Tektronix

Primer

Telephone Access Network Measurements

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About the Authors

Todd Baker is currently the Metallic Marketing Manager for the Cable Network Analysis business of Tektronix' TV/Comm division. He has served in various marketing roles in both the metallic and fiber optic segments, while continuing to work in the OSP plant environment. He holds a MBA from Portland State University, a BS in Laser Electro-Optics and an AE in Electrical Engineering from the Oregon Institute of Technology.

Rick Puckett is currently the Metallic Product Marketing Manager for the Cable Network Analysis business of Tektronix' TV/Comm division. He holds a BS in Business from Linfield College.

Preface

Who is Tektronix?

Tektronix is a portfolio of measurement, color printing, and video and networking businesses dedicated to applying technology excellence to customer challenges. Tektronix is headquartered in Wilsonville, Oregon and has operations in 23 countries outside the United States.

Tektronix is a supplier of telephone test equipment including access network analyzers for xDSL/ISDN/-POTS, metallic time domain reflectometers (MTDRs), optical time domain reflectometers (OTDRs), optical fault finders, optical power meters, digital multimeters, handheld ISDN testers, SONET test sets, protocol testers, and oscilloscopes.

What's In This Guide?

To effectively maintain and repair metallic cable faults in the outside plant environment, you need to have an understanding of which tools are best for which jobs and how these tools can be used more efficiently. This application guide will help familiarize you with the various tests that can be performed on the cable plant for both analog and digital services. This will allow you to identify and locate more faults quickly and easily.

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Chapter 1: TestWizard™ Advantage

Introduction

Having a straight-forward approach to troubleshooting or qualifying a pair is essential to success. Making random measurements, involving a great deal of guessing, requires too much time and effort. To approach the problem with a simple procedure and sequenced measurements will help you identify and locate faults quickly and accurately.

An outstanding multi-functional instrument does more than just combine several measurements into a single box. It allows them to work and communicate between themselves to provide the user with additional information and new insights.

The TestWizard™ analysis combines all this capability in a user-friendly, step-by-step approach to testing (see Figure 1-1). Using this functionality is like having an experienced technician at your side to guide you through the troubleshooting process.

Identification

To begin, TestWizard provides an automated sequence of standard tests to help identify what type of problem you may be up against. Measuring voltage and loop current determines the working status of the line, while counting load coils and measuring longitudinal balance might indicate potential loading or noise problems (Figure 1-2).

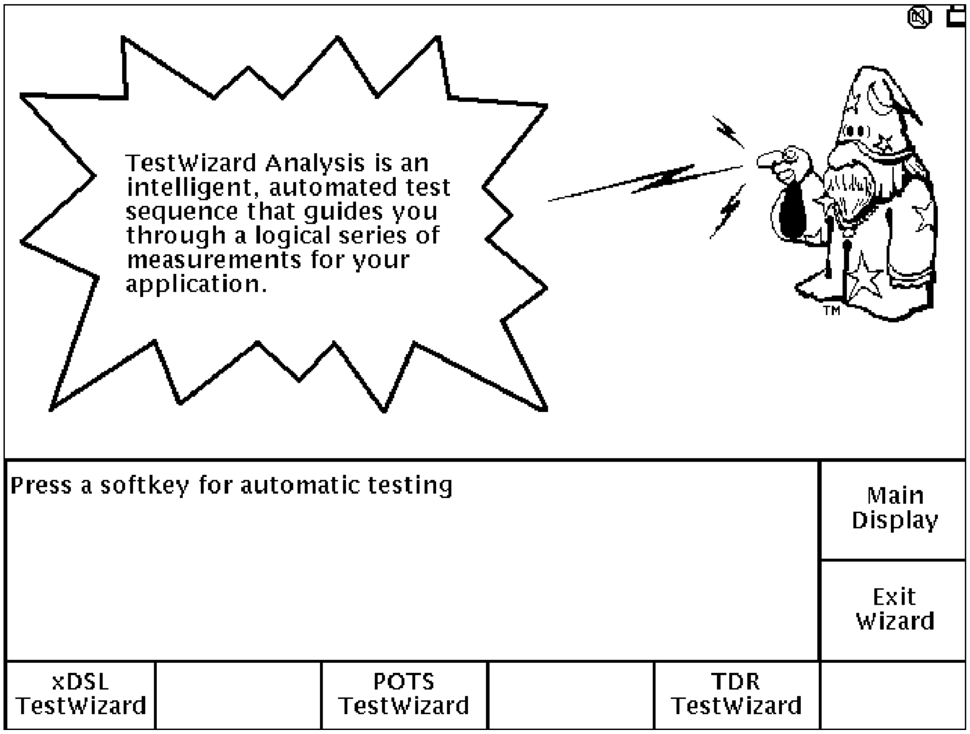


Figure 1-1. TestWizard start-up display.

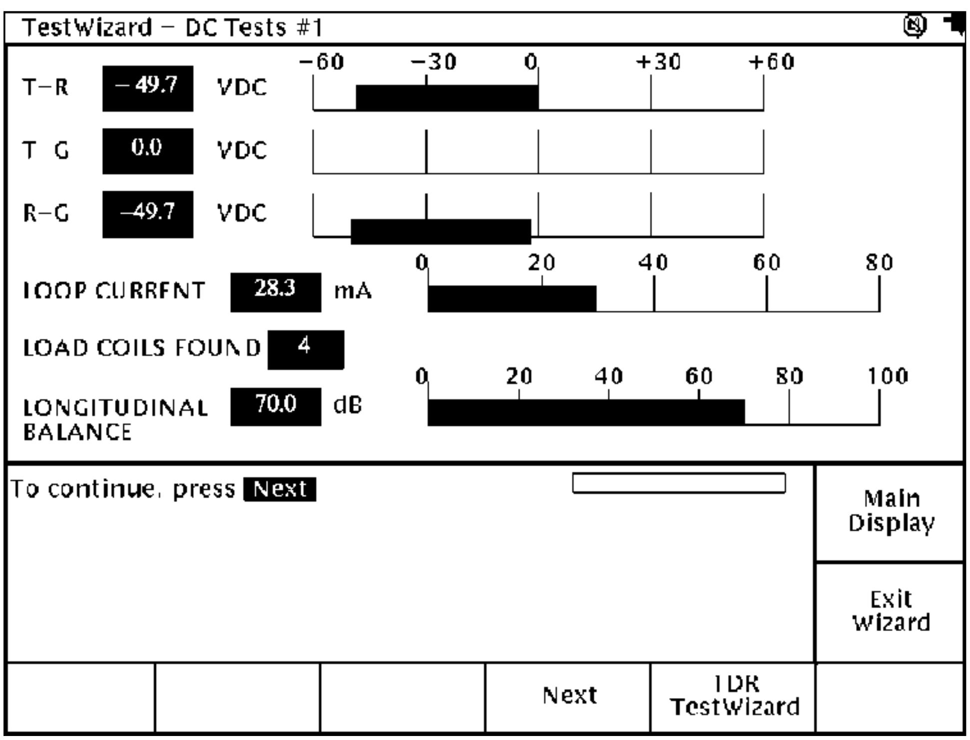


Figure 1-2. Typical TestWizard display to begin tests.

If the pair is inactive, with no voltage on the line, it is useful to determine if the cable fault is resistive or capacitive in nature. Knowing the type and severity of the fault will help you determine which test will be appropriate for actually locating the fault (Figure 1-3).

If the pair was active, with the correct voltage and current shown on the first screen, a warning message will appear. This message advises that a resistive or capacitive measurement would be incorrect, and you should move on to qualifying the transmission characteristics of the pair (Figure 1-4).

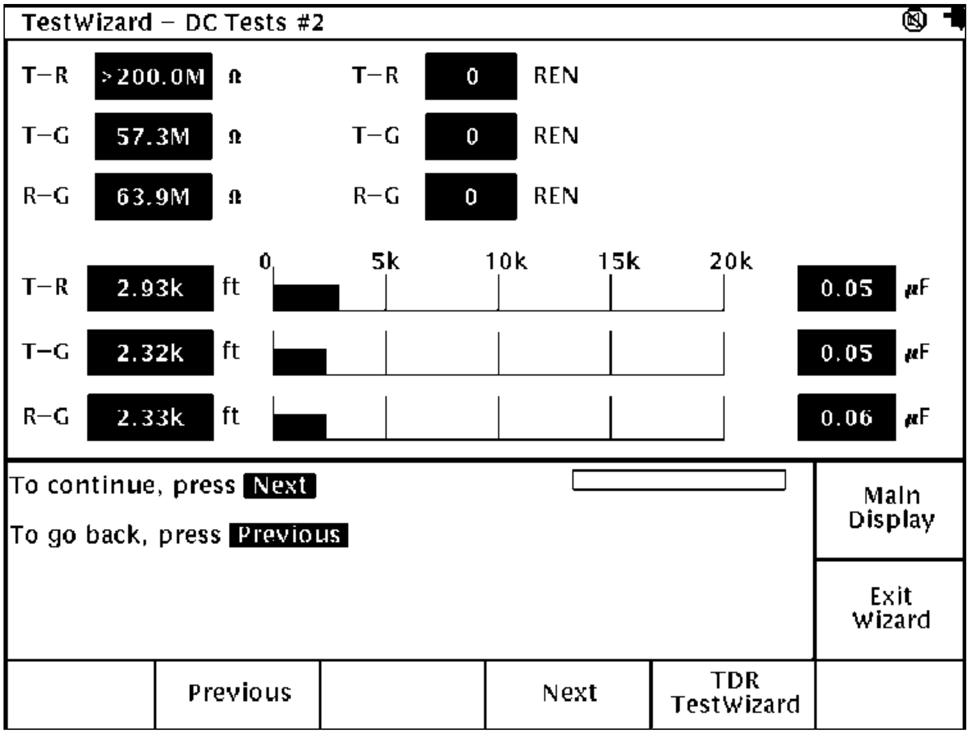


Figure 1-3. Determining if fault is resistive or capacitive.

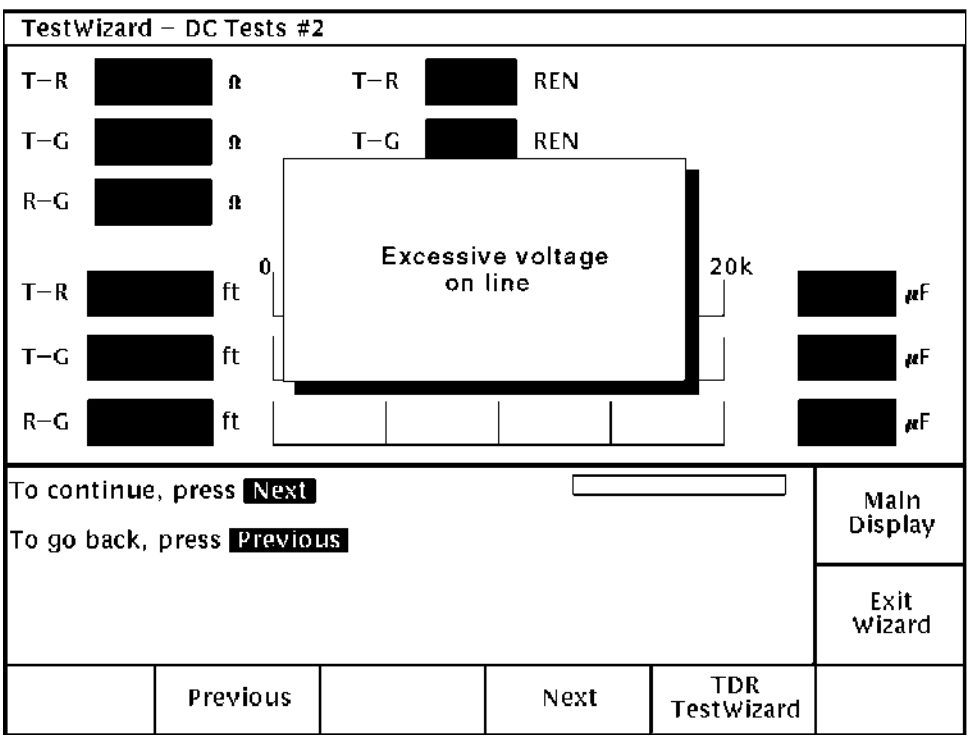


Figure 1-4. Warning message when pair is active.

Qualification

Ensuring quality service can be achieved by measuring the general transmission characteristics of a working pair. Simple loss and noise measurements determine the transmission quality of the pair and might indicate potential problems not identified in the standard DC-type tests (Figure 1-5).

Additional insight about the transmission characteristics of the pair can be gained through a slope test. By receiving a sequence of tones and plotting them across the frequency range, you might discover potential loading problems. A smooth frequency response across the service range (300 to 3,000 Hz for POTS) is desirable (Figure 1-6).

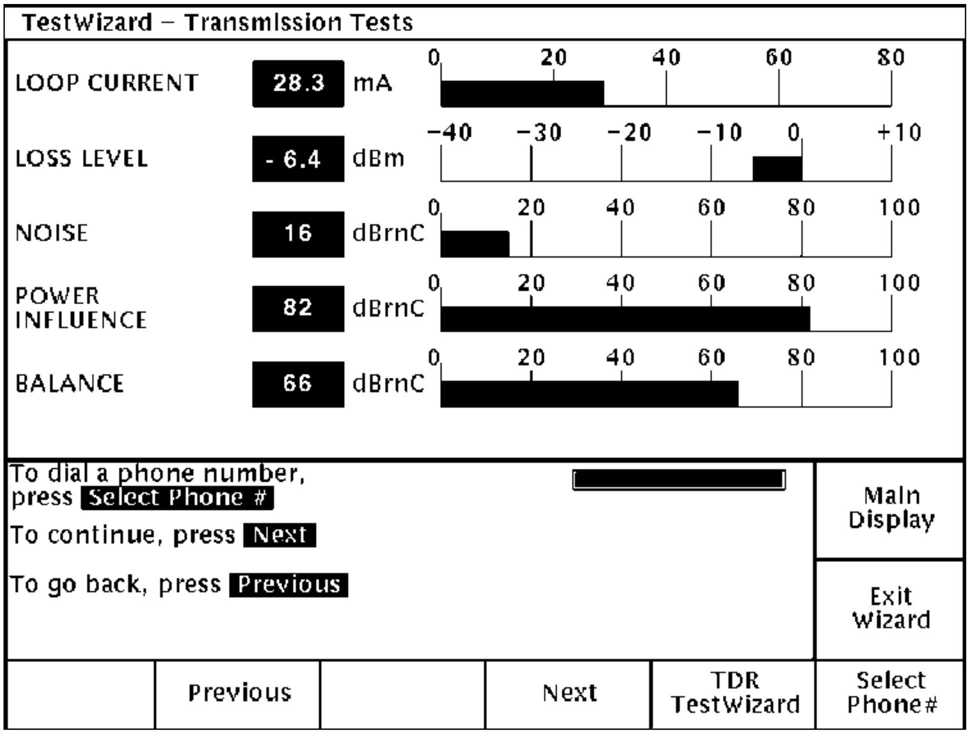


Figure 1-5. Loss and noise measurements.

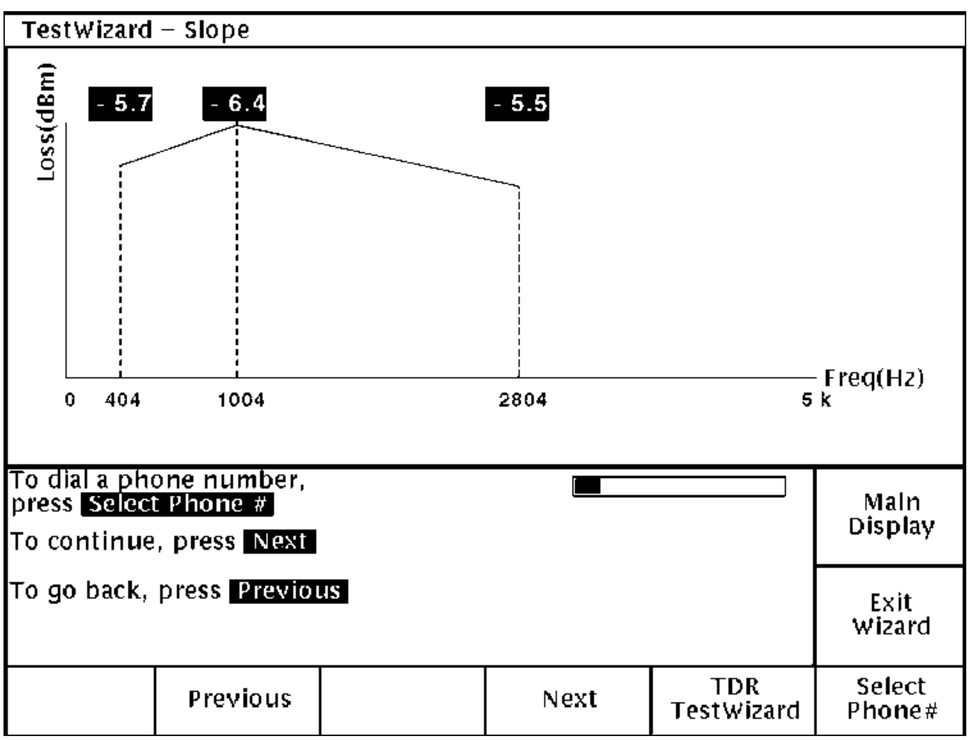


Figure 1-6. Slope test display.

Location

If a problem has been identified during the previous steps, TestWizard now allows the user to move on toward actually locating the fault. The Open (Capacitance) Meter should be used for problems identified in the capacitance section in Figure 1-3. High-resistance faults (>1 kΩ) identified on the same screen can be located using the Resistance Fault Locator (RFL). If the fault is <1 kΩ and the section is believed to be free of load coils, then the TDR TestWizard sequence is recommended (Figure 1-7).

TDR TestWizard

TDR TestWizard guides you through proper setup of the TDR by asking a few simple questions about the pair. To begin, indicate the correct cable type and size using the arrow keys, and press Next (Figure 1-8).

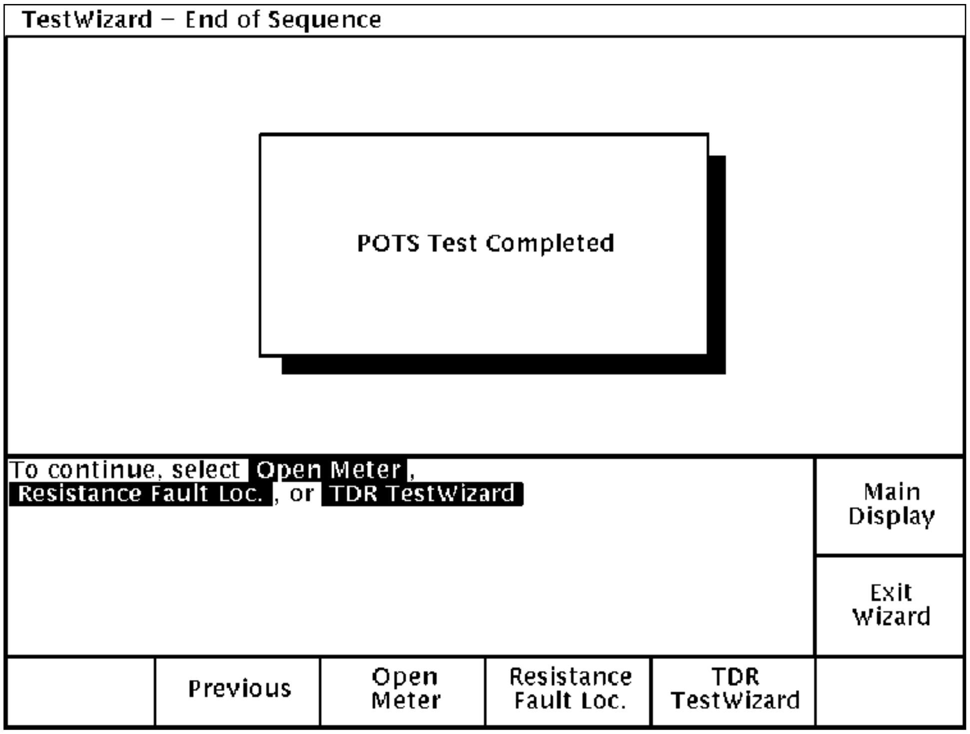
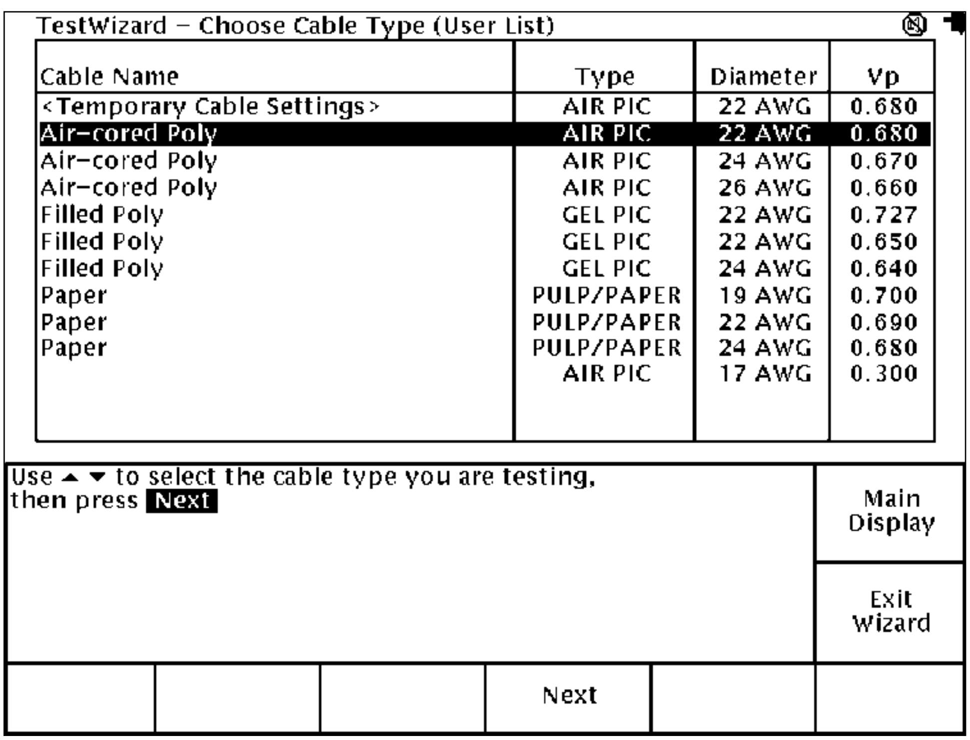


Figure 1-7. Locating the fault.



Cable Name	Type	Diameter	Vp
<Temporary Cable Settings>	AIR PIC	22 AWG	0.680
Air-cored Poly	AIR PIC	22 AWG	0.680
Air-cored Poly	AIR PIC	24 AWG	0.670
Air-cored Poly	AIR PIC	26 AWG	0.660
Filled Poly	GEL PIC	22 AWG	0.727
Filled Poly	GEL PIC	22 AWG	0.650
Filled Poly	GEL PIC	24 AWG	0.640
Paper	PULP/PAPER	19 AWG	0.700
Paper	PULP/PAPER	22 AWG	0.690
Paper	PULP/PAPER	24 AWG	0.680
	AIR PIC	17 AWG	0.300

Figure 1-8. Selecting the cable type.

Then enter the approximate length of the cable to be tested. If the length is uncertain, simply select the longest reasonable length. Highlight the selection using the arrow keys, and press Next (Figure 1-9).

Now indicate which events you would like the TDR to automatically mark on the waveform. If a catastrophic event such as a solid short or complete open is expected, you might select “Find Largest Events.” If the trouble is suspected to be more subtle, choose “Find All Events.” Highlight the appropriate selection using the arrow keys, and press Next (Figure 1-10).

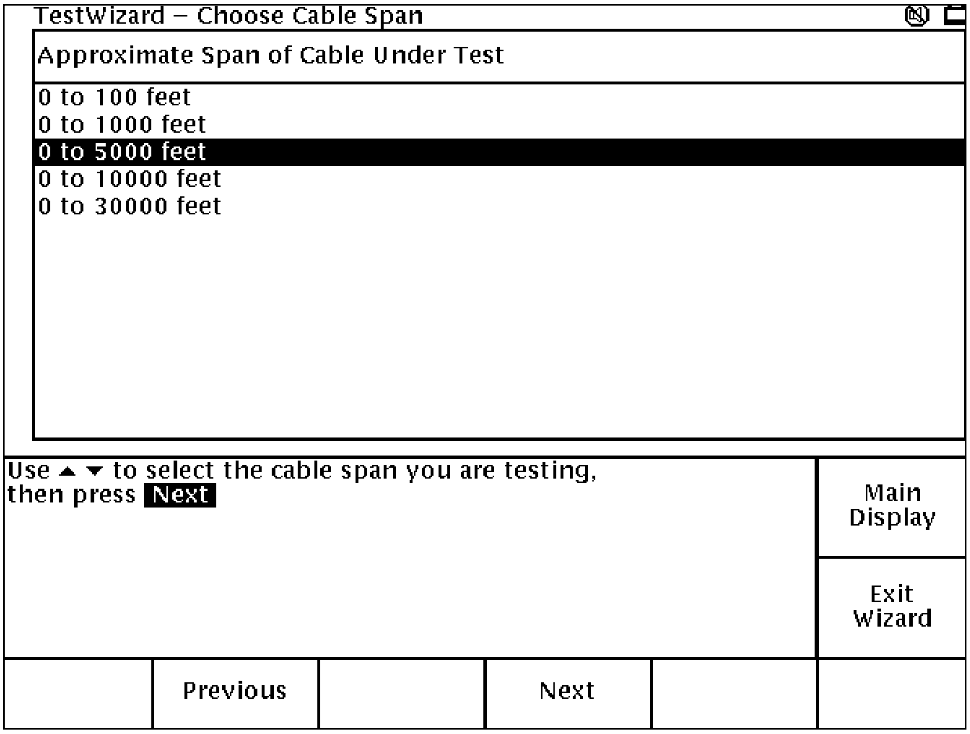


Figure 1-9. Selecting approximate cable length.

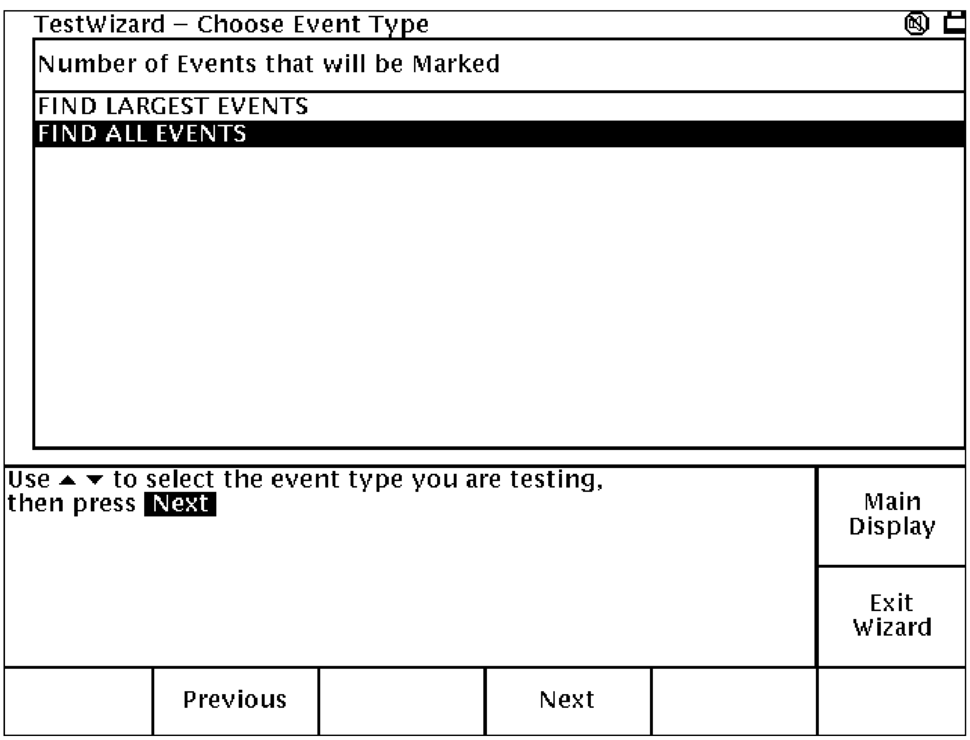


Figure 1-10. Selecting events to be marked.

The TDR TestWizard now automatically steps through the TDR test sequence using the guidelines you have just selected. The end result is an automatically marked, multiple-event waveform (Figure 1-11). You can move between events using the arrow keys, or get a close-up view of a highlighted event with the Zoom function.

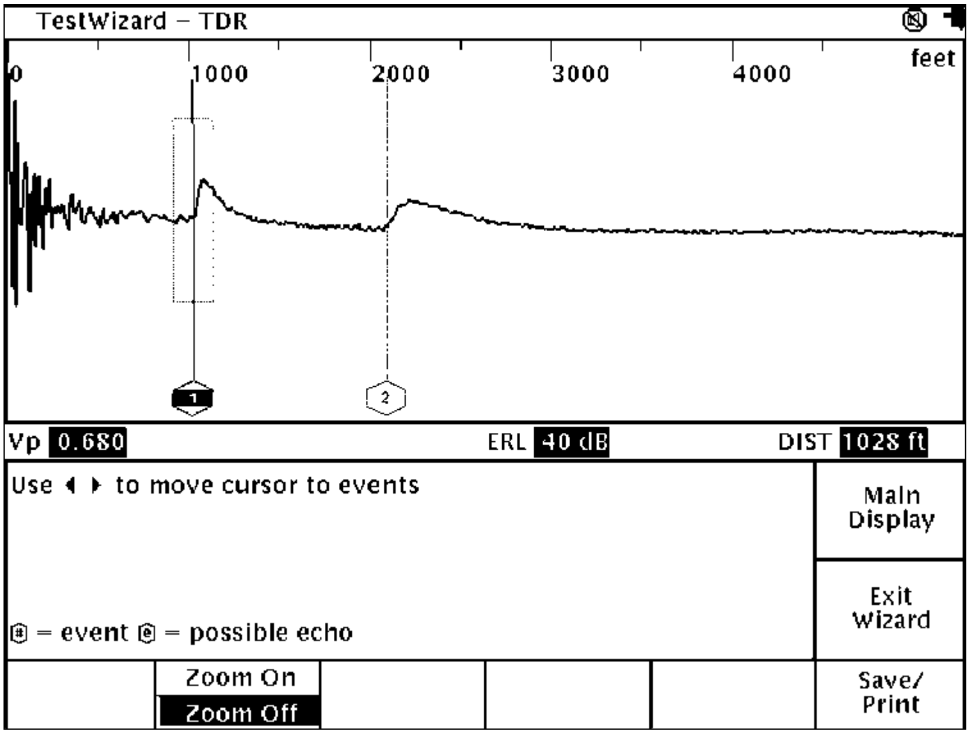


Figure 1-11. TDR TestWizard waveform.

Conclusion

The TelScout's TestWizard analysis guides a user through the qualification and troubleshooting sequence. It reminds users which tests should be performed, which order they should be taken in, and what steps will guide them toward locating the fault.

For detailed information regarding any of the tests mentioned in the TestWizard analysis, refer to the appropriate chapters in this text.

Chapter 2: Telephone Cable Construction

Introduction

Cable construction has seen many changes since the introduction of the telephone. Only in the past few decades has some standardization and consistency been achieved.

Cable Diameters

The conductor size of the cable can be measured using either gauge (AWG) or diameter (mm). Most systems are designed to use the smallest conductor size near the exchange, with larger diameters used further out toward the subscriber. This accounts for physical size, attenuation affects, and the actual cost of the conductor materials.

Table 2-1. Common Cable Types

Type	Description
Pulp	Paper slurry filled cable
Paper (LW)	Longitudinal-wrap paper cable
Paper (SW)	Spiral-wrap paper cable
Air PIC	Air-filled Plastic Insulated Cable
Gel PIC	Gel-filled Plastic Insulated Cable
Coax	Coaxial cable
Aluminum	Aluminum conductor cable

Cable Types

Many different cable types are still in active use today (see Table 2-1). Earlier pulp, paper, and aluminum cables are being replaced by newer designs such as Gel PIC. Although PIC was supposed to be the answer to water intrusion in the cable system, it still has its problems. Coaxial cables are most commonly found in CATV systems and other high-bandwidth applications.

Twisted Pairs

In twisted pair cables, pairs of conductors are twisted together to reduce the amount of crosstalk with other pairs in the cable. Each pair is twisted at a different rate, depending on its location in the binder group and the conductor size. Pulp and PIC cables have different twist factors as shown in Tables 2-2 and 2-3.

Shield

The cable shield is a metal wrapping which reduces the intrusion of AC noise and other external sources by guiding them to ground. It also provides additional strength to the physical construction of the cable. In older lead cables, the lead provided the noise reduction and physical stability.

Sheath

The cable sheath is the outer layer of the cable structure that provides protection from the outside environment. Earlier lead sheaths have been replaced by newer designs involving plastic materials. Plastic was originally thought to be the answer to moisture intrusion. Although it does temporarily guard against moisture, eventually the moisture will enter the cable through osmosis.

Velocity of Propagation

A cable's Velocity of Propagation (V_p) specification is simply a measure of how fast a signal travels in the cable (see Figure 2-2). It's typically expressed as a percentage of the speed of light with values ranging from 0.30 to 1.00. For example, a cable with a V_p value of 0.66 indicates that the signal is traveling down the cable at 66% of the speed of light. Sometimes it's referenced in actual velocity terms and can vary from 45 to 150 m/ms.

Since a Time Domain Reflectometer (TDR) is really making measurements in the time domain, the distance accuracy of the TDR is dependent upon having the correct V_p value. Identifying the correct V_p for the cable being tested will improve the distance measurements. V_p varies most greatly between cable types (e.g., Paper vs. PIC) and much less so between gauges or diameters (e.g., 19 AWG vs. 26 AWG or 0.94 mm vs. 0.40 mm).

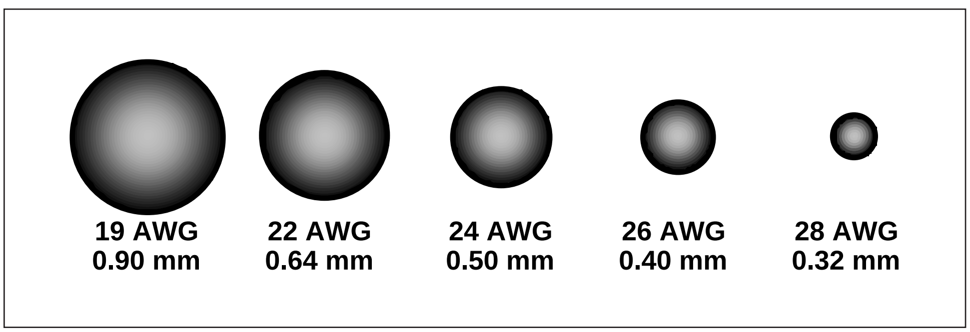


Figure 2-1. Cable diameters (relative size comparison).

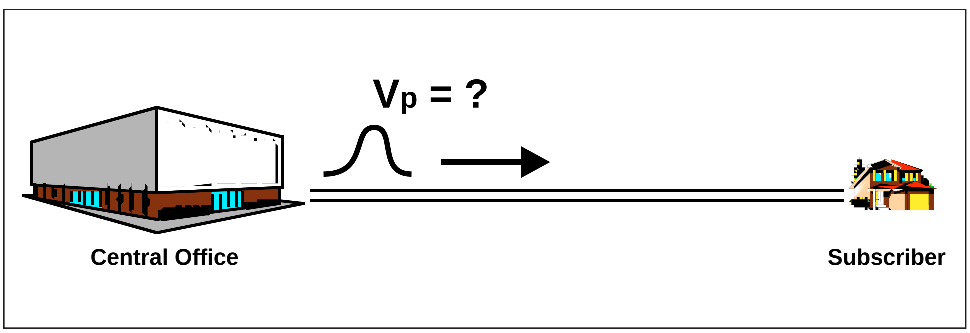


Figure 2-2. Velocity of propagation.

Conclusion

There are many different cable designs in use throughout the world. Variation between cables of different sizes, types, and twists will affect your measurements, depending upon the type of test being performed. A detailed discussion of these affects is contained in each chapter where they influence specific measurements.

Table 2-2. Pulp Cable Twists

Color	19 AWG (0.90 mm)	22 AWG (0.64 mm)	24 AWG (0.50 mm)
Green - Black	4.5	3.9	2.6
Green - Orange	3.6	3.2	3.3
Green	2.7	2.7	2.0
Red - Black	4.8	4.1	2.8
Red - Orange	3.9	3.5	3.4
Red	3.0	2.9	2.2
Blue - Black	5.1	4.3	3.0
Blue - Orange	4.2	3.7	3.6
Blue	3.3	3.1	2.4
Blue - Red (tracer)	5.4	5.1	3.8

Table 2-3. PIC Cable Twists

Number	Tip (Leg A) Color	Ring (Leg B) Color	19 AWG (0.90 mm)	22 AWG (0.64 mm)	24 AWG (0.50 mm)
1	White	Blue	2.0	2.0	2.0
2	White	Orange	5.3	4.9	3.2
3	White	Green	3.2	3.1	2.7
4	White	Brown	5.9	5.2	4.1
5	White	Slate	4.1	3.9	3.7
6	Red	Blue	2.9	2.8	2.4
7	Red	Orange	4.5	4.1	4.5
8	Red	Green	3.8	3.7	3.5
9	Red	Brown	2.3	2.2	2.2
10	Red	Slate	5.5	4.9	4.7
11	Black	Blue	2.8	2.7	3.9
12	Black	Orange	4.9	4.5	3.1
13	Black	Green	3.3	3.2	2.6
14	Black	Brown	2.6	2.5	3.3
15	Black	Slate	5.1	4.6	4.2
16	Yellow	Blue	6.1	3.5	2.9
17	Yellow	Orange	2.1	2.1	2.1
18	Yellow	Green	5.7	5.1	3.8
19	Yellow	Brown	4.8	4.3	2.8
20	Yellow	Slate	3.0	2.9	4.0
21	Violet	Blue	3.9	3.8	2.5
22	Violet	Orange	4.7	4.2	3.0
23	Violet	Green	2.4	2.4	2.3
24	Violet	Brown	3.5	3.6	3.4
25	Violet	Slate	4.3	4.0	4.4

Chapter 3: Verifying an Active Pair

Introduction

Proving a known good pair before putting it into service will save time and money by reducing repeat calls. By making a few basic tests on an active line, you can detect potential problems and determine the quality of the services being provided. Network operators use a variety of tests to ensure a pair is ready for service, but here are a few of the more common tests.

DC Voltage

DC voltage, or “battery,” is supplied by the central office or exchange (Figure 3-1). This voltage will vary depending on the location, type of service, and switch type.

An inactive pair should have no voltage, indicating that it is well insulated from other pairs in the cable. A typical active POTS or analog line should indicate 48 to 52 volts DC between Tip and Ring (T-R or A-B), zero volts between Tip and Ground (T-G or A-E), and 48 to 52 volts between Ring and Ground (R-G or B-E) (see Figure 3-2).

Loop Current

Loop current is the measure of electrical flow (Figure 3-3). It’s measured in thousandths of an ampere, referred to as milliamps (mA). The current on a pair will vary depending on the design of the system, quality of the cable pair, and any line treatments that may have been introduced.

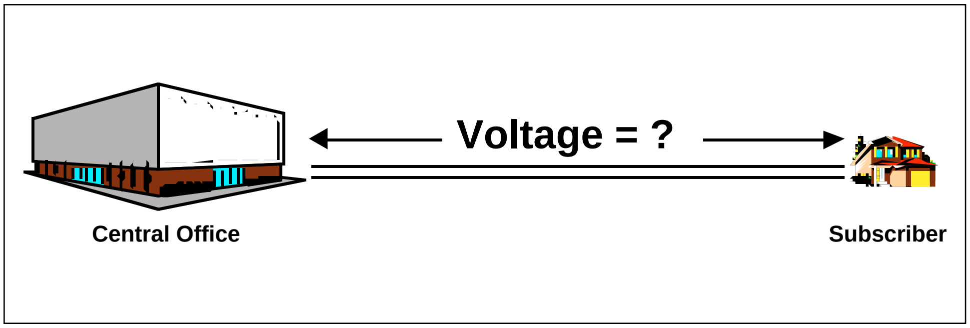


Figure 3-1. DC voltage.

