Outside Plant

Telephone Cable Testing & Fault Locating
The Telephone Outside Plant [OSP]

Aerial Cable System

Underground Cable System

Direct Buried Cable System

Manholes

X-Connect Boxes

Cable Vault

Central Office

XYZ Telco

MDF

Cable Vault
The Telephone Outside Plant
[ OSP ]

- Vertical Frame
- Horizontal Frame
- TPS
- CAMA
- Wires
- Jumper
- Switch
- Traffic
- Service
- Position
- System
- Operator-assisted long distance calls
- Computerized billing equipment for long distance calls

- Underground Plant
- Manhole
- Feeder Cable
- Cable Vault
- Tip Cables
- Protectors
- Protector Box
- Subscriber
- Aerial Plant
- Distribution Cable
- X-Connect Boxes
- Direct-Buried Plant
- Direct-Buried Drop Wire
- Protector Box
- Subscriber
- Distribution Cables
The Telephone Cable
[Definition]

It is one of several other types of communication facilities or media which is generally made up of paired, insulated copper conductors called TIP [A] and RING [B].

A cable can consist a few pairs, hundreds of pairs or thousands of pairs and the conductors can be of different sizes or gauges depending upon system requirements.

Other types of Communication Facilities

OPEN WIRE SYSTEMS [ Telegraph ]

COAXIAL SYSTEMS [ CATV ]

RADIO SYSTEMS [ Microwave, Cellular ]

COMMUNICATION SATELLITES [ Disk ]

FIBER OPTIC SYSTEMS
The Telephone Cable
[Basic Construction]

- Outer Cable Jacket [Plastic]
- Air or Jelly-filled
- Conductor Insulation [Plastic, Pulp or Paper]
- Copper Conductors
- RING [B]
- TIP [A]
- Cable Shield [Corrugated Aluminum]
The origin of the name Tip [A] and Ring [B]
The Telephone Cable
[Electrical Representation]
Effect of Cable Resistance to Signal Transmission

Note:
In a pure resistive circuit, the transmitted signal will be attenuated but its original shape is maintained. There will be no distortion of the signal.
Effect of Cable Resistance and Capacitance to Signal Transmission

Note:
In a circuit where both resistance and capacitance exist, the transmitted tones were attenuated and their original shapes were also altered or changed. In other words, the signal became distorted.

High frequencies normally suffers most because of the combined filter effect of cable resistance and capacitance. In the illustration, the high frequency tone was almost totally absorbed by the added capacitance of the cable.
**RESISTANCE**  
**[Definition]**

It is a natural characteristic of any conductor (i.e. Copper, Aluminum, Nickel, Silver, Gold, etc.) which opposes the flow of electrical current through it.
OHM

Unit of measure for Resistance

Commonly used units:

Ohm = 0 to 1
Ohms = 2 to 999
Kilo-Ohms (K) = 1000 to 999,999
Mega-Ohms (M) = 1,000,000 to 999,999,999
Giga-Ohms = 1,000,000,000
Electrical Length of a Conductor

It is the resistance of a conductor in OHMS measured at a certain temperature in °Farenheit or °Centigrade and then converted into DISTANCE (length).
Physical Length of a Conductor

It is the length measured with the use of a measuring device like a WHEEL or a RULER Tape.
## Conductor Resistance To Distance Conversion Table

<table>
<thead>
<tr>
<th>Gauge [Size]</th>
<th>Conductor Length per Ohm</th>
</tr>
</thead>
<tbody>
<tr>
<td>19 AWG (0.91 mm)</td>
<td>124.24 ft. (37.87 m)</td>
</tr>
<tr>
<td>22 AWG (0.64 mm)</td>
<td>61.75 ft. (18.82 m)</td>
</tr>
<tr>
<td>24 AWG (0.51 mm)</td>
<td>38.54 ft. (11.75 m)</td>
</tr>
<tr>
<td>26 AWG (0.41 mm)</td>
<td>24.00 ft. (7.32 m)</td>
</tr>
<tr>
<td>28 AWG (0.32 mm)</td>
<td>15.08 ft (4.60 m)</td>
</tr>
</tbody>
</table>

### Formulas:

1. For cable temperatures ABOVE 68 °F [20°C]:
   \[ Ft = Fa \left[ 1 - 0.00218 \left( t - 68 \right) \right] \]

2. For cable temperature BELOW 68 °F [20°C]:
   \[ Ft = Fa \left[ 1 + 0.00218 \left( t + 68 \right) \right] \]

Where:

- \( Ft \) = Feet / Meters per Ohm @ temperature \( t \) (°F / °C)
- \( Fa \) = Feet / Meters per Ohm @ temperature 68 °F / 20 °C

(see table above).
The "TWIST" Factor

Note:
The twisting of the conductors inside the cable makes the physical and electrical length of the pair about 3% longer than cable.
Ex.: If the electrical length of a pair is 103 feet or meters, this can be translated to 100 feet or meters of cable length.
Factors That Affect Resistance

1. Length:

The *shorter* the conductor, the *lower* its resistance.

The *longer* the conductor, the *higher* its resistance.

2. Gauge (Size):

The *bigger* the conductor, the *lower* its resistance.

The *smaller* the conductor, the *higher* its resistance.

3. Temperature:

The *lower* the conductor’s temperature, the *lower* its resistance.

The *higher* the conductor’s temperature, the *higher* its resistance.

