Slide #1

Solving Difficult
Cable Measurements

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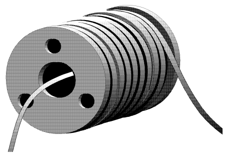
Let's talk about cable testing in this session. Cables are the most common devices, except for perhaps connectors, which may be considered as part of the cable. Virtually every system must have cabling to interconnect with other devices. There are many different considerations in selecting cables and in the related measurements to characterize them.

Introduce yourself and the topic for the next 40 minutes. Inquire if there are any customers that are currently performing cable testing and determine the level of the audience. This section is a survey rather than a detailed discussion on cable testing.

Slide #2

Agenda

- Cable types and trends
- Measurements
- Coaxial Cables
- Twisted Pair cables



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Four main topics with the most emphasis on two network analyzer measurements: SRL on coax and swept measurements on twisted pair.

This presentation is a brief overview of cables and the trends within the industry.

We'll review the typical measurements that are used to specify and characterize cables.

More specifically, we will focus on Cable TV trunk cables and the structural return loss measurement.

Twisted pair cables are widely used in computer LAN installations and provide some additional measurement issues.

Slide #3

Cable Types

Type of Cable	Application	Parameters
Coaxial	Broadcast, CATV Video	Zc, Attenuation, Capacitance Velocity of Propagation DC Reisistance Delay
Paired	Audio, LAN, Computer EIA RS232, RS423	Zc, Attenuation Capacitance Velocity of Propagation DC Resistance Crosstalk
Flat	Computer Instrumentation	Attenuation Inductance Crosstalk
Fiber Optic	FDDI, LAN Telecommunication	Aperture, Attenuation -3 dB Bandwidth

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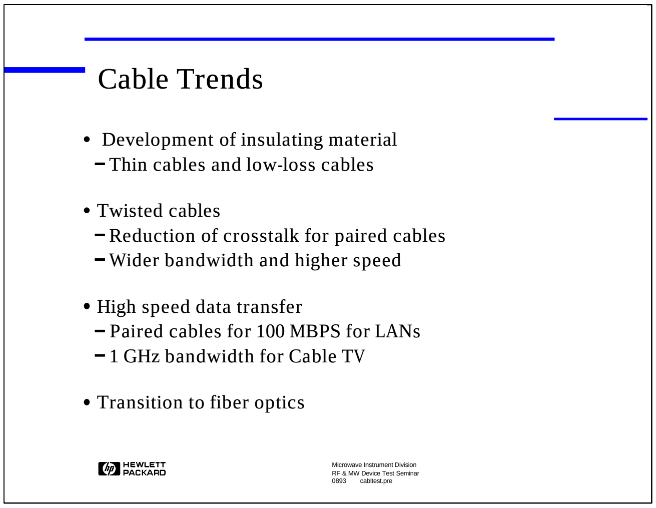
There are lots of different types of cable and some common measurements to define specifications. Overview slide.

There are four main types of cables, coaxial, paired, flat and fiber optic. Each may be used within the same system.

Specifications, and the measurements that are performed to verify them, fall into a few basic groups. For example, attenuation is a common concern in each of the four types of cable. Isolation from adjacent cables, or crosstalk is another factor in cable selection. Basic electrical properties, such as inductance and capacitance help define the operational properties. Characteristic impedance, or aperture in fiber optic systems defines their capabilities and operational environment.

Slide #4



Current changes taking place in the marketplace. Again, an overview.

Cable manufacturing processes and materials are always changing and evolving. New materials and cable configurations are continually being developed. Development of cables that are lighter, stronger and more efficient in the system operation is always taking place.

Twisted pair cables are being used widely in LANs with wider bandwidth requirements and higher operational speeds, up to 100 mega-bits. Crosstalk between pairs is a major concern as well as return loss at the higher frequencies. Cable TV operators are implementing higher bandwidths as well, up to 1 GHz and additional channels with digital transmissions.
A trend towards replacement of existing systems and creating new installations using fiber optics is present throughout all aspects of the marketplace.

Slide #5

Types of Cable Measurements

- Swept frequency
- Twisted pair
- Physical characteristics

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Topic slide for the next three slides. This is my attempt to group the types of measurements and there is some overlap. In this section the focus is on swept frequency measurements.

Let's now discuss the types of measurements that are performed on cables by both the manufacturers and the end-users. There seem to be three general categories; swept frequency measurements, twisted pair characterization and the measurements of the basic electrical properties. Many specifications are given at specific frequencies. The measurements may also be swept in frequency but specified at only a few representative frequencies. As always with specifications, there is an attempt to standardize on measurements. Different types of test equipment may be used to make the same measurements.