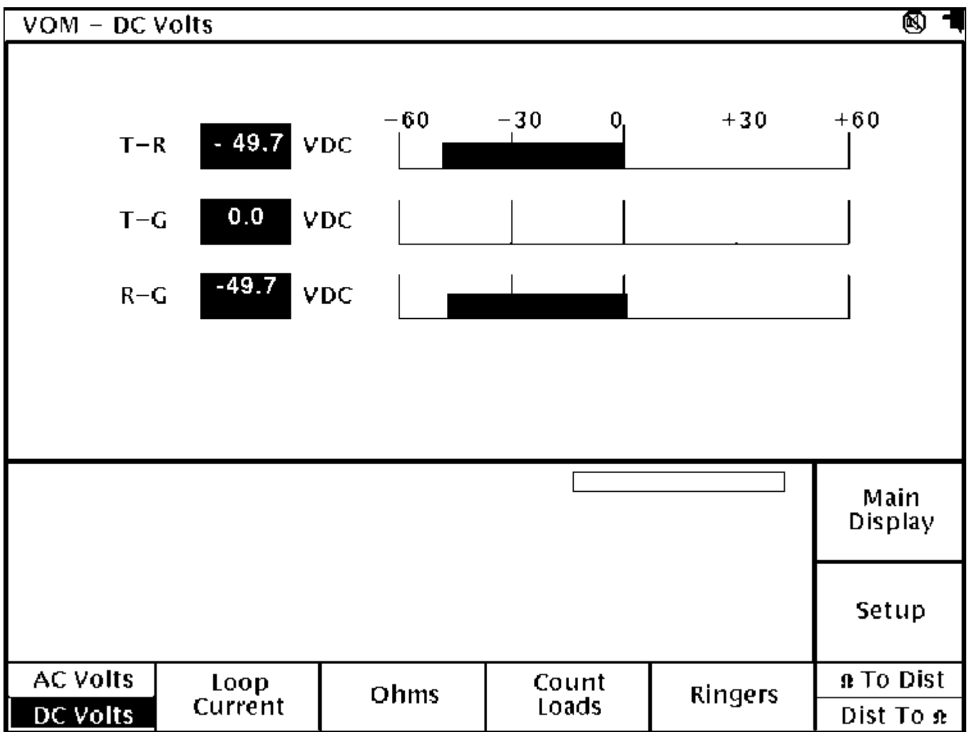


Figure 3-2. DC voltage display.

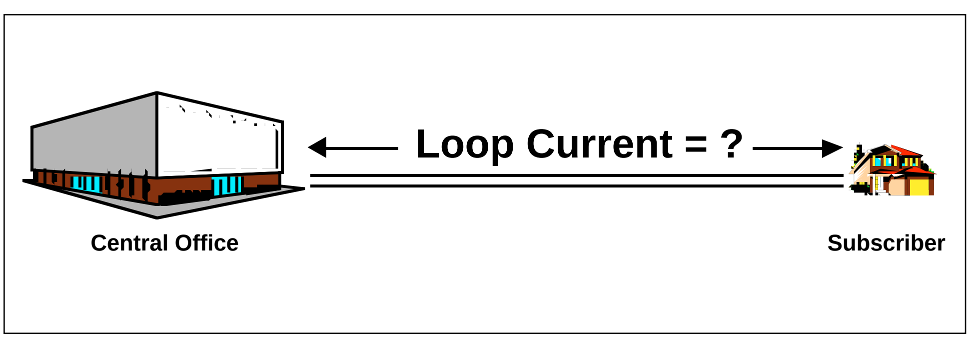


Figure 3.3. Loop current.

Like voltage, the loop current requirements depend on the service being provided. For standard POTS or analog service, the typical loop current parameters are >23 mA for acceptable service (see Figure 3-4). If the loop current falls below 20 mA, the customer might experience loss of dial tone, ringer problems, or misdials. If the current exceeds 65 mA, the customer might have voice fade-out during a call.

Lines with marginal loop currents of 20 to 23 mA can be treated with loop devices such as a Dial Long Line (DLL) or a Range Extender with Gain (REG) (see Figure 3-5). DLLs are used to treat lines with low loop current, while REGs are used for lines with both low loop current and high loss. To check for these devices, simply strap the pair and then measure the voltage to ground. A typical line will measure approximately 25 VDC to ground, the DLL will indicate either 96 VDC or 0 VDC to ground, typical, and the REG will measure 40 VDC to ground, typical.

Load Coils

Load coils are used on longer voice or analog lines to improve the frequency response by compensating for the capacitance of the cable (see Figure 3-6). A long voice line must be properly loaded, while all digital lines must be completely unloaded before being placed into service.

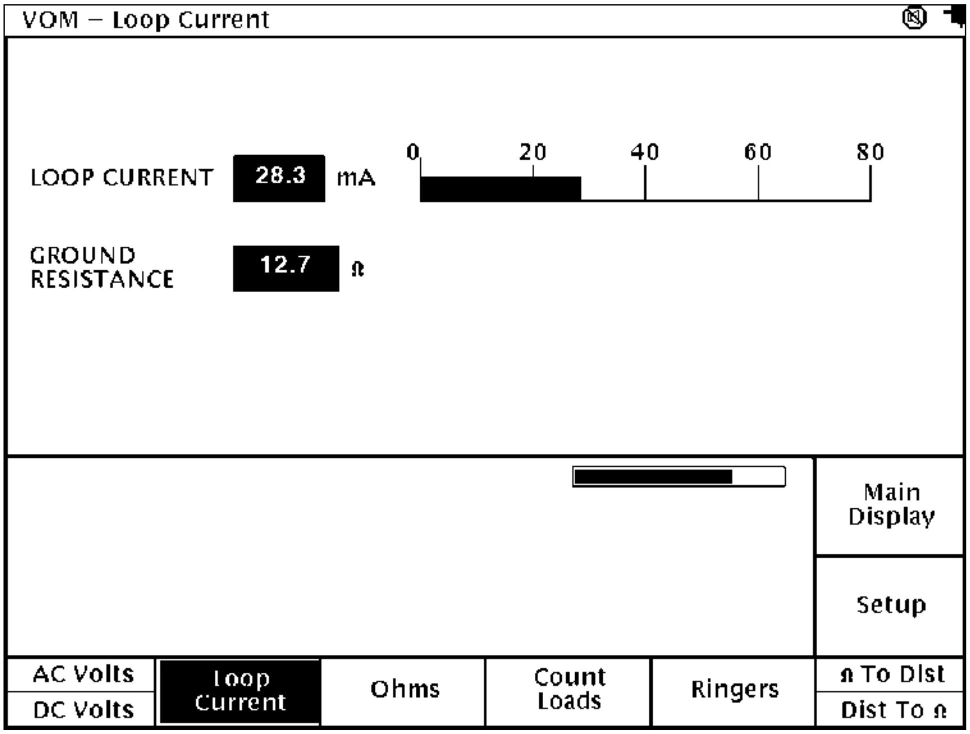


Figure 3-4. Loop current display.

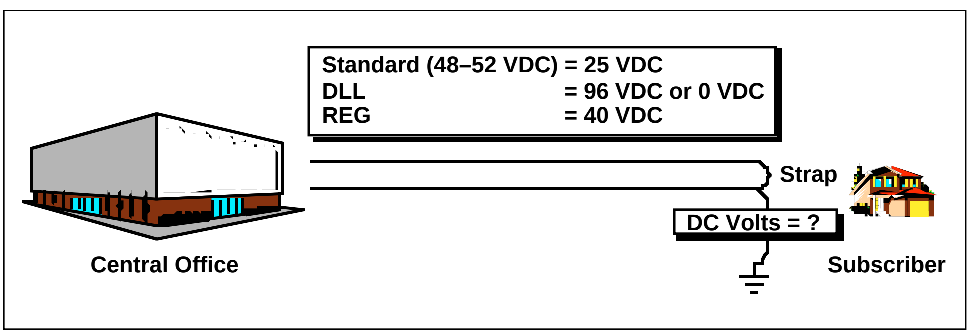


Figure 3-5. Loop treatment devices.

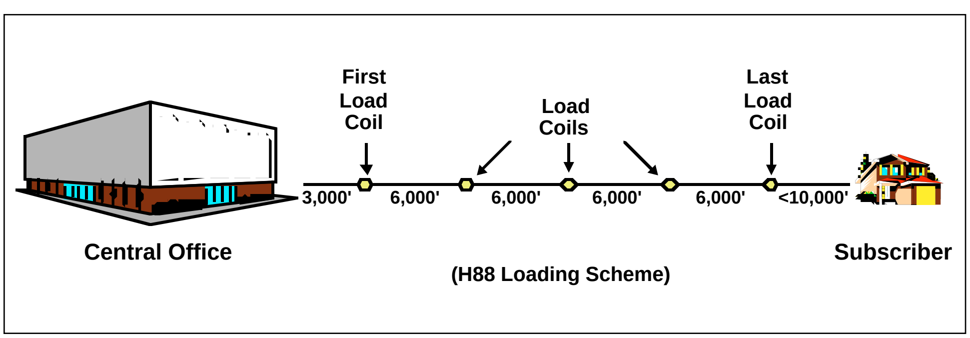


Figure 3-6. Loaded cable.

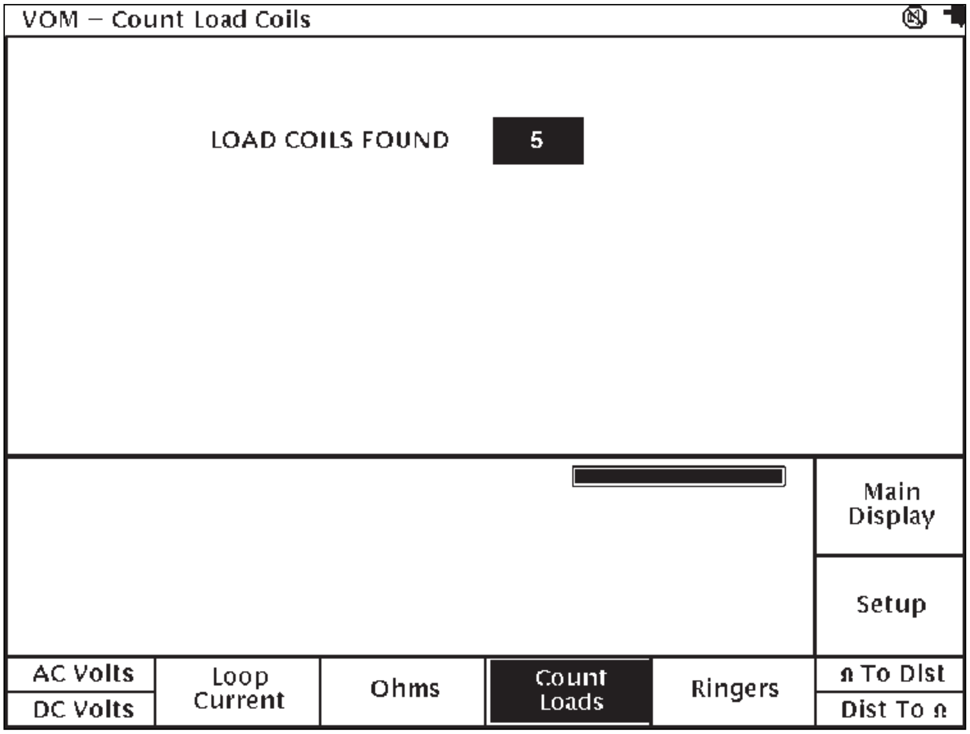


Figure 3-7. Counting load coils.

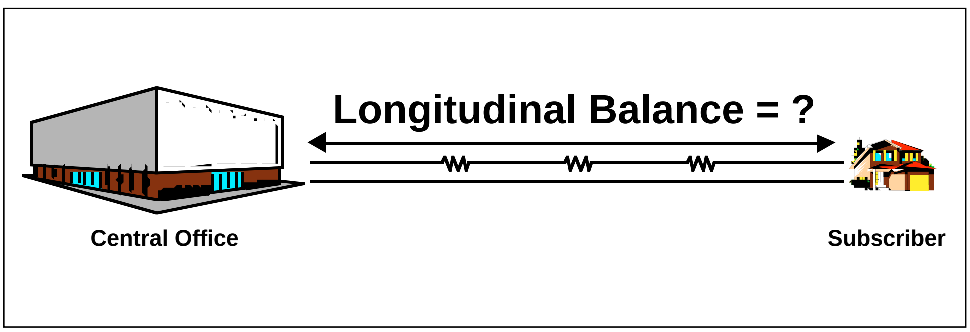


Figure 3-8. Longitudinal balance.

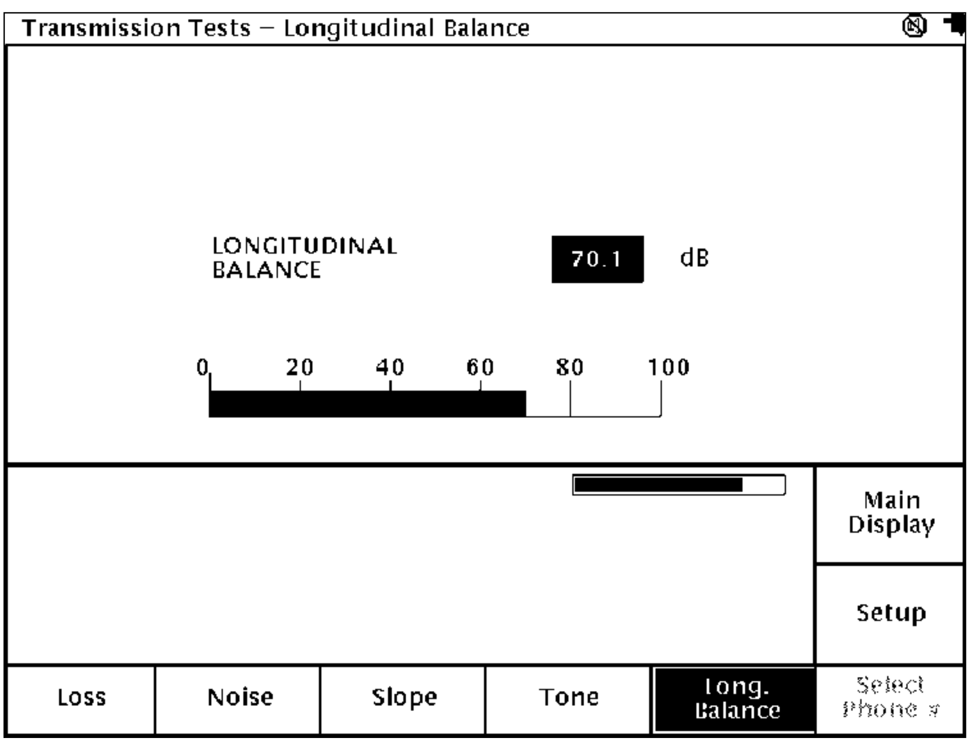


Figure 3-9. Longitudinal balance display.

By performing a quick load coil count and comparing the result to the map, you can determine if the loading is correct (see Figure 3-7).

Refer to ***Chapter 6: Load Coils*** for more detailed information on load coils and various loading schemes.

Longitudinal Balance

Longitudinal balance can be used to determine if both conductors in a pair are electrically equivalent (Figure 3-8). By inducing an AC signal onto the line, a noisy condition is simulated which allows an unbalanced pair to be identified.

Although the acceptable degree of imbalance varies between companies and service types, typically a longitudinal balance of >60 dB is desired (see Figure 3-9).

Refer to ***Chapter 12: Transmission Characteristics*** for more detailed information on longitudinal balance.

Transmission Characteristics

Transmission tests should be made as a final step before declaring a line ready for service. Once again, the type of tests required will vary depending on the company and type of service, but at a minimum, a quick loss test should be performed (Figure 3-10).

By measuring the loss of the pair at a standard frequency, typically 1004 Hz for POTS or analog service, you can quickly determine the overall quality of the line. Testing for static or low dial tone with a butt set is subjective, but a loss measurement is more stable and repeatable. If the loss is <8 dBm and the loop current is ≥23 mA, the pair can be used for service (see Figure 3-11).

For additional information on loss, noise, power influence, calculated balance, and slope measurements, refer to ***Chapter 12: Transmission Characteristics***.

Conclusion

It has been common practice to simply listen for "good" dial tone to determine the quality of a line. With today's demand on the existing copper plant, it's necessary to approach the services with more quantitative measurements. By covering the basic tests mentioned above, you can quickly ensure a pair is capable of providing quality service.

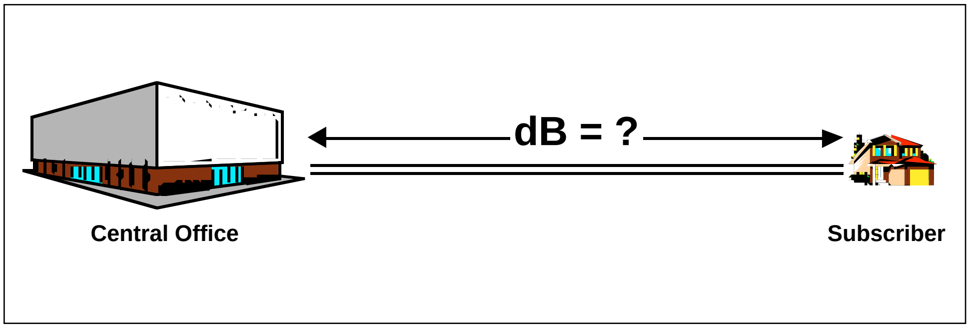


Figure 3-10. Transmission characteristics.

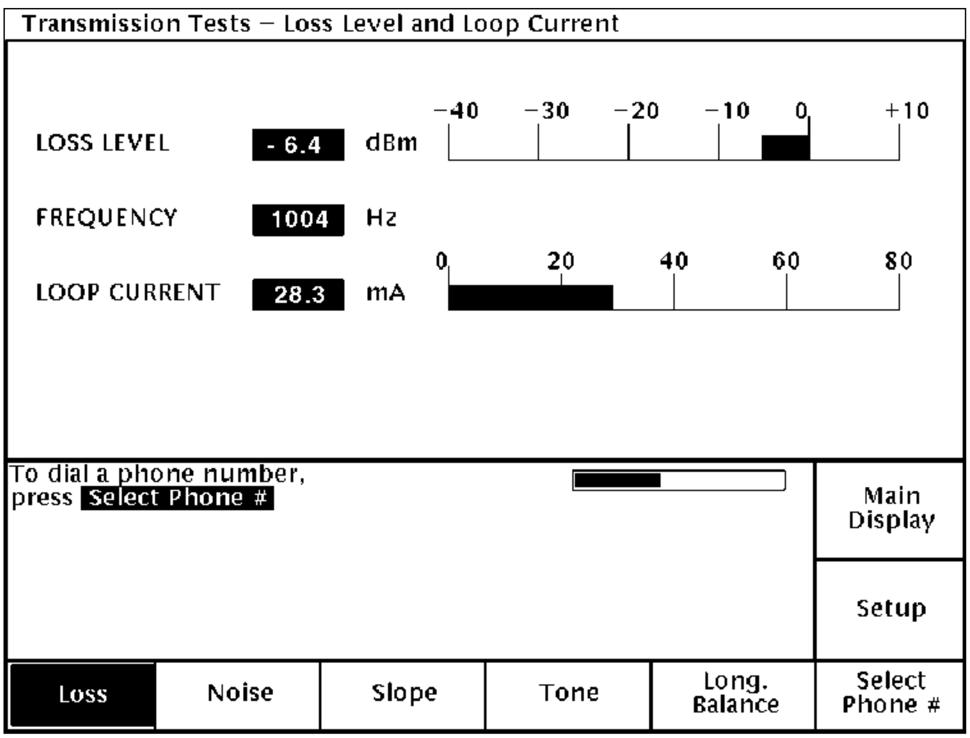


Figure 3-11. Loss display.

Chapter 4: Capacitance

Introduction

Telephone cables have a tendency to store electrical charge, much like a capacitor. A capacitor has three parts: two plates and an insulator which separates them (see Figure 4-1). A cable always has capacitance and it reduces the level of the analog (voice) signal as it travels down the cable.

Capacitance

Capacitance is measured in Farads (F). Typically it's a very small number, which is given in microfarads (µF) or nanofarads (nF). In a capacitor, the larger the plate size, the greater the capacitance and the charge it can store. Given this, one would think that the larger the cable gauge or diameter, the more capacitance it would have. However, this is not the case since most manufacturers vary the thickness of the insulation between the conductors to maintain a consistent capacitance. Therefore, the capacitance of the cable remains the same, regardless of the gauge or diameter (see Table 4-1).

Table 4-1. Cable Capacitance

Gauge	µF/mile
19	0.083
22	0.083
24	0.083
26	0.083
28	0.083
Diameter	**µF/km**
0.90 mm	0.045
0.64 mm	0.045
0.50 mm	0.045
0.40 mm	0.045
0.32 mm	0.045

Complete Open

Since capacitance does not vary with wire gauge or diameter, it's very straightforward to convert a measured capacitance into a distance. For example, if you measure the capacitance of a cable that's completely open on the end, you can determine approximately how long it is (see Figure 4-2).

In Figure 4-3 the Tip-Ground (A-E) and Ring-Ground (B-E) measurements are equal indicating the pair is balanced. Therefore, the Tip-Ring (A-B) measurement is valid and the fault is 17,160 feet, or approximately 3.25 miles (6 km) away.

In this example, we were assuming that the cable was a straight run from one end to the other without any bridged taps and laterals or any other cable faults. To verify this, a

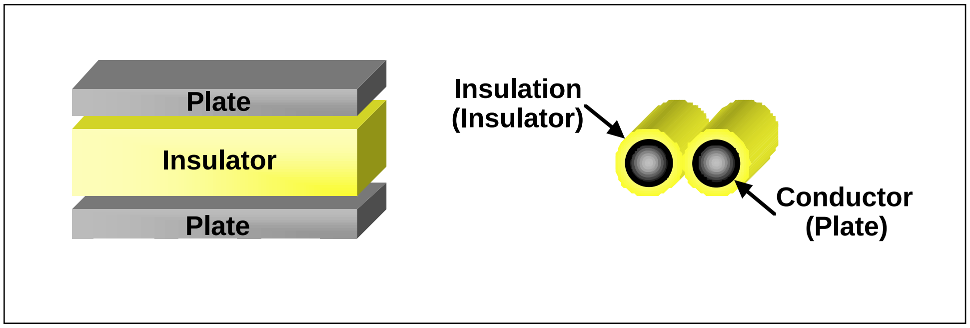


Figure 4.1. Capacitor construction.

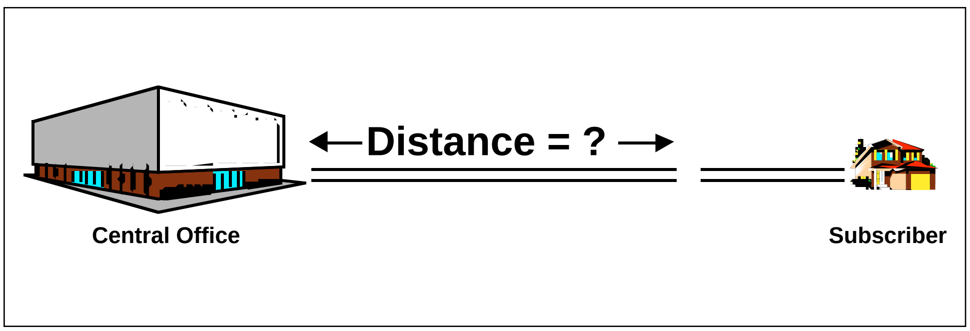


Figure 4.2. Complete open.

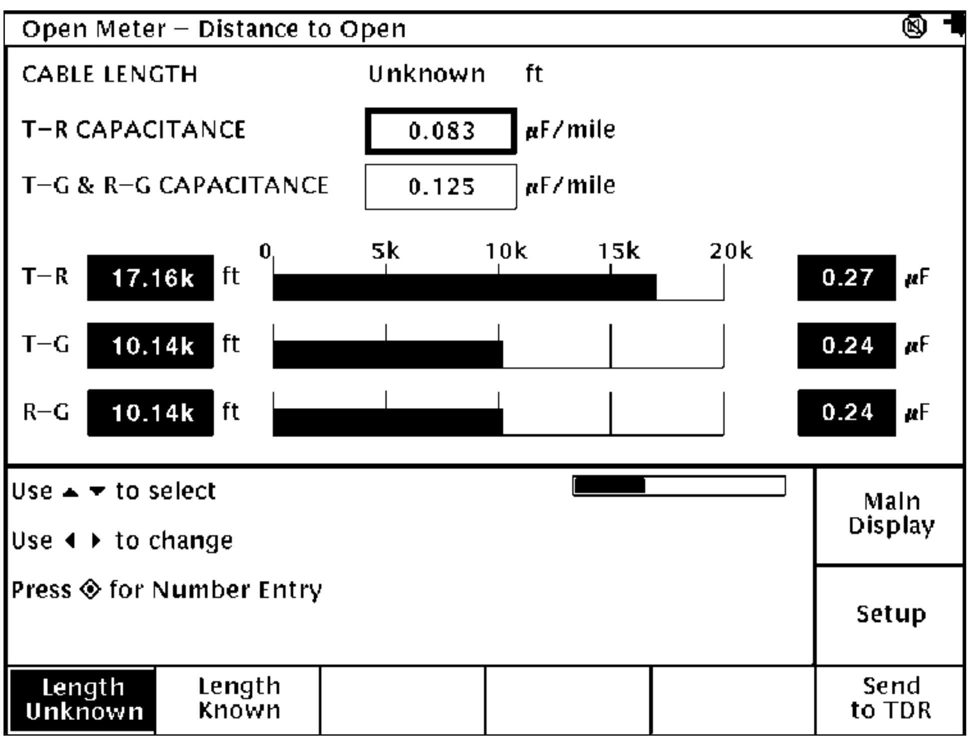


Figure 4-3. Complete open between pair.

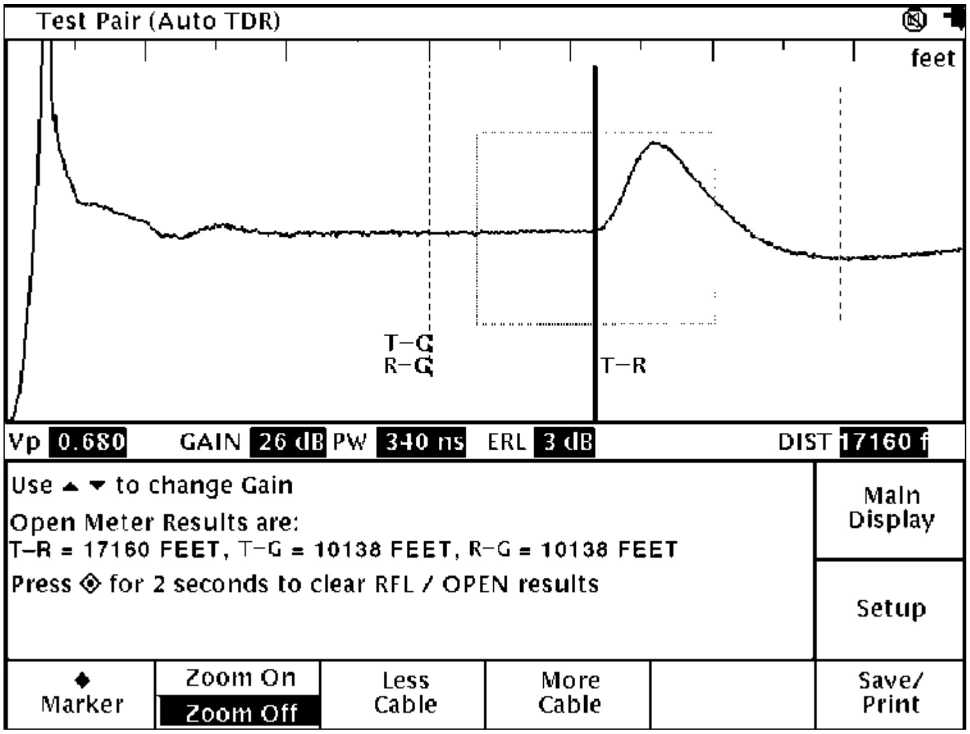


Figure 4-4. TDR waveform, complete open.

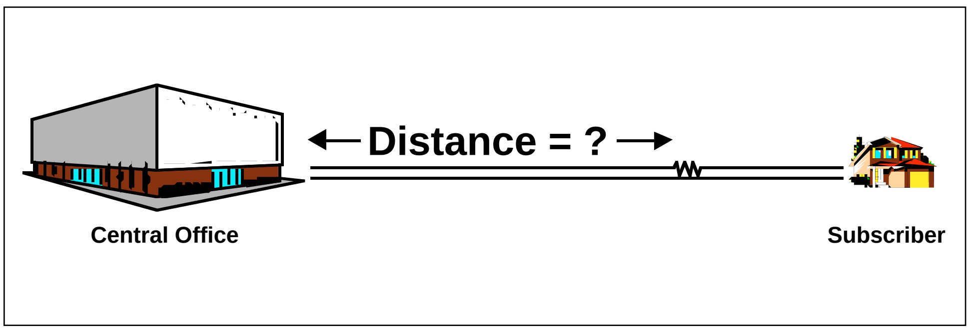


Figure 4.5. Partial open.

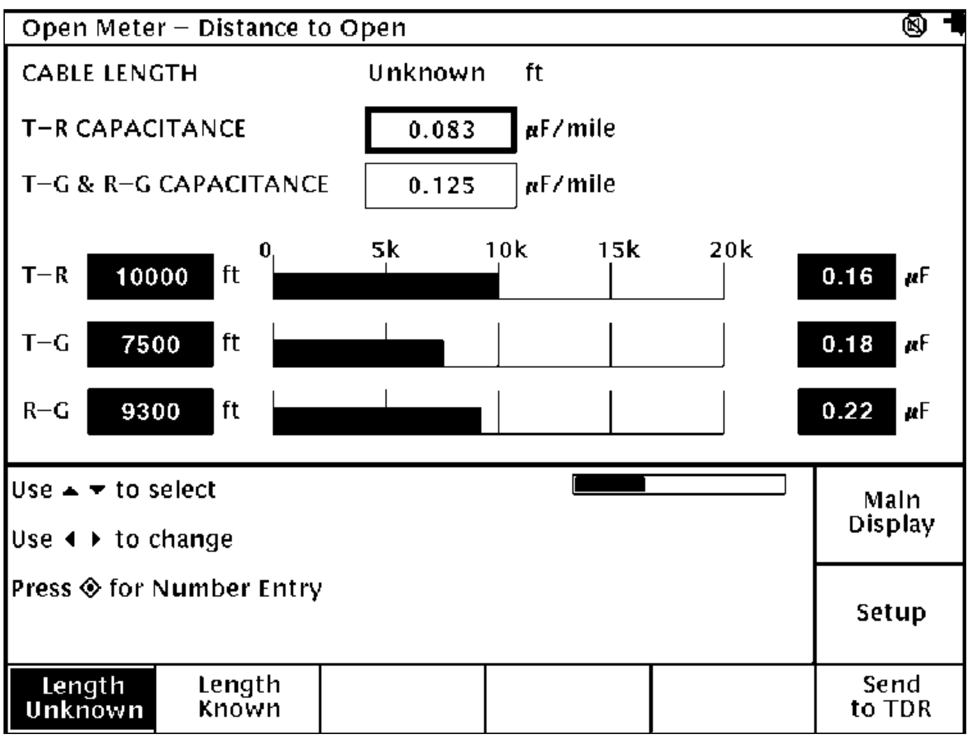


Figure 4-6. Tip (A) side open.

TDR can be used to confirm that the open meter results are correct. By simply pressing Send To TDR the open meter results are imported onto the TDR waveform. When you switch to TDR, the waveform display would show a bump at 17,160 feet (approximately 6,000 meters) (see Figure 4-4). Since the TDR does not rely on such small measurements in the µF range, the results are typically more precise.

Partial Opens

When one side of the cable pair is partially open, the pair is considered to be unbalanced (see Figure 4-5). A longitudinal balance test will indicate there's a problem with the pair, but to locate the problem you will have to use both the open meter and the TDR.

When a pair is unbalanced, the mutual capacitance reading across the pair is no longer valid. Consider the following results from your open meter (see Figure 4-6):

When the two sides of the pair are not equal, the mutual measurement is invalid and you must use the shorter of the two side readings. In this case, the only valid reading is the Tip-Ground (A-E) value of 7,500 ft (2,286 m). This is the approximate distance to the open on the Tip (A) side of the cable.

To confirm this, use a TDR to get a more precise measurement. The TDR is very sensitive to imbalances along the cable, so the partial open shows up quite clearly (see Figure 4-7).

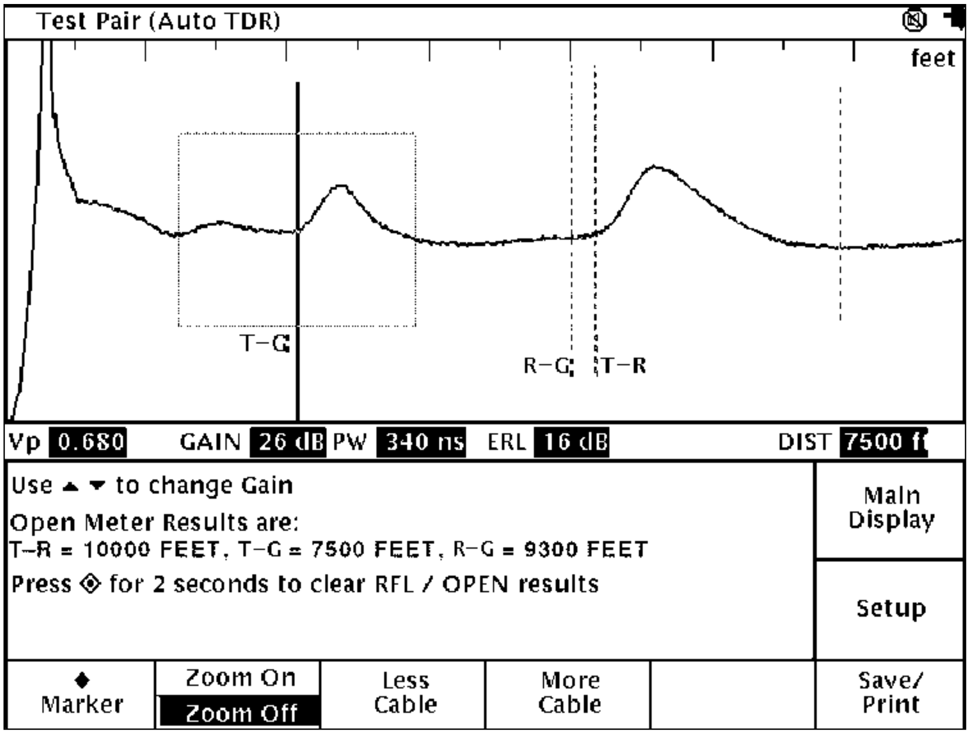


Figure 4-7. TDR waveform, partial open.

Conclusion

Capacitive faults are straightforward to identify and locate. An open meter can be used to approximate the distance to the fault, and a TDR can be used for more precise measurements. The advantage of using an open meter over a TDR is that the open meter is capable of measuring through load coils. On loaded lines, use the open meter to determine which section the fault is in, and then use the TDR on that section to determine the exact location of the fault.

Chapter 5: Resistance

Introduction

Resistance is the opposition to current flow through a conductor. All telephone conductors have some electrical resistance, but how much depends on the gauge or diameter of the cable, the length of the line, and condition of the splices and connections. This resistance in the telephone cable limits the distance the analog (voice) signal can travel down the cable.

Resistance

Resistance is measured in Ohms (Ω). To begin, it's easiest to think of resistance in terms of water flow. Much like water flowing through a pipe, the resistance to the current flow will vary depending on the size of the pipe. The larger the pipe, the more flow you will get. As the cable gauge or diameter gets smaller, the resistance increases. Therefore, the distance per ohm will vary depending on the gauge or diameter of the cable (see Tables 5-1 and 5-2).

Resistance is also very dependent on the temperature of the conductor. As the temperature increases, so does the resistance of the cable. To compensate for temperatures other than 68° F (20° C), use the following conversion factors. As you can see, if you have wide temperature variations, your distance measurements can be greatly affected.

Difference = Calculated Distance From Table x 0.00218 x (Table Temperature – Actual Temperature)

For example, if you measure 30 Ω between Tip-Ring (A-B) on 22 AWG (0.64 mm) copper cable at 84° F (28.89° C), the calculation would be:

U.S. Units Example:

30 Ω x 30.25 ft./Ω = 907.5 ft.

907.5 ft. x 0.00218 x (68° F – 84° F) = –31.65 ft.

Actual distance = 907.5 ft. – 31.65 ft. = 875.85 ft

Metric Units Example:

30 Ω x 9.22 m/Ω = 276.6 m

276.6 m x 0.00218 x (20° C – 28.89° C) = –5.36 m

Actual distance = 276.6 m – 5.36 m = 271.24 m

Table 5-1. Resistance at 68° F, U.S. Units

Gauge (AWG) Copper	Gauge (AWG) Aluminum	Feet/Ω Tip-Ring	Feet/Ω Tip-Ground or Ring-Ground
18	–	78.30	156.59
19	17	60.23	120.46
22	20	30.25	60.50
24	22	18.98	37.96
26	24	11.86	23.72
28	–	7.48	14.96

Table 5-2. Resistance at 20° C, Metric Units

Diameter (mm) Copper	Diameter (mm) Aluminum	Meter/Ω A-B	Meter/Ω A-E or B-E
1.02	–	23.86	47.73
0.90	1.15	18.36	36.72
0.64	0.81	9.22	18.44
0.50	0.64	5.79	11.57
0.40	0.50	3.62	7.23
0.32	–	2.28	4.56

Solid Short

When measuring a fault that has little or no resistance (0 Ω), known as a solid short, the distance to the fault can be calculated directly from the ohms measurement and adjusted for temperature (see Figure 5-1).

Using the ohmmeter, measure the loop resistance (see Figure 5-2). This value contains the total resistance between the test set and the fault.

Then use the Ohms-to-Distance calculator to convert the loop resistance to a distance reading (see Figure 5-3). Be certain that you adjust the parameters to correctly account for the cable gauge or diameter and the temperature of the cable itself.

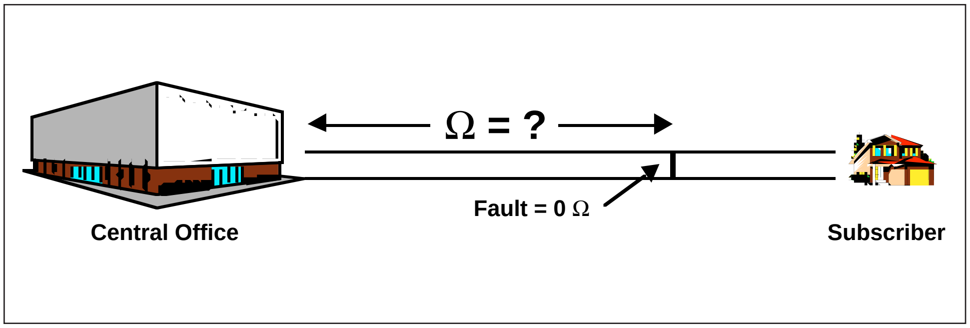


Figure 5-1. Solid short (0 Ω).

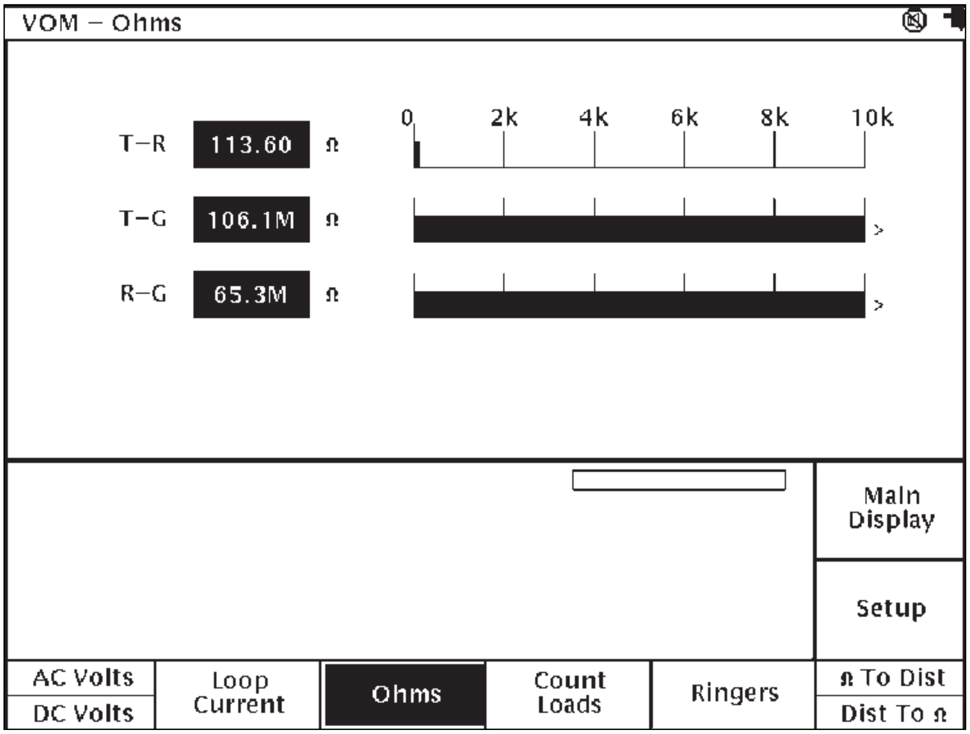


Figure 5-2. Resistance to solid short.