Therefore:

The *Length* of a conductor is a factor of *Gauge (Size)* and *Temperature*. 
Loop Resistance

Loop Resistance = \( R_1 + R_2 \)

Resistance to strap = \( \frac{R_1 + R_2}{2} \)
Resistive Balance Test

Note: For a normal cable ---

a) Measurement #1 should be equal to Measurement #2 (If they differ by 10% or more, a “partial open” exist in either Tip [A] or Ring [B] or both).

b) Measurement #3 = Measurement #1 + Measurement #2
Rt = R1 + R2 = 10 + 10 = 20 Ohms

\[
\frac{1}{Rt} = \frac{R1 + R2}{R1 \times R2} = \frac{10 + 10}{10 \times 10} = \frac{20}{100} \quad \text{or} \quad \frac{Rt}{1} = \frac{100}{20} = 5 \text{ Ohms}
\]
**Wheatstone (Resistance) Bridge**

[Basic Concept]

Conditions for NULL

\[
\begin{align*}
R1 &= R3 \\
R2 &= R4
\end{align*}
\]

\[
\begin{align*}
R1 &= 120 \\
R2 &= 120 \\
R3 &= 120 \\
R4 &= 120
\end{align*}
\]
Wheatstone Bridge
[ Precision Ohmmeter ]

Note:
R1 & R2 are fixed and ratio is known
RL1 + RL2 = Loop resistance [ Tip (A) & Ring (B) ]
R4 = Variable Resistor
G = Galvanometer [ NULL Meter ]

Conditions for NULL
\[
\frac{R1}{R3} = \frac{R2}{R4}
\]

Basic Wheatstone Bridge
Resistance Fault Locate using a Wheatstone Bridge

Basic Concept

DTF (Distance-To-Fault) = 1000 meters

DTS (Distance-To-Strap) = 1000 meters

STF (Strap-To-Fault)

Faulted Conductor

Conditions for NULL

\[
\frac{R_1}{R_2} = \frac{R_3}{R_4}
\]

Note: If the bridge nulls at 75% of DTS (1000 meters) then:

\[
\text{DTF} = 75\% \text{ of } 1000 \text{ m} = 750 \text{ m}
\]

\[
\text{STF} = 25\% \text{ of } 1000 \text{ m} = 250 \text{ m}
\]

Dynatrel 965 Subscriber Loop Analyzer

0 %

75 %

100 %

1000 meters
CAPACITANCE

It is the electrical property of a device called “Capacitor” which is created when two or more metallic plates or conductors are placed close to but electrically insulated from each other.

Capacitance permits the storage of electrical energy which means that the capacitor can be charged or discharged similar to a rechargeable battery.

Commonly used dielectric materials:
1. Paper
2. Ceramic
3. Mylar
4. Polyester
5. Mica
6. Electrolyte

Basic Construction of a Capacitor
Common types of Capacitors

1. Mica
2. Paper
3. Polyester
4. Ceramic
5. Electrolytic
Factors Affecting Capacitance

1. The Larger the plates, the higher the capacitance.
2. The closer the plates, the higher the capacitance.
3. Solid dielectric (insulation) materials increases capacitance compared to air.
How a Capacitor Works

Charging the capacitor

Charger disconnected

Charge retained

12 V lamp

Lamp lights up until capacitor is fully discharged.
More about Capacitors

\[ \frac{1}{C_t} = \frac{C_1 + C_2}{C_1 \times C_2} = \frac{1 + 1}{1} \]

\[ \frac{1}{C_t} = \frac{2}{1} \quad \text{or} \]

\[ C_t = \frac{1}{2} = 0.5 \text{ uF} \]

\[ C_1 = 1\text{ uF} \quad C_2 = 1\text{ uF} \]

\[ C_t = C_1 + C_2 = 2\text{ uF} \]
Capacitances on a telephone pair

Tip [A]  
Ring [B]  
Shield

Ring [B]  
C1  
Tip [A]  
C2  
C3  
Tip [A] to Ground Capacitance  
Ring [B] to Ground Capacitance  
Shield

Mutual Capacitance
Capacitances in a telephone cable
FARAD
Unit of measure for capacitance

Commonly-used capacitance units:

- Microfarad (uF) = 1 millionth of a FARAD
- Nanofarad (nF) = 1 thousandths of a Microfarad
- Picofarad (pF) = 1 millionth of a Microfarad
# Standard Capacitances Of Telephone Cables

<table>
<thead>
<tr>
<th>Type</th>
<th>Mutual</th>
<th>Tip[A] / Ring[B] To Ground</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircore</td>
<td>0.083 uF/Mile</td>
<td>0.125 uF/Mile</td>
</tr>
<tr>
<td></td>
<td>[ 0.052 uF/Km ]</td>
<td>[ 0.078 uF/Km ]</td>
</tr>
<tr>
<td>Jelly-Filled</td>
<td>0.083 uF/Mile</td>
<td>0.140 uF/Mile</td>
</tr>
<tr>
<td></td>
<td>[ 0.052 uF/Km ]</td>
<td>[ 0.087 uF/Km ]</td>
</tr>
<tr>
<td>2-Pair Drop</td>
<td>0.083 uF/Mile</td>
<td>0.155 uF/Mile</td>
</tr>
<tr>
<td></td>
<td>[ 0.052 uF/Km ]</td>
<td>[ 0.096 uF/Km ]</td>
</tr>
<tr>
<td>5-Pair Drop</td>
<td>0.083 uF/Mile</td>
<td>0.150 uF/Mile</td>
</tr>
<tr>
<td></td>
<td>[ 0.052 uF/Km ]</td>
<td>[ 0.093 uF/Km ]</td>
</tr>
</tbody>
</table>
How A Uniform Mutual Capacitance Of A Telephone Cable Pair Is Achieved Irrespective Of The Different Conductor Sizes (Gauges)

<table>
<thead>
<tr>
<th>'D'istance</th>
<th>=</th>
<th>the same</th>
<th>'D'istance</th>
<th>=</th>
<th>not the same</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulation Thickness</td>
<td>=</td>
<td>the same</td>
<td>Insulation Thickness</td>
<td>=</td>
<td>the same</td>
</tr>
<tr>
<td>Size/Gauge</td>
<td>=</td>
<td>not the same</td>
<td>Size/Gauge</td>
<td>=</td>
<td>not the same</td>
</tr>
<tr>
<td>Mutual Capacitance</td>
<td>=</td>
<td>not the same</td>
<td>Mutual Capacitance</td>
<td>=</td>
<td>not the same</td>
</tr>
</tbody>
</table>

Tip[A]  Ring[B]

Tip[A]  Ring[B]

Tip[A]  Ring[B]
How the 965DSP measures capacitance

1. The 965DSP transmits a Lo-Hi frequency sweep at a specified voltage across the circuit where the amount of current flow is determined. Once the amount of circuit current is known, circuit impedance is then calculated.