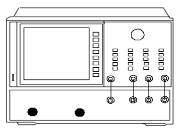
Twisted pair measurements are a series of measurements that are used to define the relationships of the pairs to each other and to other pairs within the cable.

Physical measurements are those measurements that define the basic electrical properties of the cable; e.g. resistance or capacitance.

Slide #6

Swept Frequency Measurements

- Characteristic impedance, Zc
- Insertion loss
- Return loss
  - Structural return loss
- Phase
- Group delay
- Electrical length
- Fault location TDR (FDR)



Network Analyzer

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Swept frequency measurements are used to evaluate the usable frequency range of cable and help define the type of environment for which the cable is suitable. Impedance, insertion loss and return loss are the most common measurements of a cable's characteristics. Structural return loss is a special case of return loss which will be discussed in greater detail later in this section.

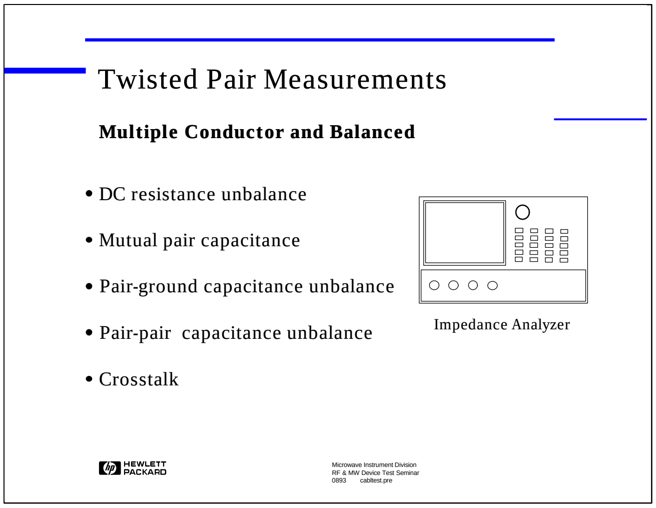
Phase changes through a cable and the deviation from linear phase or, group delay, help define the cables applications. Matched phase cables are required for many applications.

Measurement of electrical length and determining propagation delay provide further details on a cable's operation.

Examining the cable for defects and continuity is easily implemented with FDR, or Frequency Domain Reflectometry. When measuring in the frequency domain, the Fourier transform is used to convert the measurement data to the time domain display of data. More on this measurement later.

Refer to earlier discussions of the measurements in the filter section. Point out that SRL is a specialized measurements of return loss referenced to the cable impedance. There will be a discussion of time domain and gating at the end of the SRL section.

Slide #7

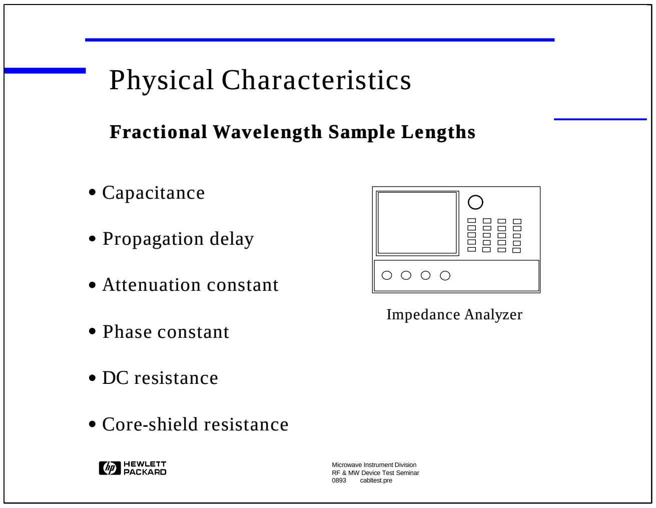


There are several measurements that are unique to twisted pairs. These measurements define the relationship between the two wires in a pair, between other pairs and the ground, or common reference. Resistance and capacitance measurements are usually made with an impedance analyzer or an LCR measuring device.

Crosstalk measurements are made by injecting a signal on one pair and measuring the signal induced on another terminated pair.

These are unique measurements based on pairs or groups of pairs and their electrical relationship with each other. Again, no attempt to define the tests, just mention that they are made in the course of characterizing twisted pair.