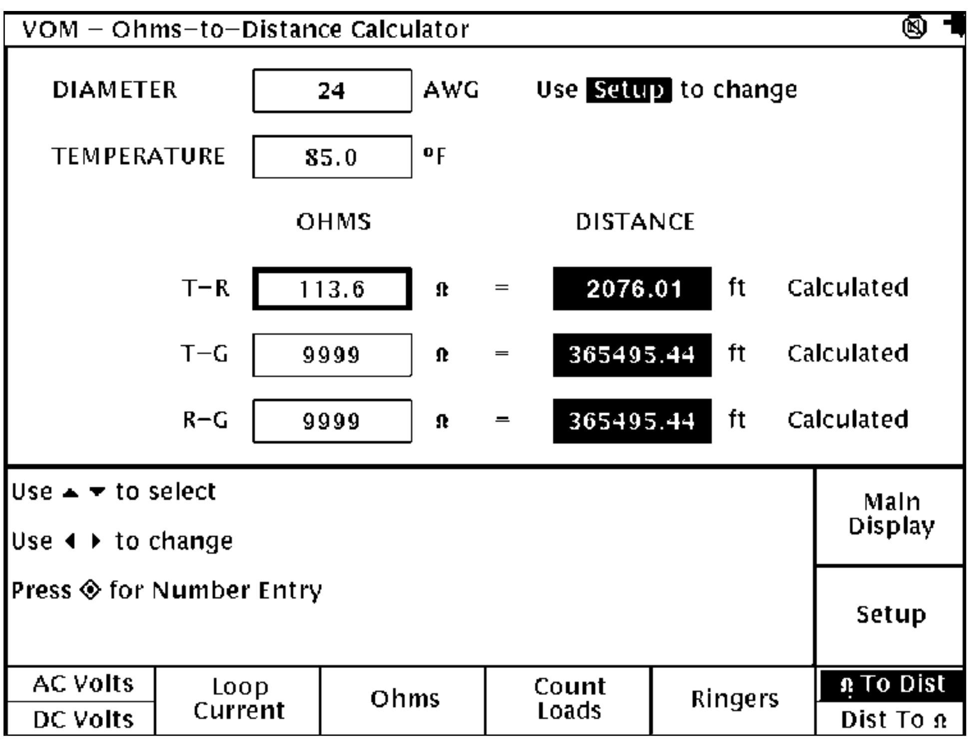


Figure 5-3. Distance to solid short.

If there are no load coils present between the test instrument and the short, you can confirm your ohms distance measurement by using the Time-Domain Reflectometer (TDR). The TDR is not affected by temperature, and only very slightly by gauge changes, which makes it more accurate for pinpointing low resistive faults (see Figure 5-4). A solid short on a TDR waveform points in the downward direction.

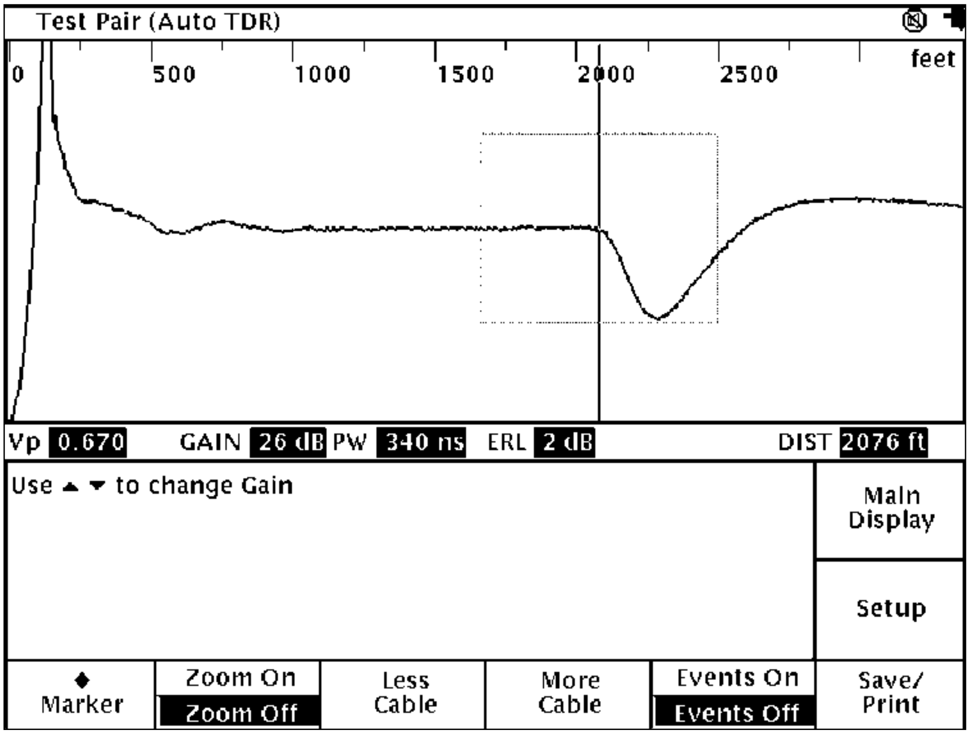


Figure 5-4. TDR waveform of solid short.

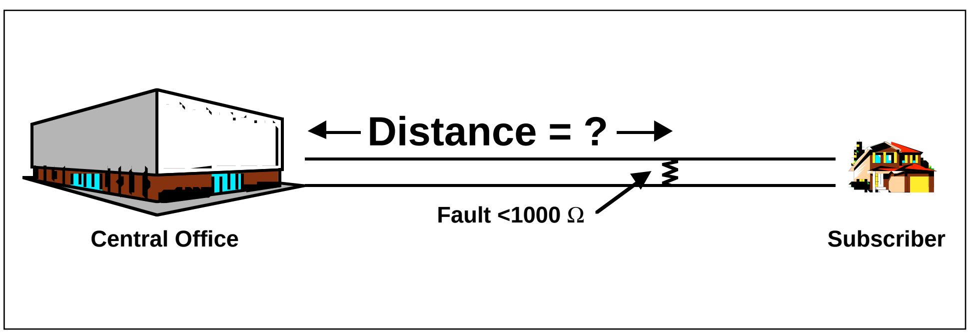


Figure 5-5. Low-resistance short (below 1000 Ω).

Low-Resistance Short

When measuring a fault that has a small resistance (<1000 Ω), known as a low-resistance short, the distance to the fault can not be calculated directly from the ohms measurement (see Figure 5-5).

If you were to simply convert the ohms measurement into a distance, the result would clearly be incorrect. For example, if you were to measure a 850 Ω fault between Tip-Ring (A-B), 25 Ω away, on 22 AWG (0.64 mm) copper cable, at 68° F (20° C), the calculation would be:

U.S. Units Example:

(25 Ω + 850 Ω) x 30.25 ft./Ω = 26,469 ft. {Incorrect!}

Metric Units Example:

(25 Ω + 850 Ω) x 9.22 m/Ω = 8,068 m {Incorrect!}

Use the ohmmeter to determine the approximate size of the fault (<1000 Ω or >1000 Ω), then determine which tool(s) would be appropriate for locating the fault.

Since the fault is under 1000 Ω, it's best to use either a TDR or a Resistance Fault Locator (RFL), commonly mis-referred to as a Resistance Bridge.

A TDR works well on resistive faults under 1000 Ω, provided there are no load coils present between the TDR and the fault. Remember, the TDR is not affected by temperature, and only very slightly by gauge changes, which makes it more accurate for pinpointing resistive faults. A low-resistance short on a TDR waveform also points in the downward direction (see Figure 5-6). The size of the downward spike will vary depending on the fault severity. The smaller the resistance, the larger the downward spike. As the fault approaches 1000 Ω, it will become increasingly difficult to identify.

A RFL measurement typically involves the use of a known good pair and requires strapping the far end of the cable. Since the RFL is calculating for the resistance, it's important to account for the correct cable gauge or diameter, and the temperature of the cable itself. Be certain to correctly connect the instrument to the cable under test, and confirm the strapping arrangement depending on the type of RFL configuration being used. In this example we will be measuring a fault between Tip and Ring (A-B), with a known good pair available. Also, be certain to test the known good pair to prove that it's not faulted as well. Do not assume that just because it's vacant, it's probably good (see Figure 5-7).

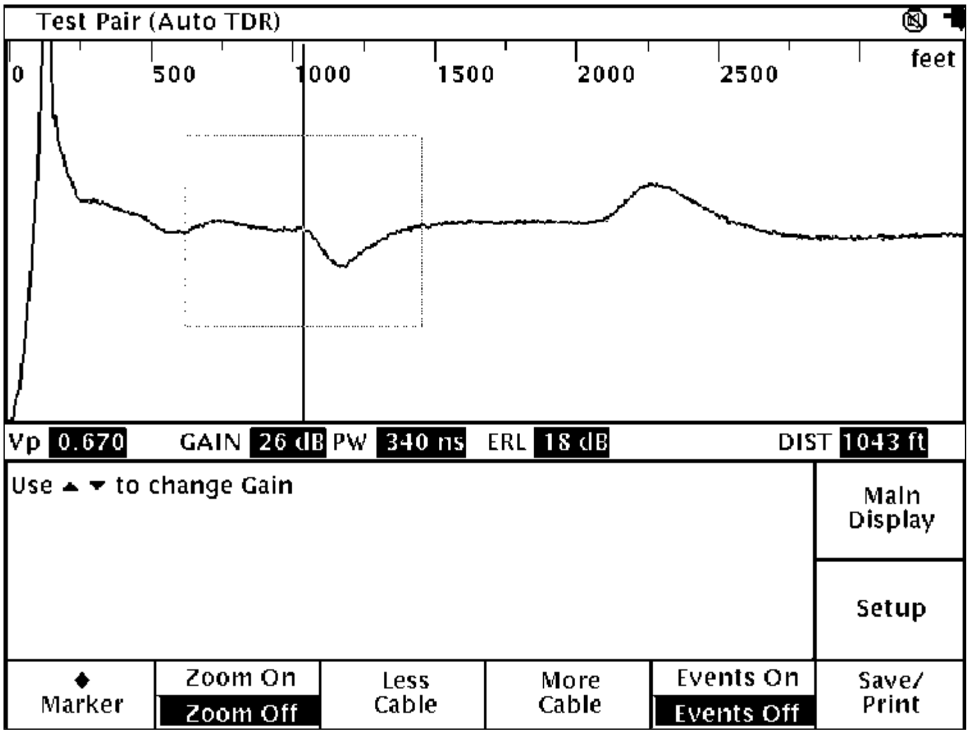


Figure 5-6. TDR waveform of low-resistance short.

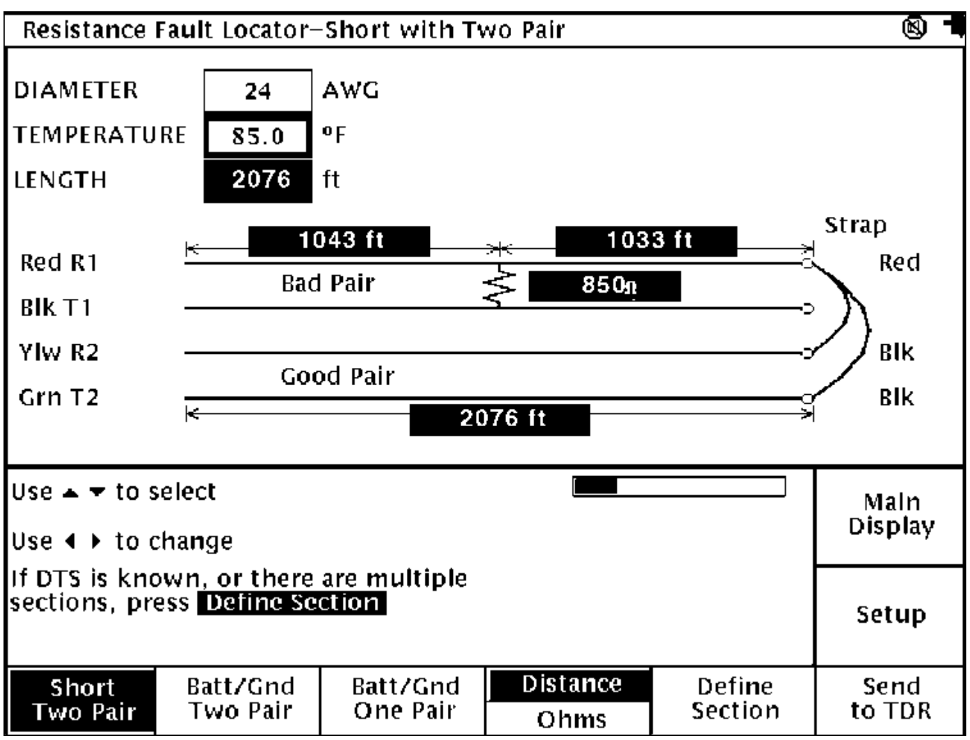


Figure 5-7. RFL for low-resistance short.

If there are no load coils between the instrument and the far end where the cable was strapped, it's always useful to compare the RFL and TDR measurements by pressing Send to TDR in RFL mode and then switching to the TDR to view the overlay (see Figure 5-8). This reduces the likelihood of an error in the RFL setup and helps compensate for any uncertainty in temperature or gauge settings. If the two measurements line up, the RFL settings were correct. If not, you may need to adjust them slightly to improve the RFL accuracy.

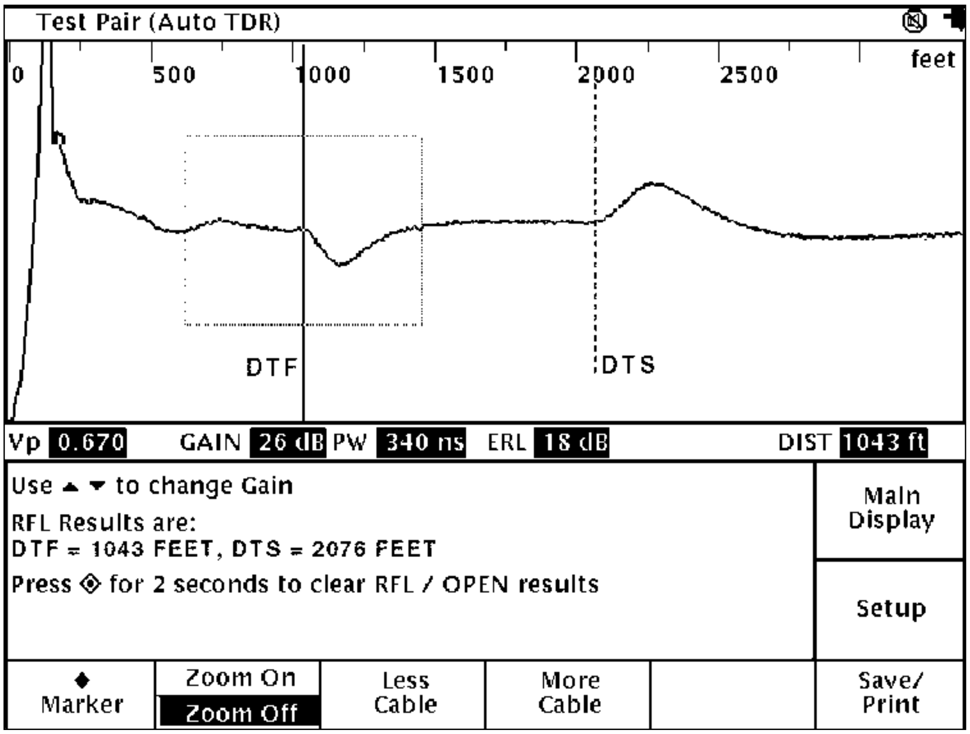


Figure 5-8. RFL and TDR comparison for low-resistance short.

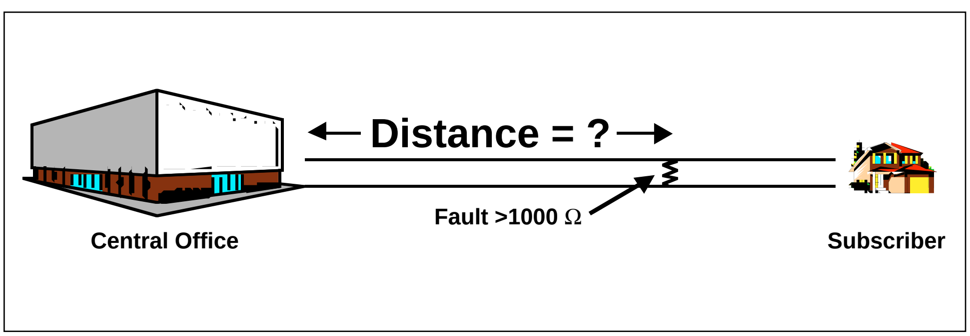


Figure 5-9. High-resistance short (above 1000 Ω).

High-Resistance Short

When measuring a fault that has a large resistance (>1000 Ω), known as a high-resistance short, the distance to the fault can not be calculated directly from the ohms measurement (see Figure 5-9).

If you were to simply convert the ohms measurement into a distance, the result would clearly be incorrect. For example, if you were to measure a 15 kΩ fault between Tip-Ring (A-B), 25 Ω away, on 22 AWG (0.64 mm) copper cable, at 68° F (20° C), the calculation would be:

U.S. Units Example:

```
(25 Ω + 15,000 Ω) x
  30.25 ft./Ω = 454,506 ft.
  {Incorrect!}
```

Metric Units Example:

```
(25 Ω + 15,000 Ω) x
  9.22 m/Ω = 138,531 m
  {Incorrect!}
```

Use the ohmmeter to determine the approximate size of the fault (<1000 Ω or >1000 Ω), then determine which tool(s) would be appropriate for locating the fault.

When the fault is known to be high resistance it's best to use a RFL, since the TDR will typically not detect faults that are over 1000 Ω. However, the TDR can again be used to adjust the RFL for temperature and gauge, if there are no load coils between the instrument and the far end of the cable where it's being strapped.

A RFL typically involves the use of a known good pair and requires strapping the far end of the cable. Since the RFL is calculating for the resistance, it's important to account for the correct cable gauge or diameter, and the temperature of the cable itself. Be certain to correctly connect the instrument to the cable under test, and confirm the strapping arrangement depending on the type of RFL configuration being used. In this example we will be measuring a fault between Tip and Ring (A-B), with a known good pair available (see Figure 5-10). Also, be certain to test the known good pair to prove that it's not faulted as well. Do not assume that just because it's vacant, that it's probably good.

If there are no load coils between the instrument and the far end where the cable was strapped, it's always useful to compare the RFL and TDR measurements by pressing Send to TDR in RFL mode and then switching to the TDR to view the overlay (see Figure 5-11). This reduces the likelihood of an error in the RFL setup and helps compensate for any uncertainty in temperature or gauge settings. If the two measurements line up, then the RFL settings were correct. If not, you may need to adjust them slightly to improve accuracy.

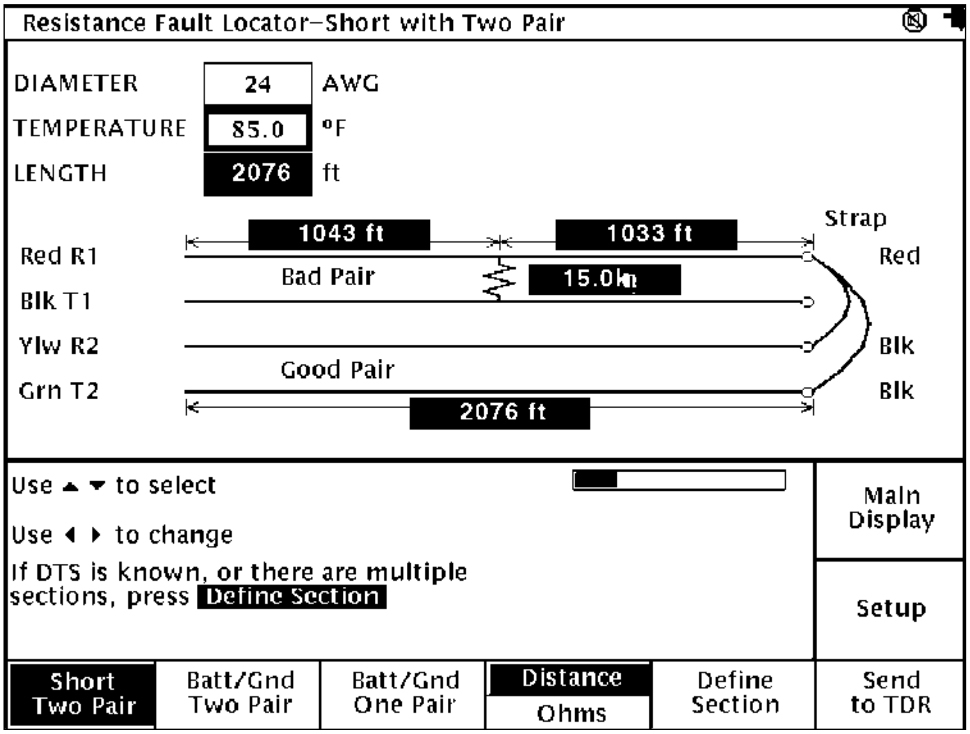


Figure 5-10. RFL for high-resistance short.

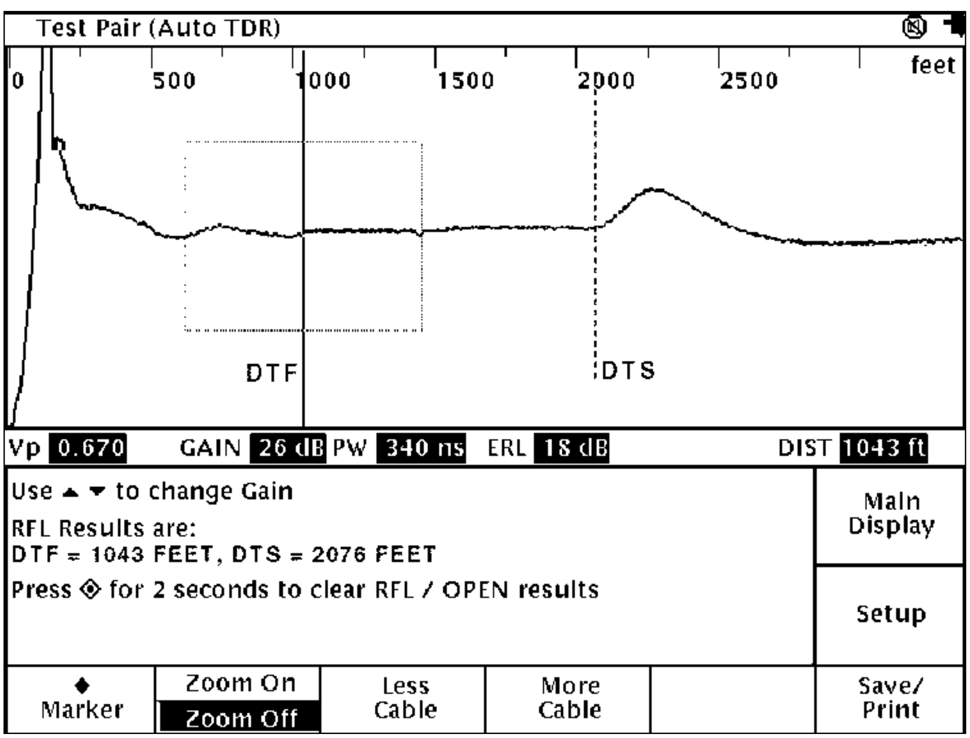


Figure 5-11. RFL and TDR comparison for high-resistance short.

Accounting for Load Coils

If load coils are present between the test instrument and the fault or strap, it's necessary to account for their increased resistance. Each load coil adds approximately 4 Ω to the resistance measurements. By counting the load coils, you can quickly compensate for their additional resistance (see Figure 5-12).

Since each load coil adds approximately 4 Ω of resistance, you can simply subtract this amount in the Ohms-to-Distance calculator (see Figure 5-13).

This same principle applies to RFL measurements. In the RFL screen, switch to display the measurements in Ohms using the Distance/Ohms key. Note how many ohms are between the instrument and the fault, commonly referred to as the Distance to Fault (DTF), and then use the Distance-to-Ohms calculator to subtract the appropriate number of ohms for the load coils.

Conclusion

High resistive faults are quite common and require more effort to pinpoint. However, by using a combination of an ohmmeter, a RFL, and a TDR, you can improve the accuracy of your measurements and reduce the amount of time required to locate the fault. On loaded lines, a load coil counter can be used to compensate for the additional resistance of each load coil.

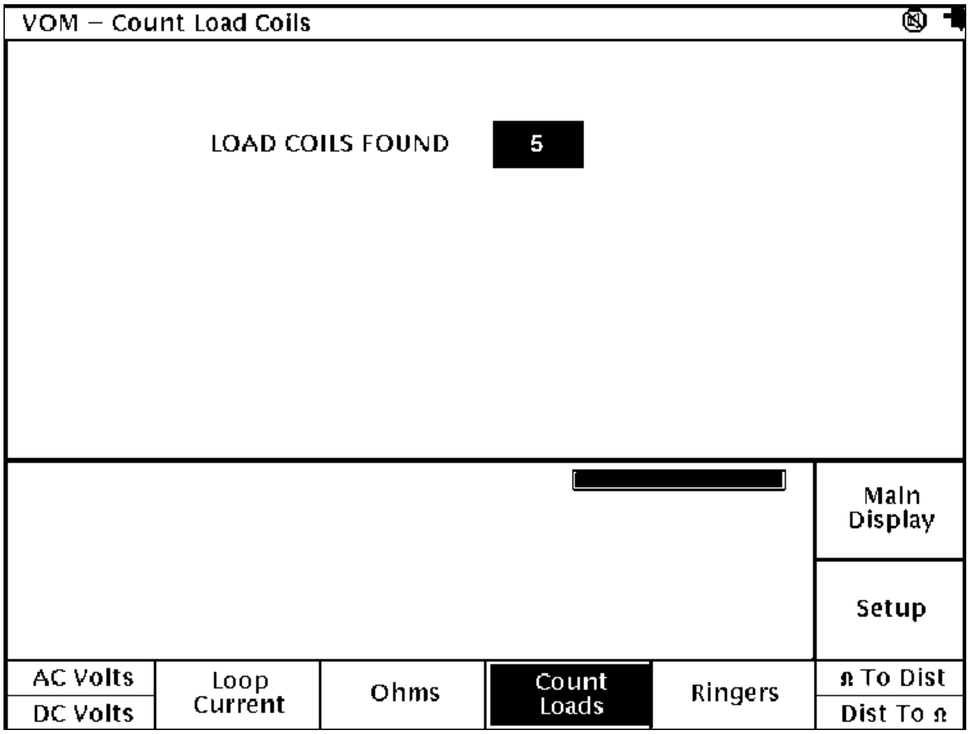


Figure 5-12. Load coil counter.

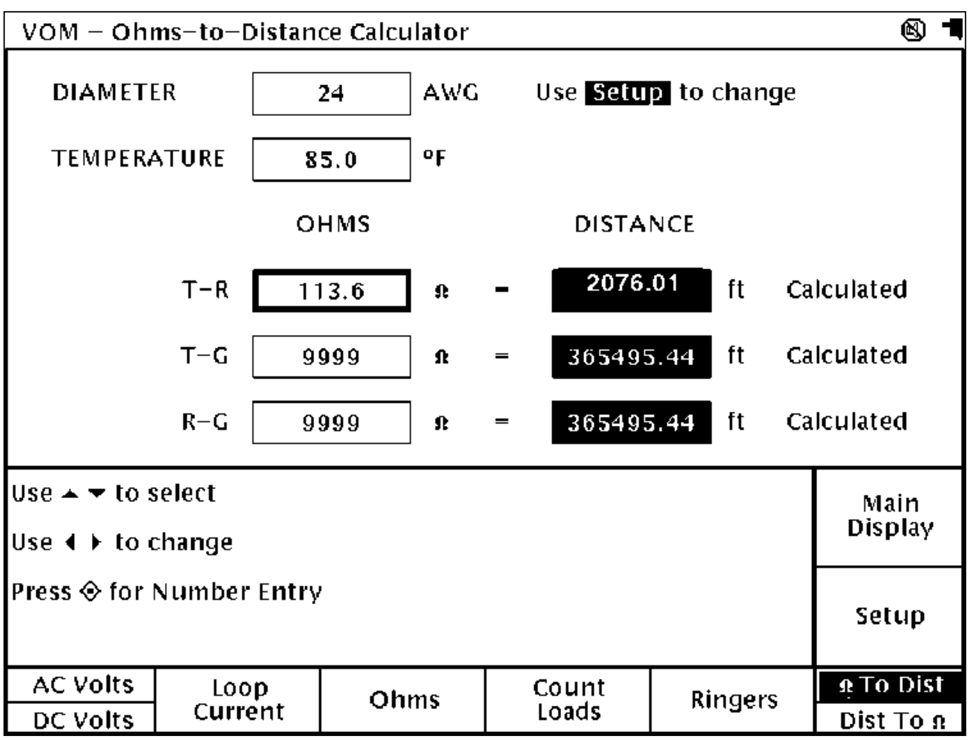


Figure 5-13. Distance to solid short, accounting for load coils.

Chapter 6: Load Coils

Introduction

With the advent of digital transmissions (e.g., T1/E1, ISDN, and xDSL) over telephone lines, some of the analog POTS requirements must fall by the wayside for proper transmission. One of these, the load coil, must be located and removed in order to transmit these high-frequency signals.

A load coil is typically either a 66 mH or 88 mH (millihenry) inductor that is used in analog (voice) telephone systems. They are used because, over long cable lengths, higher-frequency signals are attenuated due to an increase in capacitance. To counteract this capacitance, load coils are spaced along the line. This spacing creates a “tuned” circuit for voice frequencies (300 to 3000 Hz). Figure 6-1 shows a graph of the relative level of power for loaded and unloaded circuits.

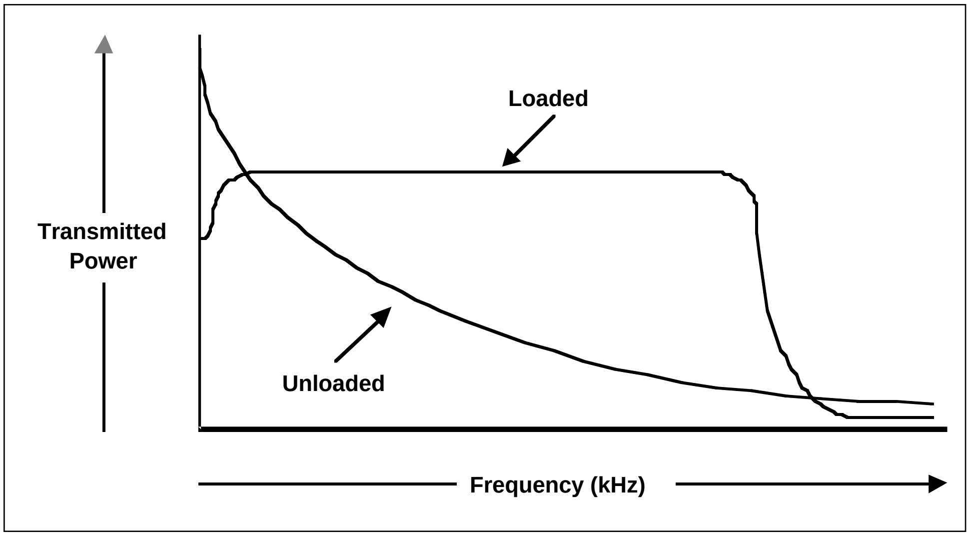


Figure 6-1. Frequency characteristics.

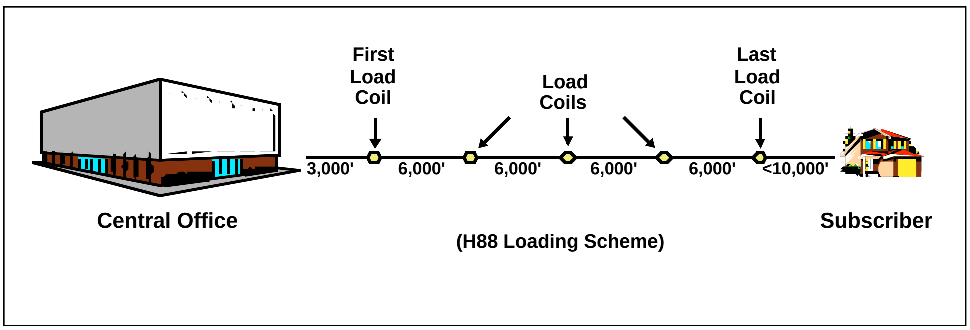


Figure 6-2. Loading scheme.

As illustrated, a higher level of power is transmitted at voice frequencies through the cable with load coils. These coils must be properly spaced for the system to work. In the United States, coils must be used on cables that are over 18,000 feet (5.5 km) in length. Internationally, this might vary based on loss specifications of the system. In an H88 loading scheme, the first load coil is at approximately 3,000 feet (915 m) from the central office or exchange (see Figure 6-2). Subsequent load coils are spaced approximately 6,000 feet (1,830 m) apart, although a coil may not be necessary over the last 10,000 feet (3 km) to the subscriber.

Unfortunately, loaded analog systems and digital systems are not compatible. As seen in Figure 6-1, high frequencies are more heavily attenuated when there are load coils in the line. You cannot pass digital and high-frequency signals through the coils. (For more detail on frequency and loss, refer to ***Chapter 12: Transmission Characteristics*** regarding transmission characteristics.)

Counting Load Coils

Using a load coil counter will help identify approximately how many load coils are on the line. During deployment of digital services, it's important to remember that any load coils are unacceptable. Simply use the load coil counter to check for one or more load coils, and then use the TDR to locate the first one (see Figure 6-3).

Locating Load Coils

The TDR is the only piece of test gear available that can simply and accurately locate load coils. A TDR sends high-frequency pulses down the line, and senses reflected energy. The technique is much like radar. Because the pulses contain high-frequency energy, they cannot pass through a load coil. The coil (shown in Figure 6-4) looks like a large increase in cable impedance and it's similar to the open circuit waveform (shown in Figure 6-5).

Notice the shape of the load-coil reflection has a more rounded appearance than an open and it appears at about 6,000 feet (1,830 m). Generally, you should see the first load from the central office at about 3,000 feet (915 m) and then subsequent load coils at approximately 6,000 foot (1,830 m) intervals for H88 loading, although you will only be able to see the first one. This is particularly important for those analog systems that are not operating properly. If there are complaints of high-frequency voice attenuation or problems with touch-tone phone dialer dropout, check for missing load coils.

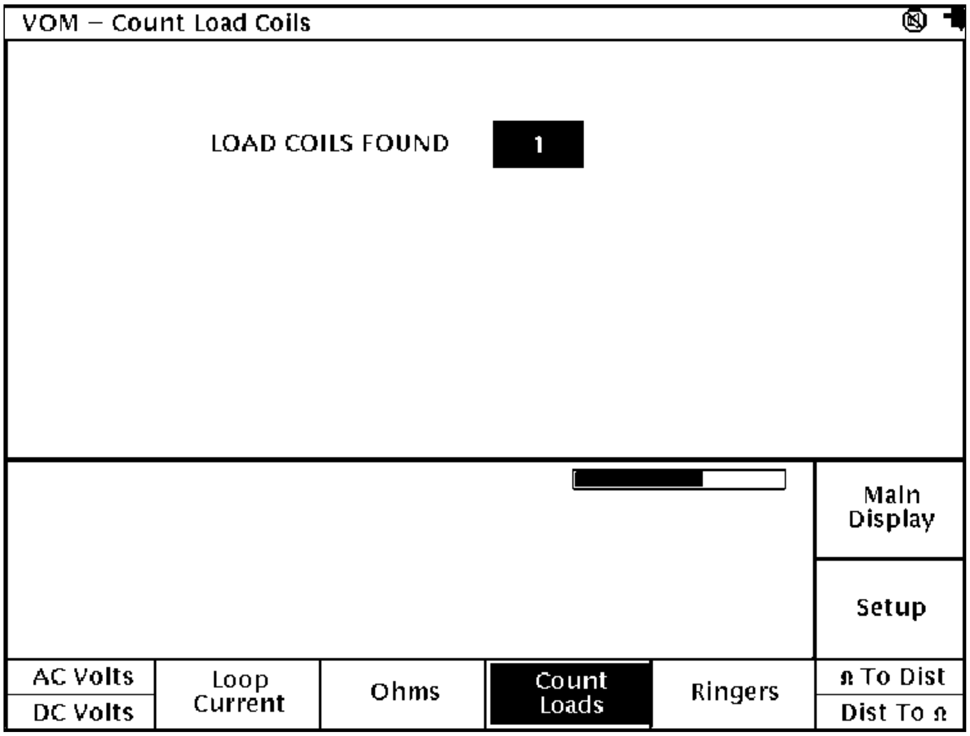


Figure 6-3. Counting load coils.

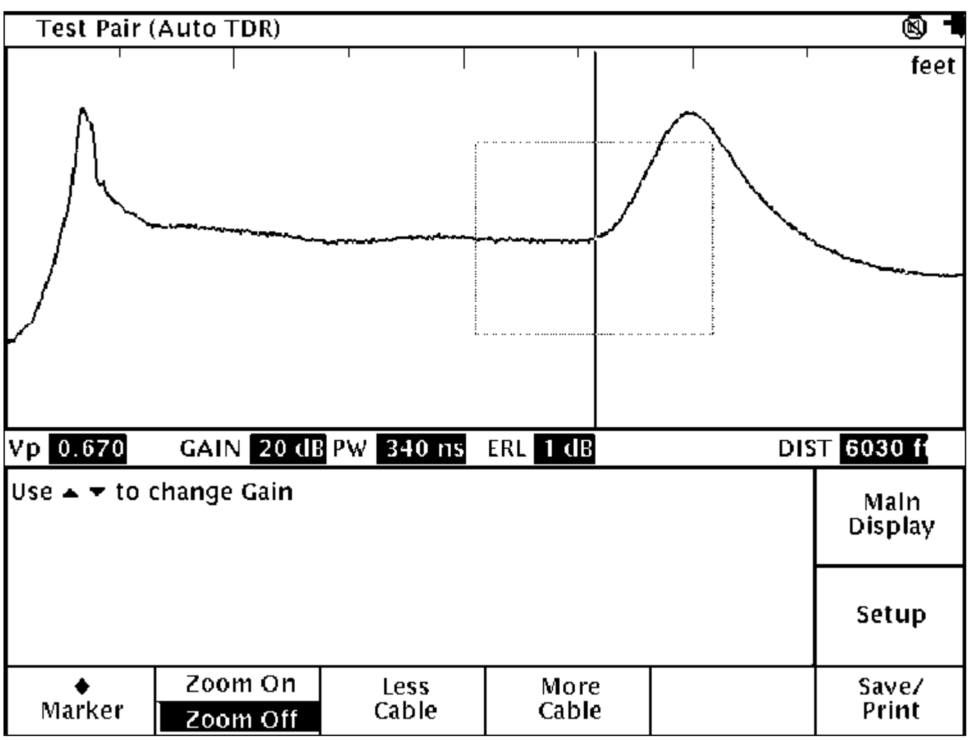


Figure 6-4. Load coil TDR.

The TDR can also be used to compensate for other test equipment, particularly the resistance fault locator (RFL). Load coils will create an inaccuracy in the RFL, as they add about four ohms of resistance to the measurement. For example, four ohms equates to about 497 feet (152 m) on 19 AWG (0.90 mm) wire. This means that the RFL measurement will measure almost 500 feet (152 m) longer for each load coil in the circuit. If you suspect an error in your RFL measurement, use a load coil counter to identify how many there are and a TDR to locate them. Then compensate for the error.

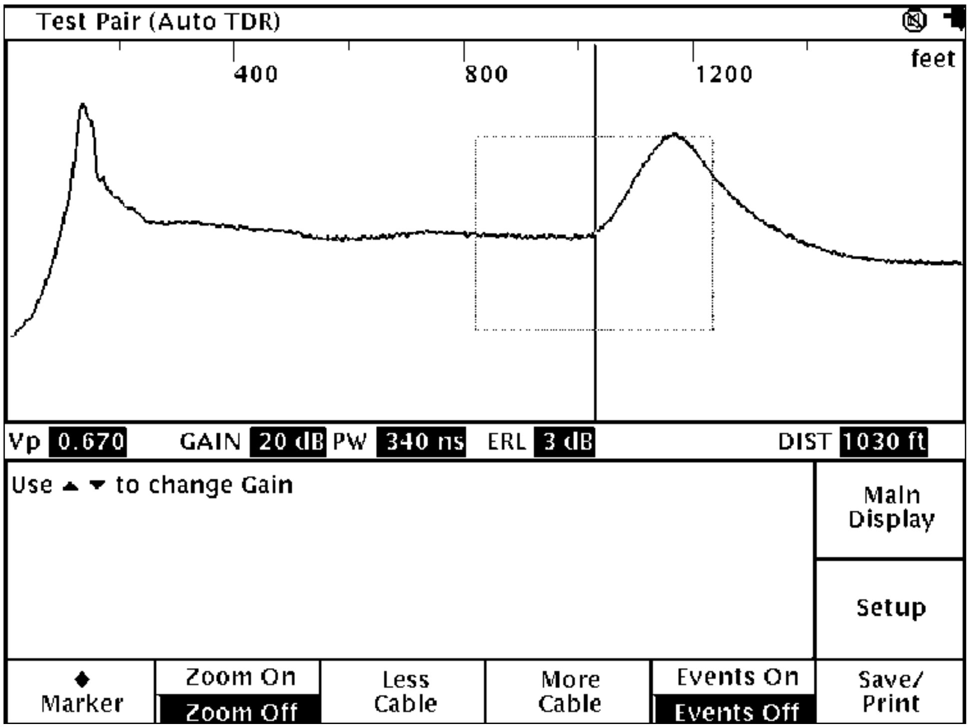


Figure 6-5. Open circuit TDR.

Conclusion

Load coils are a requirement for some analog (voice) telephone systems. Missing load coils can cause problems for subscribers in analog systems. However, they are a problem for high-frequency systems such as T1/E1, ISDN, and xDSL. And, when using a resistance fault locator, coils will cause measurement inaccuracy.