2. Once the circuit impedance is known, the value of the two unknown factors $R = \text{?}$ Ohms and $X_C = \text{?}$ Ohms are calculated with the use of sophisticated mathematical process.

3. When the value of $X_C$ is found, it is translated into capacitance and then into distance based on pre-programmed Capacitance-To-Distance table in the software.

Example:

<table>
<thead>
<tr>
<th>Impedance</th>
<th>= 600 ohms</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R$</td>
<td>= 40 ohms</td>
</tr>
<tr>
<td>$X_C$</td>
<td>= 560 ohms = 0.083uF = 1 mile (length of cable)</td>
</tr>
<tr>
<td>$X_L$</td>
<td>= 0 ohms (insignificant in this example)</td>
</tr>
</tbody>
</table>
How length of Tip[A] is measured with the 965DSP “OPEN” Meter

Note:
When the length of Tip[A] is being measured, the Red test lead is shorted to Green (Shield/Ground) through an internal switch thus grounding the Ring[B] conductor.

The total capacitive reactance of C3 and C2 (in ohms) translated into distance (in feet or meters) represents the length of Tip[A].
How length of Ring[B] is measured with the 965DSP “OPEN” Meter

Note:

When the length of Ring[B] is being measured, the Black test lead is shorted to Green (Shield/Ground) through an internal switch thus grounding the Tip[A] conductor.

The total capacitive reactance of C3 and C1 (in ohms) translated into distance (in feet or meters) represents the length of Ring[B].
How Mutual length is measured with the 965DSP “OPEN” Meter

Note:

‘Mutual’ length is measured between ‘Tip [A]’ and ‘Ring[B]’ with all the test leads floating. Also take note that ‘C1’ and ‘C3’ are connected in series through the cable shield and then in parallel to ‘C2’. The ‘Mutual’ capacitance will then be ‘C2’ plus the series capacitances of ‘C1’ and ‘C3’.
Categories & Types Of Cable Faults

A. Resistance Faults:
   1. Ground
   2. Short
   3. Cross
   4. Battery Cross

B. Capacitance Faults:
   1. Complete Open
   2. Partial Open
   3. Dirty Open
   4. Split
1. GROUND:
A fault between ‘**Tip [A]**’ and ‘**Ground**’, ‘**Ring [B]**’ and ‘**Ground**’ or both conductors and ‘**Ground**’.

2. SHORT:
A fault between ‘**Tip [A]**’ and ‘**Ring [B]**’ conductors.
3. CROSS:
A fault between a non-working (pair under test) and another or other non-working pairs.

Note:
To locate a ‘CROSS’, the pairs involved must be identified, initially.

4. Battery CROSS:
A fault between a working pair and a non-working pair (pair under test).

Note:

a) To locate a ‘Battery CROSS’, there is no need to identify the working pair. The fault locate procedure is the same as locating a ‘GROUND’ due to the battery’s internal resistance to ‘GROUND’

b) In a ‘Solid Cross Fault’, the voltage reading on the pair under test is quite high (the same or very close to the CO battery voltage) while in a ‘Non-solid Cross Fault’ the voltage reading is very much lower.
**B: Capacitance Faults**

1. **Complete OPEN:**
   A fault where a conductor is cut off completely.

2. **Partial OPEN:**
   A fault where a high resistance path developed on a conductor. (Ex. Corroding splice)
3. Dirty OPEN:
Any combination of a ‘RESISTANCE’ and ‘CAPACITANCE’ faults
4. SPLIT:
A splicing error where one conductor of a pair (normally ‘Tip [A]’ because they the same color) is spliced to ‘Tip [A]’ of another pair.
1. Fault Analysis:
   - Analyze symptoms carefully.
   - Determine the category and type of fault or faults.

2. Fault Locate to a Cable Section:
   - Determine the faulted cable section and isolate other sections without fault.
   - From a measured fault location, always consider the nearest access point (Splice, X-Connect box, or a Terminal) as the prime suspect.

3. Fault Locate (Pinpoint).
   - Determine the exact physical length of the cable section under test and calibrate the test set to that length. (i.e. If the section length is 500 feet or meters, select “DTS (Distance-To-Strap) Known” in RFL Setup and enter this length).
   - Use a separate good pair, as much as possible.

   **Note:**
   For short cable sections it is better to run your own “good pair” using a roll of MDF jumper wire rather than look for one in the cable.

4. Repair or Fix the Fault or Faults.

5. Verify that the line works.
1. Check and Measure possible Voltages (AC & DC) on the line:
   a) between Tip[A] and Ring[B]
   b) between Ring[B] and Ground
   c) between Tip[A] and Ground

2. Check and Measure Insulation (Leakages) Resistances
   a) between Tip[A] and Ring[B]
   b) between Ring[B] and Ground
   c) between Tip[A] and Ground

3. With the OPENS Meter, check the capacitance lengths of Tip[A] & Ring[B] and compare.
   The lengths should be equal or within 10% of each other.