Slide #8



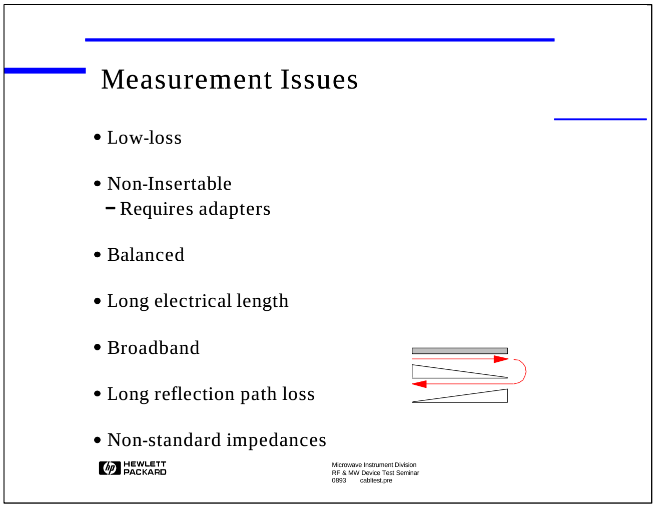
Fractional wavelength samples of the cable are measured. The lengths are determined by the test frequency of the analyzer, usually one-eighth of the wavelength. Using fractional wavelengths of cable removes the presence of lumped parameters which one would observe in a longer length of cable.

These basic electrical properties are usually measured with an LCR tester or an impedance analyzer. These measurements may be made at several frequencies, or continuously, but are usually specified at single frequencies.

The characteristic impedance may also be measured in this fashion.

These are the low frequency measurements that are usually made on short lengths of cable, usually wavelength/8 . These are basic physical measurements and not really mentioned again.

Slide #9



These are the tough measurements that will be summarized at the end of the section. Each topic is discussed again. The diagram illustrates the path loss through the cable and the reflections returning to the input port.

There are several fundamental characteristics of cables that make measurements difficult. Low loss is a desirable feature of cables. But, mismatch with the source and termination can cause reflections. Calibration with the full 12-term error correction and the use of a test set will solve this problem.

Adapters are required to perform connections with the cable and must be accounted for in the calibration and measurement.

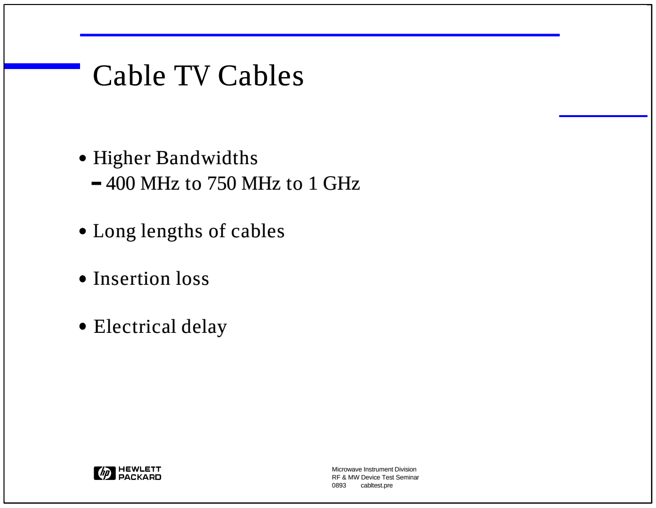
Balanced pairs require a signal format conversion to equal and opposite voltages in the pair with no relation to ground.

Long electrical length causes propagation delays and may require stepping the sweep to keep the source and receiver in synchronization.

The long cables also require high dynamic range due to path losses in the signal traveling through the cable in a return loss measurement. The test system must have a dynamic range greater that twice the insertion loss to observe effects from the far end of the cable.

Cables are not always 50 ohms and may require special test set or matching networks to measure.

Slide #10



Let's examine the measurements on cable TV cables in detail. The same concerns and measurements would also apply to and long cable run; e.g. antenna feeds.

Higher bandwidths are evolving and are affecting the test requirements and test equipment needs. Higher frequency testing will lead to more stringent requirements in test equipment.

Long runs of cable require higher dynamic range for both insertion loss and reflection measurements.

Insertion losses increase with higher frequencies.

Electrical delay must be taken into consideration due to long lengths.

This slide describes the typical measurement environment for reels of cable TV cables. Long cables mean big losses. There's a table of losses per cable reel on the next slide. Slow sweeps or step mode are used to compensate for the electrical delay through the cable.

Slide #11

Cable Attenuation at 1 GHz

Trunk Cables

Cable Size	Attenuation db/100'	db/Reel
0.750"	1.74	43.5
0.875"	1.53	38.3
1.000"	1.44	36.0
TX840	1.53	38.3
TX1160	1.20	30.0

Feeder Cables

Cable Size	Attenuation db/100'	db/Reel
0.412"	3.10	96.1
0.500	2.53	69.3
0.625"	2.11	52.8
TX565	2.17	54.3

Drop Cables

Cable Size	Attenuation db/100'	db/Reel
59	7.92	79.2
6	5.42	64.2
611	5.41	54.1
11	4.31	43.1

Requires Dynamic Range!