The load coil counter and TDR are invaluable tools for identifying and locating load coils to restore proper service to your customers.

Chapter 7: Bridged Tap and Lateral

Introduction

A bridged tap and lateral is a circuit that has been used in analog (voice) telephone systems for many years. The bridged tap itself is a mechanism for attaching an additional circuit to the normal distribution cable. It's effectively a splice with a two-wire input and a four-wire output. One leg allows the normal distribution path to continue further along, the other leg is attached to the lateral. A lateral is defined as any portion of a cable pair that is not in the direct path between the user and the central office (see Figure 7-1).

Problems with Laterals

Various service and maintenance problems can occur because of laterals. With an increase in digital services, locating bridged taps and their associated laterals has become more critical because they are a detriment to such services. Even though most laterals are relatively short in length, they create big problems on voice circuits that have been converted to digital. A lateral creates a second path for digital signals transmitted on the same circuit. The digital signals travel down the lateral and are reflected by the open end. The reflected signals, or echoes, travel back toward and onto the main circuit, where they mix with "good" digital signals. These echoes effectively render the data useless. For a digital circuit to operate properly, the laterals must be removed.

Laterals on analog (voice) circuits can also create problems on the main distribution cable. For example, if there's a fault on a given lateral, it can exhibit itself as poor service on the distribution cable. Again, it's important to be able to locate all laterals, so proper cable troubleshooting can take place when service problems occur.

Finally, unknown laterals can also cause inaccuracies in other test equipment. An example of this is the open meter. An unknown lateral adds capacitance to a cable pair and leads to a measurement error where the pair under test measures longer than it actually is.

Lateral Location

The open (capacitance) meter is the most common tool for determining the length of an open cable. Unfortunately, the open meter will only indicate the total amount of cable on the pair, including all bridged taps and laterals (see Figure 7-2).

A TDR is the only tool that will locate bridged taps and laterals. It's helpful if you can compare capacitance and resistance length measurements to determine the length of a lateral. Open meters are able to tell the estimated length of a lateral. Once this is determined, connect the TDR to the cable and look for the characteristic bridged tap/lateral waveform

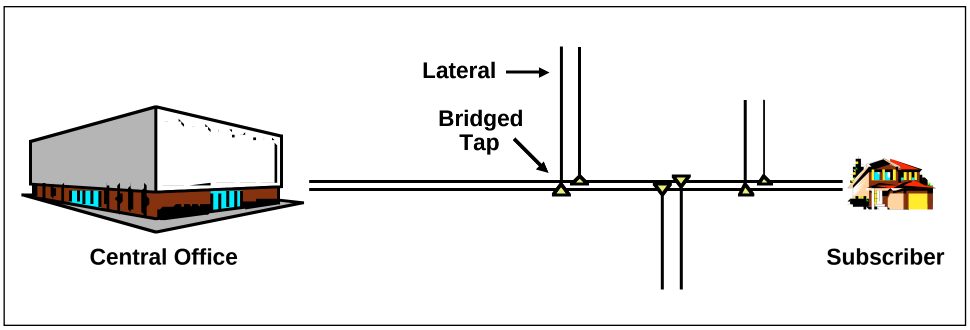


Figure 7-1. Bridged taps and laterals.

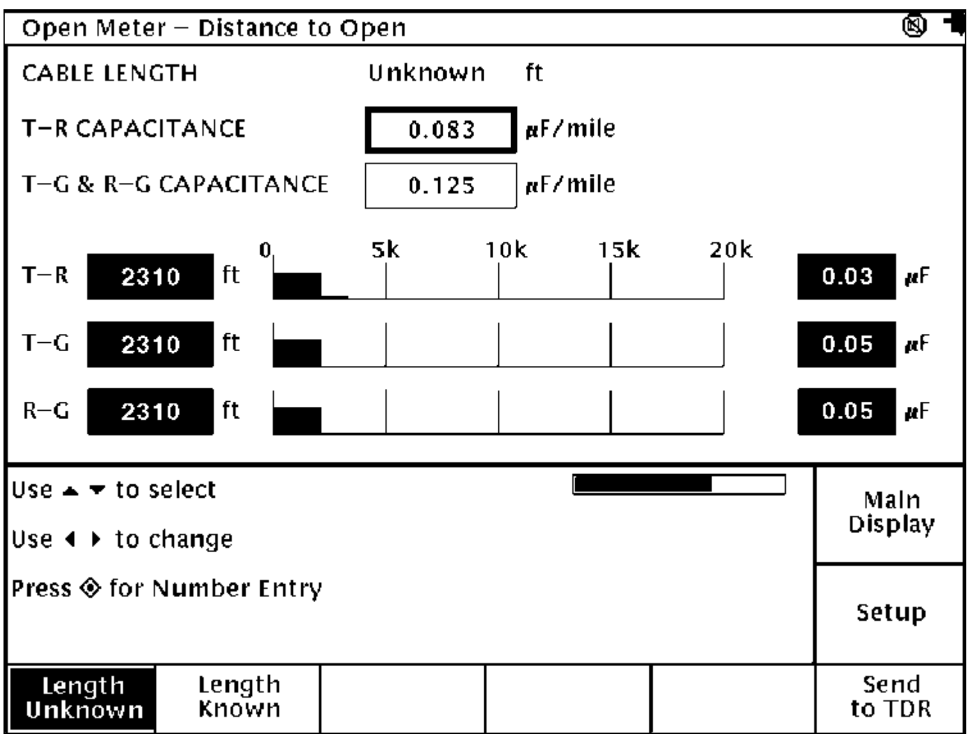


Figure 7-2. Open meter results with bridged taps.

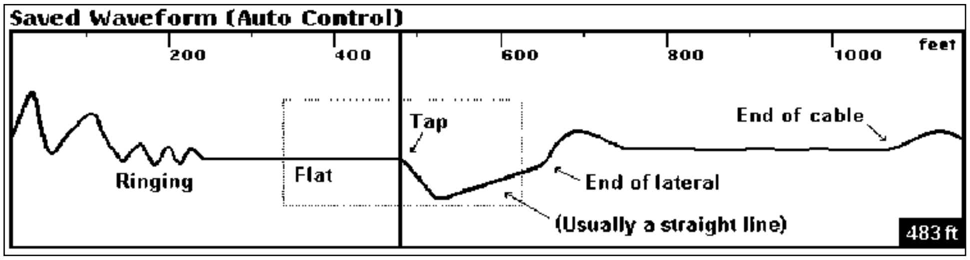


Figure 7-3. Bridged tap and lateral example.

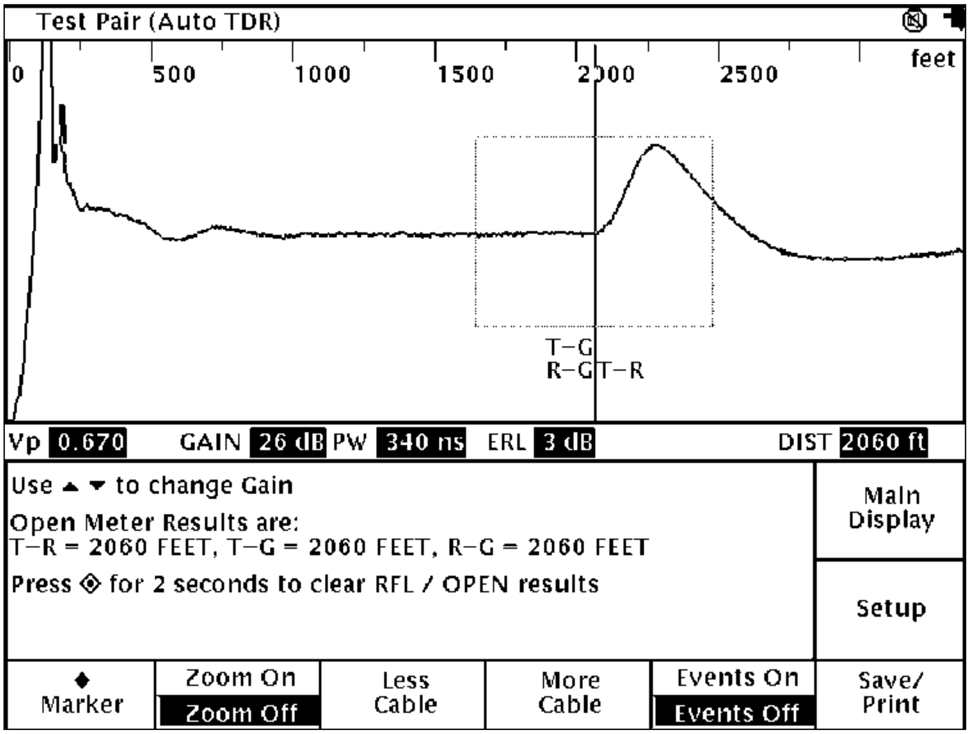


Figure 7-4. Open cable with no taps.

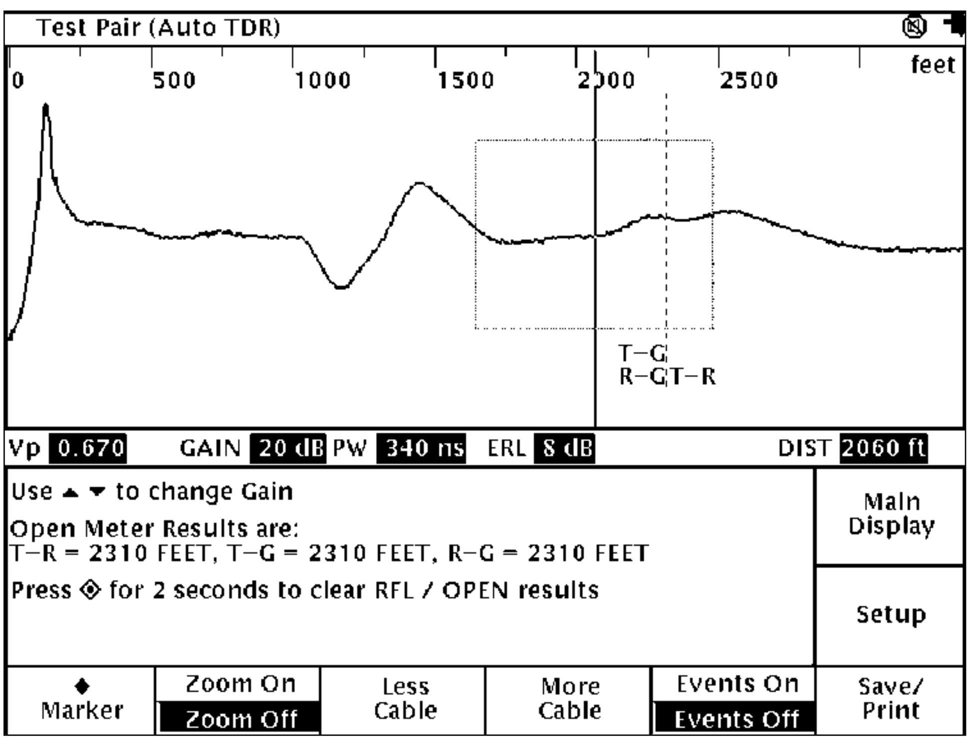


Figure 7-5. Open cable with one tap.

with a lateral of the anticipated length. An example of a TDR waveform for a bridged tap and lateral is shown in Figure 7-3.

The classic tap and lateral waveform looks very similar to a TDR waveform of water in the cable (refer to ***Chapter 10: Water*** for more detailed information). The only noticeable difference is that the reflection from the lateral itself is a straight line, not curved as in a water reflection.

Figures 7-4 and 7-5 show an untapped open section and a tapped section (tap at 1032 feet), with the corresponding open meter results sent to the TDR for direct comparison. Notice how the open meter measurement is affected by the introduction of a lateral. Also note how the open end at 2060 feet is distorted on the tapped section. This is because some of the TDR signal was lost going through the tap and lateral. An ideal way to see these waveforms simultaneously is to use the TDR's test and reference ports for a good pair/bad pair comparison.

An unfortunate characteristic of laterals is that where you find one, you will likely find others. Similar to the echoing problem of laterals and digital transmission, TDR waveforms are very much affected by multiple laterals. Waveform interpretation becomes very difficult with two or more laterals on the pair under test.

Figure 7-6 shows a pair similar to Figure 7-5, except with an additional tap at approximately 1650 feet. Note that the open end at 2060 feet is almost not visible due to the energy lost through the two laterals. When multiple laterals occur, it's best to locate the first tap, get access at the splice (or beyond), and then locate the next tap. Proceed until all of the taps have been located.

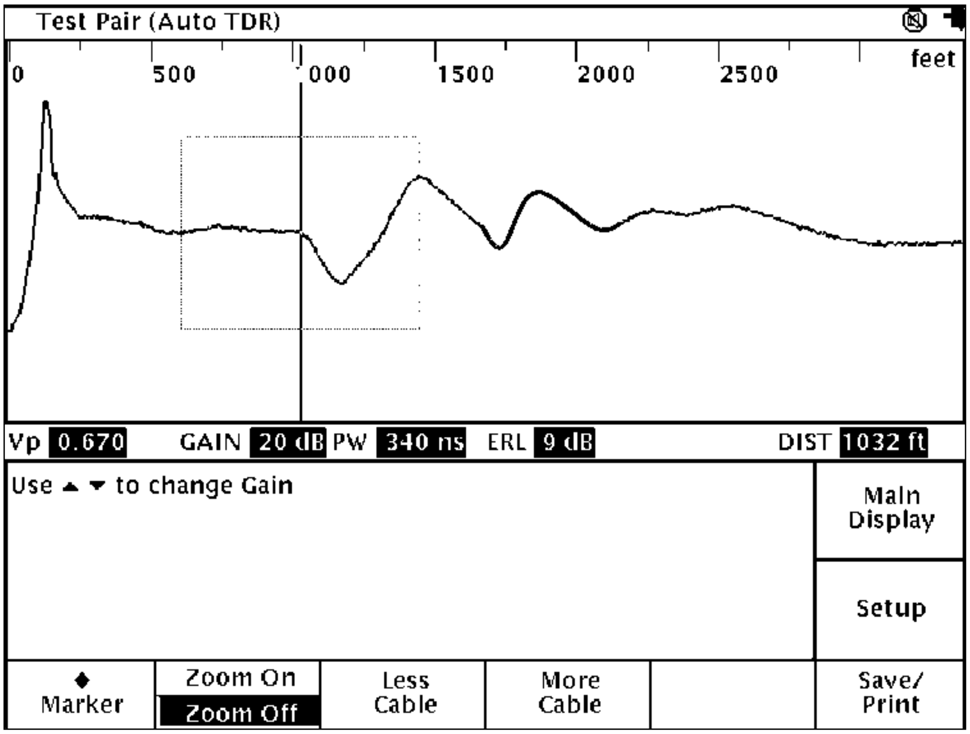


Figure 7-6. Open cable with multiple taps.

Conclusion

Bridged taps and laterals have been used in analog (voice) telephone systems for many years. However, they are a problem for digital services such as T1/E1, ISDN, and xDSL. Locating and removing bridged taps and laterals is essential for maintaining quality digital service. Refer to ***Chapter 17: Upgrading Your Cable Plant for Digital Services*** for more detailed information regarding this subject.

Chapter 8: Split Pairs

Introduction

Split pairs are probably the most difficult problem in telephone cable systems. They are also one of the most time-consuming faults to locate. The customer will likely be moved to a different pair to solve the immediate problem, leaving the split until it's necessary to reclaim it. When all of the pairs in the system are consumed, the split must be repaired for proper operation.

In many installations, split pairs represent the single largest opportunity to reclaim pairs for use. Fixing a split is much cheaper than a work-around or a cable replacement. Using an ID tone and a Time Domain Reflectometer (TDR) is one of the easiest methods for quickly and reliably locating the split.

Cause and Symptoms

Splits are caused by people. They are almost always located at a splice point and occur when two tips (Leg A) of the same color are inadvertently spliced together (see Figure 8-1).

Splits usually lead to an unacceptable amount of crosstalk to the customer. This is due in large part to the susceptibility of a cable to stray signals when the pair becomes untwisted. In effect, the wire acts as an antenna.

A common way to solve a crosstalk problem due to a split pair is to cut to clear. That is, to splice the customer into a "good" pair. Another common technique is to correct the problem at a splice further down the cable. This is called a resplit or corrected split. This is the simplest solution but, of course, it does not solve the problem. Ultimately, the section must be repaired.

Fault Location

Some pieces of test gear might not be able to identify if a pair is split. For example, an ohm (resistance) meter is ineffective because resistance is unaffected by a split. The ohmmeter will measure the approximate cable length because the resistance is basically unchanged. An open (capacitance) meter will show that there's a problem and it can indicate the length of the split. However, it cannot locate where the split has occurred.

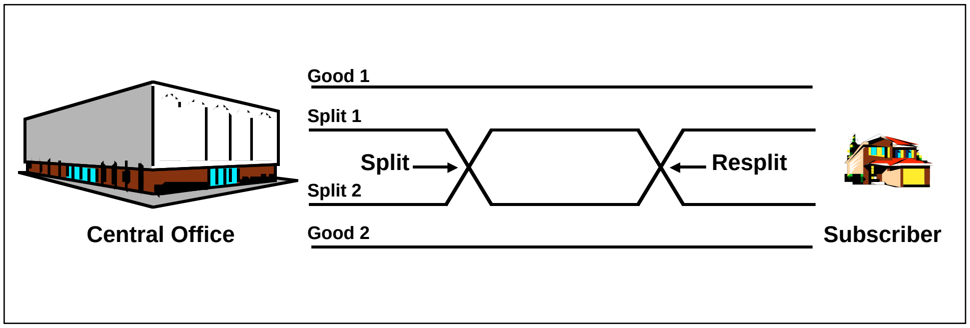


Figure 8-1. Split and resplit.

Using a 577.5 Hz identification (ID) tone on the known split pair will help identify which pair it's split with. Usually it's located within the same binder group. Next, use a TDR since it's the only piece of test equipment that can locate splits and resplits.

There are two ways to locate them with a TDR.

Crosstalk Mode

The simplest method is to perform a TDR crosstalk test. This is done by connecting both split pairs to the TEST and REFERENCE ports of the TDR. In this test, the TDR sends a signal down the test pair and samples reflections from the reference pair. Typically, the waveform will be flat, except where the crosstalk occurs at the split. At the crosstalk point, there will be a sharp spike at the location of the split. This spike may be positive or negative, depending on how the test leads are connected to the TDR (see Figure 8-2).

Pair Comparison Mode

Another technique is to set the TDR in pair comparison mode and compare one of the split pairs to a known good pair. (Comparing the two split pairs will give no indication of the fault.) The split pair will show a larger reflection at the splice where the split occurs. In Figure 8-3, the split is at 1032 feet (315 m) on the top waveform. This is also where the higher crosstalk occurs. Also note that if you can see the open at the far end of the cable, the distance for a split cable will measure shorter than a good cable in the same bundle. The split section has lower capacitance, allowing the signal to travel faster. Since the signal travels faster, the TDR interprets this as a shorter section.

If the section also contains a resplit, the easiest method for locating it is to find the split first, then locate the resplit using one of the two methods described previously.

Conclusion

Split pairs are a common, but difficult problem in telephone cable circuits. When split pairs are encountered they should be fixed, rather than ignored. Few test tools can locate splits in the system. Locating splits is easy with an ID tone and a TDR. With a minimal amount of training, you can use these tools to locate splits in a matter of seconds.

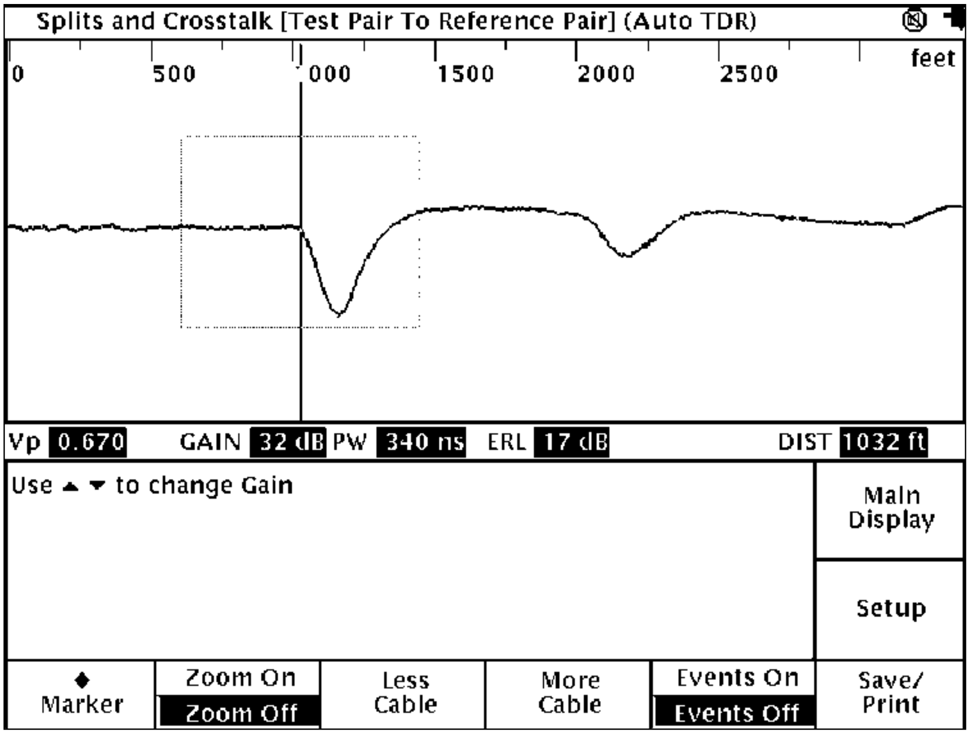


Figure 8-2. Split in crosstalk mode.

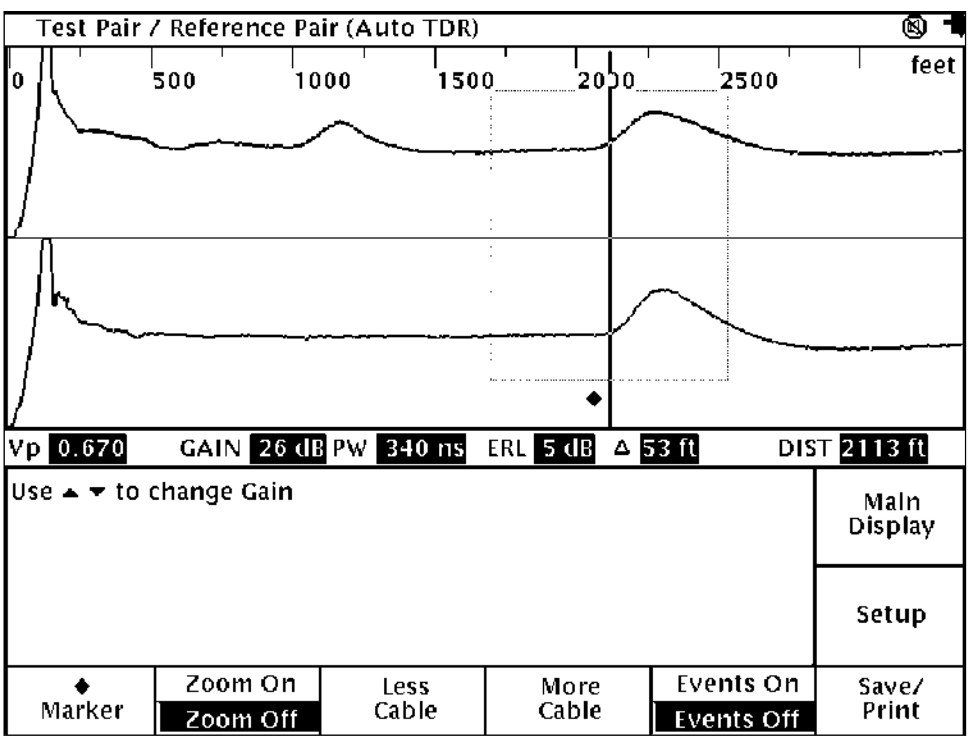


Figure 8-3. Split in comparison mode.

Chapter 9: Ringers

Introduction

Determining the wiring configuration for the telephone ringing circuit is essential for proper service. The original wiring configuration depended upon which type of service the customer was receiving (Dedicated vs Multi-Party Line).

REN

The telephone ringer is measured in standard units of 1.0 for each full ringer equivalent on the line. This value, known as Ringer Equivalence Number (REN), will vary depending on the number and type of phones connected to the pair. Older C4 or type 5200 phones have a REN of 1.0 µF, while other phones may have as little as 0.47 µF per REN. Newer digital and cordless phones typically measure between 0.1 to 1.0 REN for each phone. A maximum of 5 REN is allowable. If there are more than 5 REN, the ring voltage might not be sufficient enough to actually ring the phones.

When the telephones are connected properly between the pair for a dedicated line, you will see 0.1 to 5.0 REN between Tip and Ring (A-B), and 0 REN between each side to ground (see Figures 9-1 and 9-2).

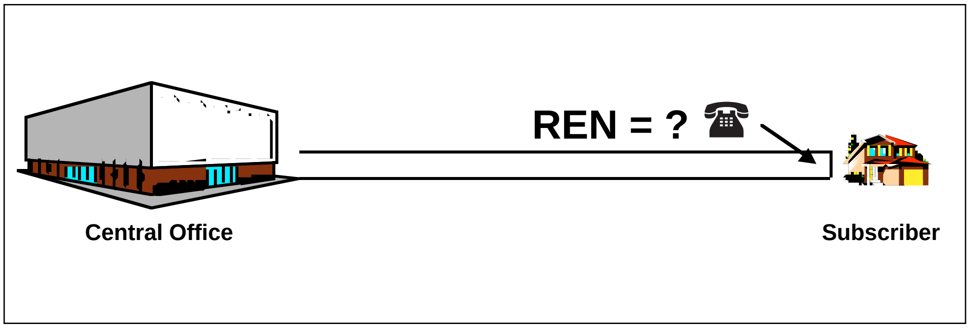


Figure 9-1. Ringer between pair.

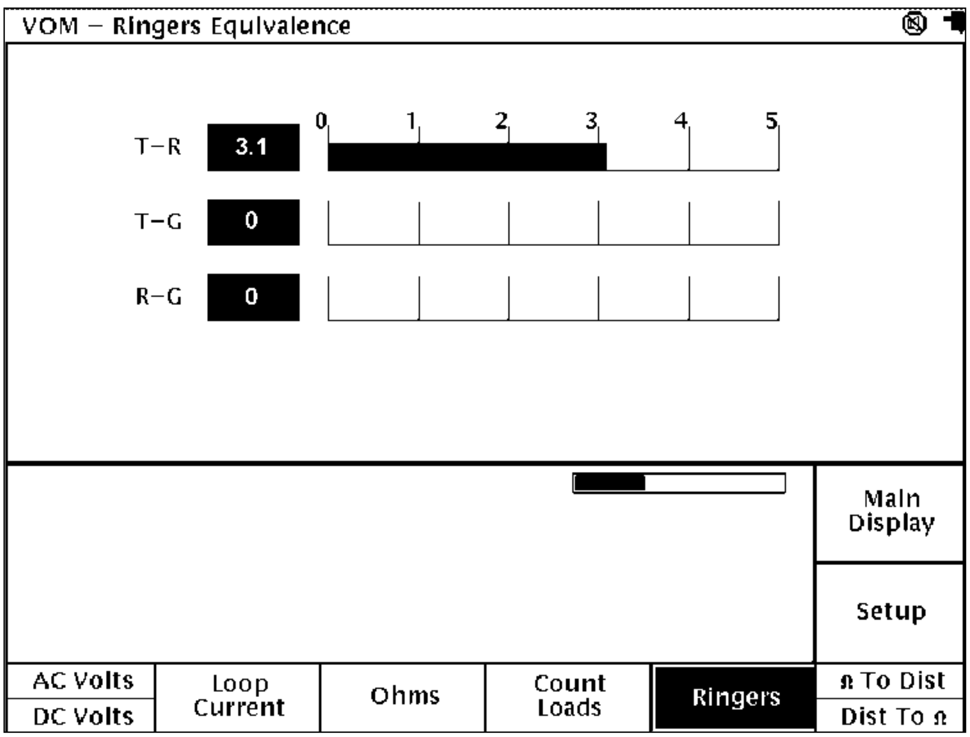


Figure 9-2. Ringer display with ringers between pair.

Occasionally the ringers will be wired from either side to ground, rather than across the pair (see Figure 9-3). This might be correct for a multi-party line, but if the subscriber has been assigned a dedicated line the problem will need to be corrected (see Figure 9-4).

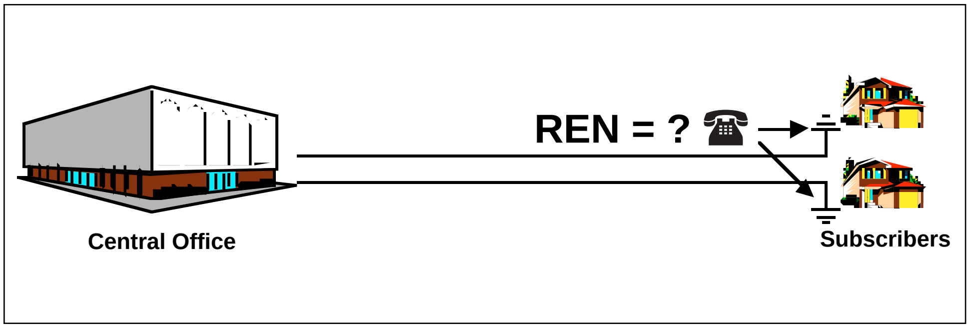


Figure 9-3. Ringers between ground.

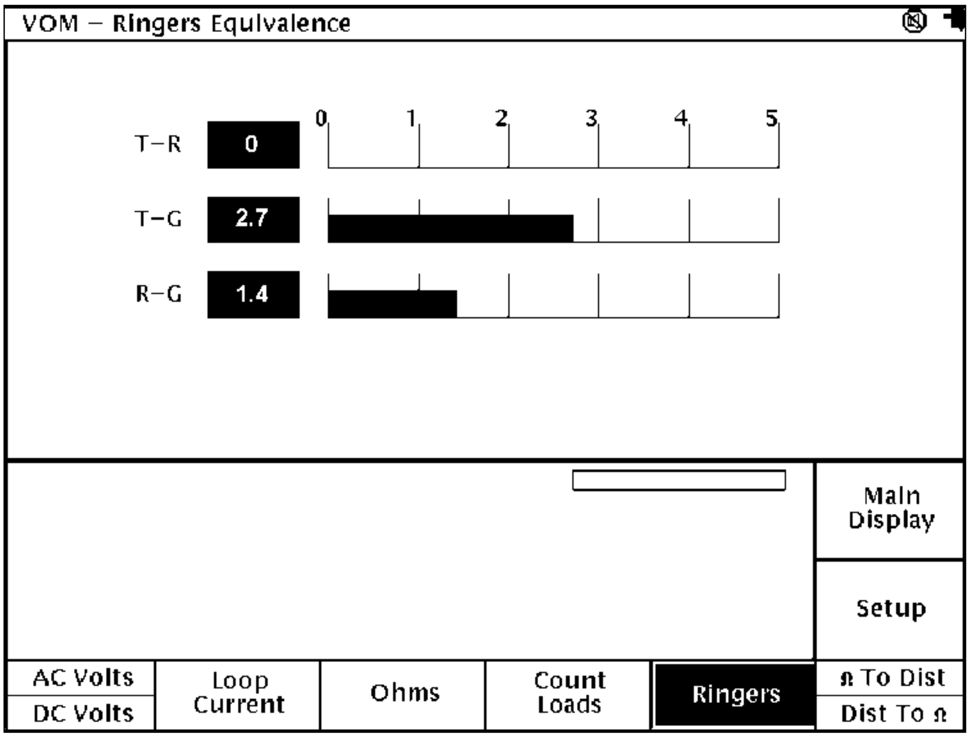


Figure 9-4. Ringer display with ringers between ground.

Conclusion

Determining the appropriate ringer (REN) configuration is important for proper service. Since there are a variety of phones available today, it's impossible to determine exactly how many phones are connected by looking at the REN measurement. Remember, it's not the exact number of phones which is important, but rather how they are connected.

Chapter 10: Water

Introduction

Despite many precautions to keep it out of telephone cabling, water in the cable system is probably the most common cause of faults in the system. There are many types of faults induced by water, but probably the most common fault is the high-resistance short.

The symptoms of water in the cable or in a splice will vary over time. Typically, the first symptom a customer will hear is noise on the line. This is because a tiny bit of current is leaking from the Tip (Leg A) to the Ring (Leg B) in the pair. From a technician's viewpoint, the pair will have a high resistance fault when checked with an ohmmeter. If the problem is only a singular wet splice, on the Tip side (Leg A) for instance, the pair will appear unbalanced. Over time, if the problem is allowed to persist, the customer might not get a dial tone.

Locating a Wet Section

A wet cable section typically affects multiple cable pairs (see Figure 10-1). When testing a vacant or inactive pair, it's not uncommon to find foreign voltage on it from other active pairs in the cable. The presence of foreign battery will cause most test methods, such as an open (capacitance) meter or ohmmeter, to fail or give inaccurate results. In this case, a TDR is the only piece of test equipment capable of locating the water causing the fault.

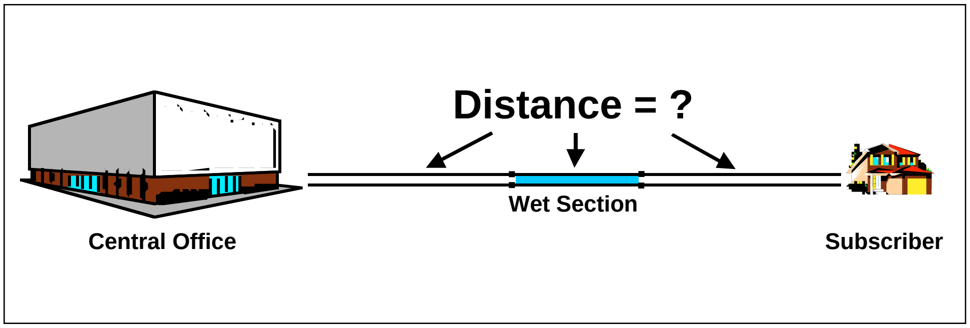


Figure 10-1. Wet section.

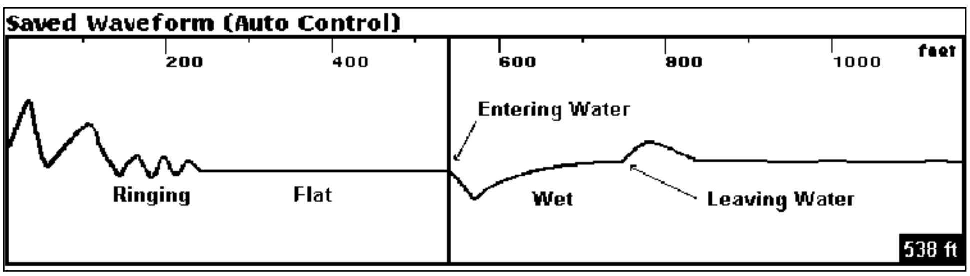


Figure 10-2. Classic wet cable TDR waveform.

Figure 10-2 shows a classic wet cable TDR waveform. It has three key elements. First, there's a downward dip where the cable enters the wet section. Second, the wet section is usually curved slightly and might also be noisy (it's not really noise, but simply an irregular impedance which causes an uneven waveform through this section of the cable). Finally, there's an upward rise at the end of the wet section where the cable leaves the water.

It's important to note that water attenuates a TDR signal very quickly. A long length of water may prevent you from seeing the end of the wet section. The waveform shown here is an ideal case.

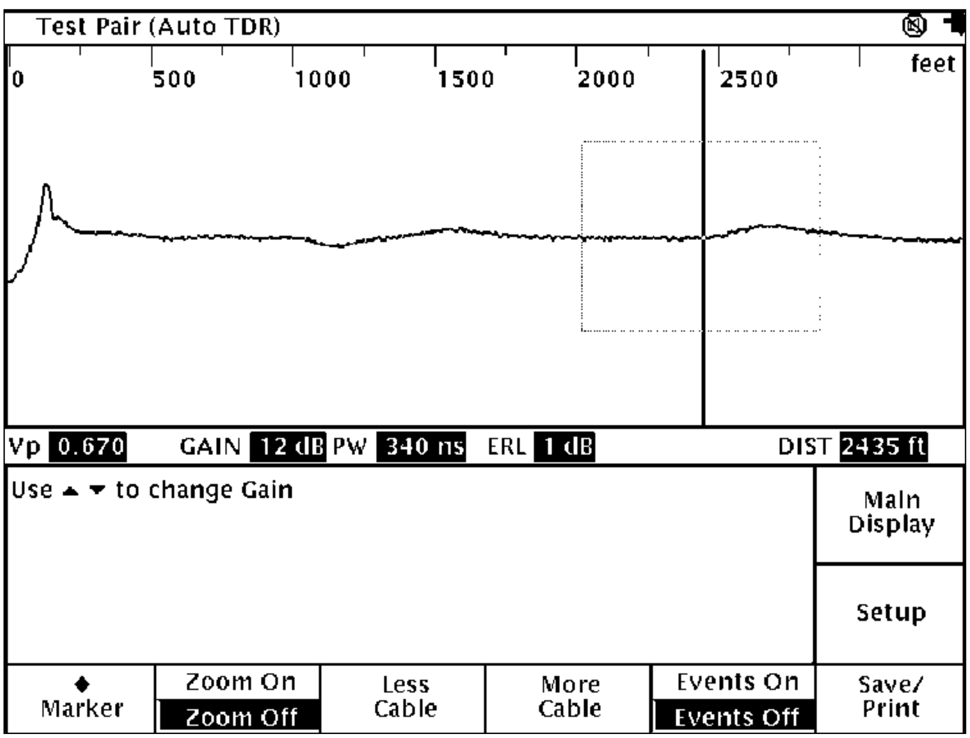


Figure 10-3. TDR waveform of water.

Figure 10-3 shows a real TDR waveform of water. In this case, there was water in a splice which has resulted in a large reflection at the splice and a wet section of aircore PIC following. It's a little difficult to see at first, but by increasing the gain it becomes much more obvious as shown in Figure 10-4.

Now it's much easier to see the classic downward dip after the splice with the uneven waveform through the wet section. You can see the upward reflection where the cable leaves the water at about 1300 feet. You can also clearly see the end of the cable out past 2400 feet.

As stated earlier, water attenuates the TDR signal. It also has the effect of "slowing down" the TDR signal. The water changes the velocity of propagation (V_p) through the wet section, which makes it difficult to measure the actual length of affected cable. If a section is wet, and doesn't have any foreign voltage, the open (capacitance) measurement will also indicate the section is longer than its actual length. The water in the cable significantly increases the amount of capacitance in the wet section.

It's apparent from the display (Figure 10-4) that the wet section begins at 1022 feet, but how do we calculate the total length that's affected? It's actually very easy. As an example, from the cable map, the total length should be 2380 feet. We can measure both dry portions of the cable and infer the result. We've measured the near end, so now we can measure the far end simply by placing the cursor at the point where the wet section ends (the upward rise), then pressing the Marker key. A triangle appears on the waveform display at the cursor location and a delta distance is shown (see Figure 10-5).

Next, move the cursor to the end of the cable and read the delta distance. In this case, it's 1091 feet. So the wet section ends 1091 feet from the actual end of the cable. This means that there's 2113 feet of dry cable (1022 feet at the near end plus 1091 feet at the far end). The total amount of cable, minus the dry cable (2380 feet minus 2113 feet) equals the amount of wet cable (267 feet). This waveform can be used to document whether the cable needs to be replaced or repaired.

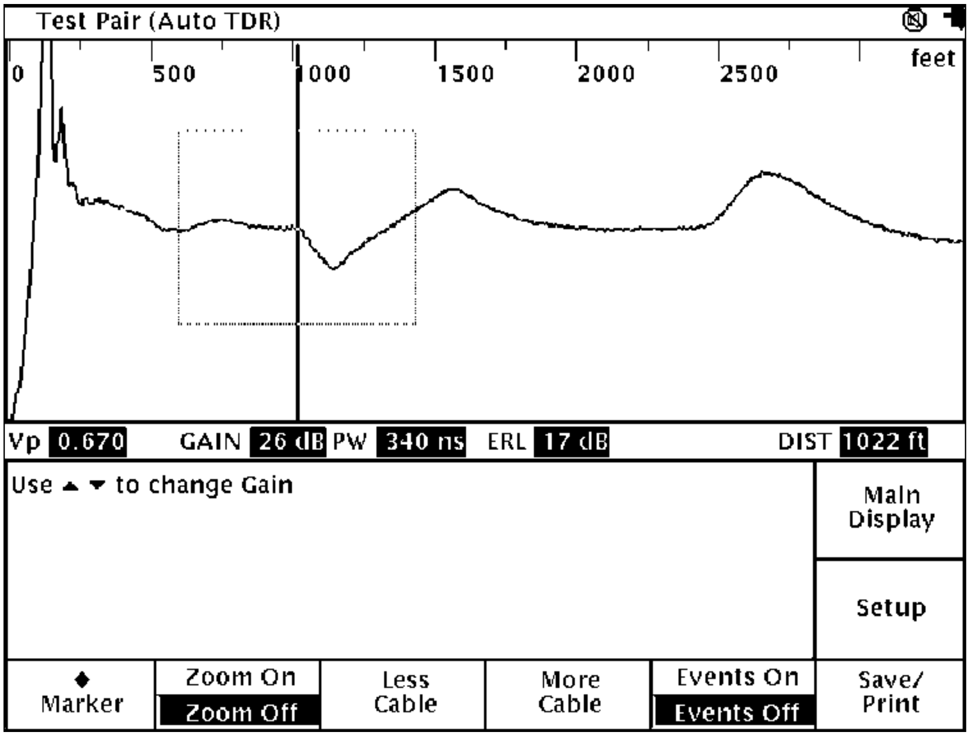


Figure 10-4. Water with gain.