4. Perform a Resistance Balance Test using the Ohmmeter or Special Resistance Test in the Tool Box.
   a) Strap Tip[A] and Ring[B] to Shield/Ground at the far-end.
   b) Measure Tip[A] to Shield/Ground Resistance.
   c) Measure Ring[B] to Shield/Ground Resistance.
   d) Measure Loop Resistance (Tip[A] + Ring[B] ohms)

   **Note:**
   Measurements **(b) and (c)** should be equal or within 10% , otherwise an “open” or a “partial open” exists.
Factors that can cause errors in fault locate measurements

1. Poor Connections will affect RFL measurements.
   a) Test Leads
   b) Strap

   Note:
   A 1/4 (0.25) ohm resistance introduced into a 22AWG (0.61mm) conductor will constitute an error of about 16 feet (5 meters).

2. Incorrect assumption of conductor gauge (size) will affect RFL measurements.
   A one gauge higher or lower assumption will result into a 40\% to 50\% error.

3. Inequalities of conductor resistances will affect RFL measurements.
   a) Variations of gauge created during the cable manufacturing process.
   b) Unequal twisting of pairs.
   c) Resistances introduced by connectors used during splicing.
   d) Inequalities of temperature along the cable length.

4. Random distribution of moisture or water in the cable will affect OPEN measurements.

5. Induced currents (from Power lines, lighting and traction circuits) during the fault locate process will affect both RFL and OPEN measurements.
OF ALL TELEPHONE CABLE FAULTS ARE LOCATED
IN AN ACCESS POINT
(ex: Splices, Terminals, Cross-Connect or Protector Boxes, etc.)

THE OTHER

CAN BE IN MID-SPAN.

This means that the access point closest to the fault locate measurement must be checked first before considering the fault to be in mid-span.
CABLE FAULT LOCATING

- It is “NOT” an “EXACT SCIENCE”.
- It is an “ART”.
- The name of the game is “SKILL”.

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1. **Insulation Test:** Use this test to determine possible Resistance Faults like a **SHORT, GROUND, CROSS** or **BATTERY CROSS**.

**Note:**
Leave the far-end open (do not strap). Connect the test leads as shown above. Press the OHMS key and write down the resistance readings between the following:

- Tip[A] / Ring[B] = ______________ Ohms
- Ring[B] / Ground = ______________ Ohms
- Tip[A] / Ground = ______________ Ohms

A reading of 3.3 Meg-Ohms or less is will affect service which can trigger a formal complaint from the Subscriber. To avoid the customer initiating a complaint, it is suggested that the fault must be located and fixed before the fault value goes down to 3.3Meg.

At this same time, since a Capacitance Balance Test does not require putting a far-end strap, the same hookup above can be used to check for possible OPEN faults using an OPEN Meter.

2. Resistance-Balance Test: This test is used to determine possible existence of Capacitance Faults on a pair, like a COMPLETE OPEN, PARTIAL OPEN or DIRTY OPEN.

Note:
In this test, the continuity of conductors TIP[A] and RING [B] are measured and compared using Shield/Ground as a reference. This is to check for possible opens on the pair, like COMPLETE OPEN, PARTIAL OPEN, or DIRTY OPEN.

Strap the far-end and connect the test leads, as shown above. Press the OHMS key and write down the resistance reading between the following:

- Tip[A] / Ring[B] = _______________ Ohms
- Ring[B] / Ground = _______________ Ohms
- Tip[A] / Ground = _______________ Ohms

If Tip[A] to Shield/Ground and Ring[B] to Shield/Ground resistances differ by 10% or more, an OPEN exists on the pair.
Resistance Fault Locate (RFL) Hookups
Resistance Fault Locate (RFL) Hookups

1. Ground:

**Option A: Using a Separate Good Pair**

- **Green** (Ground)
- **Yellow** (Ring[B])
- **Red** (Tip[A])
- **Black** (Shield / Ground)
- **Separate Good Pair**

**Pair Under Test**

**Ground**

**Fault**

**Strap**

**Option B: Single Pair (Single Good Conductor)**

- **Green** (Ring[B] - Good Conductor)
- **Red** (Tip[A])
- **Black** (Shield / Ground)

**Ground**

**Fault**

**Strap**
Resistance Fault Locate (RFL) Hookups (con’t)

2. Short:

Option A: Using a Separate Good Pair

Option B: Single Pair (Single Good Conductor)
Resistance Fault Locate (RFL) Hookups (con’t)

3. Cross:

Option A: Using a Separate Good Pair

Option B: Ring [B] conductors of each pair used as a GOOD pair if they are clean (no faults).
C. Cross:

Option C: Using a Single Good Conductor

Resistance Fault Locate (RFL) Hookups (con’t)
4. Battery Cross:

Option A: Separate Good Pair

Note: The Tip[A] conductors from each pair can be used used as the GOOD pair.
4. Battery Cross:

**Option B: Single Good Conductor**

![Diagram of Battery Cross with 965DSP, Green, Red, Black, and -48VDC connections]

**Note:** Use this option if only one GOOD conductor is available.
RFL TIPS

The use of a "Separate Good Pair" is always the most accurate way to locate any type of a resistance fault.
“Separate Good Pair”

It can be any pair of any gauge, longer or shorter than the faulted one, it doesn’t matter.

For short cable section lengths (1000 feet or less), the good pair can be a reel of a CO jumper wire or a telephone jacketed wire placed above ground.
“Separate Good Pair”

It can be any pair of any gauge, longer or shorter than the faulted one, it doesn’t matter.

For long cable section lengths (several thousand feet), the good pair can come from another cable adjacent to the cable with the faulted pair.
How To Extend The “Far-End Strap” If Necessary

Reel of CO jumper wire or telephone jacketed wire or any two wires, same length (any gauge)

Good Pair [ from a distant cable ]

Faulted Pair

Near-End

Short

Far-End Strap

End-1

End-2

Far-End

Common

Strap extension

Faulted Pair

Near-End

Short

Far-End
Fault Locating Tips

**RFL (Resistance Fault Locate):**

1. Always draw a diagram of the fault for better analysis.

2. There are three factors that are always involved in RFL (Resistance Fault Locating) - Gauge, Length and Temperature of the cable. Any two of the three must be known for RFL to work. The best option is to know the Gauge and Length of the section under test and the test set will compute the cable temperature. This is done during RFL Setup.