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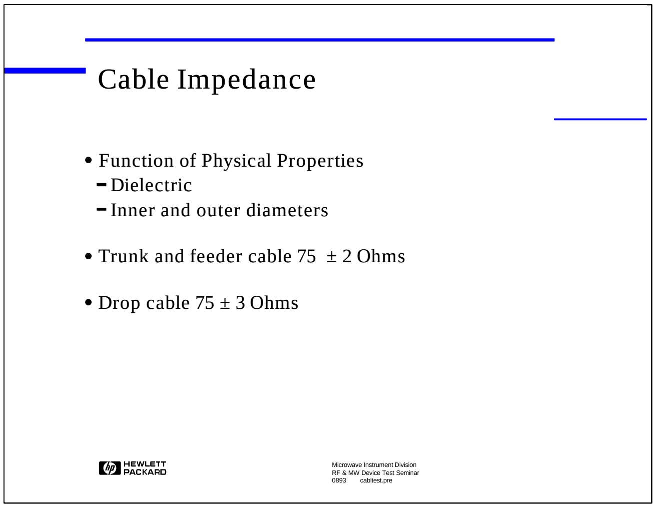
Here are some typical attenuation or insertion loss values for reels of cable. High dynamic range is required to measure these values. As discussed in the filter section, dynamic range is a function of the highest signal input to the sensitivity of the system. Dynamic range must exceed the measurement requirements by 10 dB. Simply matching the required range yields a 100% error rate.

Consider a TDR or reflection loss measurement where the transit loss through the cable is doubled.

Trunk and drop cables are relatively low-loss compared to the feeder cables.

Point out that these tables are for 1 GHz, the new upper frequency limits for the cable systems. The losses through the cable make insertion loss measurements impossible for broadband systems. Recount that dynamic range must exceed the measurement values by 20 dB to achieve +- 1 dB accuracy. Point out that the .5 inch feeder cable will be measured in the video demo and read the values.

Slide #12



Cable impedance in a coaxial cable at higher frequencies is primarily a function of the physical dimensions and dielectric quality of the cable.

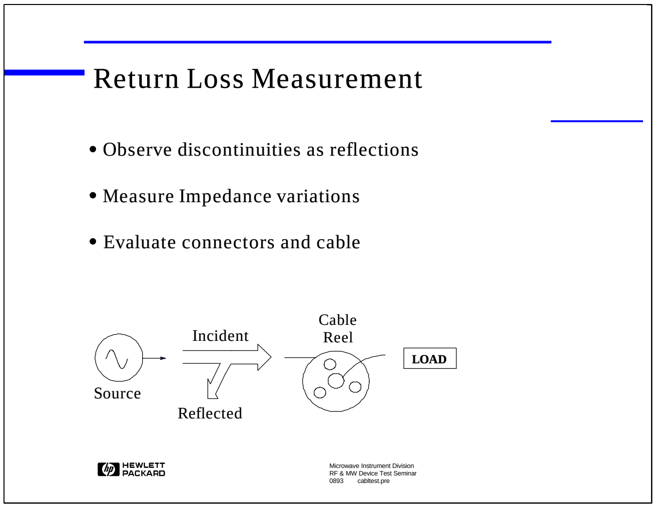
Trunk and feeder cables impedance tolerance is tighter than drop cables which reflect the generally more expensive and higher quality cable.

Impedance variation within the cable may be viewed as a reflection or return loss.

Cable measurements are made at 75 ohms. The cables have a large tolerance in impedance values.

The cable impedance does change with frequency and is not a perfect match with the test set.

Slide #13



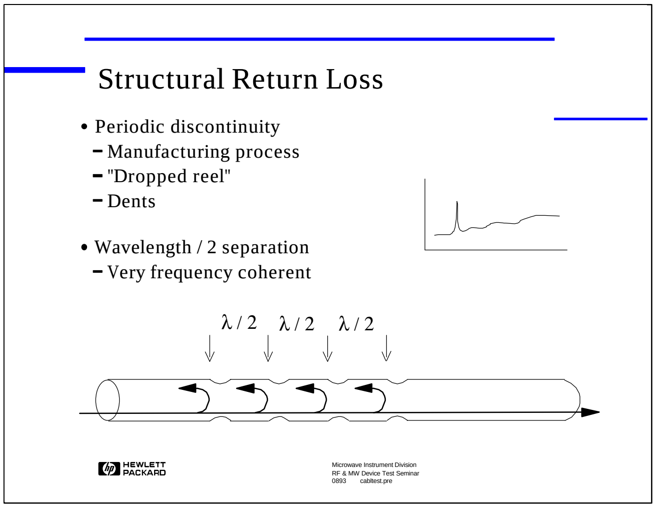
This measurement is easily made on one end of a cable. The amount of signal that is reflected is compared to the signal that is injected.