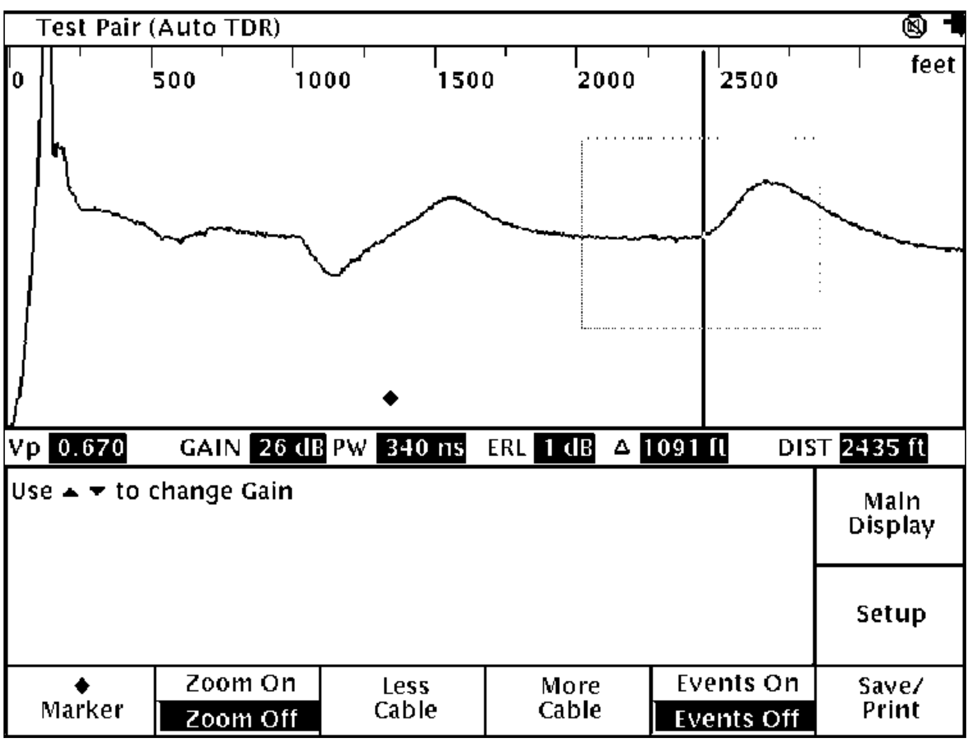


Figure 10-5. Measuring sections of water using the marker.

Calculating Wet Section Length:

Distance to Start of Wet Section:	**1022 ft.**
Distance from End of Wet Section to End of Cable:	**+1091 ft.**
Total Amount of Dry Cable:	**2113 ft.**

Total Cable Length On Map:	**2380 ft.**
Total Amount of Dry Cable:	**-2113 ft.**
Length of Wet Section:	**267 ft.**

This example above was for a cable in which the open end was visible beyond the water. This is not always the case. In the event that you cannot see the far end, it will be necessary to test the pair from both ends to accurately find the beginning and end of the wet section.

Conclusion

There are many ways that water can get into your cable system. Water leads to various types of faults that can, in turn, cause transmission problems for your customers. When water seeps into the telephone cable, determining its location becomes a high priority. TDRs are invaluable for quickly locating water in telephone cable systems.

Chapter 11: Intermittent Faults

Introduction

As most telephone technicians who repair cables for a living can tell you, the most difficult problems to find are those that are intermittent. Typically, if a technician is assigned this type of fault, he/she waits for a long period of time until the fault occurs and then hopes it will last long enough to measure it. This is expensive, time-consuming, and there's no guarantee that the fault will occur while the technician is watching. A time domain reflectometer (TDR) can automate this process, maximizing your productivity.

The Tektronix TelScout TDRs come with a special feature that allows any change in the condition of the pair under test to be stored and examined later. This means that the TDR can be connected to a pair for a period of time without any user involvement, and all information acquired over that period will be retained. This allows you to perform other tasks while the TDR monitors the cable.

An Example

A particular telephone pair works most of the time. However, at unpredictable times of the day, the customer experiences problems with the line. The TDR waveform of the line is shown in Figure 11-1. The large upward reflection at 2060 feet is the pedestal at the end of the cable.

Even with the vertical gain increased, no major fault is shown over the entire length of cable under test (see Figure 11-2). A relatively good splice is located near 1000 feet.

At this point, you could wait and watch the waveform until something changes. However, the problem might not recur for many hours. A more cost-effective alternative is to connect a TDR to the problem pair and select the Test Pair [Intermittent] feature. The TDR monitors the cable continuously and displays any deviation from it's characteristic impedance, allowing the intermittent fault to be pinpointed.

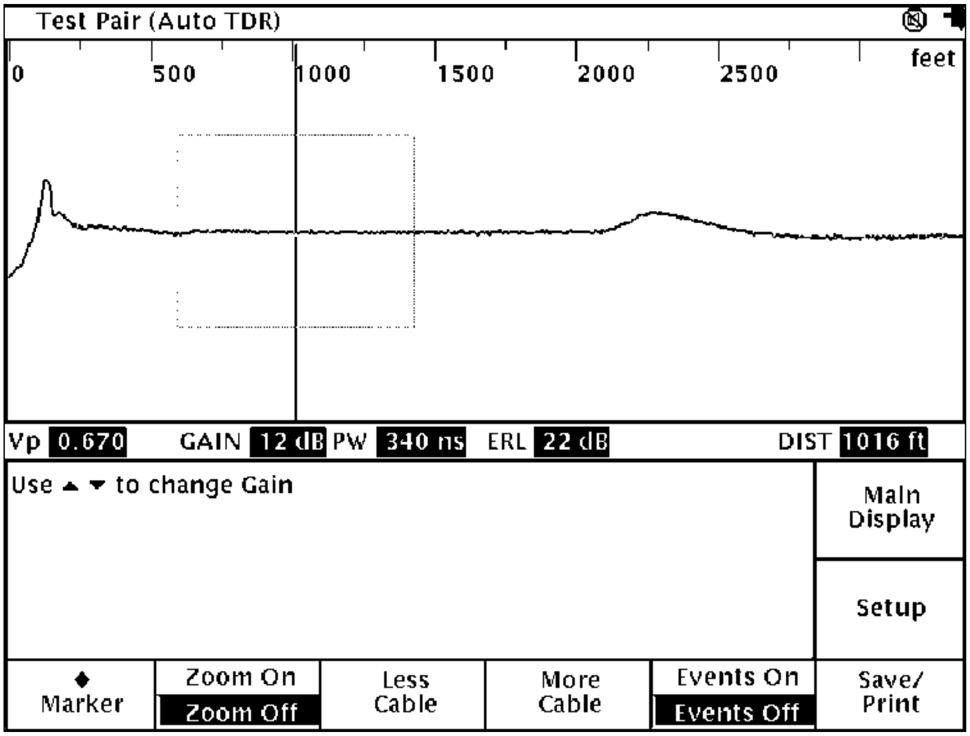


Figure 11-1. Working pair.

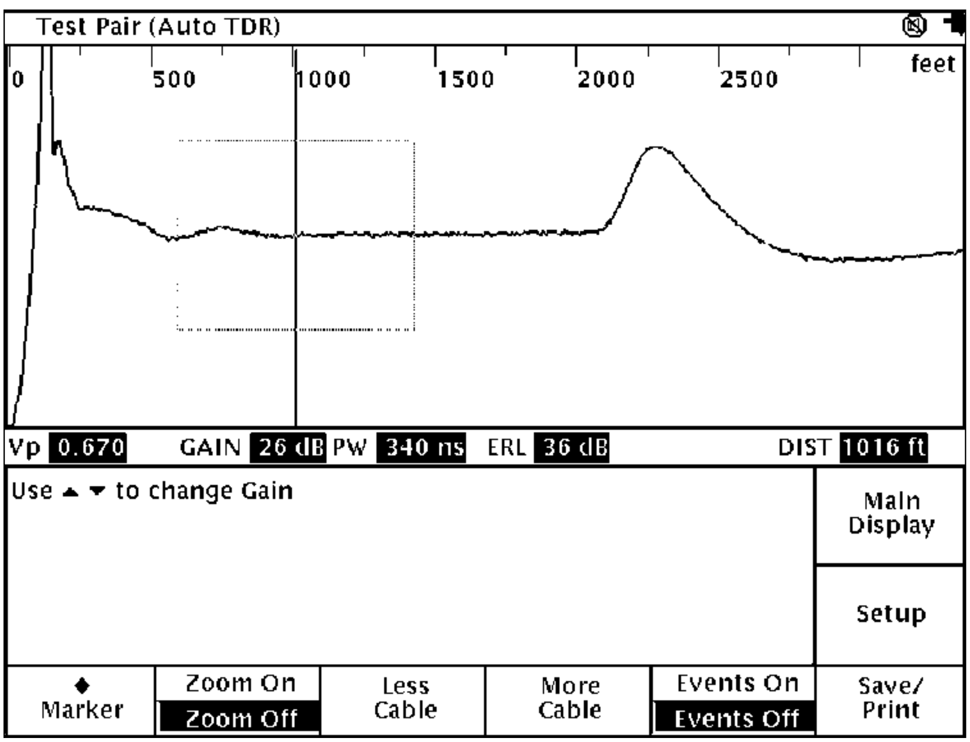


Figure 11-2. Working pair with gain.

Fault location

In order to use the intermittent fault finding feature, access the Setup menu and press the Test Type softkey. Scroll to the Test Pair [Intermittent] selection using the up and down arrow keys (see Figure 11-3).

Press the Return to Test key to return to the measurement display. Now the TDR can be connected to the pair and the entire length of cable can be viewed by pressing More Cable in auto mode. Be sure that you are viewing the full length where you expect the fault to occur.

The TDR will continue to acquire waveforms and periodically the instrument can be checked for any results. The final result should look something like Figure 11-4, if the intermittent fault does recur.

NOTE: Be very careful with the instrument controls. Pressing More Cable, Less Cable, Expand, Setup, Save/Print, or the up/down arrow keys after the intermittent is acquired will cause the TelScout Series to reset. In this case, the intermittent waveform is erased and a new waveform reacquired.

If Figure 11-4 is compared to Figure 11-1, an obvious difference can be seen. An open appears where none was previously seen. By simply moving the cursor to the leading edge of the open and reading the distance from the display, the location of the fault can be determined.

In this case, the distance to the fault coincides with the splice in Figure 11-2. Occasional vibration or some other intermittent event loosened the connection so that it was not making contact. This resulted in something resembling a partially open condition. You can see that the open at the far pedestal has been reduced in size because the amount of signal reaching that end has been reduced due to the poor connection.

Conclusion

Intermittent faults can create serious problems for customers and repair technicians. Almost every type of cable system is susceptible to this problem. The Tektronix TelScout Series in Intermittent mode allows the system to be monitored for these faults without wasting time and money waiting for them to occur.

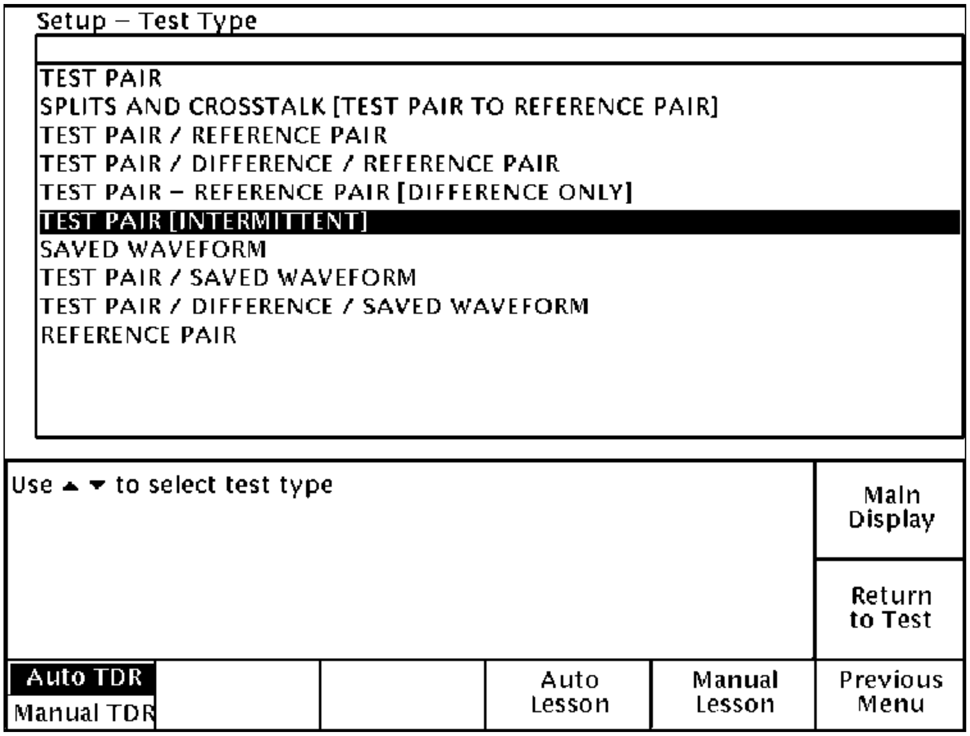


Figure 11-3. Test Type menu.

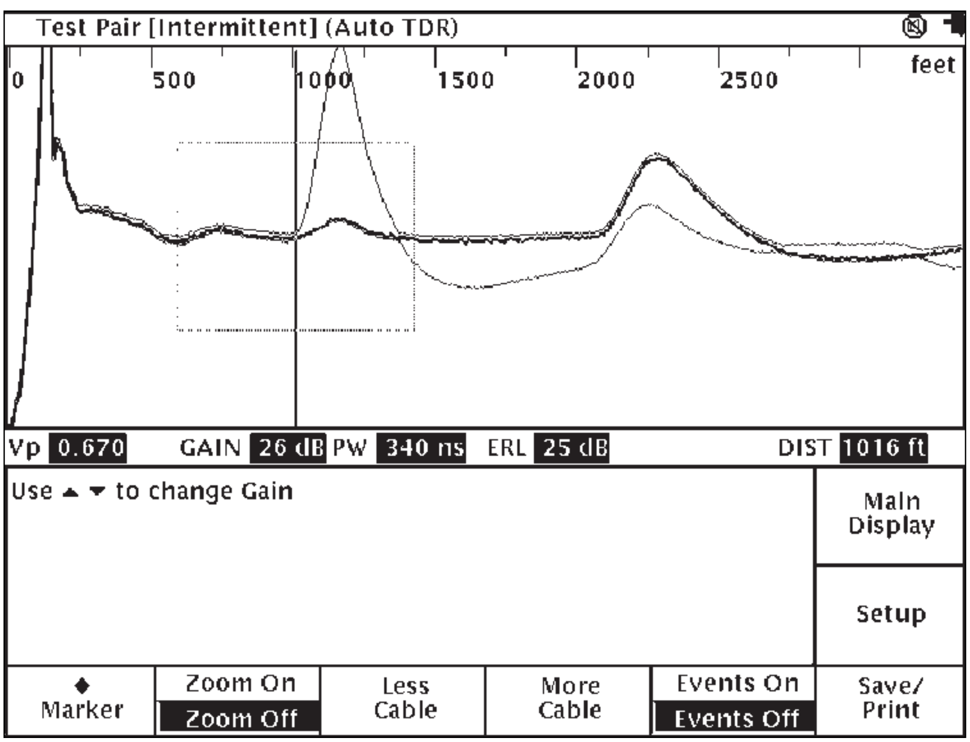


Figure 11-4. Intermittent fault.

Chapter 12: Transmission Characteristics

Introduction

Measuring the general transmission characteristics of an active pair is a necessary step in ensuring quality service. The specific transmission requirements vary between companies and service types, but the following guidelines will help reduce repeat calls and enable you to provide more reliable service.

Loss

Loss, or circuit loss, is due to a combination of factors including capacitance, resistance, and inductance. Loss is typically measured in dBm, which is in reference to a standard 0 dBm milliwatt tone of 1004 Hz (or 1020 Hz). Since the reference level in the central office or exchange is at 0 dBm, any loss associated with the pair will indicate a negative value. Therefore, a –8 dBm pair would have more loss than another pair, which has only –7 dBm of loss (see Figure 12-1).

A loss below –8 dBm at 1004 Hz (or 1020 Hz) is considered acceptable for most analog or voice services. If the loss exceeds –8 dBm, the subscriber will begin experiencing dialing and volume problems. Long lines with high loss might require a Range Extender with Gain (REG) to boost the current to compensate for the loss. If the line is less than the recommended loop length, you might be able to correct the problem by identifying excessive bridged taps or additional cable that extends beyond the customer (see Figure 12-2).

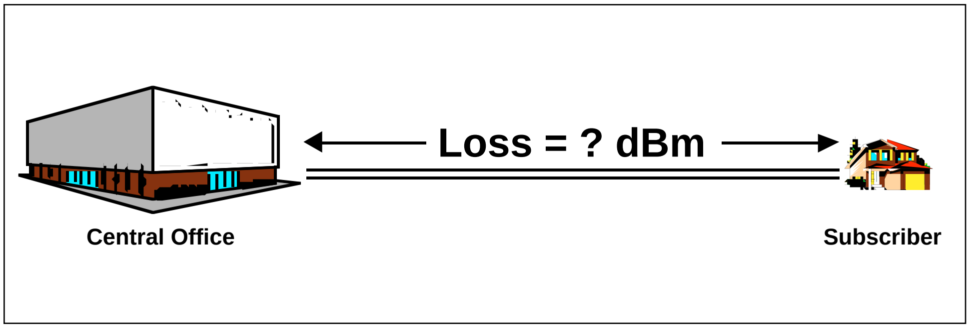


Figure 12-1. Loss at specific frequency.

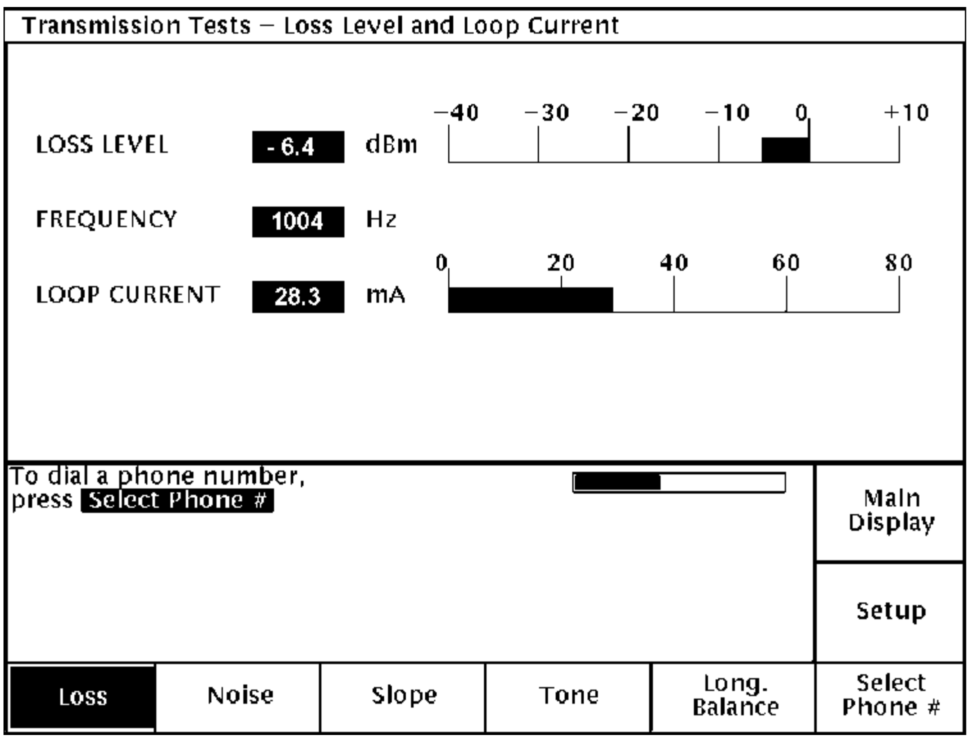


Figure 12-2. Loss measurement.

Noise

If the loss measurement indicates an acceptable amount of loss with adequate loop current, a valid Noise measurement can be made. Metallic Noise, or Transverse Noise, on the line is commonly attributed to either a capacitive or resistive fault on a conductor. This imbalance of one of the conductors vs the other makes the pair susceptible to noise (see Figure 12-3).

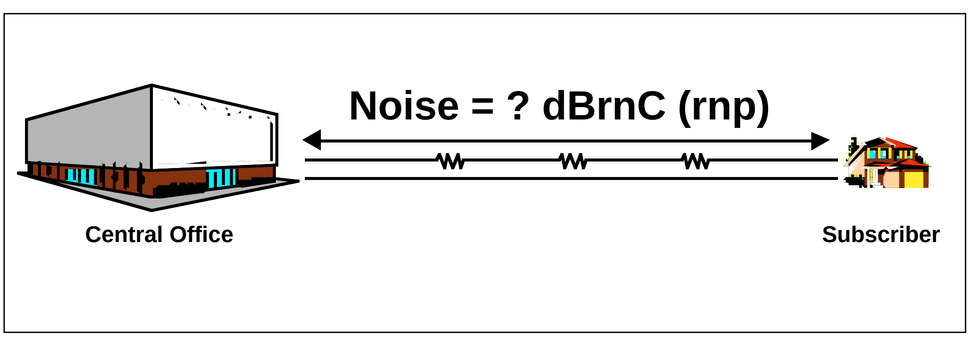


Figure 12-3. Metallic noise.

Noise is typically a weighted measurement given in dBrnC (C-message weighted) or dBrnp (Psophometric weighted), and measured using a terminated line in the central office or exchange. A noise value of less than 20 dBrnC (dBrnp) is desired for proper analog or voice service (see Figure 12-4).

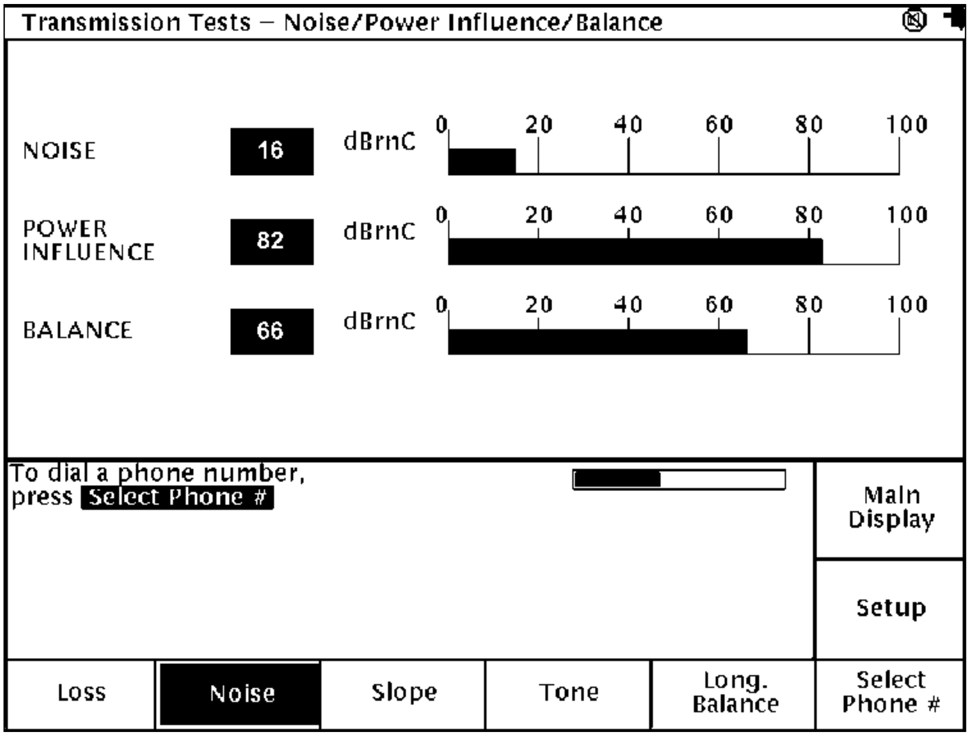


Figure 12-4. Noise measurement.

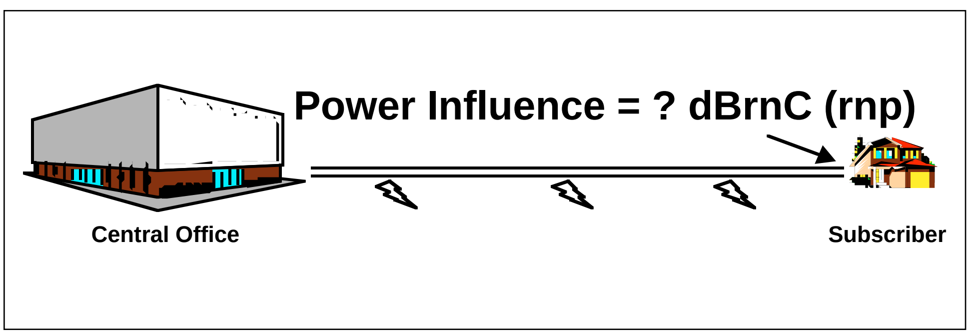


Figure 12-5. Power influence.

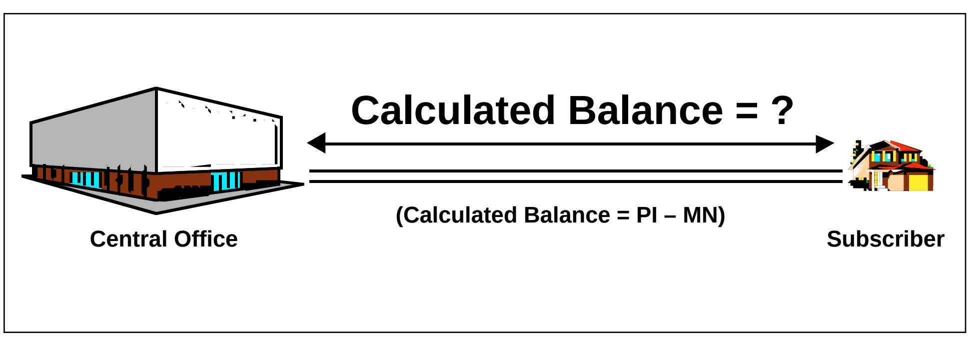


Figure 12-6. Calculated balance.

Power Influence

The outside influence of AC power can be measured on a pair using the Power Influence, or Longitudinal Noise, test. Power influence is commonly caused by a bad shield bond or ground connection, but can also be related to problems from faulty power equipment such as a bad transformer. It's typically measured along with a noise test so the Calculated Balance of the pair can be determined (see Figure 12-5).

Power Influence is also a weighted measurement given in either dBrnC (C-message weighted) or dBrnp (Psophometric weighted). A Power Influence value of greater than 80 dBrnC (dBrnp) is preferred for proper analog service. If the value falls below 70 dBrnC (dBrnp) and can not be accurately measured, a Longitudinal Balance or "stressed noise" test should be performed. (See Figure 12-4 for a Power Influence example.)

Calculated Balance

Calculated Balance represents the overall quality of the noise and power influence measurements (see Figure 12-6). To determine calculated balance, simply subtract the noise measurement from the power influence result:

```
Calculated Balance =
  Power Influence - Noise
```

To keep the noise and power influence values in their correct ranges, the calculated balance result should be greater than 60 dB (see Figure 12-4 for a Calculated Balance example).

Longitudinal Balance

If the power influence reading is less than 70 dBrnC (dBrnp), or there's voltage present on the line, it's necessary to use the longitudinal balance measurement instead of calculated balance (see Figure 12-7). Longitudinal balance helps to identify capacitive or resistive problems which cause one conductor to not be electrically equivalent to its matching conductor.

The longitudinal balance test stresses the line by introducing AC noise. A 1004 Hz signal at –90 dBm is sent down the pair, allowing minor capacitive, resistive, and inductive imbalances to be detected (see Figure 12-8). The introduction of an AC signal is necessary since the power influence of the pair is below the measurable threshold.

Like calculated balance, the longitudinal balance measurement should also be greater than 60 dB to ensure proper analog service (see Figure 12-9).

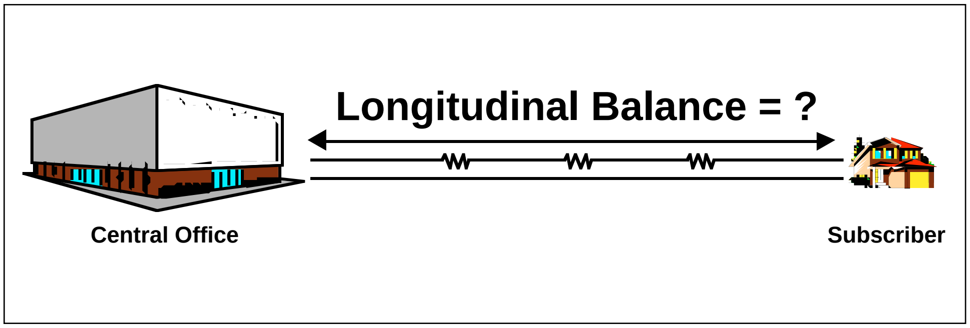


Figure 12-7. Longitudinal balance.

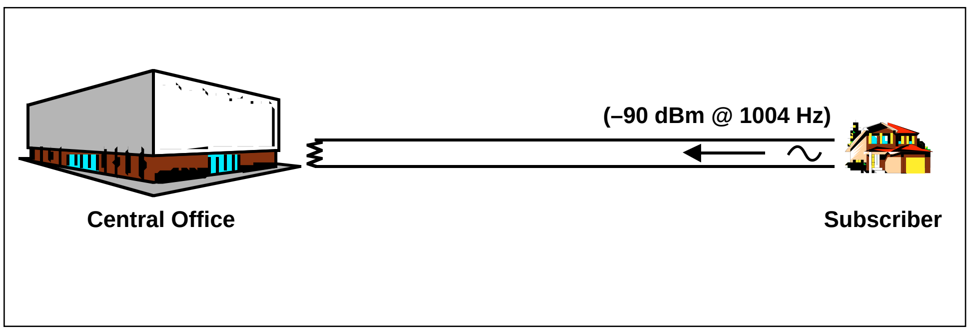


Figure 12-8. Longitudinal balance technique.

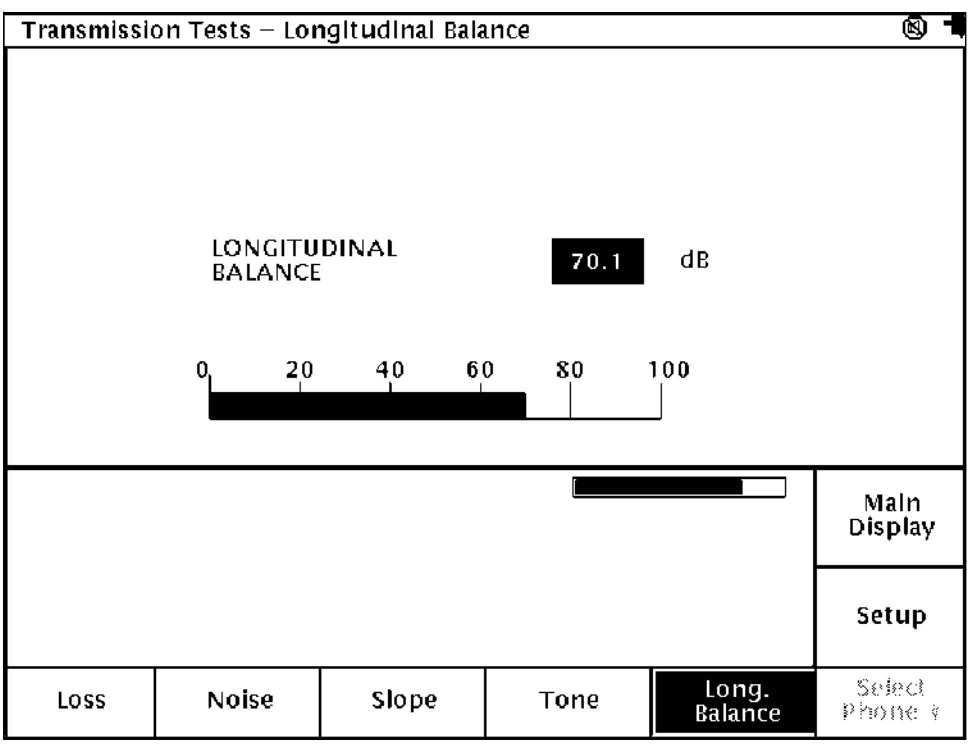


Figure 12-9. Longitudinal balance measurement.

Slope

A more advanced transmission measurement such as slope will help detect more troublesome line problems. Slope is a loss measurement of multiple frequencies, typically being sent from the central office or exchange at 0 dBm (see Figure 12-10).

A good slope plot should indicate the line is carrying higher and lower frequencies at approximately the same level as those in the mid-range. By plotting these values, a technician can determine if the line is meeting the expected characteristics for a particular service. It may also be possible to detect improperly loaded analog lines and pairs with excessive bridged taps and laterals (see Figure 12-11).

Acceptable calculated slope values depend on the type of service being provided. For a standard analog or voice line, the response should be flat between 404 to 2804 Hz and then begin dropping off quickly (see Figure 12-12).

Conclusion

Transmission tests help technicians identify problems that might not be apparent when performing the standard DC tests such as volts, ohms, or capacitance. To ensure quality service, it's necessary to quickly perform a few basic transmission tests to verify the line meets proper service requirements.

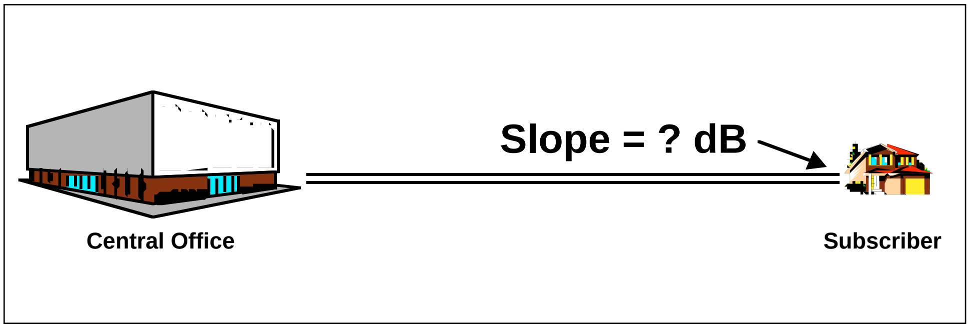


Figure 12-10. Slope: Loss at multiple frequencies.

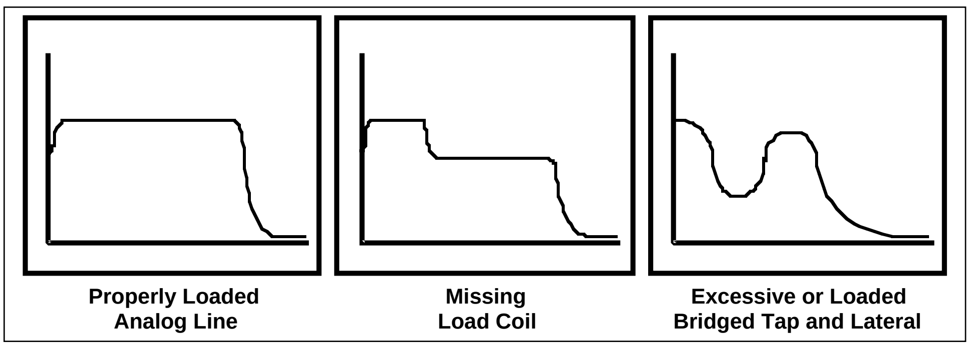


Figure 12-11. Slope plot examples.

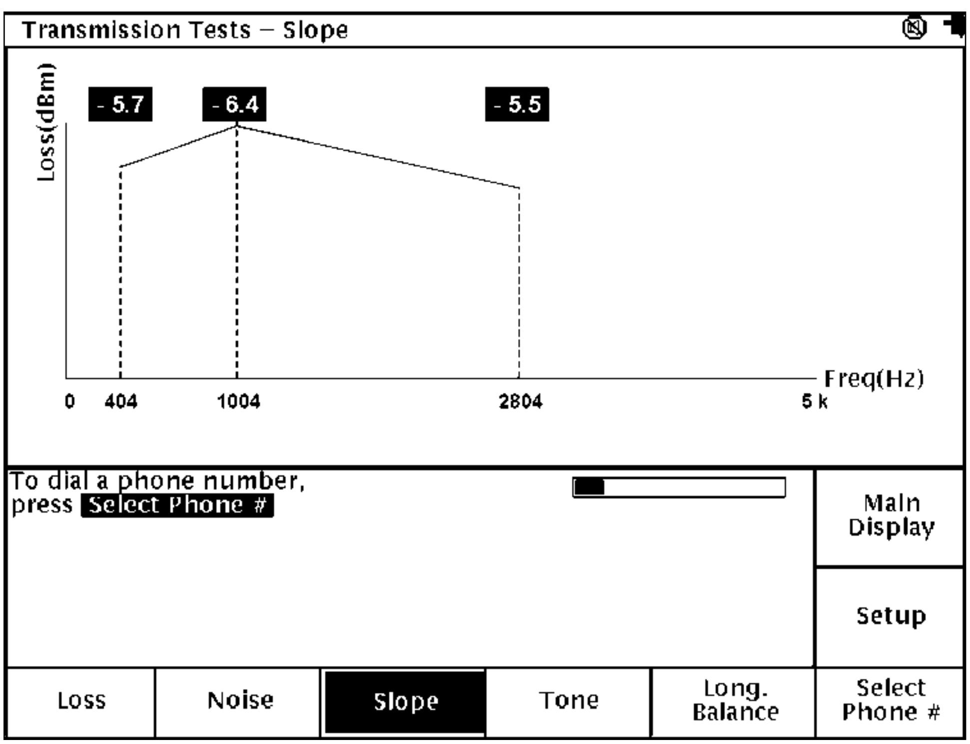


Figure 12-12. Slope measurement.

Chapter 13: Finding an Unknown Velocity of Propagation

Introduction

A cable's Velocity of Propagation (V_p) specification is simply a measure of how fast a signal travels in the cable. It's typically expressed as a percentage of the speed of light with values ranging from 0.30 to 1.00. For example, a cable with a V_p value of 0.66 indicates that the signal is traveling down the cable at 66% of the speed of light. Sometimes it's referenced in actual velocity terms and can vary from 45 to 150 m/ms.

Since a Time Domain Reflectometer (TDR) is really making measurements in the time domain, the distance accuracy of the TDR is dependent upon having the correct V_p value. Newer, high-performance TDRs automatically select the correct V_p value for the type of cable you choose in the Cable Type menu as shown in Figure 13-1.

Unknown Cable Type

Occasionally, you might run across a cable type that is either not in the menu, or different from the one shown. In this case, you will have to determine the correct V_p for that particular cable. An easy way to find the cable's V_p is to use a known length of the cable and adjust the TDR's V_p setting until the open on the waveform matches up with the end of the cable.

If your TelScout model does not indicate an Auto Control or Manual Control selection, simply select an approximate cable type and use Define Cables to adjust the Temporary Cable Setting's V_p until the distance of the sample cable lines up with the actual distance.

If your Tektronix TelScout TDR indicates an Auto control or Manual Control selection, follow the steps below:

NOTE: The following example uses a piece of cable that's exactly 1000 feet long as a reference.

Step 1. Turn the TelScout TDR on.

Step 2. Press Setup to display the main Setup menu (see Figure 13-1).

Step 3. Press Auto / Manual Control to switch the TDR into Manual mode. Depending on your TelScout model, you may have to press Test Type first in order to locate the Auto / Manual Control selection.

Step 4. Return to the TDR waveform display. The instrument shows a manual measurement display.

Step 5. Connect the TelScout test pairs to the cable of known length.

Step 6. Use the left and right arrow keys to move the cursor to zero.

Step 7. Press Span. The Span key should now be highlighted.