3. A pair may have some light faults in it but it can be used as a ‘Good Pair’ as long as the light fault is at least 200 times better than the magnitude of the fault in the faulted pair. Ex: If the fault on a pair is 1 kilo-ohms, a pair with a 200 kilo-ohm fault can be used as a good pair. Of course, the higher the magnitude, the better.

4. For best RFL accuracy, make a long cable section shorter by going to the middle of the section and open the pair to cut it in half. Check for the fault in one direction and then the other and then isolate the clean side. Repeat the process until the cable section becomes short enough where the following becomes practical:
   a) the length of a short section can easily be measured physically with a roller tape. If gauge and section length are known, the test set will compute cable temperature.
   b) With a short cable section, the use of a reel of jumper wire as a “Good Pair” placed above ground is now possible, instead of digging into the cable for a good one. Saves time. With a separate good pair and knowing the gauge and length of the section is the best and most accurate RFL option.

5. The procedure in locating a ‘Battery Cross’ is exactly the same as that for a ‘Ground’ fault.

6. In a ‘Single Pair Hookup’, the best good conductor to use is the mate of the faulted one and the next best is any good conductor from any of the adjacent pairs in the same group. Ex: If a pair has TIP(A) is faulted and RING(B) is good, RING(B) is then the best good conductor to use to shoot the fault on TIP(A).

7. If DTF (Distance-To-Fault) and DTS (Distance-To-Strap) are equal, the fault is either at the strap or beyond.
Estimating Cable Temperatures

**Aerial Cable:**

1. If cable is not in direct sunlight. Add 20°F or 15°C whichever is used, to the air temperature.

2. If cable is in direct sunlight. Add 40°F or 30°C whichever is used, to the air temperature.

**Buried Cable:**

1. Use temperature of tap water. Let water flow out of a water faucet for several minutes and then measure the temperature using a common household thermometer.

2. In cold climates, use soil temperature at cable depth.
# Gauge (Size) Conversion Table

<table>
<thead>
<tr>
<th>FROM GAUGE</th>
<th>TO GAUGE</th>
<th>MULTIPLY BY</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>22</td>
<td>0.497</td>
</tr>
<tr>
<td>--</td>
<td>24</td>
<td>0.310</td>
</tr>
<tr>
<td>--</td>
<td>26</td>
<td>0.193</td>
</tr>
<tr>
<td>--</td>
<td>28</td>
<td>0.121</td>
</tr>
<tr>
<td>22</td>
<td>19</td>
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</tr>
<tr>
<td>--</td>
<td>24</td>
<td>0.624</td>
</tr>
<tr>
<td>--</td>
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<td>0.389</td>
</tr>
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<td>--</td>
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<td>24</td>
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<tr>
<td>--</td>
<td>22</td>
<td>1.600</td>
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<tr>
<td>--</td>
<td>26</td>
<td>0.623</td>
</tr>
<tr>
<td>--</td>
<td>28</td>
<td>0.391</td>
</tr>
<tr>
<td>26</td>
<td>19</td>
<td>5.180</td>
</tr>
<tr>
<td>--</td>
<td>22</td>
<td>2.570</td>
</tr>
<tr>
<td>--</td>
<td>24</td>
<td>1.610</td>
</tr>
<tr>
<td>--</td>
<td>28</td>
<td>0.628</td>
</tr>
<tr>
<td>28</td>
<td>19</td>
<td>8.240</td>
</tr>
<tr>
<td>--</td>
<td>22</td>
<td>4.090</td>
</tr>
<tr>
<td>--</td>
<td>24</td>
<td>2.560</td>
</tr>
<tr>
<td>--</td>
<td>26</td>
<td>1.590</td>
</tr>
</tbody>
</table>

**Example:** Convert the following into 19AWG.

400 feet of 24AWG + 350 feet of 22AWG + 800 feet of 19AWG

400 x 3.220 = 1,288 feet of 19AWG

350 x 2.010 = 703 feet of 19AWG

800 x 1.000 = 800 feet of 19AWG

Total = 2,791 feet of 19AWG
How To Determine Length of Cable In A Reel - Using RFL

Option #1:
1. Create a “SHORT” at the far-end of Pair #2 and strap it to Pair #1 (Good Pair) and connect the 965DSP clips as shown below.
2. Press the RFL key and do the following:
   a) Select “Separate Pair” option.
   b) Press the “Tab” key:
      - Highlight the correct gauge (size) of the pair.
      - Press the ‘Select’ key and enter cable temperature (ex: 70 °F)
3. Press the ‘Enter’ key to accept options.
4. Press the ‘Enter’ key to continue.
5. The DTF (Distance -To-Fault) or DTS (Distance-To- Strap) measurement will be the length of the cable.
Option #2:
1. Press the RFL key.
2. Short the pair at the far-end and connect the 965DSP test clips, as shown below.
3. Press the ‘Tab’ key to select ‘Single Pair’.
4. Press the ‘Setup’ key and do the following:
   a) Highlight the correct gauge (size) of the pair.
   c) Press the ‘Tab’ key and enter cable temperature (ex: 70 °F).
5. Press the ‘Enter’ key to accept the options.
6. Press the ‘Enter’ key to continue
4. The DTS (Distance-To-Strap) reading will be the length of the cable.
Measuring Distance To A Solid Short - Using RFL

Note:
This procedure only applies to a solid “short”, meaning (0 ohm- resistance), otherwise use the standard RFL procedure using a separate good pair or a single good conductor.