Any discontinuities or physical variations are observed as a reflected signal. Impedance variations also appear as discontinuities as each change reflects power.

Connectors and the cable interface may also generate reflections. Connector quality and match may be also examined.

Reflection loss measurement is just as discussed in the earlier sections.

Slide #14



Structural return loss is a special case of return loss measurements. Physical deformation of the cable, by handling or manufacturing process, cause reflections.

Structural return loss occurs when these periodic deformations sum at a half-wavelength spacing and reflect the input signal.

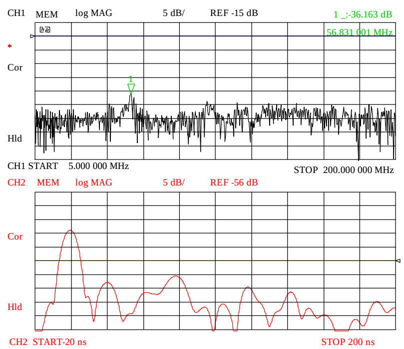
A narrow spike of high return loss results from a specific frequency component being reflected from the cable and not transmitted through the cable.

When the effects from these small discontinuities are summed, they represent a major effect on the transmission capability of the cable. Periodic spacing of irregularities in time or distance leads to a cumulative effect in frequency.

The periodic discontinuities may be distributed over the entire cable. The best example is an extrusion machine which has a jaw that grasps the cable and pulls to draw out the cable. If the jaw is mis-adjusted, a periodic dent is placed in the cable each time the jaw seizes the cable and pulls. These dents may be too small to observe their reflections directly, but can cause an accumulative effect on the cable return loss quality.

Slide #15

Structural Return Loss



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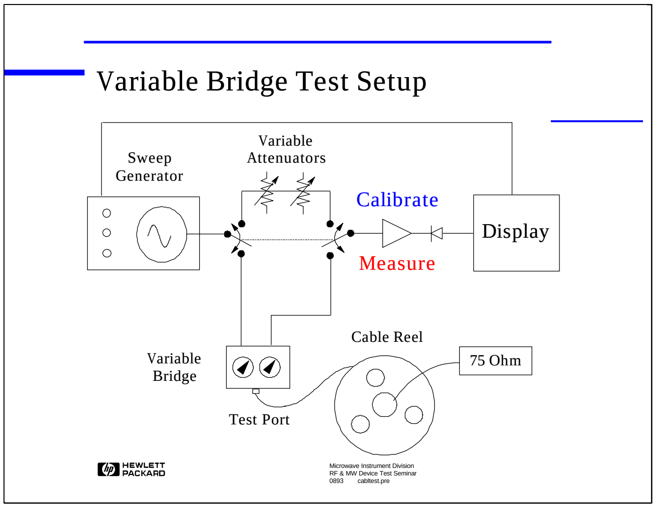
Here is the plot of a network analyzer return loss measurement and the corresponding time domain display. A 75 ohm test set was used to match the impedance of the trunk cable.

The return loss from a good cable and a damaged cable are shown in the upper plot. The lower plot shows the time domain display of the return loss measurement. The peaks represent the reflections from the cable. The connector is the first reflection in both cables. The additional reflections in the bad cable cause the increase in return loss as shown in the upper display.

There is a new plot which shows SRL and the insertion loss effect at the same frequency. This is a realistic example. Note the scales for the plots and the markers. The dip in the insertion loss is just a few dB with the SRL being 15 dB or so out of spec. The old plots, one good cable and one cable after denting, are the same results as shown in the video tape. Show the video tape at this point. Be sure to point out that the dents are an attempt to simulate SRL, but from just a few dents rather than the distributed dents throughout the cable.

Slide #16



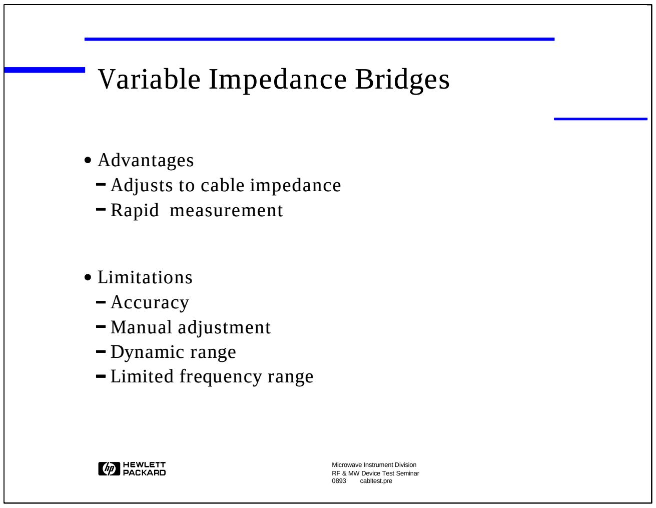
Structural return loss measurements were originally made with a variable bridge, a sweeper and a detector. The impedance of the cable is matched and measured, by adjusting the bridge for a minimum return loss and reading the value from the bridge dial. Cable impedance variation may also be eliminated by adjusting the bridge.

