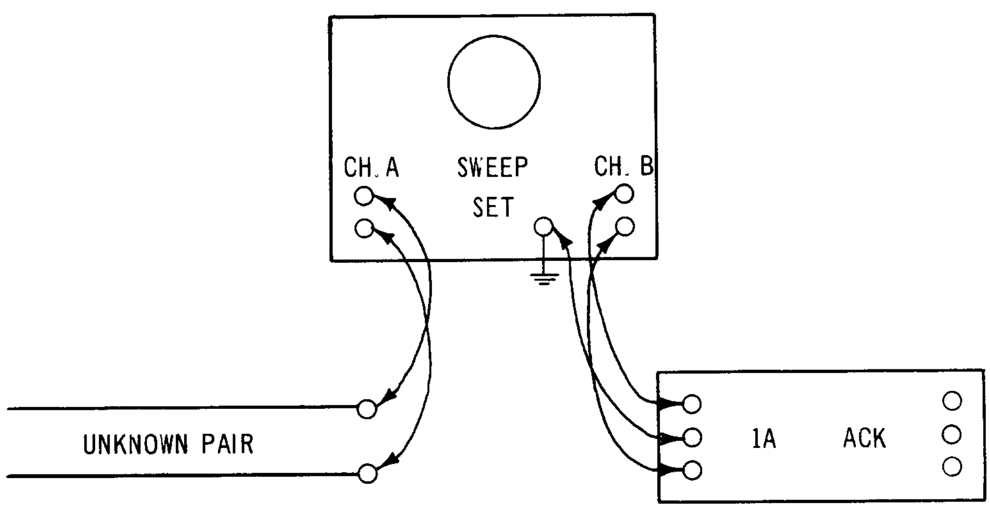


Fig. 2 — Arrangement for Impedance Comparison Technique

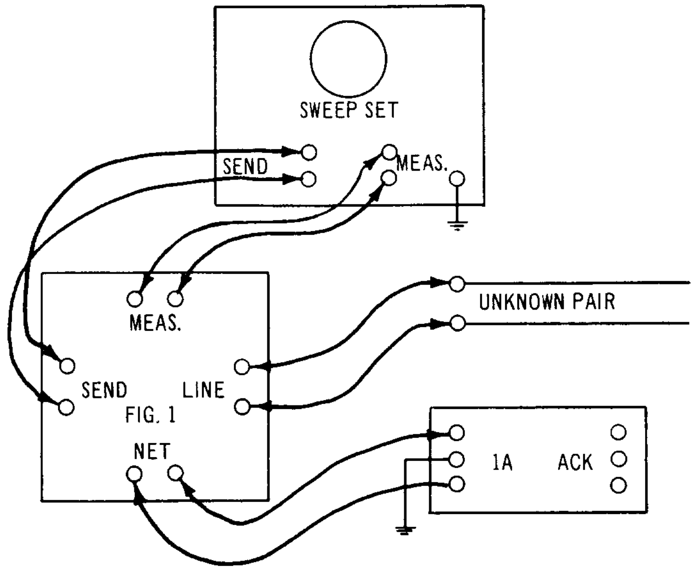


Fig. 3 – Arrangement for Return Loss Technique

ficial cable kit is connected to the NET jack. When the set does not have a built-in hybrid, the equipment may be arranged as in Fig. 3 using the hybrid of Fig. 1. The gain of the sweep set detector may be adjusted to compensate for the transhybrid loss by setting the sweep trace at zero level with the line jacks open or shorted.

2.07 Irregularities are introduced into the artificial pair until a combination is found which produces the maximum return loss over the entire sweep range. When the best combination is found, the irregularities introduced into the artificial pair simulate those in the pair under test.

2.08 When an irregularity exists, the return loss curve will usually exhibit sharp variations. It may be desirable to stop the sweep at the frequency of poorest return loss and introduce changes in the artificial pair, looking for an irregularity which produces a large improvement. The sweep oscillator should then be restarted to insure that the return loss has not become worse at some other frequency. When more than one irregularity exists, the major ones will generally be found first and minor ones will then be detected.

2.09 Irregularities may result in initial return loss measurements as low as 0 db at some frequency, and they may be on the order of 10 db, depending on the type and location. By making changes in the artificial line, it should be possible to improve the comparison return loss to 20 db or better between 500 and 2500 cps and thus both locate and identify irregularities.

3. TESTS ON NONLOADED PAIRS

3.01 Nonloaded trunk cable pairs will normally be fairly short, and troubles can be located quite accurately. Pairs being cleared of loading coils for carrier use will usually present the most difficult problems.