1. Connect the 965DSP test clips, as shown below.
2. Press the RFL key.
3. Press the ‘Tab’ key to select ‘Single Pair’.
4. Press the ‘Setup’ key and do the following:
   a) Highlight the correct gauge (size) of the pair.
   c) Press the ‘Tab’ key and enter cable temperature (ex: 70 ºF).
5. Press the ‘Enter’ key to accept the options.
6. Press the ‘Enter’ key to continue
4. The DTS (Distance-To-Strap) reading will be the location of the solid short.
**Fault Locating Tips**

**OPENS Locate:**

1. Make sure the ‘GREEN’ clip is connected to the cable shield (ground) when locating opens.
2. Cable ‘gauge and temperature’ will not affect cable capacitance.
3. For accuracy, always calibrate the test set to a good pair in the same cable as the faulted one.
4. ‘OPENS’ Locate does not require a strap. Use it first when analyzing cable faults.
5. If ‘MUTUAL’ measurement is 10% or more longer than Tip [A] or Ring [B], the cable shield can be open due to a missing bond, corroded bond connections or it went open due to extreme cable temperature changes.

**TDR (Time Domain Reflectometer):**

In most cases, a TDR (Time Domain Reflectometer) which uses RADAR technology is a better test set to use for locating any type of OPENS [Complete Open, Partial (high-resistance) Open or Dirty Open (a combination of resistance and capacitance faults)].

But never use a TDR when you do not exactly know what type of fault/faults or line treatment devices (load coils, build-out capacitors) you are looking for.
# Metric Conversion Table

<table>
<thead>
<tr>
<th>Metric Unit</th>
<th>Metric Length</th>
<th>Approximate U.S. Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric (m)</td>
<td>1.0 m</td>
<td>39.4 inches</td>
</tr>
<tr>
<td>Millimeter (mm)</td>
<td>.001 m</td>
<td>.0384 inches</td>
</tr>
<tr>
<td>Micrometer (um)</td>
<td>.000 001 m</td>
<td>.000 0394 inches</td>
</tr>
<tr>
<td>Nanometer (nm)</td>
<td>.000 000 001 m</td>
<td>.000 000 0394 inches</td>
</tr>
<tr>
<td>Angstrom (A)</td>
<td>.000 000 000 1 m</td>
<td>.000 000 00394 inches</td>
</tr>
</tbody>
</table>
### Prefixes and symbols to form decimal multiples and/or submultiples.

<table>
<thead>
<tr>
<th>Power of Ten</th>
<th>E Notation</th>
<th>Decimal Equivalent</th>
<th>Prefix</th>
<th>Phonic</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^{12}$</td>
<td>E + 12</td>
<td>1 000 000 000 000</td>
<td>tera</td>
<td>ter’a</td>
<td>T</td>
</tr>
<tr>
<td>$10^{9}$</td>
<td>E + 09</td>
<td>1 000 000 000</td>
<td>giga</td>
<td>gi’ga</td>
<td>G</td>
</tr>
<tr>
<td>$10^{6}$</td>
<td>E + 06</td>
<td>1 000 000</td>
<td>mega</td>
<td>meg’a</td>
<td>M</td>
</tr>
<tr>
<td>$10^{3}$</td>
<td>E + 03</td>
<td>1 000</td>
<td>kilo</td>
<td>kil’o</td>
<td>k</td>
</tr>
<tr>
<td>$10^{2}$</td>
<td>E + 02</td>
<td>100</td>
<td>hecto</td>
<td>hek’to</td>
<td>h</td>
</tr>
<tr>
<td>10</td>
<td>E + 01</td>
<td>10</td>
<td>deka</td>
<td>dek’a</td>
<td>da</td>
</tr>
<tr>
<td>$10^{-1}$</td>
<td>E-01</td>
<td>0.1</td>
<td>deci</td>
<td>des’i</td>
<td>d</td>
</tr>
<tr>
<td>$10^{-2}$</td>
<td>E-02</td>
<td>0.01</td>
<td>centi</td>
<td>sen’ti</td>
<td>c</td>
</tr>
<tr>
<td>$10^{-3}$</td>
<td>E-03</td>
<td>0.001</td>
<td>milli</td>
<td>mil’I</td>
<td>m</td>
</tr>
<tr>
<td>$10^{-6}$</td>
<td>E-06</td>
<td>0. 000 001</td>
<td>micro</td>
<td>mi’kro</td>
<td>u</td>
</tr>
<tr>
<td>$10^{-9}$</td>
<td>E-09</td>
<td>0.000 000 001</td>
<td>nano</td>
<td>nan’o</td>
<td>n</td>
</tr>
<tr>
<td>$10^{-12}$</td>
<td>E-12</td>
<td>0.000 000 000 001</td>
<td>pico</td>
<td>pe’ko</td>
<td>p</td>
</tr>
<tr>
<td>$10^{-15}$</td>
<td>E-15</td>
<td>0.000 000 000 000 001</td>
<td>femto</td>
<td>fem’to</td>
<td>f</td>
</tr>
<tr>
<td>$10^{-18}$</td>
<td>E-18</td>
<td>0.000 000 000 000 000 001</td>
<td>atto</td>
<td>at’to</td>
<td>a</td>
</tr>
</tbody>
</table>
Locating OPENS by Ratio

Measuring distance to an open using cable SHIELD as reference.

Requirement: Length of cable section under test must be known.