Once a signal level is observed, the switch is thrown and the attenuator adjusted to match the signal level. Subtracting the attenuator setting from the source level determines the signal level being measured.

This manual measurement requires a skilled operator.

This is the original and most common measurement setup for SRL on cables. Many customers still use this system. This is the grease pencil world, where you adjust an attenuator to match a level on the display.

Slide #17



The variable bridge allows a rapid measurement and does a good job of matching the cable impedance, but.

As frequency increases the bridge lacks good directivity.

Repeatability is as good as the operator and equipment. Accuracy is a function of the calibration of the attenuators and the bridge.

The measurements must be made manually.

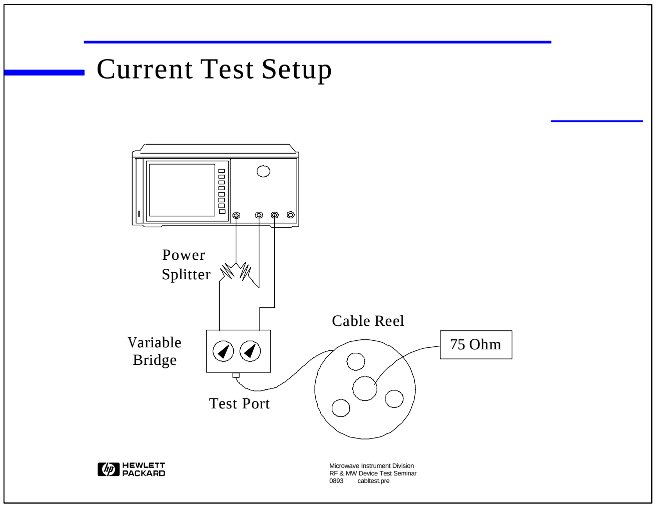
Dynamic range is limited to the amount of power in the source and the noise floor of the detector.

The frequency range of the measurements is limited by the sweeper, bridge and detector.

Quick summary. The old system has lots of shortcomings. No calibration for anything as a test system except for attenuators and sweeper calibration cycles.

ERROR: the second sentence should read: As frequency increases, the bridge lacks good raw directivity. The sentence will be removed in revisions!

Slide #18



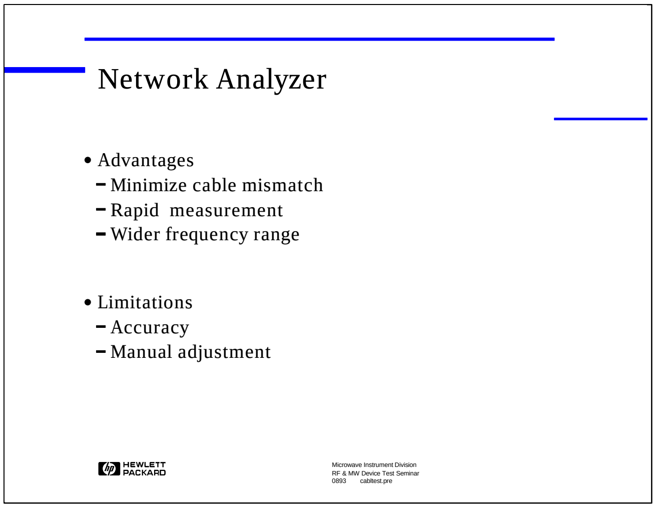
This is the proposed system for the SCTE measurement. Better measurement but still the same problems/limitations with the variable bridge.

Most customers are now using the variable bridge and the network analyzer to perform their cable testing measurements. The network analyzer provides a calibrated measurement and the additional frequency range that is required.

The analyzer is set to the desired test range and the bridge is adjusted to match and balance the cable being tested. The measurement is performed even more rapidly as the substitution method is not required to establish the signal levels.

The Society of Cable Test Engineers (SCTE) recommends this setup as part of their standard practices for measuring structural return loss.