3.02 A common trouble is the presence of one or more loads placed or left connected in error. A typical case is shown in Fig. 4. The impedance curve for an unterminated nonloaded pair is normally smooth, but the presence of a coil will create a bump in the curve. The magnitude of the bump will depend on the distance to the irregularity. The coil can be located by the techniques of Part 2.

3.03 Another type of trouble is the presence of unsuspected bridged tap or misplaced build-out capacitors. Neither of these troubles has any effect on the smoothness of the impedance curve of nonloaded pairs. Both have the effect of making the pair look longer than its actual length. This condition may be detected when the real pair is compared with the artificial pair.

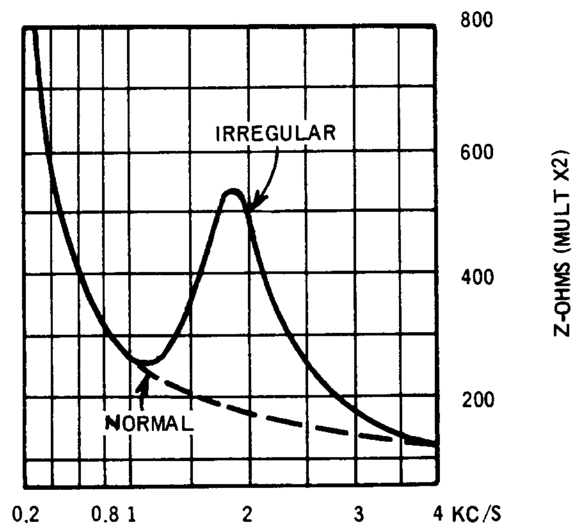


Fig. 4 – Effect of Load Connected in Error on Open Circuit Nonloaded Pair Impedance

3.04 The presence of bridged tap or build-out capacitors may be detected by high-frequency insertion loss tests, usually made when checking carrier pairs. Sweep tests can determine the approximate magnitude of the trouble but not the location. If the magnitude is known, however, it should be possible to determine the possible locations from the cable records.

3.05 The arrangement used is that shown in Fig. 3. A precision decade capacitor is connected to the far-end section of the ACK. The capacitor is adjusted to obtain the best return loss with the sweep oscillator fixed in the range 200 to 250 cps.

3.06 Changes in the decade capacitor can be detected in the order of $\pm.001$ μf. Normal variations in the shunt capacitance of the cable pair may be as much as 5%. Thus, settings of less than .01 μf on the decade capacitor may not indicate a trouble. Decade capacitor settings larger than .01 μf may be considered as significant.

3.07 A capacitor reading of .035 μf, for example, would be equivalent to about 2250 feet of cable pair with .082 μf shunt capacitance per mile. It is also equivalent to a build-out capacitor of .035 μf. An inspection of the cable layout, looking for lateral branches in the sheath or build-out capacitors in other complements, should reveal the possible trouble locations.

3.08 In measuring the shunt capacitances of nonloaded pairs, it is well to remember that cables vary substantially in their nominal shunt capacitance. If an unknown section of the pair should be made up of low capacitance cable, it will be necessary to shorten the ACK to get the best return loss measurement. This type of situation is most likely to occur, of course, in old cables.

3.09 Although troubles such as opens, shorts and grounds, may be located by standard DC tests, they may also appear when making sweep tests and can also be located by simulation or pair matching. Extremely distorted impedance curves may indicate loaded bridged taps.

4. TESTS ON LOADED PAIRS

4.01 The procedure for trouble locations in loaded cable pairs is generally the same as for nonloaded pairs, but the types of fault differ. As in the case of nonloaded pairs, impedance measurements may locate major irregularities, but the most precise results are obtained by pair matching. The equipment arrangements may be as shown in Fig. 2 or Fig. 3.

4.02 Tests should first be made to determine that the required number of loading coils have been placed. Either method of testing may be used. A logical procedure should be followed, conditioned somewhat by what is known about the cable structure. In general, test for missing coils, wrong weight coils, doubled coils, omitted and reversed sides, etc. If the cable has other load spacing arrangements on other complements, check the possibilities of extra loading coils placed in error between specified loading points.

4.03 Load spacing should be tested next. When build-out capacitors are required, the absence of a capacitor will make a loading section appear short, and doubled capacitors will make the section appear long. When capacitors are placed on the wrong side of a loading coil, the loading section on the proper side of the coil will appear to be too short and the section on the wrong side will appear to be too long.

4.04 Bridged tap between loads will make a load section appear too long. Thus, a diagram of the cable layout should be available for comparison when testing for uniformity and conformance with plans.