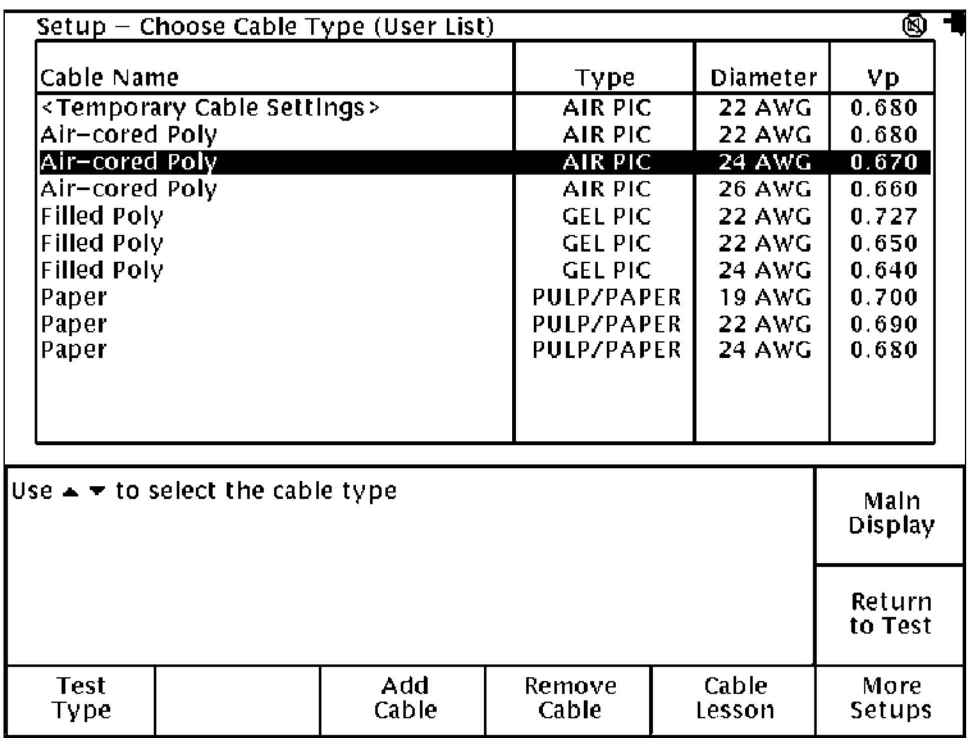


Figure 13-1. Cable Type Menu.

Step 8. Use the up and down arrow keys to adjust the span so the open end of the cable appears on the right half of the display (see Figure 13-2).

Step 9. Press Span again to turn off control of the distance range and allow the up and down arrows to adjust the V_p.

Step 10. Use the left and right arrow keys to move the cursor to the leading edge of the reflected pulse (the open end of the cable) (see Figure 13-3).

Step 11. Note the distance in the lower right corner of the measurement display. If this distance is not the exact measured distance of your cable, the V_p is not correct.

Step 12. Press Vp. The V_p key should now be highlighted.

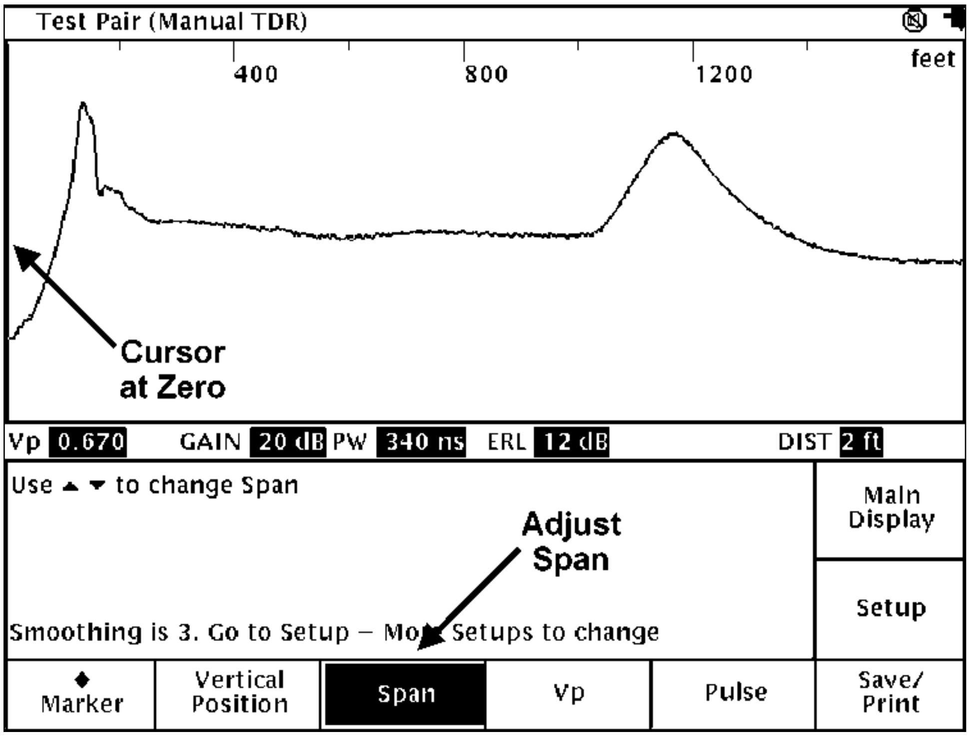


Figure 13-2. Adjusting the span.

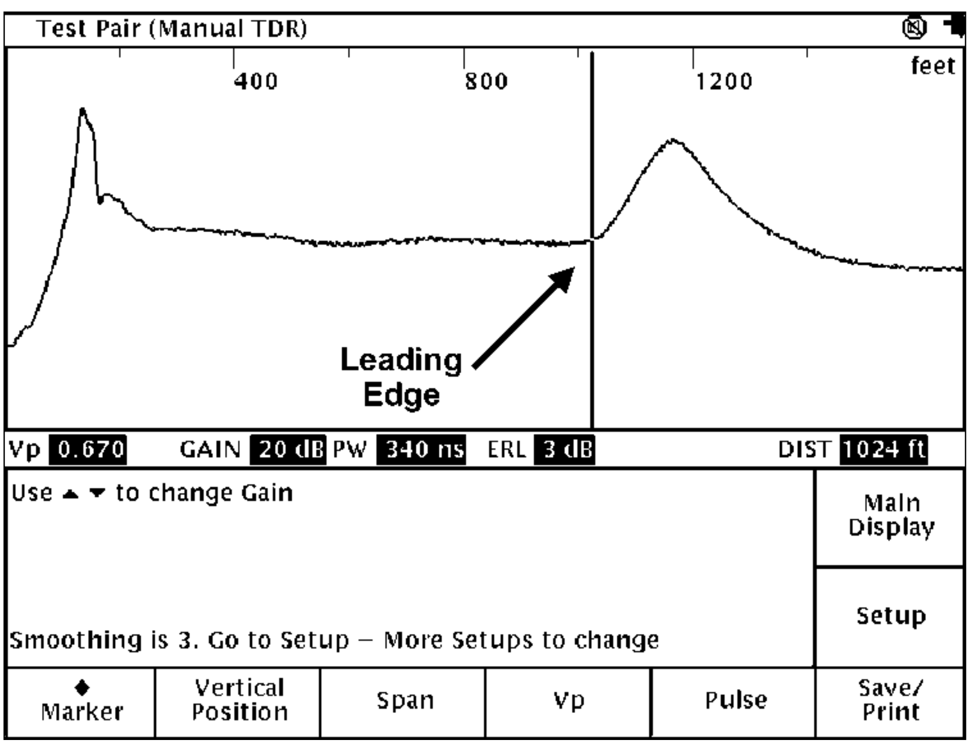


Figure 13-3. Cursor placement.

Step 13. Use the up and down arrow keys to adjust the V_p until the distance display matches the known cable length (1000 feet in this example) (see Figure 13-4).

Step 14. The V_p value shown on the display is now the correct V_p of this cable. Record this number for later use, or store it as a new cable type using the appropriate keys in the Setup menu.

Conclusion

Identifying the correct V_p for the cable being tested will improve the distance measurements. Notice from the TDR Setup menu that V_p varies most greatly between cable types (e.g., Paper vs. PIC) and much less so between gauges or diameters (e.g., 19 AWG vs. 26 AWG or 0.94 mm vs. 0.40 mm).

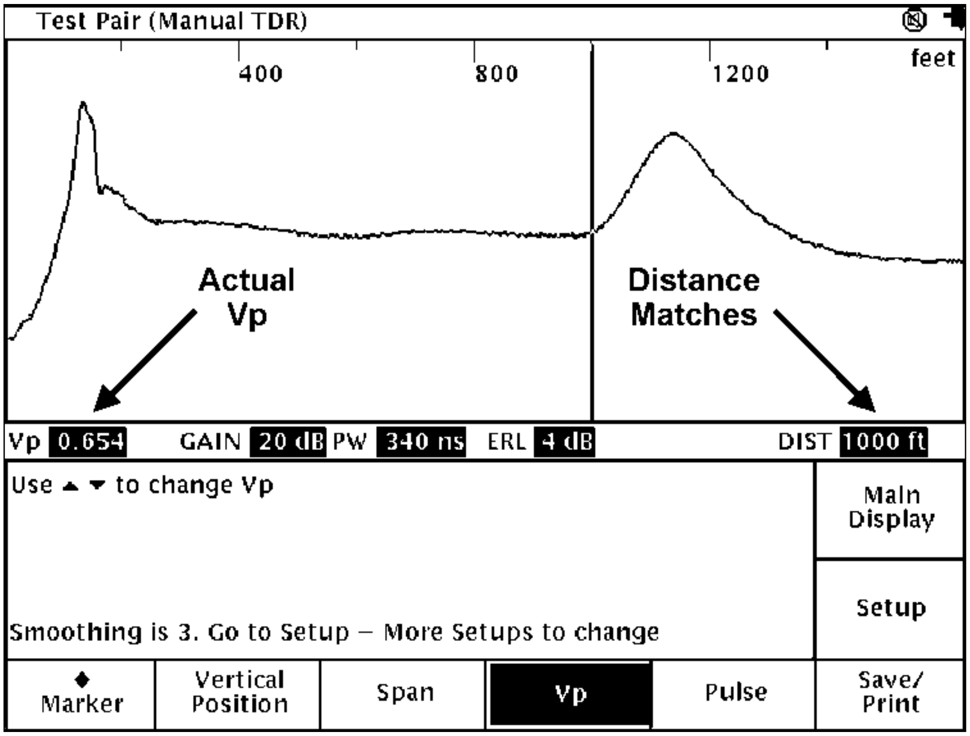


Figure 13-4. Adjusting V_p until distances match.

Chapter 14: Cable Effects on TDR Range

Introduction

The measurement range of a TDR is affected by the cable condition and diameter of the cable you are testing. This chapter discusses these factors and how to set up the TDR correctly to achieve more accurate cable measurements.

Cable Condition

The physical condition of the cable can affect the range of the TDR. If the cable is old, or of poor quality, there's likely to be corrosion or other forms of degradation that will decrease the ability of a signal to travel down the pair. TDR signals are also affected by these conditions, so the measurement range will be decreased.

Cable Diameter

The larger the diameter of the wire, the less a signal is attenuated as it travels down the pair. The current telephone architecture accounts for this by changing the wire diameter as you get further away from the central office/exchange. For long loops, the cable plant begins with a smaller wire diameter (high attenuation) and then converts to a larger wire diameter (lower attenuation) as it gets farther out toward the customer.

This concept also holds true for TDR signals. When testing a 22 AWG (0.64 mm) pair, you will be able to see farther than on a 24 AWG (0.50 mm) pair (see Figures 14-1 and 14-2).

TDR Setup

If the TDR is set up incorrectly by choosing the wrong cable diameter, the measurement range is reduced. In our example, we have chosen the 19 AWG (0.90 mm) cable from the Setup menu, but the cable type under test is actually 24 AWG (0.50 mm). Notice that when the TDR is not properly set up, the measurement range is reduced and consequently the open at 19.11 kft. is not visible (see Figures 14-3, 14-4, and 14-5).

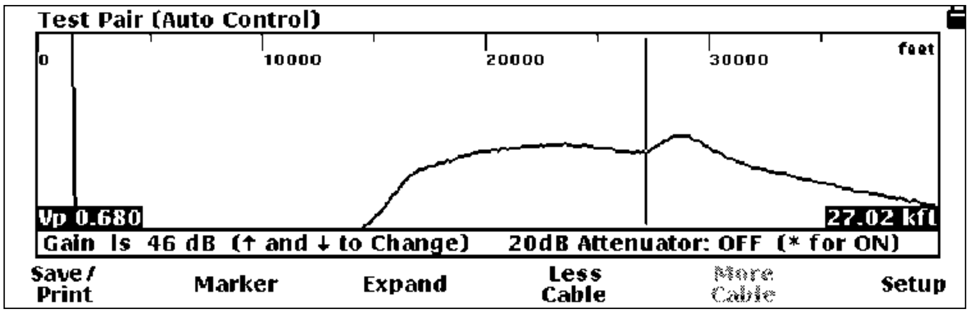


Figure 14-1. Long range fault on 22 AWG (0.64 mm).

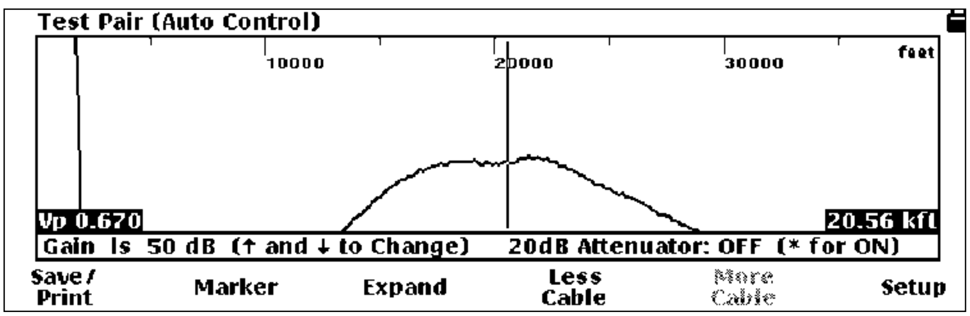


Figure 14-2. Long range fault on 24 AWG (0.50 mm).

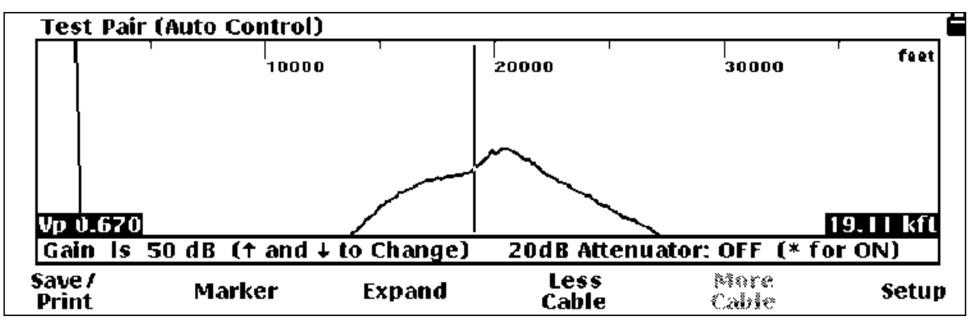


Figure 14-3. Long range fault on 24 AWG (0.50 mm) – using 24 AWG (0.50 mm) setup.

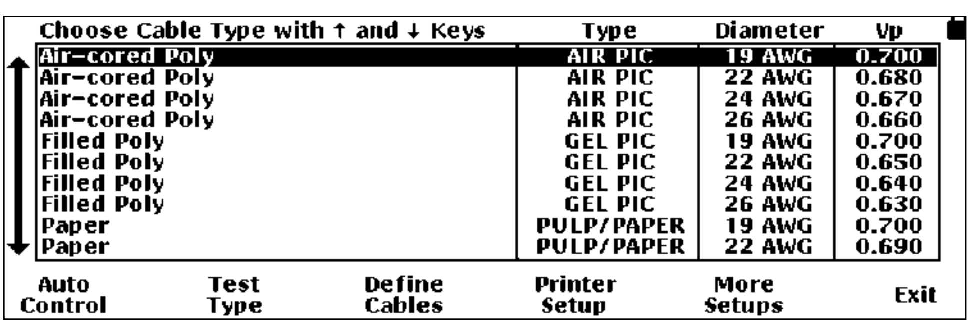


Figure 14-4. Changing to 19 AWG (0.90 mm) in setup menu.

The TDR's perceived measurement range has been reduced because the instrument has automatically chosen the appropriate gain (amplification) settings for 19 AWG (0.90 mm), rather than the ones for 24 AWG (0.50 mm).

When the gain setting is manually adjusted to the same setting used automatically for 24 AWG (0.50 mm), the 19 AWG (0.90 mm) waveform shows the fault (see Figure 14-6).

Note that the distance to the fault on the 19 AWG (0.90 mm) waveform is not correct. The difference is due to the Velocity of Propagation difference between 19 AWG (0.90 mm) and 24 AWG (0.50 mm).

Conclusion

The measurement range of a TDR is affected by a combination of cable-related factors. Cable condition and cable diameter determine how far out you can locate faults on the pair. Incorrect set up of the TDR will also contribute to a decrease in the perceived range of the TDR.

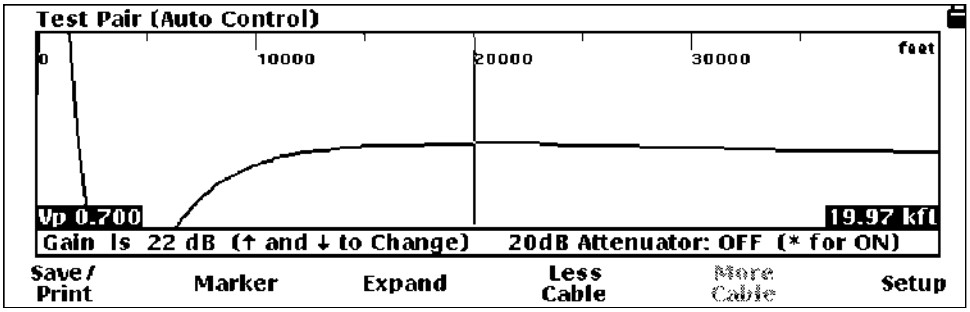


Figure 14-5. Long range fault on 24 AWG (0.50 mm) – using 19 AWG (0.90 mm) setup.

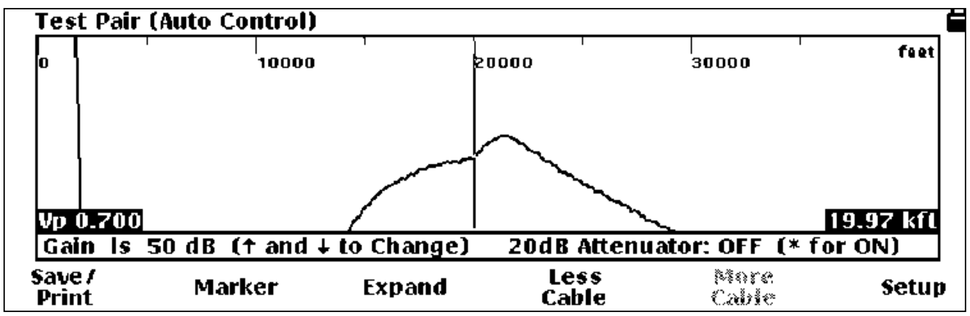


Figure 14-6. Long range fault on 24 AWG (0.50 mm) – using 19 AWG (0.90 mm) setup with gain added to match automatic setting for 24 AWG (0.50 mm).

Chapter 15: TDR Measurement Range

Introduction

"How far does your TDR see?" is a common question asked by people looking to purchase a TDR for locating faults on telephone cables. This is a very important question which doesn't have a simple answer due to a number of factors affecting range. Another important consideration when evaluating TDR's is how close to the TDR you can see faults.

TDR-Related Factors Affecting Range

There are a number of factors that can affect the distance over which a TDR can locate faults. The most important parameters that are TDR-related are pulse amplitude and pulse width.

Pulse amplitude refers to the amount of voltage produced by the TDR pulse. In general, the higher the amplitude, the farther the TDR can see. However, amplitudes that are too high might produce distorted waveforms that make fault location very difficult. The Tektronix TelScout series of TDRs have pulse amplitudes of 20 volts or less, which is sufficient for all telephony applications.

Pulse width also affects range. Pulse width is measured in time, but can also be thought of as distance when using a TDR. The longer the pulse width, the farther the TDR can see. But there's a tradeoff. Pulse width also affects the resolution of a TDR. That is, a short pulse width allows you to see potential faults very near the TDR or two faults very close together. But a short pulse width has very little energy to send down the cable, so the TDR cannot see very far. A long pulse width has the opposite characteristics. It allows the TDR to see down long lengths of cable, but because of the length of time (or distance) that the pulse covers, it's more difficult to view events near the TDR or two faults very close together.

In Auto mode, the Tektronix TelScout Series chooses the correct pulse width for you automatically. When the displayed range is short (e.g., 60 feet or 20 meters), the TelScout Series uses a short pulse width. When the displayed range is very long (e.g., 18,000 feet or 6 km), it will use a longer pulse width. This ensures that the optimum pulse width is always used for a given instrument setting. It's also possible to choose your own pulse width settings in Manual mode on some TelScout models.

Another important factor to consider is the filtering or averaging capability of the TDR. There are two types of filtering provided by the TelScout Series: low-frequency filtering and high-frequency filtering. Low-frequency filtering provides protection from 50 and 60 Hz noise emitted from power lines, electric motors, and the like. High-frequency filtering gives the TDR the ability to process signals that it receives by displaying an averaged result. Both of these types of filtering produce a clearer waveform that makes fault location easier, especially on very long cables.

Cable-Related Factors Affecting Range

There are factors affecting TDR range that are related to the cable itself: wire diameter, cable quality, and the connection between the TDR and the cable.

Wire diameter is a straightforward factor. As with all transmissions, the larger the diameter of the wire, the less the TDR signal is attenuated. Therefore, you will get more range on 22 AWG (0.64 mm) than 26 AWG (0.40 mm). Telephone cables are set up following this principle. The farther from the central office/exchange, the larger the wire diameter.

Cable quality can also affect range. If a cable is old or of poor quality, there's likely to be corrosion or other forms of breakdown that will decrease the ability of the wire to carry a signal. TDR signals are affected by this as well, so the range will be limited.

Finally, how you connect the TDR to the cable can affect range. A good quality connection ensures that the maximum amount of signal is coupled into the cable under test.

In terms of actual connection, an ideal solution would be to solder each connection from the TDR to the pair under test, but this is impractical. Using clip leads and/or banana jacks is probably the best solution for accessing telephone cables.

A Long-range Example

Figure 15-1 shows a length of 24 AWG (0.50 mm) that's about 24,000 feet (8 km) long. Note that it's difficult to see the open at the end of the cable. This is because the signal has been attenuated.

Because of this attenuation, the pulse width has been maximized and the amount of vertical gain has been increased significantly. And, unfortunately, there's a lot of noise amplified with this increase. This causes the waveform to have a serrated look.

Figure 15-2 shows the same waveform with filtering added. Notice that the waveform is much cleaner and it's easier to see the point where the open begins. The distance measurement is much more accurate in this case.

Conclusion

Fault location over long lengths of telephone cables has several factors that can affect the distance you can actually see. There are TDR-related parameters, such as pulse amplitude and pulse width; and there are cable-related factors, such as wire diameter, cable quality, and connection quality. These combine to limit the actual range of the TDR. To overcome these limitations, the TelScout Series provides the most features of any TDR for telephony applications.

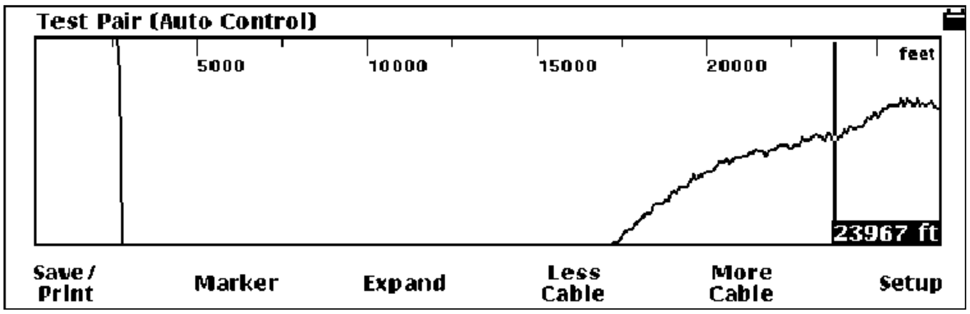


Figure 15-1. Long pair with open.

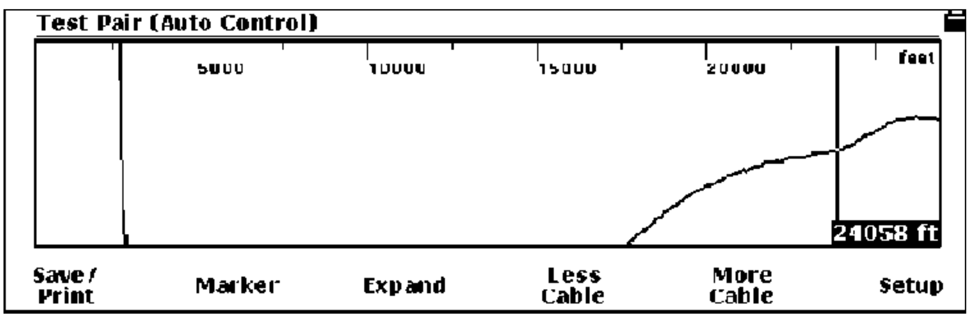


Figure 15-2. Long pair with open (filtering added).

Chapter 16: Documentation

Introduction

The primary use of field test equipment is for identification and location of a fault for repair. Once you have located it and made the repair, you can move on to the next case of trouble. However, more difficult problems such as a wet section of cable needing replacement, might require documentation as proof for engineering. For owners of TelScout Series with Save/Print capability, this chapter will walk through the complete documentation process step-by-step.

Storing TDR Waveforms

Storing TDR waveforms for later use or for transfer to a PC is an easy task. Simply follow these steps:

Step 1. Acquire the TDR waveform to be saved (see Figure 16-1).

Step 2. Press the Save/Print key. This accesses the saved waveform menu, which lists the existing stored waveforms and any empty slots (see Figure 16-2).

Step 3. Using the ▲▼ keys, move the highlighted bar to the first available empty slot. Any new waveforms that you wish to save may be added to an empty slot or you may overwrite an existing waveform (in our example we will use an empty slot).

Step 4. Press Store or Save to place the waveform in that slot.

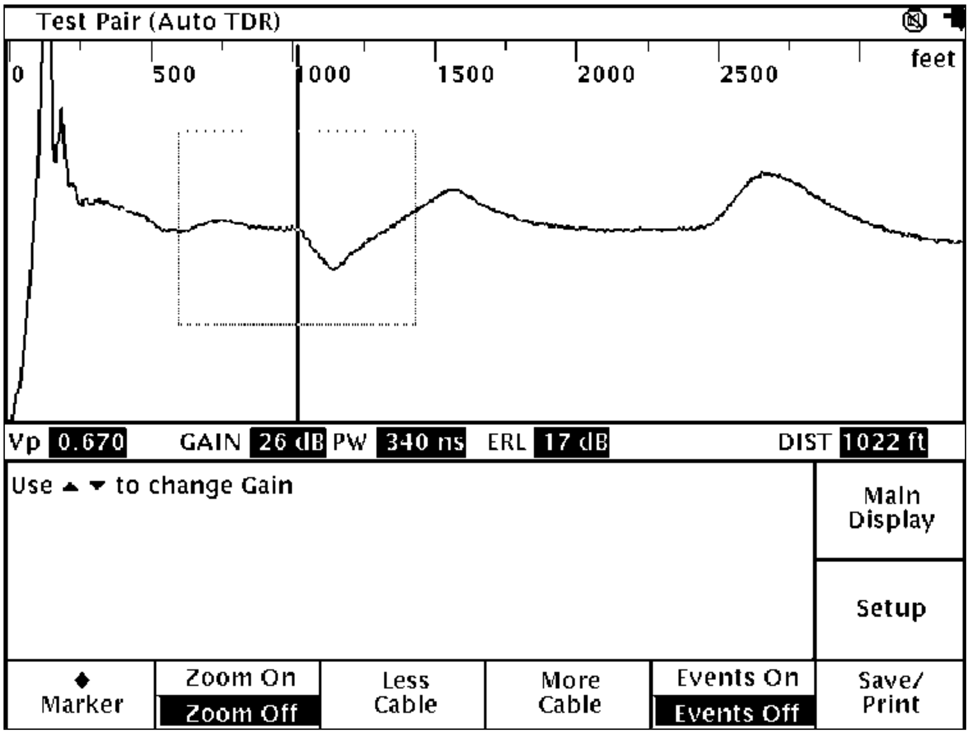


Figure 16-1. Typical TDR waveform.

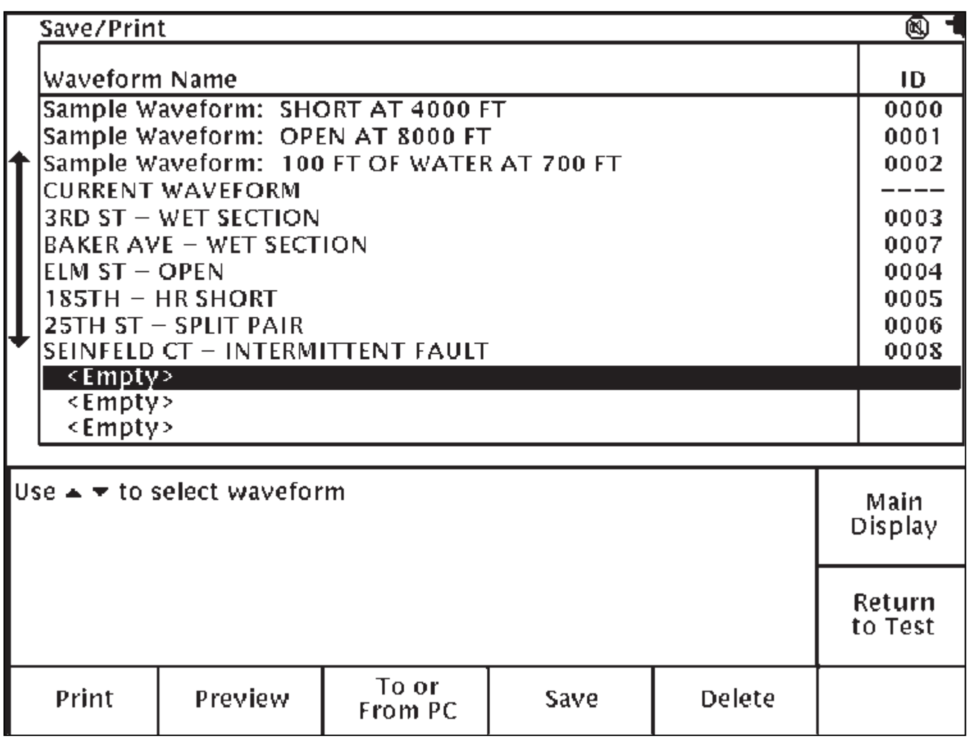


Figure 16-2. Save / Print Menu (empty slot).

Step 5. Using the appropriate keys, enter any notes you wish to make regarding the waveform. These notes are stored with the waveform. The file name itself is automatically assigned by the slot in which you store the waveform (see Figure 16-3).

Step 6. Press Done to return to the Save/Print menu when finished typing in the notes. In our example, we have entered the text "ACME LANE – WET SECTION" for our waveform notes (see Figure 16-4).

The ACME LANE – WET SECTION waveform has been successfully stored and can now be recalled on the TDR, printed to a serial printer, or transferred to a PC.

Transferring TDR Waveforms To/From a PC

Transferring stored waveforms to or from a PC is useful for archiving or electronic documentation. Using the optional MCTAP PC software from Tektronix allows you to transfer, manipulate, analyze, and document TelScout TDR waveforms on a PC. To transfer data from the TelScout Series to your PC, simply follow these steps:

Step 1. Load the Tektronix MCTAP software onto your PC following the instructions included with the software package. It's most useful to install it in its own directory since the downloaded waveforms will automatically be placed in this working directory.

Step 2. Connect the serial cable (Tektronix part number 012-1379-00) that was provided with your MCTAP software package between the TelScout Series and the PC.

Step 3. Run the MCTAP software and select Transfer from the menu bar in MCTAP.

Step 4. Select Upload/-Download from the transfer menu in MCTAP.

Step 5. Turn on the TelScout and go to the TDR display.

Step 6. Select Save/Print from the TDR display.

Step 7. Select To or From PC from the Save/Print menu on the TDR display.

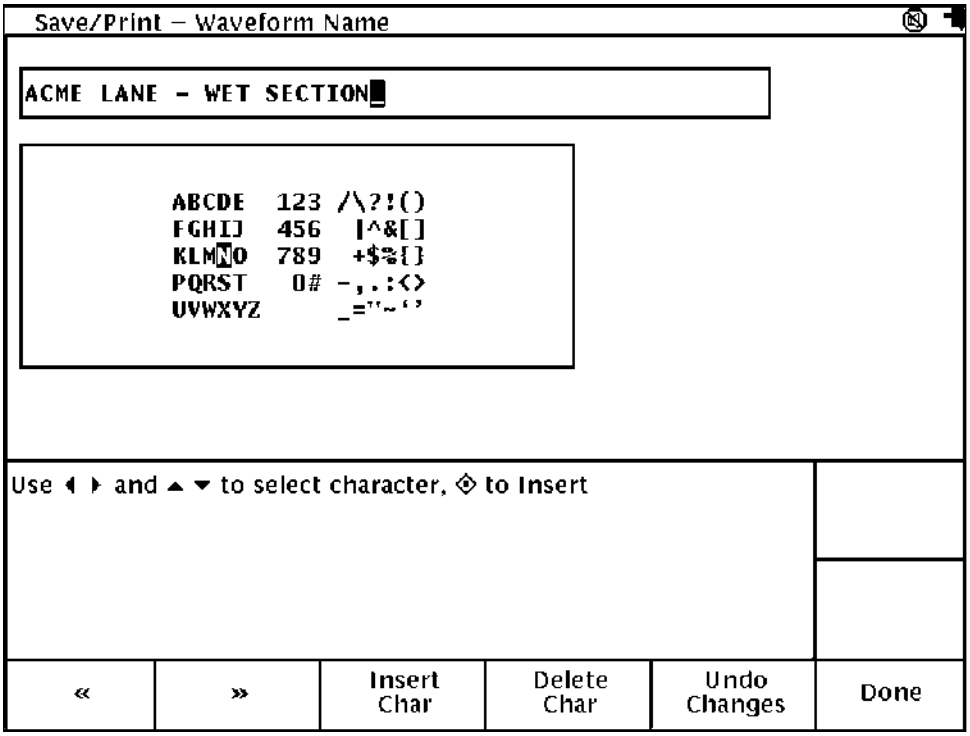


Figure 16-3. Waveform notes.

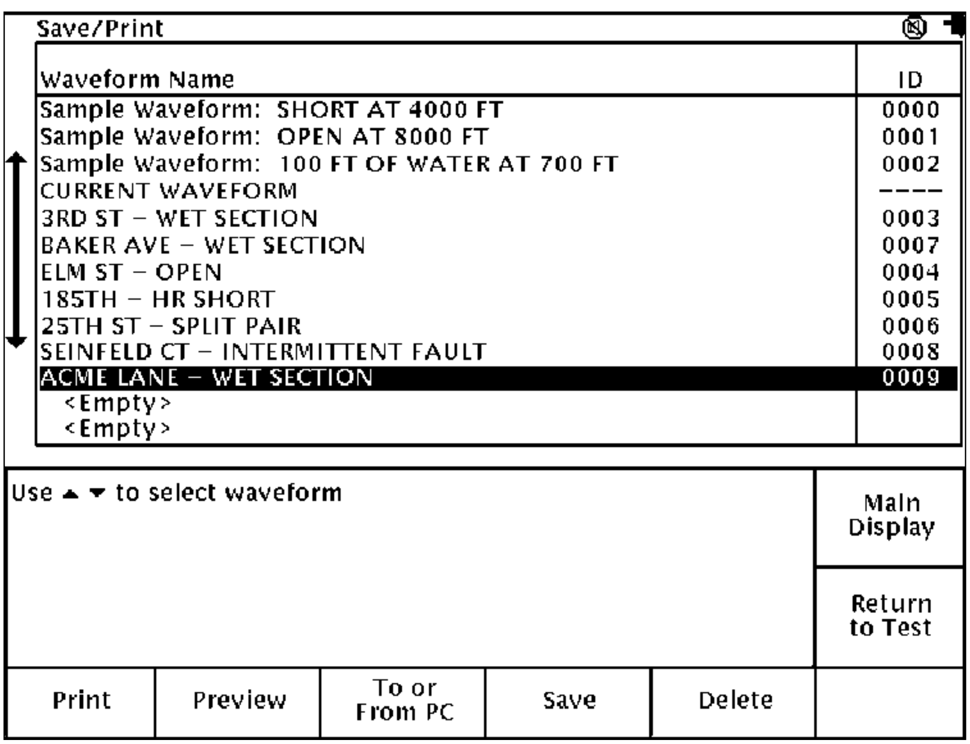


Figure 16-4. Save/Print Menu (saved).

Step 8. Verify that the Baud Rate, Flow Control, and Format parameters are set correctly. If they are not, you must change them at this time. The recommended settings are:

Baud Rate: Typically 9600, but must match the MCTAP settings.

Flow Control: Typically set to None.

Format: Typically set to 8-None.

Step 9. Use the ▲▼ keys to highlight the appropriate transfer type, depending on what information you wish to upload/-download.

Step 10. Press Start Transfer to begin the transfer.

If downloading, the files will now be copied to your MCTAP directory, with the originals still remaining in the TelScout memory. If uploading, the files in the MCTAP directory will be copied to the TelScout, with the originals remaining in the MCTAP directory on the PC. For more detail, refer to the MCTAP documentation and the on-line lessons in the TelScout help files.

Printing TDR Waveforms

Printing either a saved or current TDR waveform directly from the TelScout is also easy. Simply follow these steps:

Step 1. Turn on the TelScout Series and go to the TDR display.

Step 2. Select Save/Print from the TDR display.

Step 3. Use the ▲▼ keys to select the waveform you want to print.

Step 4. Select Print.

Step 5. Use the ▲▼ keys to highlight the type of printer you will be using (see Figure 16-5).

Step 6. Verify that the Baud Rate, Flow Control, and Format parameters are set correctly. If they are not, you must change them at this time. (If you do not know how the printer is set up, check the printer manual.) For more information on the TelScout serial controls, refer to the on-line Serial Lesson for help.

Step 7. Connect the printer cable between the TelScout serial port and the serial port on the printer. (Be certain the printer has a serial port, and not just a parallel port. Refer to the printer manual to confirm this.)

NOTE: You will need one of two types of cables. The most common is the IBM PC/AT Printer cable. This works with all types of printers supported by the TelScout (except the Seiko series). For the Seiko series, use an IBM PC/AT Modem cable. Both cables are 9-pin to 25-pin cables, available from most computer supply stores. Tektronix also offers the cables under the following part numbers:

PC/AT Printer Cable – 012-1313-00

PC/AT Modem Cable – 012-1462-00

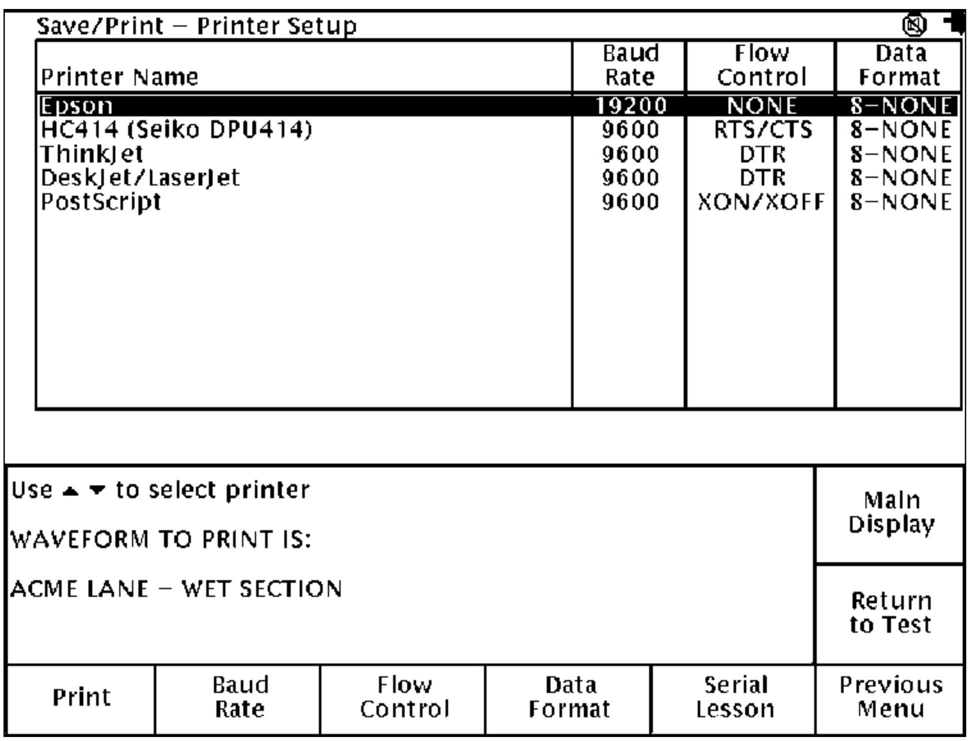


Figure 16-5. Printer setup screen.

Step 8. Press Exit or Done. This returns you to the same screen as in Figure 16-4. You can either print the current waveform, or you can print a stored waveform. We will print our stored waveform, ACME LANE – WET SECTION.

Step 9. Press Print Saved or Print (see Figure 16-6).