Slide #19

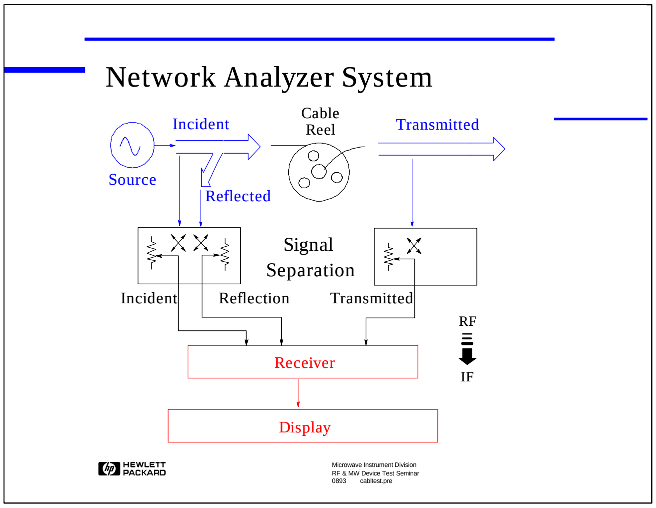


The system can be calibrated, but as soon as you tweak the bridge, the CAL is gone! This is the current solution and may be contested by the audience. Focus on calibration of the test set. New title on slide to identify the variable bridge solution.

The network analyzer adds the needed dynamic range and a calibrated measurement to the system, but the limitations of the variable bridge still affect the measurement. The directivity, repeatability and accuracy of the variable bridge technique is limited.

The bridge is usually varied to match the cable impedance. The bridge may be calibrated to a fixed standard, but the measurement is influenced by adjusting the bridge. Resisting the urge to adjust the bridge is necessary to obtain a good measurement. Even minor adjustments, "tweaks", can significantly affect the measurement results and cause the cable to pass the test requirements.

Slide #20



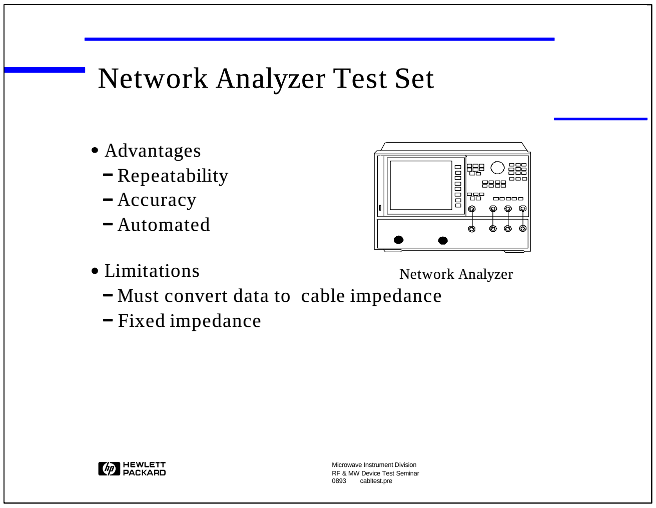
Using a network analyzer for the same measurement offers several advantages. But, first let's review the major components of the analyzer.

A 75 Ohm test set is used to provide the connections to the cable. A bridge configuration provides both the reflected and incident signal separation, as well as a load for transmission testing or the insertion loss measurement.

The receiver signal is converted to an IF signal and then measured and displayed.

This is the same diagram used in other sessions. Nothing new, just a review of the components.

Slide #21



This is the solution for accuracy and repeatability, but you must correct for the cable impedance and adjust your data to measure structural return loss.

Using a test set provides a standard reference for the measurement system.

Better directivity is provided by the test set, especially at higher frequencies.

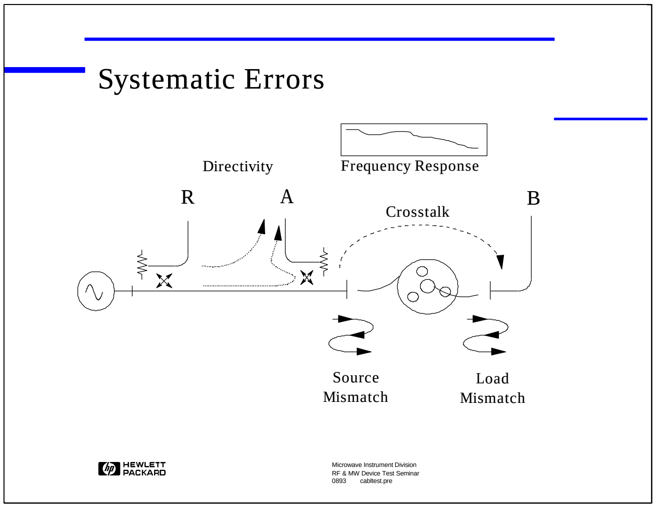
Repeatability of data from test-to-test is excellent.