TABLE I

Shunt Capacitance Values — MF						
		NOMINAL VALUE PER MILE				
LENGTH FT.	.066	.069	.072	.079	.082	.084
100	.001	.001	.001	.001	.002	.002
200	.003	.003	.003	.003	.003	.003
300	.004	.004	.004	.004	.005	.005
400	.005	.005	.005	.006	.006	.006
500	.006	.007	.007	.007	.008	.008
600	.008	.008	.008	.009	.009	.010
700	.009	.009	.010	.010	.011	.011
800	.010	.010	.011	.012	.012	.013
900	.011	.012	.012	.013	.014	.014
1000	.013	.013	.014	.015	.016	.016
1500	.019	.020	.020	.022	.023	.024
2000	.025	.026	.027	.030	.031	.032
2500	.031	.033	.034	.037	.039	.040
3000	.038	.039	.041	.045	.047	.048
6000	.075	.078	.082	.090	.093	.095

4.05 The return loss technique will generally be most effective in testing load spacing. It will sometimes be difficult to get the desired combination of sections in the ACK to simulate section lengths. The nearest shorter length available should be used. The decade capacitor may then be shunted across the artificial line and adjusted for maximum return loss. The total shunt capacitance in a load section of the ACK must be close to the total shunt capacitance of the same load section of the real pair to produce best return loss.

4.06 Table I provides shunt capacitance values for various lengths of cable of the types likely to be found in exchange trunk plant. Combinations of capacitors which can simulate these values may be useful in simulating the real pair with the artificial cable kit.

4.07 When more than one loading section length may be irregular, each should be checked, beginning with the one nearest the office. As each section is checked, a fixed capacitor of suitable value may be connected across the artificial pair, and the decade capacitor may then be moved to the next section. The process is then repeated until the artificial pair becomes an exact duplicate of the real pair.

4.08 When testing for series irregularities such as missing loads, it may be desirable to put a short at the distant end of the pair when the trouble appears to be near the distant end. The artificial pair must also be shorted for comparison tests. This will increase the sensitivity in locating irregularities near the distant end. When testing for shunt irregularities, the distant end should be open for maximum sensitivity.

4.09 When loaded pairs are made quite long by connecting pairs through an intermediate office, the tests should be made in both directions from the intermediate office for maximum effectiveness. When a pair is more than about 10 miles long and there is any doubt about the location of troubles near the distant end, tests can be made from both ends of the cable.

5. NOISE INDICATIONS

5.01 Noise is sometimes indicated by a widening or tearing of the trace. This may be caused by an unbalance, foreign EMF, or a cross with another pair. The noise signal required to produce such a condition is substantially greater than the metallic noise signals usually found on a well-balanced pair.

5.02 When a noise indication is noted, the pair balance may be checked by comparing the tip-ground and ring-ground impedances. The impedance curves should be identical in shape and magnitude.

5.03 When the pair is crossed with another pair, the tip-ground and ring-ground impedances will be different, and there will be tearing of the sweep trace for the crossed side when signals are present on the other pair.

5.04 When there is no apparent cause for the noise indications, noise measurements should be made with a 3A Noise Measuring Set in the standard manner to determine whether noise is objectionable in the terminated condition.

6. COMPLEMENT TESTING

6.01 The location of an irregularity does not necessarily complete an investigation. It may point to similar trouble on other pairs in the complement or an opposite type of trouble in another complement.

6.02 If a trouble is identified as a result of a transmission complaint, it may be well to verify whether the trouble is an isolated one or common to an entire complement. This may be done by comparing the bad pair with other pairs in the same complement. If other pairs have the same trouble, the impedance curves should match. Comparison of the pairs on a return loss basis will produce high return loss values if the pairs have a common trouble, but a low return loss will be produced if the other pairs have no fault or different troubles.

6.03 When loading coils or build-out capacitors are misplaced, further testing should be done. If a loading coil is missing, there may be two coils on some other pair. If all the loading coils are missing on a complement at a given location, the coils may all have been spliced into another complement. When following up results of completion tests, complementary troubles should always be suspected. When locating troubles as a result of trouble reports, some sampling of conditions in other cable complements may be desirable to insure that the trouble conditions are completely known before opening the cable.

7. REPORTS

7.01 Reports of irregularities found should be made in accordance with administrative practices. Work sheets may also be used to provide detailed data if the troubles are located in connection with completion of a construction project. An identifying number may be placed on the diagram or work sheet at each trouble location. A set of notes should then be attached outlining in detail the nature of the trouble or troubles at each location.