Procedure:
1. Connect the test set as shown in the illustration and make the “A” measurement.
2. Move the test set to the far-end and make the “B” measurement.
3. Calculate distance to the open using the formula, below:
   \[ d = \frac{(A \text{ or } B) \times D}{C} \text{ meters to open} \]

   Where:
   - \( d \) = Distance-To-Open
   - \( (A \text{ or } B) \) means whichever is shorter.
   - \( D \) = Length of cable section under test.
   - \( C \) = \( A + B \)

Example:
- \( D = 290 \text{ m} \)
- \( A = 110 \text{ m} \)
- \( B = 240 \text{ m} \)
- \( C = A + B = 110 + 240 = 350 \text{ m} \)
- \[ d = \frac{A \times D}{C} = \frac{110 \times 290}{350} = 91.14 \text{ m} \]

Note: The **RED** and **GREEN** leads are used so consider the **Ring [B]** measurement only.
Locating OPENS by Ratio

Measuring distance to an open shield using Earth/Soil as reference.

Note: The RED and GREEN leads are used so consider the Ring [B] measurement only.
Locating OPENS by Ratio

Measuring distance to an open shield using a group of conductors as reference.

Note: The RED and GREEN leads are used, consider the Ring [B] measurement only.
Dynatel 965DSP
Subscriber Loop Testing & Analysis
3M
Subscriber Loop Components

Fig. 1: Standard Telephone Circuit

Fig. 2: Telephone Circuit with REG (Range Extender with Gain).
**Why analyze a Subscriber Loop?**

A: To evaluate a cable pair before it is put into service.

### Generally Accepted Criteria for POTS (Plain Old Telephone Service)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Acceptable</th>
<th>Marginal</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Voltage</strong></td>
<td>48 to 52VDC</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Loop Current</strong></td>
<td>-23 mA or more</td>
<td>-20 mA to &lt;-23 mA</td>
<td>&lt; -20 mA</td>
</tr>
<tr>
<td><strong>Circuit Loss</strong></td>
<td>-8.5 dBm or less</td>
<td></td>
<td>&gt; -8.5 dBm</td>
</tr>
<tr>
<td><strong>Power Influence</strong></td>
<td>80 dBrnC or less</td>
<td>&gt; -80 dBrnC to &lt; -90 dBrnC</td>
<td>-90 dBrnC or more</td>
</tr>
<tr>
<td><strong>Circuit Noise</strong></td>
<td>20 dBrnC</td>
<td>&gt; 20 dBrnC to &lt; 30 dBrnC</td>
<td>-30 dBrnC or more</td>
</tr>
<tr>
<td><strong>Balance</strong></td>
<td>60 dB</td>
<td>&gt; 50 dB to &lt; 60 dB</td>
<td>50 dB or less</td>
</tr>
<tr>
<td><strong>Station Ground Resistance</strong></td>
<td>25 ohms or less</td>
<td></td>
<td>&gt; 25 ohms</td>
</tr>
<tr>
<td><strong>Slope</strong></td>
<td>7.5 dB or less</td>
<td></td>
<td>&gt; 7.5 dB</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Insulation Good</th>
<th>Light Fault</th>
<th>Heavy Fault</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Service Affected)</td>
<td></td>
<td>(Out Of Service)</td>
</tr>
<tr>
<td><strong>Insulation Resistance</strong></td>
<td>3.3 Meg or more</td>
<td>&gt; 2.8 K ohms to &lt; 3.3 Meg</td>
<td>2.8 K ohms or less</td>
</tr>
</tbody>
</table>
Why analyze a Subscriber Loop?

B: To identify and isolate the cause of a problem on a partially working cable pair.

Common Subscriber complaints:

1. No dial tone.
2. Continuous dial tone.
3. Signal is too weak can not hear on long distance calls.
4. Occasionally get wrong numbers.
5. Line is too noisy.
Note:
This example shows distances of the RZs based on a 22AWG (0.64mm) cable.
If the Engineers undergauge, RZ18 could start as close as 18Kft. (5,486m).
A Load Coil is used to cancel out the effects of too much capacitance on the pair as it gets longer so that voice frequency signals can be transmitted at longer distances (ie: 18000 to 34000 feet)
# Load Coil Schemes

<table>
<thead>
<tr>
<th>Loading System</th>
<th>Bandwidth</th>
<th>Cutoff Frequency</th>
<th>Inductance</th>
<th>Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-44</td>
<td>2400 Hz</td>
<td>6943 Hz</td>
<td>44 mH</td>
<td>3000 Ft</td>
</tr>
<tr>
<td>D-66</td>
<td>3100 Hz</td>
<td>4629 Hz</td>
<td>66 mH</td>
<td>4500 Ft</td>
</tr>
<tr>
<td>H88</td>
<td>4500 Hz</td>
<td>3471 Hz</td>
<td>88 mH</td>
<td>6000 Ft</td>
</tr>
</tbody>
</table>
Resistance Design Examples

14.5Kft (4,420m)
26AWG (0.41mm) 1300 ohms
14,500Ft. (4,420m)

9Kft (2,743m)
26AWG (0.41mm) 1300 ohms
9Kft (2,743m) 18,000Ft. (5,486m)

22Kft (6,706m)
24AWG (0.51mm) 1300 ohms
22Kft (6,706m)

13Kft (3,962m)
24AWG (0.51mm) 1300 ohms
15Kft (4,572m) 22AWG (0.64mm) 28,000Ft. (8,534m)

34Kft (10,363m)
22AWG (0.64mm) 1300 ohms
34,000Ft. (10,363m)
**Build Outs**

Cable build outs are primarily designed to make cable pairs electrically longer when cable sections are physically too short.

**Build Out Configurations**

1. **Build Out Capacitor [BOC]** - it is used when the length of cable section is more than half of the cable spacing required. (ie: H-88 coils require 6000 feet of cable spacing. If the cable section is more than 3000 feet but less then 6000 feet, a build out capacitor [BOC] must be used.

![BoC Diagram](image)

2. **Build Out Lattice [BOL]** - it is used when the length of the cable section is less than half of the cable spacing required. (ie: if the cable section is less than 3000 feet).