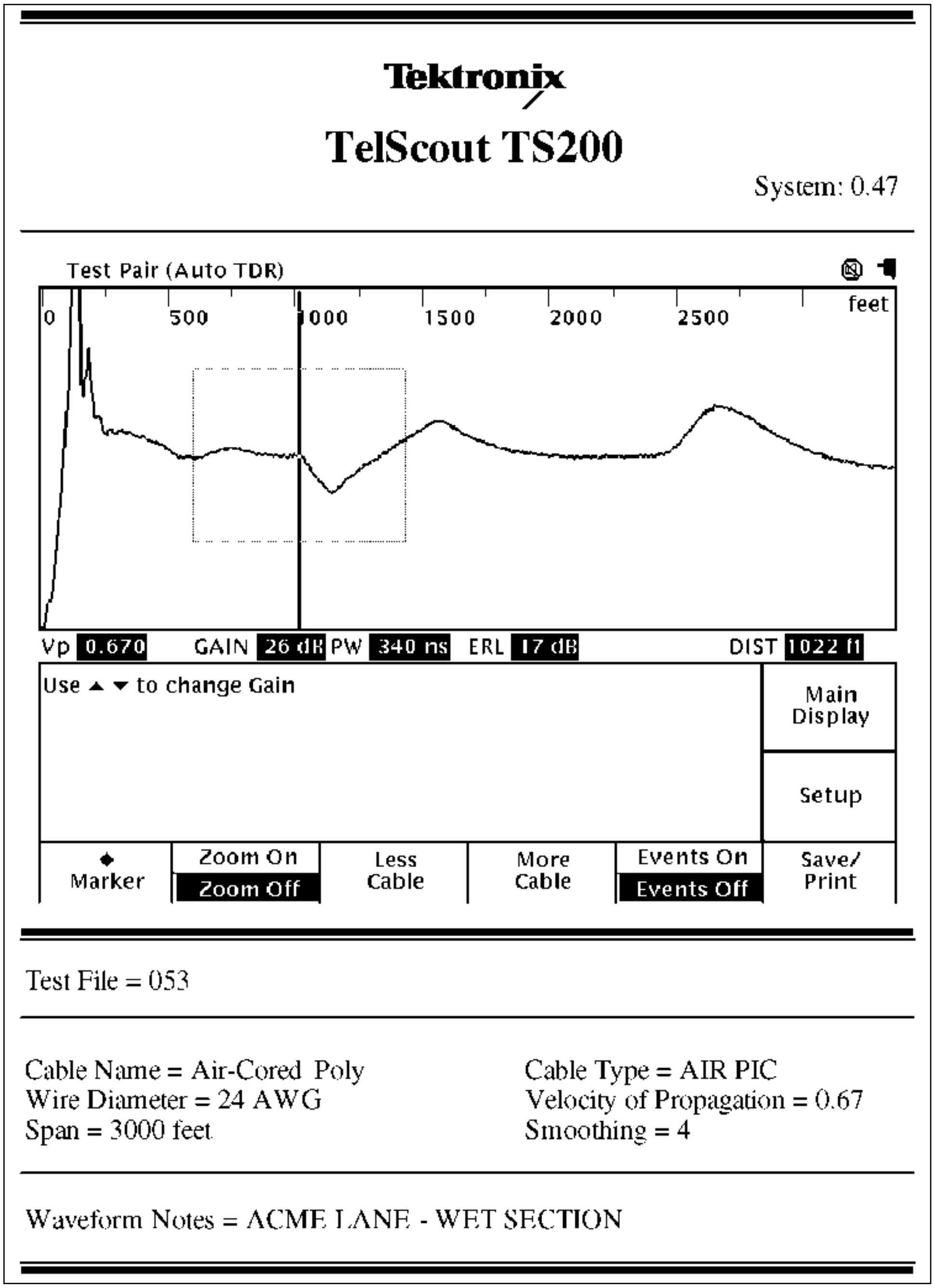


Figure 16-6. Sample printout.

Conclusion

Storage and documentation is made easy with self-prompting screens and menus. For additional information, extensive on-line help and informative lessons are also available in the TelScout Series.

Introduction

As the demand increases for bandwidth-hungry applications such as Internet Access, Video-on-Demand, Distance Learning, and Telecommuting, new digital services will be pushed further out on the cable plant. Large-scale deployment of these new digital services will require a faster, easier way to determine if a subscriber's existing POTS line is capable of supporting their high-speed requirements.

Table 17-1. xDSL Service Types

Service	Definition	# Pairs Used	Bit Rate
ADSL	Asymmetric Digital Subscriber Line	1	<9 Mbps (variable)
HDSL	High-bit-rate Digital Subscriber Line	2	1.544 Mbps
IDSL	Integrated Digital Subscriber Line	1	160 kbps
SDSL	Single-pair Digital Subscriber Line	1	784 kbps
VDSL	Very-high-bit-rate Digital Subscriber Line	1	<52.8 Mbps (variable)

ISDN Overview

In the 1980s, the Integrated Services Digital Network (ISDN) was introduced. Although the concept did not catch on immediately, it has now begun to gain in popularity and telephone companies are beginning to offer these and other digital services to many parts of the country.

Without going into a great deal of technical detail, ISDN-BRI (basic rate interface) is a fractional T1 service that is made up of two 64-kbit per second (kbps) B-channels and one 16 kbps D-channel. The B-channels carry voice and data, while the D-channel provides signal and packet networking (all carried on one twisted pair). Telephone companies deliver this service over what is called the U-interface, which is existing unshielded twisted pairs from the telephone company, accessed from an RJ-11 or RJ-45 wall outlet.

xDSL Overview

In basic terms, generic Digital Subscriber Line (xDSL) allows customers the benefits of high-speed digital access to the telephone network. Depending on the type of xDSL service, the data rate and loop requirements will vary. Most xDSL deployment is currently aimed at the business community, which uses HDSL and SDSL primarily. Residential trials and commercial deployments are in the early stages, with ADSL the prime offering. Definitions and a general overview for each of the service types is listed in Table 17-1.

The advantage of xDSL is in its ability to remove data traffic off of the Public Switched Telephone Network (PSTN), which was not originally designed for the long call lengths of data usage. Some services such as ADSL allow the standard analog POTS signal to ride below the digital signal on the same pair. At either end it can be split off from the digital portion, allowing the traditional reliability of analog POTS (see Figure 17-1).

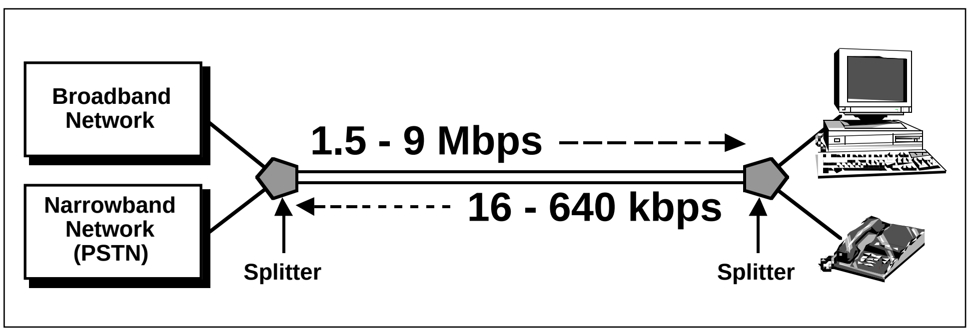


Figure 17-1. ADSL design (with splitter).

Deployment Problems

As these new digital services find their way onto twisted pair, the demands on the cable plant in terms of line availability and the quality of the service on those lines continues to grow. Using twisted pair that has been previously used for voice transmissions can create problems for the signals being passed in a digital system. Two common elements in a voice circuit, the load coil and the bridged tap and lateral, will in most cases render the circuit useless. These elements must be removed or revised before digital transmissions will pass smoothly. The key to simplified deployment is to perform a logical sequence of tests to pre-qualify the line and locate any potential problems.

Loop Length

The maximum loop length varies depending on the type of service being deployed (see Figure 17-2 and Table 17-2). ADSL and VDSL are variable rate services where service quality and throughput will degrade over longer distances. Services can be affected by the actual cable length, gauge or diameter, bridged taps and laterals, and crosstalk from other pairs (see Figures 17-3 and 17-4).

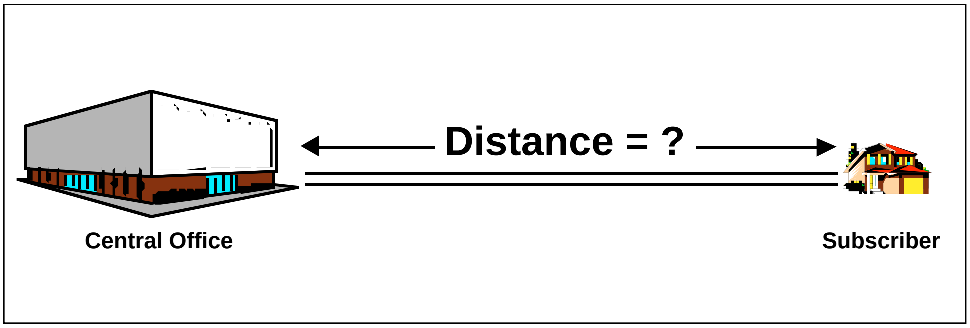


Figure 17-2. Loop length.

Table 17-2. Loop Length Requirements for Digital Service

	ISDN	ADSL	HDSL	IDSL	SDSL	VDSL
Loop Length	<18,000 ft. (<5.9 km)	<18,000 ft. (<5.9 km)	<12,000 ft. (<3.9 km)	<18,000 ft. (<5.9 km)	<12,000 ft. (<3.9 km)	< 4,500 ft. (<1.5 km)

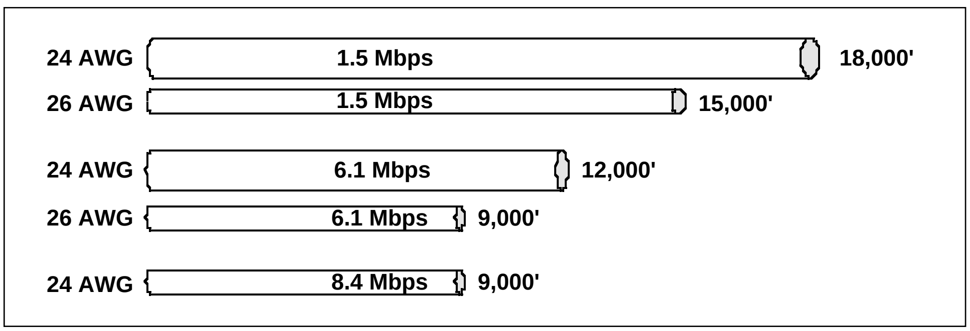


Figure 17-3. ADSL data rates.

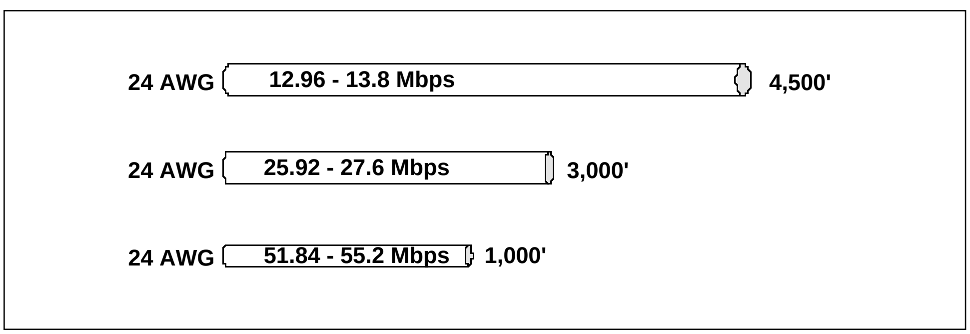


Figure 17-4. VDSL data rates.

The actual loop length can be measured using an Open Meter, a TDR, or both. It's best to use both tools and compare the results (see Figure 17-5).

Load Coils

A load coil is typically either a 66 mH or 88 mH (millihenry) inductor that is used in analog (voice) telephone systems. They are used because, over long cable lengths, higher-frequency signals are attenuated due to an increase in capacitance. To counteract this capacitance, load coils are spaced along the line. This spacing creates a "tuned" circuit for voice frequencies (300 to 3000 Hz).

In the United States, coils must be used on cables that are over 18,000 feet (5.5 km) in length. Internationally, this might vary based on loss specifications of the system. In an H88 loading scheme, the first load coil is at approximately 3,000 feet (915 m) from the central office or exchange (see Figure 17-6). Subsequent load coils are spaced approximately 6,000 feet (1,830 m) apart, although a coil may not be necessary over the last 10,000 feet (3 km) to the subscriber.

Unfortunately, loaded analog systems and digital systems are not compatible (see Table 17-3). You cannot pass digital and high-frequency signals through the coils. (For more detail on frequency and loss, refer to ***Chapter 12: Transmission Characteristics***.)

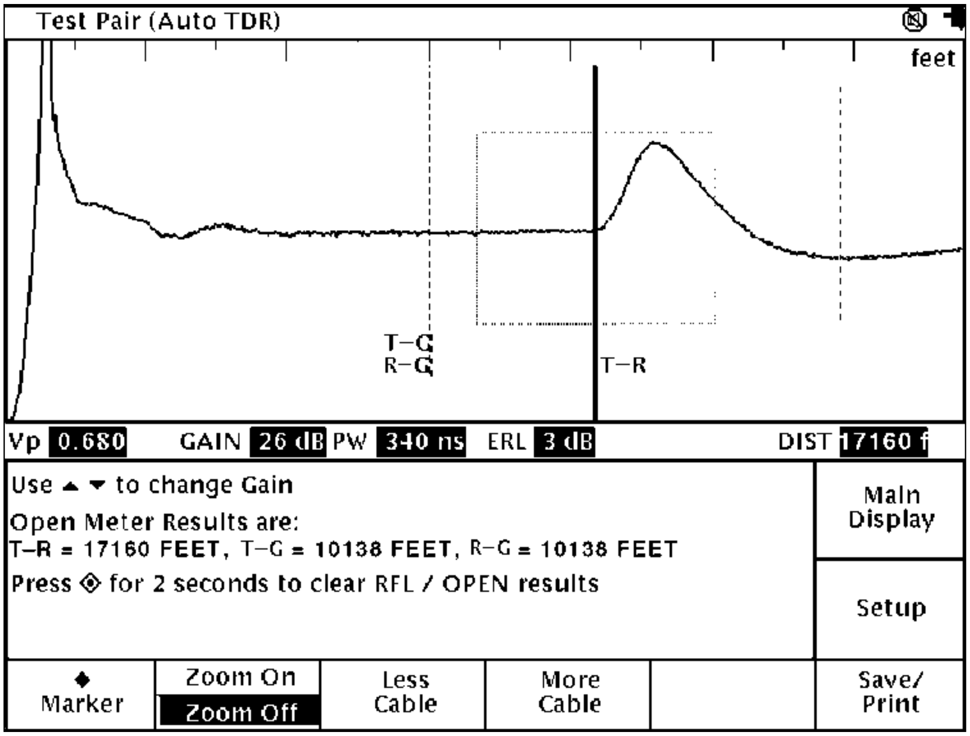


Figure 17-5. Loop length result for digital services.

Table 17-3. Load Coil Requirements for Digital Service

	ISDN	ADSL	HDSL	IDSL	SDSL	VDSL
Load Coils	0	0	0	0	0	0

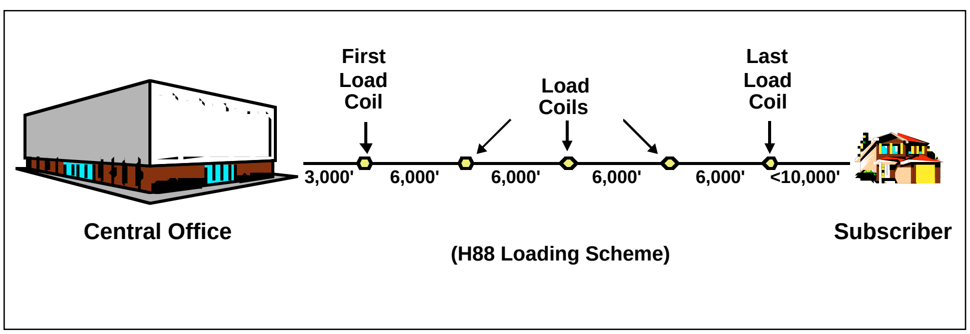


Figure 17-6. H88 loading scheme.

Using a load coil counter will help identify approximately how many load coils are on the line. During deployment of digital services, it's important to remember that any load coils are unacceptable. Simply use the load coil counter to check for one or more load coils, and then use the TDR to locate the first one (see Figure 17-7).

The TDR is the only piece of test gear available that can simply and accurately locate load coils. A TDR sends high frequency pulses down the line and senses reflected energy. The technique is much like radar. Because the pulses contain high-frequency energy, they cannot pass through a load coil. The coil (shown in Figure 17-8) looks like a large increase in cable impedance and is similar to the open circuit waveform (shown in Figure 17-9).

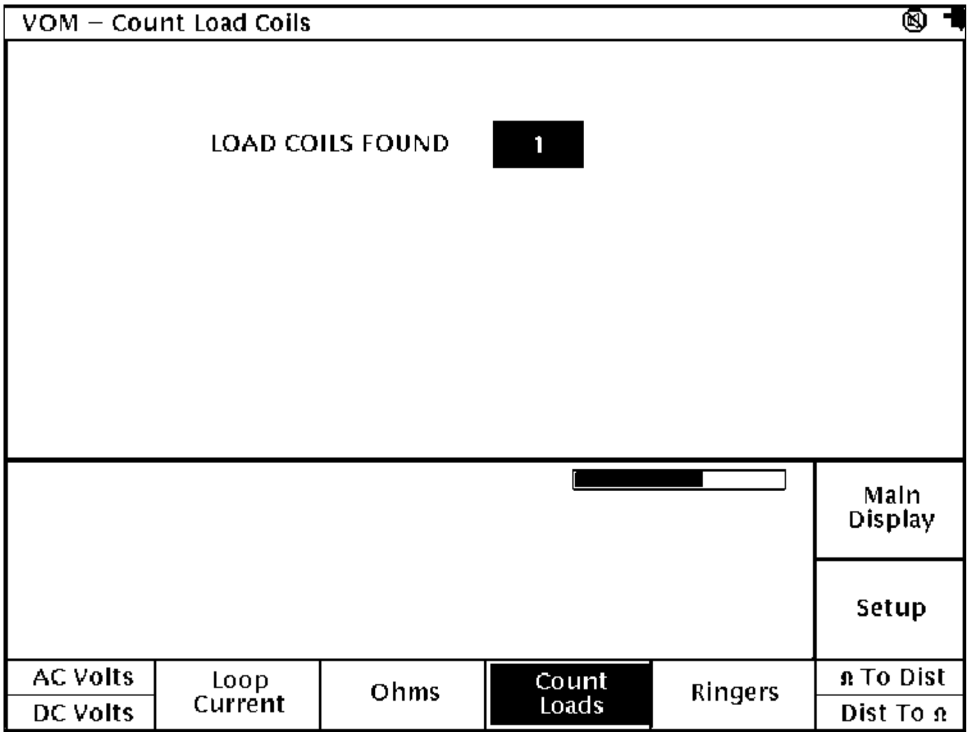


Figure 17-7. Counting load coils.

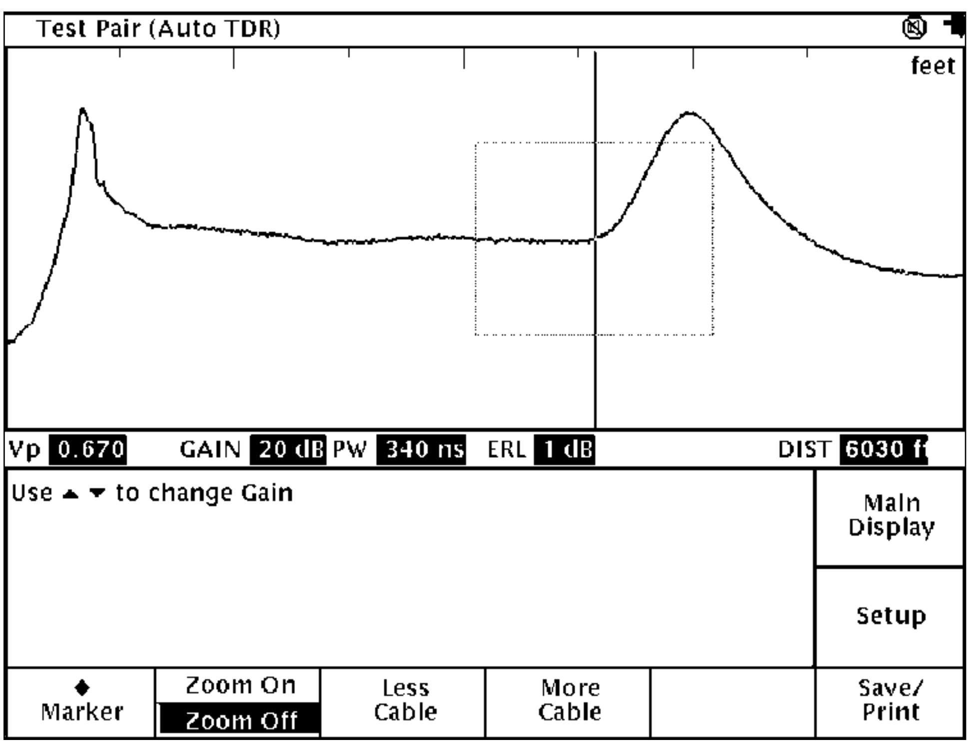


Figure 17-8. Load coils.

Notice that the shape of the load coil reflection has a more rounded appearance than an open and it appears at about 6000 feet (1,830 m). Generally, you should see the first load coil 3,000 feet (915 m) from the central office and then subsequent load coils at approximately 6000 foot (1,830 m) intervals for H88 loading, although you will only be able to see the first one. To locate multiple load coils, simply locate the first one and remove it. While there, connect onto the line and search again. This process can then be repeated for as many load coils as are on the line.

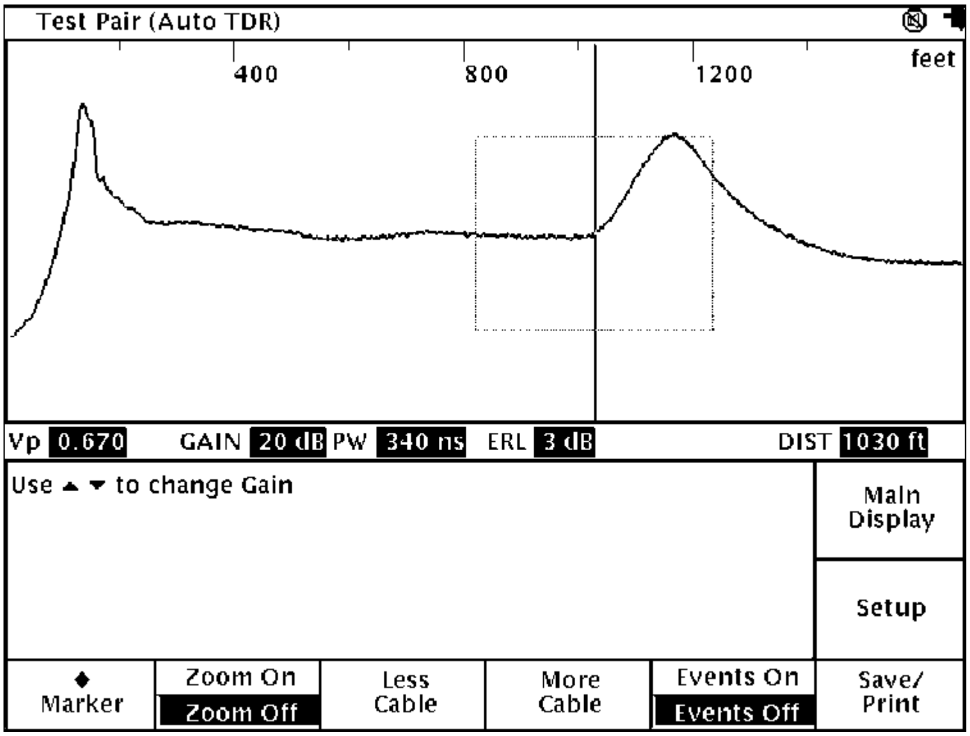


Figure 17-9. Open circuit.

Loop Resistance

The maximum loop resistance varies depending on the type of service being deployed and the expected service quality (see Table 17-4). The actual loop resistance can be affected by the cable length, conductor type, gauge or diameter, and general cable condition (see Figure 17-10).

Table 17-4. Loop Resistance Requirements for Digital Service

	ISDN	ADSL	HDSL	IDSL	SDSL	VDSL
Loop Resistance	<1,300 Ω	<1,300 Ω	<900 Ω	<1,300 Ω	<900 Ω	<325 Ω

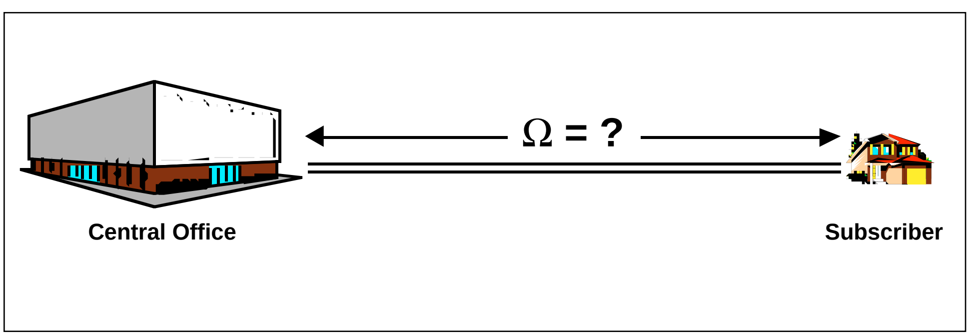


Figure 17-10. Loop resistance.

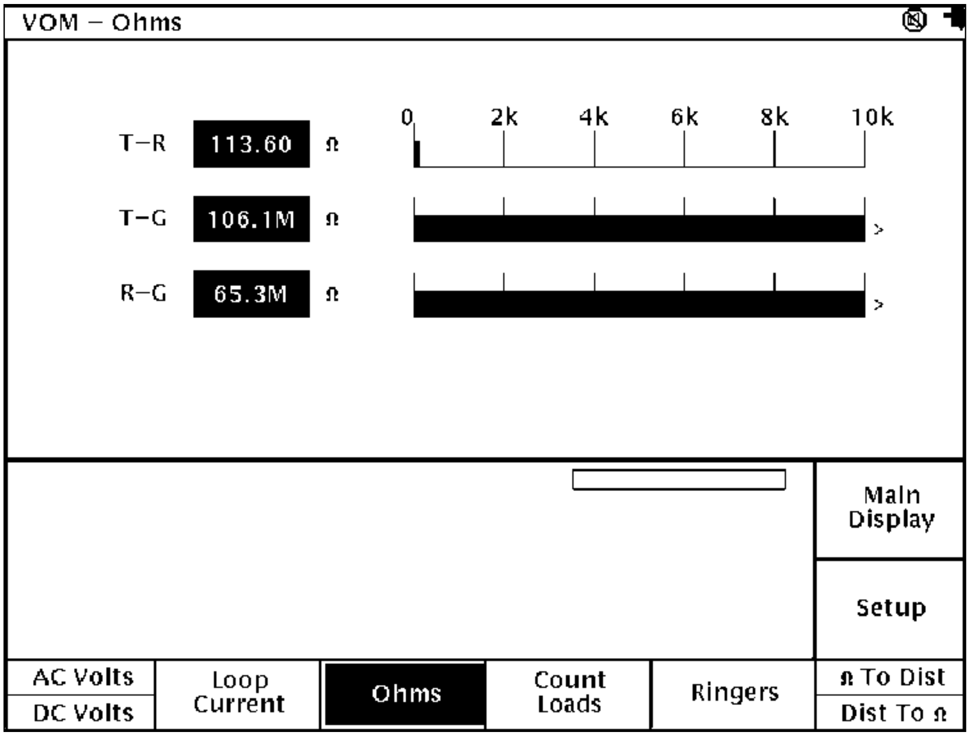


Figure 17-11. Loop resistance results for digital services.

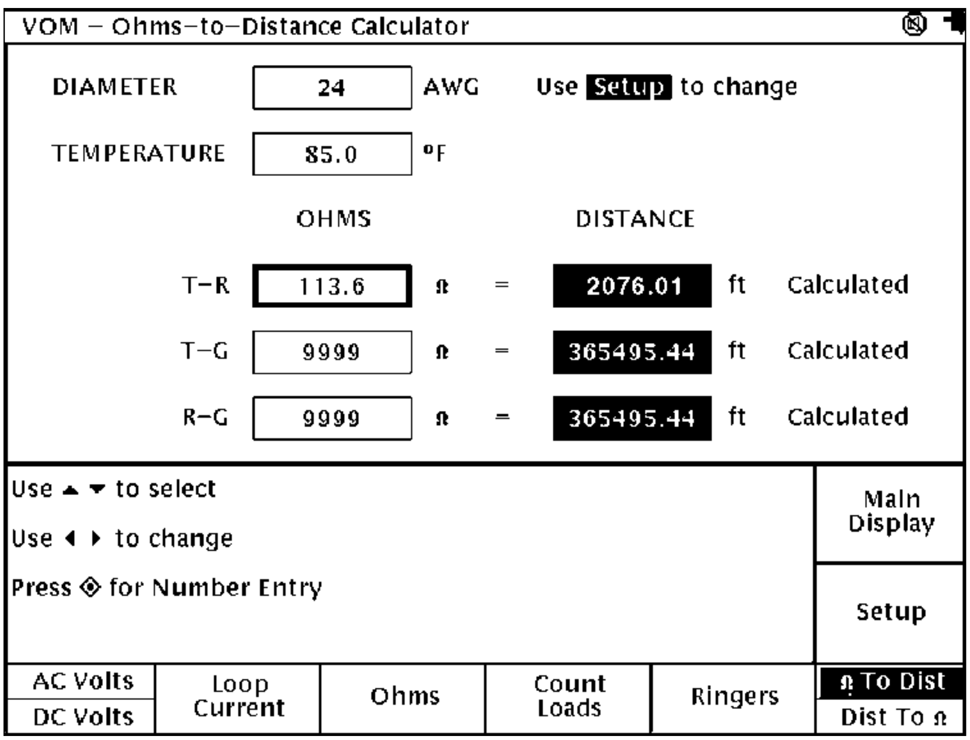


Figure 17-12. Ohms-to-distance calculation for digital services.

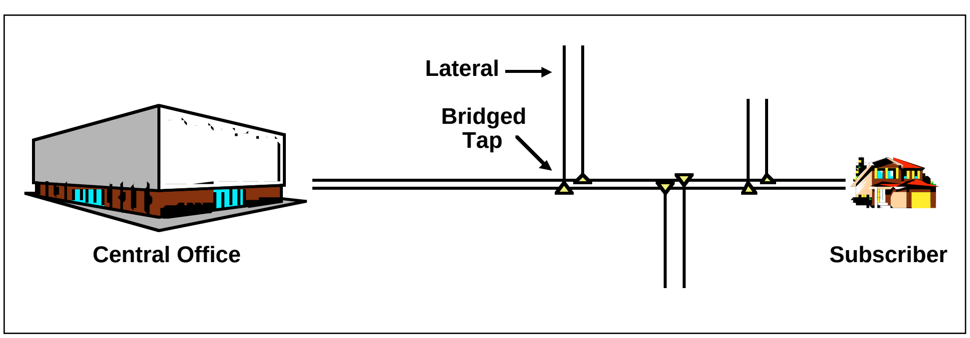


Figure 17-13. Bridged taps and laterals.

Measuring the actual loop resistance for the digital line can be done using an ohm meter, with Tip, Ring, and Ground (A, B, E) strapped together at the far end (see Figure 17-11).

Once the total loop resistance is measured, you can also estimate the length of the loop using an Ohms-to-Distance calculator that accounts for the cable type, gauge or diameter, and the temperature of the cable itself (see Figure 17-12).

Bridged Taps and Laterals

Bridged taps and laterals have been used for many years. A bridged tap is used to connect another section of cable, known as a lateral, to provide POTS or analog service at various points along the main route of the cable (see Figure 17-13). A lateral is commonly defined as any section of cable that is not on the direct path between the central office and the subscriber.

These laterals are acceptable in a standard POTS or analog line, but they typically cause problems for digital services. The digital signal travels down the cable to the subscriber, but it's also transmitted down each section as well. Echoes from these laterals recombine with the original signal to the subscriber, causing errors in the signal.

Some digital technologies provide limited echo cancellation, but in a majority of the cases, you may still need to remove the laterals to provide reliable service. Other test equipment, such as an open meter, may be able to identify that there's extra cable between the central office and the subscriber, but only a TDR is capable of locating each tap and the length of the laterals. This is extremely useful since you now know where to go to remove the lateral and how long the section is that you just removed.

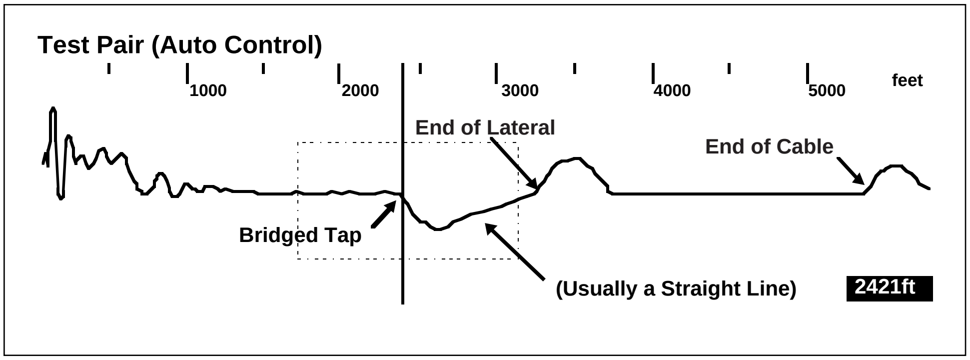


Figure 17-14. Bridged tap and lateral example.

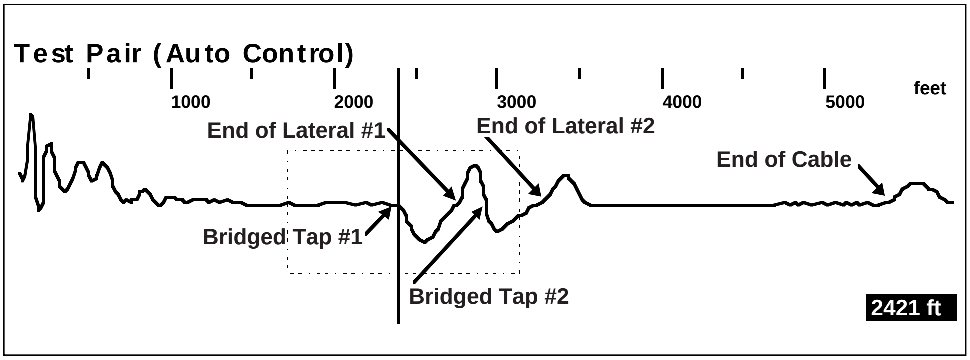


Figure 17-15. Multiple bridged tap and lateral example.

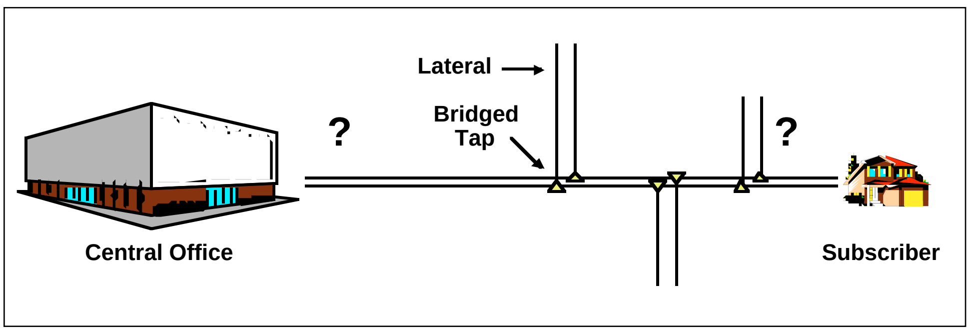


Figure 17-16. Closest bridged tap.

Table 17-5. Closest Bridged Tap Requirements for Digital Service

	ISDN	ADSL	HDSL	IDSL	SDSL	VDSL
Closest Tap	>1,000 ft. (>328 m)	>1,000 ft. (>328 m)	>1,000 ft. (>328 m)	>1,000 ft. (>328 m)	>1,000 ft. (>328 m)	>1,000 ft. (> 328 m)

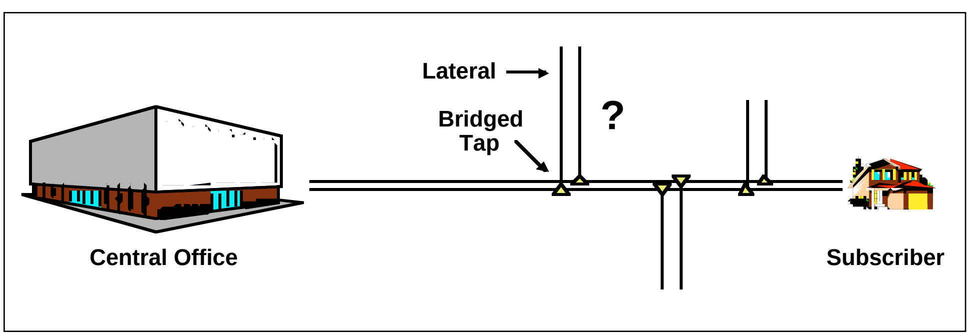


Figure 17-17. Longest bridged tap.

Table 17-6. Longest Bridged Tap Requirements for Digital Service

	ISDN	ADSL	HDSL	IDSL	SDSL	VDSL
Longest Tap	<2,000 ft. (<656 m)	<2,000 ft. (<656 m)	<2,000 ft. (<656 m)	<2,000 ft. (<656 m)	<2,000 ft. (<656 m)	<2,000 ft. (<656 m)

On a TDR waveform, the tap is shown as a downward spike with a straight sloping line that represents the lateral. The upward bump at the end of the straight line indicates the open end of the lateral (see Figure 17-14.) Each bridged tap and lateral will be displayed on the TDR waveform, so the more there are, the more difficult it may become to interpret the waveform (see Figure 17-15). The easiest way to eliminate this confusion is to locate the first tap and remove the lateral. Once this has been done, you can shoot the line again and remove the next one. Simply repeat this process until all of the taps and laterals within the limit have been removed.

To make certain a digital line conforms to its deployment requirements for bridged taps, the following three steps will improve your success rate.

Step 1. Check Closest Bridged Taps.

First, find and remove any bridged taps within the closest limit of each end (see Figure 17-16 and Table 17-5).

Step 2. Check Longest Bridged Taps.

Then check to make sure the remaining long bridged taps do not exceed the maximum lateral length limit (see Figure 17-17 and Table 17-6).

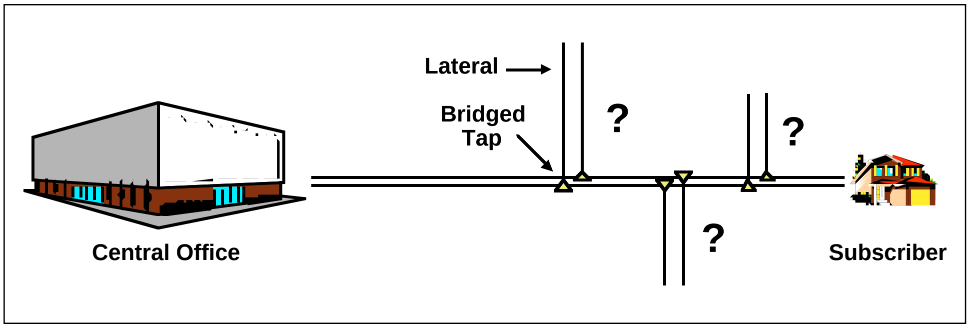


Figure 17-18. Total bridged taps.

Table 17-7. Total Bridged Tap Requirements for Digital Service

	ISDN	ADSL	HDSL	IDSL	SDSL	VDSL
Total Taps	<2,500 ft. (<820 m)	<2,500 ft. (<820 m)	<2,500 ft. (<820 m)	<2,500 ft. (<820 m)	<2,500 ft. (<820 m)	<2,500 ft. (<820 m)

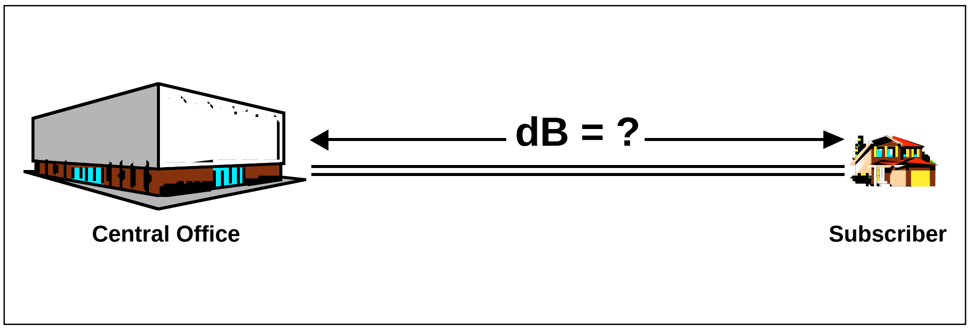


Figure 17-19. Loop loss.