![BOL Diagram](image)
How to compute the equivalent length of build-out capacitor and subtract it from Distance To Open measurements

<table>
<thead>
<tr>
<th>Standard Tip[A] or Ring [B] to Shield/Ground Capacitances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircore</td>
</tr>
<tr>
<td>Jelly-Filled</td>
</tr>
<tr>
<td>2-Pair Drop</td>
</tr>
<tr>
<td>5-Pair Drop</td>
</tr>
</tbody>
</table>

Example:

Ring is open at 7000 feet

Aircore (Tip[A] /Ring[B] to Shield /Ground capacitances

\[
\begin{align*}
0.125\text{uF} / 5280 \text{ feet} &= 0.000024 \text{ uF} / \text{feet} \\
0.000024 \text{ uF} \times 1000 &= 0.024\text{uF} / 1000 \text{ feet}
\end{align*}
\]

Build-Out capacitor across Tip[A] & Ring[B]

\[
\begin{align*}
0.0314 \text{uF} / 0.024 \text{ uF} &= 1.308 \\
1.308 \times 1000 \text{ feet} &= 1308 \text{ feet (equivalent length of build-out capacitor)}
\end{align*}
\]

Distance to Open on Ring [B]

\[
7000 \text{ feet} - 1308 \text{ feet} = 5692 \text{ feet}
\]
**Noise and Power Influence Measurements**

Fig. 1: Circuit Noise (Noise Metallic) is measured between Tip[A] & Ring[B]

Fig. 2: Power Influence is measured between Tip[A] & Ring[B] (shorted together internally) and Shield/Ground
**Circuit Noise Basics**

$\text{I}_p$ - Current flowing through the power line.

$\text{I}_T$ - Induced current on the Tip[A] conductor from the power line.

$\text{I}_R$ - Induced current into the Ring[B] conductor from the power line.

**Power induction parameters:**

1. Influence - depends on power utility load; therefore it varies during the day.

2. Coupling - depends on the length of exposure and separation between Telco and Power utility.

3. Susceptibility - depends on cable pair balance, shield continuity and low resistance grounds. If the pair is well-balanced, $\text{I}_T$ and $\text{I}_R$ will be equal and self-cancellation occurs and Noise = 0.

Note: 1 & 2 above, usually are beyond the control of the Telco and rarely can they do anything about them.
Circuit Noise Basics
(con’t)

I_p - Current flowing through the power line.
I_sp - Induced current on the cable shield from the power line.
I_t - Induced current on the Tip[A] conductor from the power line.
I_r - Induced current into the Ring[B] conductor from the power line.
I_ts - Induced current on the Tip[A] conductor from the cable shield.
I_rs - Induced current on the Ring [B] conductor from the cable shield.

Note: 1. If the pair is well balanced, the opposing currents I_t vs I_r and I_ts vs I_rs will be equal and therefore cancel out.
2. A perfectly balanced pair can be noise-free even without a cable shield.
3. A good shield continuity and low resistance grounds can reduce Power Influence by 15dBmC.
## Relationship between dBnC and dBm

<table>
<thead>
<tr>
<th>Noise dBnC</th>
<th>Signal Level dBm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Noisy</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>0</td>
</tr>
<tr>
<td>80</td>
<td>-10</td>
</tr>
<tr>
<td>70</td>
<td>-20</td>
</tr>
<tr>
<td>60</td>
<td>-30</td>
</tr>
<tr>
<td>50</td>
<td>-40</td>
</tr>
<tr>
<td>40</td>
<td>-50</td>
</tr>
<tr>
<td>30</td>
<td>-60</td>
</tr>
<tr>
<td>20</td>
<td>-70</td>
</tr>
<tr>
<td>10</td>
<td>-80</td>
</tr>
<tr>
<td>Very Quiet</td>
<td>0</td>
</tr>
</tbody>
</table>

**dBnC** = dB reference to noise with C-Message Weighting

**dBm** = dB reference to milliwatt

**Note:** dBm - dBm = dB
3M Training Center Telephone Numbers

Line Assignments:

<table>
<thead>
<tr>
<th>Left Side</th>
<th>Right Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 9-984-2983</td>
<td>5. 9-984-2966</td>
</tr>
<tr>
<td>2. 9-884-2974</td>
<td>6. 9-984-2977</td>
</tr>
<tr>
<td>3. 9-984-2966</td>
<td>7. 9-984-2978</td>
</tr>
<tr>
<td>4. 9-984-2988</td>
<td>8. 9-984-2979</td>
</tr>
</tbody>
</table>

3M 1020B Access Numbers - Training Room:

| 1. 9-984-2036             | 6. 9-984-2048               |
| 2. 9-984-2040             | 7. 9-984-2052               |
| 3. 9-984-2041             | 8. 9-984-2975               |
| 4. 9-984-2041             | 9. 9-418-1458 (10 Frequency Step Tone 1004Hz, 404Hz, 650Hz, 1004Hz, 1300Hz, 1704Hz, 2000Hz, 2300Hz, 2804, 3000Hz, 5000Hz) then disconnect. Duration per frequency is 5 seconds with 1 second quiet intervals. All frequencies are transmitted @ 0 dBm.) |

Southwestern Bell Telephone Company

Milliwatt Tone Sources (1004 Hz.):


Quiet Line:


ANA (Automatic Number Announcer): 9-830

NYNEX Programmable Test Line (18- Frequency Tone Source) *8-518-435-2332 When initial 1004Hz tone stops, press 5 to switch source from Milliwatt to 17 frequency Step Tone - 304Hz, 404Hz, 604Hz, 804Hz, 1004Hz, 1204Hz, 1404Hz, 1604Hz, 1804Hz, 2004Hz, 2204Hz, 2404Hz, 2604Hz, 2804Hz, 3004Hz, 32004Hz, 3404Hz. Press *5 to set tone levels at 0 dBm at the C.O.