Table 17-8. Loop Loss Requirements for Digital Service

	ISDN	ADSL	HDSL	IDSL	SDSL	VDSL
Loop Loss	<–39 dB	Variable	<–35 dB	<–39 dB	<–35 dB	Variable
Nyquist Frequency	40 kHz	–	196 kHz	40 kHz	196 kHz	–

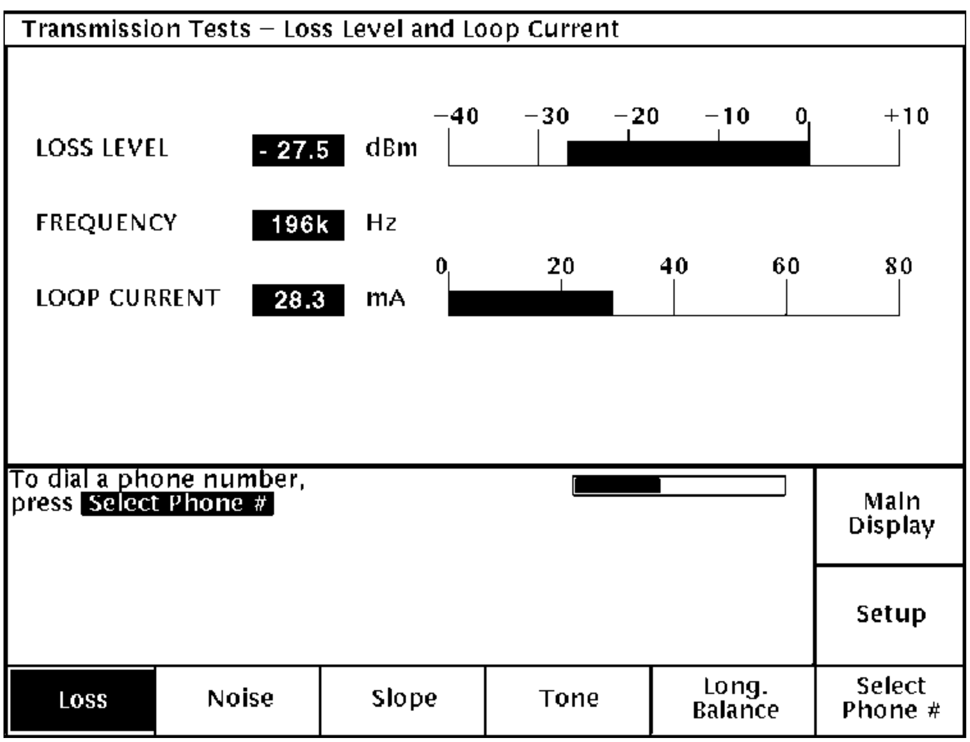


Figure 17-20. Loop loss results for digital services.

Step 3. Check Total Bridged Taps.

Finally, verify that the total amount of bridged taps on the line does not exceed the maximum limit. The easiest way to do this is to compare your TDR waveform with your open meter results (see Figure 17-18 and Table 17-7).

Loop Loss

The maximum loop loss varies depending on the type of service being deployed. Since the transmission frequencies vary between the different digital services, the frequency used to measure the loss will also vary (see Figure 17-19 and Table 17-8)

Measuring the loss of the digital line at the correct frequency will give you a general indication of whether or not the line has the potential for supporting digital services. It's a good qualitative test to confirm that all of your previous steps have eliminated any problem areas that the line might have (see Figure 17-20).

Crosstalk

Most digital services are intolerant of too much crosstalk between the pair you are using and other pairs in the binder group. A common source of crosstalk that is easily corrected is the split pair. Splits are wiring mistakes caused by splicing one wire of a pair to another wire in an adjacent pair. Resplits (or corrected splits) occur when someone recognizes which pairs are split and decides to match them back up farther down the line (see Figure 17-21).

These splits and resplits can cause an apparently good POTS line to reject digital services. Traditional POTS test equipment makes finding a split or resplit difficult at best. Toning or complicated capacitance measurements are seldom practical or successful. The TDR is capable of easily locating the fault. A split on a standard TDR waveform appears as a bump, since there's a higher impedance change. The resplit will show as a dip since the pair is coming back together and lowers the impedance (see Figure 17-22).

If your TDR is equipped with a crosstalk mode, it will make finding the splits and resplits even easier. By connecting the TDR's test and reference leads to the split pairs, the TDR will only display where the pairs are split and resplit. The rest of the cable is displayed as a flat line (see Figure 17-23). Notice that the bumps and dips are in the opposite direction from those in Figure 17-22. Their direction depends on which way the leads are connected, but remember that in crosstalk mode you are only concerned with anything that is not a flat line. This mode makes locating the split and resplit fast and simple.

Conclusion

Large-scale deployment of digital services will require a faster, easier, and more cost effective way to determine if the existing POTS line can handle it. By using the field test equipment available today, you can quickly pre-qualify the physical plant to determine where potential digital problems might be. Following this sample checklist and stepping through the test sequence will minimize deployment time.

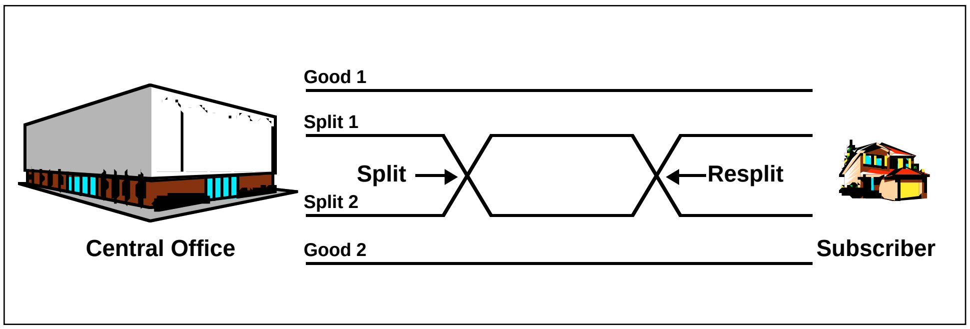


Figure 17-21. Splits and resplits.

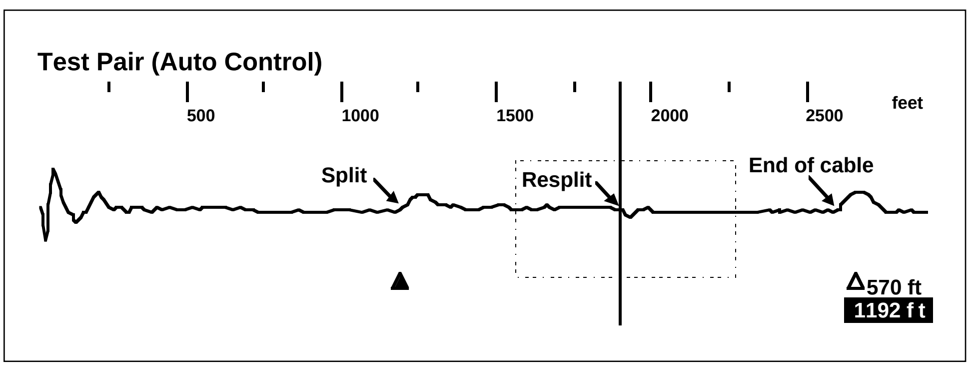


Figure 17-22. Split and resplit example.

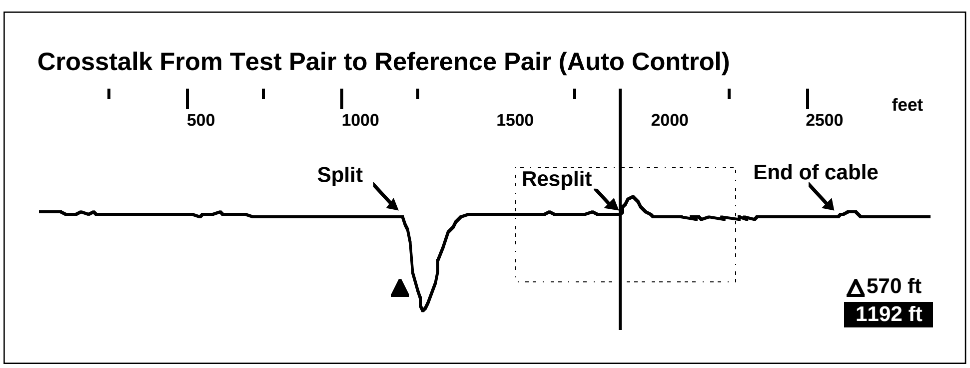


Figure 17-23. Split and resplit in crosstalk mode.

Table 17-9. Digital Service Parameters

	ISDN	ADSL	HDSL	IDSL	SDSL	VDSL
Number of Pairs	2	1	2	1	1	1
Bit Rate	144 kbps	9 Mbps (Variable)	1.544 Mbps	160 kbps	784 kbps	52.8 Mbps (Variable)
Loop Length	<18,000 ft. (< 5.9 km)	<18,000 ft. (<5.9 km)	<12,000 ft. (<3.9 km)	<18,000 ft. (<5.9 km)	<12,000 ft. (<3.9 km)	<4,500 ft. (<1.5 km)
Load Coils	0	0	0	0	0	0
Loop Resistance	<1,300 Ω	<1,300 Ω	<900 Ω	<1,300 Ω	<900 Ω	<325 Ω
Closest Tap	>1,000 ft. (>328 m)	>1,000 ft. (>328 m)	>1,000 ft. (>328 m)	>1,000 ft. (>328 m)	>1,000 ft. (>328 m)	>1,000 ft. (>328 m)
Longest Tap	<2,000 ft. (<656 m)	<2,000 ft. (<656 m)	<2,000 ft. (<656 m)	<2,000 ft. (<656 m)	<2,000 ft. (<656 m)	<2,000 ft. (<656 m)
Total Taps	<2,500 ft. (<820 m)	<2,500 ft. (<820 m)	<2,500 ft. (<820 m)	<2,500 ft. (<820 m)	<2,500 ft. (<820 m)	<2,500 ft. (<820 m)
Loop Loss	<–39 dB	Variable	<–35 dB	<–39 dB	<–35 dB	Variable
Nyquist Frequency	40 kHz	N/A	196 kHz	40 kHz	196 kHz	N/A

Appendix A: Telephony Color Codes

Pair Colors

PAIR #	TIP	RING
1	W	BL
2	W	O
3	W	G
4	W	BR
5	W	S
6	R	BL
7	R	O
8	R	G
9	R	BR
10	R	S
11	BK	BL
12	BK	O
13	BK	G
14	BK	BR
15	BK	S
16	Y	BL
17	Y	O
18	Y	G
19	Y	BR
20	Y	S
21	V	BL
22	V	O
23	V	G
24	V	BR
25	V	S

Binder Colors

Binder Group #	Pairs	Binder Colors
1	1 – 25	BL-W
2	26 – 50	O-W
3	51 – 75	G-W
4	76 – 100	BR-W
5	101 – 125	S-W
6	126 – 150	BL-R
7	151 – 175	O-R
8	176 – 200	G-R
9	201 – 225	BR-R
10	226 – 250	S-R
11	251 – 275	BL-BK
12	276 – 300	O-BK
13	301 – 325	G-BK
14	326 – 350	BR-BK
15	351 – 375	S-BK
16	376 – 400	BL-Y
17	401 – 425	O-Y
18	426 – 450	G-Y
19	451 – 475	BR-Y
20	476 – 500	S-Y
21	501 – 525	BL-V
22	526 – 550	O-V
23	551 – 575	G-V
24	576 – 600	BR-V
25	–	–

Abbreviations

Abbreviation	Color
BL	Blue
O	Orange
G	Green
BR	Brown
S	Slate
W	White
R	Red
BK	Black
Y	Yellow
V	Violet

Appendix B: Glossary

AC (Alternating Current) – A method of delivering electrical energy by periodically changing the direction of the flow of electrons in the circuit or cable. Even electrical signals designed to deliver direct current (DC) usually fluctuate enough to have an AC component.

Access Network – The pair of copper wires that connects the end user to the telephone company's central office, which serves as the gateway to the global telephone network. These wires, originally installed for analog communication, may be the same wires used for newer digital services, which require new equipment at both the user's end and the telephone company.

Accuracy – The difference between a measured, generated, or displayed value and its true value.

ADSL (Asymmetric Digital Subscriber Line) – A digital service that provides 1.5 Mbps to 9 Mbps of downstream data to the subscriber with 16 kbps of duplex for controls between the subscriber and the central office.

ATM (Asynchronous Transfer Mode) – A form of fast packet switching that allows for data transmission via BISDN, which is a faster form of digital communications than ISDN.

AWG (American Wire Gauge) – Used to indicate the thickness of the conductor.

B-channel (Bearer Channel) – A 64 kbps bearer channel used for delivering data or voice communications over ISDN. The standard BRI connection includes two B-channels for a total uncompressed capacity of 128 kbps.

Balance – The condition of a cable pair where both conductors are electrically equivalent in terms of capacitance and resistance.

BISDN (Broadband ISDN) – A type of ISDN service that uses fiber optic lines and ATM to deliver bearer services with data transmission rates of more than 150 Mbps.

BRI (Basic Rate Interface) – A defined interface to ISDN that includes two B-channels and one D-channel. It's commonly referred to as 2B+D. Other configuration options are available within the BRI interface, depending on your local telephone company (e.g., B or 2B with no D).

Bridged Tap – 1) Any section of a cable pair not in the direct electrical path between the central office and the user's premises. 2) The multiple appearances of the same cable pair at several distribution points.

Build Out Capacitor – An electrical circuit which adds capacitance to a pair, making it appear electrically longer than it actually is. It's commonly used in loaded cable sections where there's physically not enough cable between load coils.

Cable Attenuation – The amount of signal that's absorbed as the signal propagates down the cable. Cable attenuation is typically lower at low frequencies and higher at high frequencies. This should be accounted for by TDRs that measure return loss. Cable attenuation is usually expressed in decibels (dB) at one or several frequencies. See also dB.

Cable Fault – Any condition that makes the cable less efficient at delivering electrical energy. Water leaking through the insulation, poorly mated connectors, and bad splices are typical types of cable faults.

Calculated Balance – See Balance.

CAP (1) Competitive Access Provider – A carrier in competition with the local provider offering access to the network.

CAP (2) Carrierless Amplitude and Phase modulation – A transmission technology used for digital services where the signal is modulated into two wide frequency bands using passband modulation techniques.

CO (Central Office) – The site where local telephone switches reside for all of that system's call routing and other functions. In some countries, this is also referred to as the exchange.

CPE (Customer Premise Equipment) – Equipment located on the customer's side of the network interface box.

Common Multiplier Prefixes

Prefix	Symbol	Multiplier	Description	Example
Mega-	M	x 1,000,000	One million of something	1 MΩ = 1 million ohms
kilo-	k	x 1,000	One thousand of something	1 kΩ = 1 thousand ohms
milli-	m	x 0.001	One thousandth of something	1 mA = 1 thousandth of an amp
micro-	µ	x 0.000001	One millionth of something	1 µF = 1 millionth of a Farad
nano-	n	x 0.000000001	One billionth of something	1 nF = 1 billionth of a Farad
pico-	p	x 0.000000000001	One trillionth of something	1 pF = 1 trillionth of a Farad

Crosstalk – Noise, signal, or tone that is induced onto a pair from other pairs within a cable.

Current – See Loop Current.

dB (Decibel) – A method of expressing power or voltage ratios. The decibel scale is logarithmic. It's often used to express the efficiency of power distribution systems when the ratio consists of the energy put into the system divided by the energy delivered (or in some cases, lost) by the system. The formula for decibels is:

$$dB = 20 \log (V_i/V_o).$$

D-channel (Data channel) – A separate channel for out-of-band signaling between the user and the ISDN network. The D-channel can also be used to deliver X.25 data packets at up to 16 kbps.

DC (Direct Current) – A method of delivering electrical energy by maintaining a constant flow of electrons in one direction. Even circuits designed to generate only alternating current (AC) often have a DC component.

Demarcation Point – The point at the customer premises where the line from the telephone company meets the premises wiring. From the demarcation point, the end user is typically responsible for the wiring. The physical device that provides the means to connect the telephone company's wire to the premises wiring is called a network interface box.

DLL (Dial Long Line) – A loop treatment device used to compensate for low loop current when the loss measurement is acceptable.

DMT (Discrete Multi-Tone) – A transmission technology used for digital services where the signal is divided into 256 sub-channels using a digital signal processor.

Downstream Channel – The frequency-multiplexed band in a CATV channel that distributes signals from the head end to the users.

DTMF (Discrete Tone Multi-Frequency) – A common technique of sending multiple frequencies simultaneously for dialing.

Exchange – See Central Office.

FEXT (Far End Crosstalk) – A measurement of the amount of crosstalk when measured at the far end of the pair.

FTTB – Fiber to the Building.

FTTC – Fiber to the Curb.

FTTH – Fiber to the Home.

HDSL (High-bit-rate Digital Subscriber Line) – A digital service that provides 1.544 Mbps between the subscriber and the central office over two pairs.

HFC (Hybrid Fiber/Coax) – A broadband deployment strategy that uses fiber from the central office/head end out to the subscriber's area, then uses coaxial cable to reach the subscriber.

IDSL (Integrated Digital Subscriber Line) – A digital service that provides ISDN (160 kbps) over a DSL line between the subscriber and the central office over a single pair.

Incident Pulse – The pulse of electrical energy sent out by the TDR. The waveform shown by the TDR consists of this pulse and the reflections of it coming back from the cable being tested.

Insulation – A protective coating on an electrical conductor that does not readily allow electrical energy to flow away from the conductive part of the cable or circuit. Insulation is also called dielectric. The kind of dielectric used in a cable determines how fast electricity can travel through the cable (see Velocity of Propagation).

ISDN (Integrated Services Digital Network) – A digital service that provides two B-channels at 64 kbps and one D-channel at 16 kbps. Voice and/or data can be carried over the B-channels while the D-channel is used for control and signaling information.

Lateral – See Bridged Tap.

LCD (Liquid Crystal Display) – A kind of display commonly used in field test equipment and laptop computers. The terms LCD and display are often used interchangeably in this manual.

Load Coil – An induction device employed in local loops that exceed 18,000 feet in length. It compensates for wire capacitance and boosts voice-grade frequencies. Loading coils must be removed for higher-speed digital services since they do not allow the higher frequencies to pass through.

Local Loop – See Access Network.

Longitudinal Balance – A test which induces an AC signal onto the pair, allowing minor capacitive, resistive, and inductive imbalances to be detected.

Longitudinal Noise – See Power Influence.

Loop Current – The flow of electricity through a conductor. It's typically measured in milliamps (mA), which is 1/1000th of an amp.

Metallic Noise – See Noise.

MTDR (Metallic Time Domain Reflectometer) – See TDR.

National ISDN – As defined by Bellcore, National ISDN 1 (NI-1) is an agreement among telephone companies and CPE vendors to jointly provide the first phase of standards-based ISDN. NI-1 is a collection of standards to allow CPE to work across different telephone company switches using BRI.

NEXT (Near End Crosstalk) – A measurement of the amount of crosstalk when measured at the near end of the pair.

Noise – Any unwanted electrical energy that interferes with a signal or measurement. Most noise is random with respect to the signals sent by the TDR to make a measurement and appears on the waveform.

Open Circuit – In a cable, a broken conductor that does not allow electrical energy to flow through it. These circuits are also called broken circuits. The circuit is "open" to the air, which appears as a very high impedance.

OSP (Outside Plant) – Any cable located between the central office/head end and the subscriber.

PET (Pulse Echo Tester) – See TDR.

POTS (Plain Old Telephone Service) – Standard analog voice-grade telephone service from 300 to 3000 Hz.

PRI (Primary Rate Interface) – An ISDN interface designed for high-volume data communication. The North American PRI service consists of 23 B-channels at 64 kbps each and one D-channel at 16 kbps.

PSTN (Public Switched Telephone Network) – The telephone network used to connect analog/voice circuits.

PUC (Public Utilities Commission) – An agency that regulates telephone company practices in the United States and monitors service and quality.

RBOC – Regional Bell Operating Company.

REG (Range Extender with Gain) – A loop treatment device used to compensate for both low loop current and high loss.

SDSL (Single-pair Digital Subscriber Line) – A digital service that provides 784 Mbps between the subscriber and the central office over a single pair.

Short Circuit – In a cable, two conductors that are touching one another to allow electrical energy to flow between them. These circuits are also called shorts or resistive faults. The circuit is "shorted," which appears as a low impedance.

Split – Something that happens in cable splicing when one wire of a pair gets spliced to the wire of an adjacent pair. This is commonly referred to as a split pair.

Subscriber – A customer who receives a variety of services from the telephone company.

TDR (Time-Domain Reflectometer) – An instrument that sends out pulses of energy and measures the time interval of the reflections (also called cable radar or pulse echo tester). If the velocity of the energy through the cable is known, distances to faults in the cable can be computed and displayed. Conversely, the speed that energy travels through a cable of known length can also be computed. The way in which the energy is reflected and the amount of the energy reflected indicate the condition of the cable.

Telco – Common term referring to the local telephone company or provider.

Transverse Noise – See Noise.

Upstream Channel – A collection of frequencies on a CATV channel reserved for transmission from the terminal next to the user's TV set to (upstream) the CATV company's computer.

VDSL (Very-high-bit-rate Digital Subscriber Line) – A digital service that provides up to 52.8 Mbps between the subscriber and the central office over a single pair.

Velocity of Propagation (V_p) – The speed that electricity travels in a cable is often expressed as the relative velocity of propagation. This value is a ratio of the speed in the cable to the speed of light. It's typically expressed as a percentage of the speed of light with values ranging from 0.30 to 1.00.

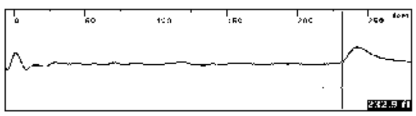
xDSL (Generic Digital Subscriber Line) – Used to denote generic digital subscriber line service, including ADSL, HDSL, VDSL, and others.

Appendix C: TelScout® TS90 Quick Reference

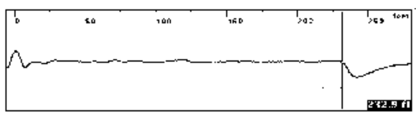
Distance/Open/Short

1. Press RESET TO METRIC or RESET TO US (not necessary if previously set).
2. Press SETUP.
3. Use ▲▼ to select the cable type to be tested.
4. Connect the test leads to the cable under test.
5. Press TEST TYPE.
6. Use ▲▼ to select TEST PAIR.
7. Press EXIT.
8. Press MORE CABLE until the reflection is seen.
9. Use ▲▼ to adjust the waveform height.
10. Press ◄► to move the cursor to the leading edge of the reflection.

Typical Open



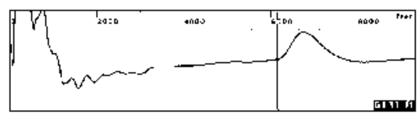
Typical Short



Load Coils

1. Press RESET TO METRIC or RESET TO US (not necessary if previously set).
2. Press SETUP.
3. Use ▲▼ to select the cable type to be tested.
4. Connect the test leads to the cable under test.
5. Press TEST TYPE.
6. Use ▲▼ to select TEST PAIR.
7. Press EXIT.
8. Press MORE CABLE until the reflection is seen.
9. Use ▲▼ to adjust the waveform height.
10. Press ◄► to move the cursor to the leading edge of the load coil.

Typical Load Coil

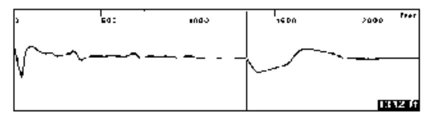


NOTE: Load coil waveforms look very similar to an Open waveform. Typically, the load coil will be located at its appropriate spacing, depending on the loading scheme being used.

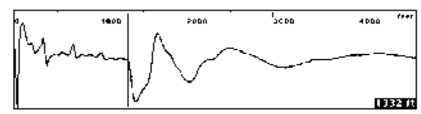
Bridged Taps and Laterals

1. Press RESET TO METRIC or RESET TO US (not necessary if previously set).
2. Press SETUP.
3. Use ▲▼ to select the cable type to be tested.
4. Connect the test leads to the cable under test.
5. Press TEST TYPE.
6. Use ▲▼ to select TEST PAIR.
7. Press EXIT.
8. Press MORE CABLE until the reflection is seen.
9. Use ▲▼ to adjust the waveform height.
10. Press ◄► to move the cursor to the leading edge of the bridged tap.

Single Bridged Tap



Multiple Bridged Taps

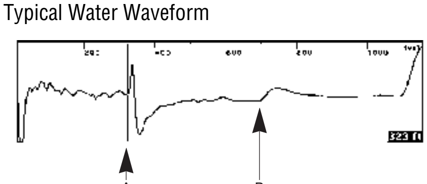


NOTE: If there is more than one bridged tap on the pair, the additional lateral might be sufficient to obscure the end of the cable. If necessary, remove the first bridged tap and retest the cable to locate the next tap.

Water

1. Press RESET TO METRIC or RESET TO US (not necessary if previously set).
2. Press SETUP.
3. Use ▲▼ to select the cable type to be tested.
4. Connect the test leads to the cable under test.
5. Press TEST TYPE.
6. Use ▲▼ to select TEST PAIR.
7. Press EXIT.
8. Press MORE CABLE until the reflection is seen.
9. Use ▲▼ to adjust the waveform height.
10. Press ◄► to move the cursor to the beginning of the wet section (see A below). This is the distance to the water.
11. Press ◄► to move the cursor to the end of the wet section (see B below).
12. A to B is the wet section.

Typical Water Waveform

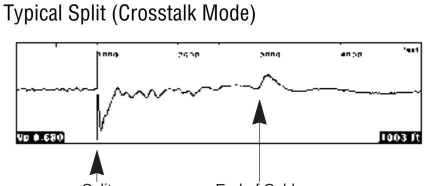


NOTE: The distance from the front panel to the water (A) is correct. The wet section distance (A to B) is not correct due to the Vp being changed by the water. Subtract the dry section distance from the cable map to obtain the wet distance, or measure from both ends of the cable to the wet section.

Split Pair

1. Press RESET TO METRIC or RESET TO US (not necessary if previously set).
2. Press SETUP.
3. Use ▲▼ to select the cable type to be tested.
4. Connect the TEST leads to the first split pair.
5. Connect the REFERENCE leads to the second split pair.
6. Press TEST TYPE.
7. Use ▲▼ to select SPLITS OR CROSSTALK.
8. Press EXIT.
9. Press MORE CABLE until the reflection is seen.
10. Use ▲▼ to adjust the waveform height.
11. Press ◄► to move the cursor to the split.

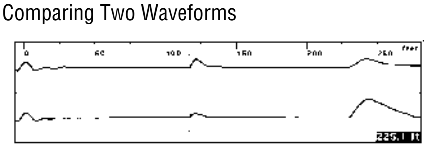
Typical Split (Crosstalk Mode)



Comparing Two Pairs

1. Press RESET TO METRIC or RESET TO US (not necessary if previously set).
2. Press SETUP.
3. Use ▲▼ to select the cable type to be tested.
4. Connect the TEST leads to the first pair.
5. Connect the REFERENCE leads to the second split pair.
6. Press TEST TYPE.
7. Use ▲▼ to select TEST PAIR / REFERENCE PAIR.
8. Press EXIT. Both the test pair waveform and the reference pair waveform are displayed (test pair waveform I on top).
9. Press MORE CABLE until the reflection is seen.
10. Use ▲▼ to adjust the waveform height.
11. Press ◄► to move the cursor to the leading edge of the event.

Comparing Two Waveforms

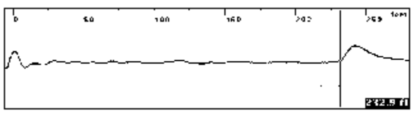


Appendix D: TelScout® TS100 Quick Reference

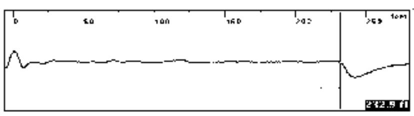
Distance / Open / Short

1. Press RESET TO METRIC or RESET TO US (not necessary if previously set).
2. Press SETUP.
3. Use ▲▼ to select the cable type to be tested.
4. Connect the test leads to the cable under test.
5. Press TEST TYPE.
6. Use ▲▼ to select TEST PAIR.
7. Press EXIT.
8. Press MORE CABLE until the reflection is seen.
9. Use ▲▼ to adjust the waveform height.
10. Press ◀▶ to move the cursor to the leading edge of the reflection.

Typical Open



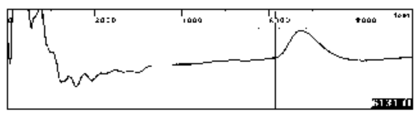
Typical Short



Load Coils

1. Press RESET TO METRIC or RESET TO US (not necessary if previously set).
2. Press SETUP.
3. Use ▲▼ to select the cable type to be tested.
4. Connect the test leads to the cable under test.
5. Press TEST TYPE.
6. Use ▲▼ to select TEST PAIR.
7. Press EXIT.
8. Press MORE CABLE until the reflection is seen.
9. Use ▲▼ to adjust the waveform height.
10. Press ◀▶ to move the cursor to the leading edge of the load coil.

Typical Load Coil

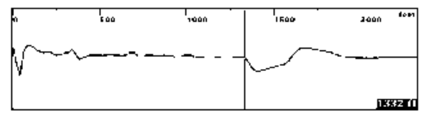


NOTE: Load coil waveforms look very similar to an Open waveform. Typically, the load coil will be located at its appropriate spacing, depending on the loading scheme being used.

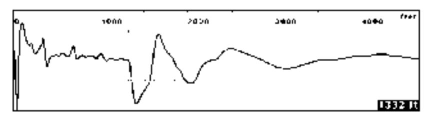
Bridged Taps and Laterals

1. Press RESET TO METRIC or RESET TO US (not necessary if previously set).
2. Press SETUP.
3. Use ▲▼ to select the cable type to be tested.
4. Connect the test leads to the cable under test.
5. Press TEST TYPE.
6. Use ▲▼ to select TEST PAIR.
7. Press EXIT.
8. Press MORE CABLE until the reflection is seen.
9. Use ▲▼ to adjust the waveform height.
10. Press ◀▶ to move the cursor to the leading edge of the bridged tap.

Single Bridged Tap



Multiple Bridged Taps

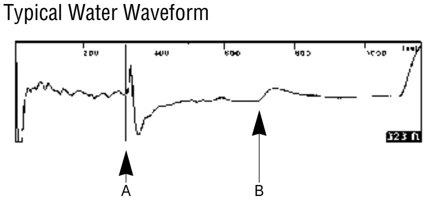


NOTE: If there is more than one bridged tap on the pair, the additional lateral might be sufficient to obscure the end of the cable. If necessary, remove the first bridged tap and retest the cable to locate the next tap.

Water

1. Press RESET TO METRIC or RESET TO US (not necessary if previously set).
2. Press SETUP.
3. Use ▲▼ to select the cable type to be tested.
4. Connect the test leads to the cable under test.
5. Press TEST TYPE.
6. Use ▲▼ to select TEST PAIR.
7. Press EXIT.
8. Press MORE CABLE until the reflection is seen.
9. Use ▲▼ to adjust the waveform height.
10. Press ◀▶ to move the cursor to the beginning of the wet section (see A below). This is the distance to the water.
11. Press ◀▶ to move the cursor to the end of the wet section (see B below).
12. A to B is the wet section.

Typical Water Waveform

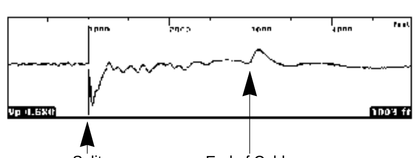


NOTE: The distance from the front panel to the water (A) is correct. The wet section distance (A to B) is not correct due to the Vp being changed by the water. Subtract the dry section distance from the cable map to obtain the wet distance, or measure from both ends of the cable to the wet section.

Split Pair

1. Press RESET TO METRIC or RESET TO US (not necessary if previously set).
2. Press SETUP.
3. Use ▲▼ to select the cable type to be tested.
4. Connect the TEST leads to the first split pair.
5. Connect the REFERENCE leads to the second split pair.
6. Press TEST TYPE.
7. Use ▲▼ to select SPLITS OR CROSSTALK.
8. Press EXIT.
9. Press MORE CABLE until the reflection is seen.
10. Use ▲▼ to adjust the waveform height.
11. Press ◀▶ to move the cursor to the split.

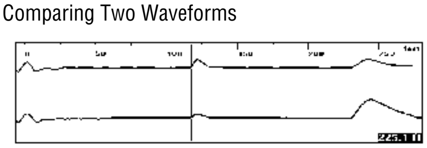
Typical Split (Crosstalk Mode)



Comparing Two Pairs

1. Press RESET TO METRIC or RESET TO US (not necessary if previously set).
2. Press SETUP.
3. Use ▲▼ to select the cable type to be tested.
4. Connect the TEST leads to the first pair.
5. Connect the REFERENCE leads to the second split pair.
6. Press TEST TYPE.
7. Use ▲▼ to select TEST PAIR / REFERENCE PAIR.
8. Press EXIT. Both the test pair waveform and the reference pair waveform are displayed (test pair waveform I on top).
9. Press MORE CABLE until the reflection is seen.
10. Use ▲▼ to adjust the waveform height.
11. Press ◀▶ to move the cursor to the leading edge of the event.

Comparing Two Waveforms



NOTE: By selecting a different TEST TYPE, you can also compare the current waveform vs a saved waveform.

Appendix E: TelScout® TS200 Quick Reference

Nominal Test Values for Typical Analog Service (POTS)

	Nominal Value
DC Volts	48 to 52 VDC
Loop Current	>23 mA
Loop Resistance	<1,300 Ω for unloaded loop
Load Coils	Varies, depending on loop length
Ringers (REN)	0.1 to 5.0 REN
Loss	<–8 dBm at 1004 Hz
Noise	<20 dBrnC (dBrnp)
Power Influence	>80 dBrnC (dBrnp)
Calculated Balance	>60 dB
Slope	Varies, depending on service type
Longitudinal Balance	>60 dB

Nominal Test Values for Typical Digital Services

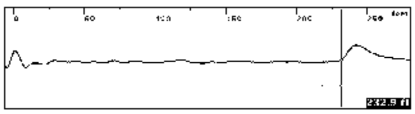
	ISDN	ADSL	HDSL	IDSL	SDSL	VDSL
No. of Pairs	1	1	2	1	1	1
Bit Rate	144 kbps	9 Mbps (Variable)	1.544 Mbps	160 kbps	784 kbps	52.8 Mbps (Variable)
Loop Length	<18,000 ft. (<5.9 km)	<18,000 ft. (<5.9 km)	<12,000 ft. (<3.9 km)	<18,000 ft. (<5.9 km)	<12,000 ft. (<3.9 km)	<4,500 ft. (<1.5 km)
Load Coils	0	0	0	0	0	0
Loop Resistance	<1,300 Ω	<1,300 Ω	<900 Ω	<1,300 Ω	<900 Ω	<325 Ω
Closest Tap	>1,000 ft. (>32 m)	>1,000 ft. (>328 m)	>1,000 ft. (>328 m)	>1,000 ft. (>328 m)	>1,000 ft. (>328 m)	>1,000 ft. (>328 m)
Longest Tap	<2,000 ft. (<656 m)	<2,000 ft. (<656 m)	<2,000 ft. (<656 m)	<2,000 ft. (<656 m)	<2,000 ft. (<656 m)	<2,000 ft. (<656 m)
Total Taps	<2,500 ft. (<820 m)	<2,500 ft. (<820 m)	<2,500 ft. (<820 m)	<2,500 ft. (<820 m)	<2,500 ft. (<820 m)	<2,500 ft. (<820 m)
Loop Loss	–39 dB	Variable	<–35 dB	<–39 dB	<–35 dB	Variable
Nyquist Frequency	40 kHz	N/A	196 kHz	40 kHz	196 kHz	N/A

Appendix F: TelScout TS200 Quick Reference (TDR Capability)

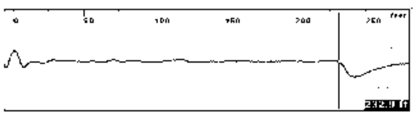
Distance/Open/Short

1. Press RESET TO METRIC or RESET TO US (not necessary if previously set).
2. Press SETUP.
3. Use ▲▼ to select the cable type to be tested.
4. Connect the test leads to the cable under test.
5. Press TEST TYPE.
6. Use ▲▼ to select TEST PAIR.
7. Press EXIT.
8. Press MORE CABLE until the reflection is seen.
9. Use ▲▼ to adjust the waveform height.
10. Press ◀▶ to move the cursor to the leading edge of the reflection.

Typical Open



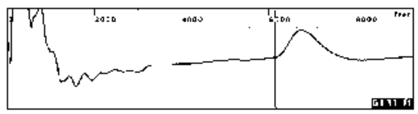
Typical Short



Load Coils

1. Press RESET TO METRIC or RESET TO US (not necessary if previously set).
2. Press SETUP.
3. Use ▲▼ to select the cable type to be tested.
4. Connect the test leads to the cable under test.
5. Press TEST TYPE.
6. Use ▲▼ to select TEST PAIR.
7. Press EXIT.
8. Press MORE CABLE until the reflection is seen.
9. Use ▲▼ to adjust the waveform height.
10. Press ◀▶ to move the cursor to the leading edge of the load coil.

Typical Load Coil

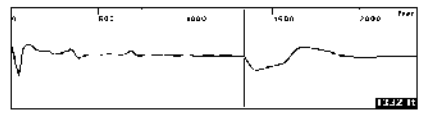


NOTE: Load coil waveforms look very similar to an Open waveform. Typically, the load coil will be located at its appropriate spacing, depending on the loading scheme being used.

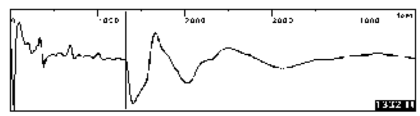
Bridged Taps and Laterals

1. Press RESET TO METRIC or RESET TO US (not necessary if previously set).
2. Press SETUP.
3. Use ▲▼ to select the cable type to be tested.
4. Connect the test leads to the cable under test.
5. Press TEST TYPE.
6. Use ▲▼ to select TEST PAIR.
7. Press EXIT.
8. Press MORE CABLE until the reflection is seen.
9. Use ▲▼ to adjust the waveform height.
10. Press ◀▶ to move the cursor to the leading edge of the bridged tap.

Single Bridged Tap



Multiple Bridged Taps

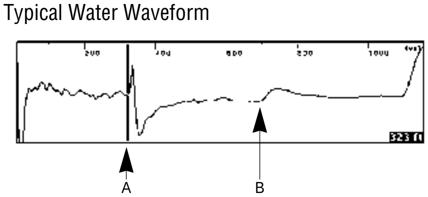


NOTE: If there is more than one bridged tap on the pair, the additional lateral might be sufficient to obscure the end of the cable. If necessary, remove the first bridged tap and retest the cable to locate the next tap.

Water

1. Press RESET TO METRIC or RESET TO US (not necessary if previously set).
2. Press SETUP.
3. Use ▲▼ to select the cable type to be tested.
4. Connect the test leads to the cable under test.
5. Press TEST TYPE.
6. Use ▲▼ to select TEST PAIR.
7. Press EXIT.
8. Press MORE CABLE until the reflection is seen.
9. Use ▲▼ to adjust the waveform height.
10. Press ◀▶ to move the cursor to the beginning of the wet section (see A below). This is the distance to the water.
11. Press ◀▶ to move the cursor to the end of the wet section (see B below).
12. A to B is the wet section.

Typical Water Waveform

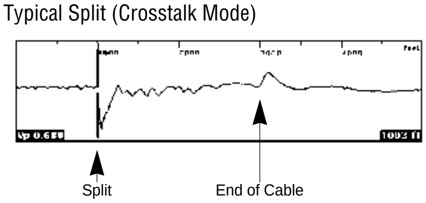


NOTE: The distance from the front panel to the water (A) is correct. The wet section distance (A to B) is not correct due to the Vp being changed by the water. Subtract the dry section distance from the cable map to obtain the wet distance, or measure from both ends of the cable to the wet section.

Split Pair

1. Press RESET TO METRIC or RESET TO US (not necessary if previously set).
2. Press SETUP.
3. Use ▲▼ to select the cable type to be tested.
4. Connect the TEST leads to the first split pair.
5. Connect the REFERENCE leads to the second split pair.
6. Press TEST TYPE.
7. Use ▲▼ to select SPLITS OR CROSSTALK.
8. Press EXIT.
9. Press MORE CABLE until the reflection is seen.
10. Use ▲▼ to adjust the waveform height.
11. Press ◀▶ to move the cursor to the split.

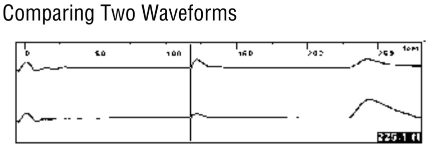
Typical Split (Crosstalk Mode)



Comparing Two Pairs

1. Press RESET TO METRIC or RESET TO US (not necessary if previously set).
2. Press SETUP.
3. Use ▲▼ to select the cable type to be tested.
4. Connect the TEST leads to the first pair.
5. Connect the REFERENCE leads to the second split pair.
6. Press TEST TYPE.
7. Use ▲▼ to select TEST PAIR / REFERENCE PAIR.
8. Press EXIT. Both the test pair waveform and the reference pair waveform are displayed (test pair waveform I on top).
9. Press MORE CABLE until the reflection is seen.
10. Use ▲▼ to adjust the waveform height.
11. Press ◀▶ to move the cursor to the leading edge of the event.

Comparing Two Waveforms



NOTE: By selecting a different TEST TYPE, you can also compare the current waveform vs a saved waveform.

For further information, contact Tektronix:

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