Accuracy is enhanced by the calibration with known standards and the use of full 2-port 12 term error correction.

Automation allows the operator to focus on the measurement results rather than the measurement process.

The limitations of this test setup are that the measurement is performed to the 75 Ohm test set reference, not the cable impedance. The data must be compared to the impedance of the cable to conform with the structural return loss measurement definition.

Slide #22



Re-emphasizing the features of the full 2-port calibration and the errors that are removed. This slide is used in other sessions and should deserve only a brief mention of the errors.

Let's review the test set configuration and the associated errors. The systematic errors present in the test set are shown in this diagram. All of these errors may be removed by calibration with a known set of standards. Calibrating out these errors adds a high degree of accuracy and repeatability to the measurement.

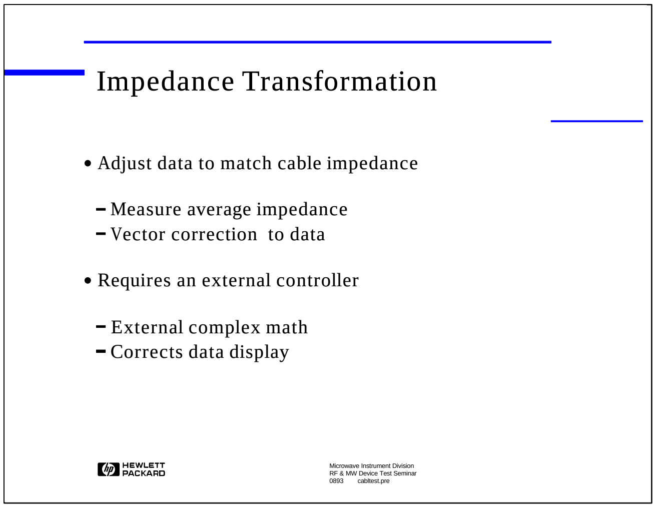
Directivity error is caused by a signal path that does not pass out through the test set port to the cable under test. This signal passes through the test set to the input port or is reflected back from the input port.

Crosstalk is the signal that is coupled around the test set ports, from the output to the input port.

Source and load mismatch are the errors associated in the quality of the test port terminations.

Frequency response is the error associated with increasing frequency and the response of the test set.

Slide #23



Because of the fixed test set impedance, the return loss data must be transformed to the average cable impedance. The trace data is averaged out to obtain an average value and this value is used to perform a vector correction on the trace data. These values obtained are then structural return loss and comparable to the variable bridge technique.

The transformation must be performed with an external computer using complex math, or in the case of the newer analyzers, with built-in IBASIC .

If the measured trace data values are sufficiently below the specifications, no transformations need be performed.

The transformation is not difficult and can be done. If the data is below a certain level, the transformation need not be performed. The transformation will lower the SRL value. The benefits of an automated search and accurate, consistent measurements far outweigh the conversion time. IBASIC can also perform the transformation in the 8751.

Slide #24

Time Domain Gating

- Examine or remove response from connector
  - Reduce reflections
  - Increase resolution
  - View cable response only

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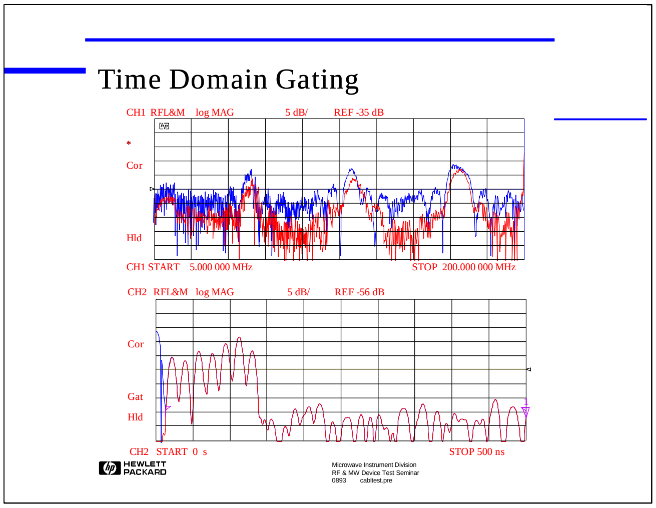
As mentioned earlier, time domain gating may be used to examine individual responses from the cable under test. The sums of the individual components may obscure the device being examined. For example, at higher frequencies a poorly fitting slip-on connector may cause a larger reflection than the cable. The cable may be viewed independently from the connector by gating and viewing only the cable response.

Underlying signals which are masked may now be viewed.

Refer to the earlier discussions about SAW filter measurements in the filters section.

Slide #25



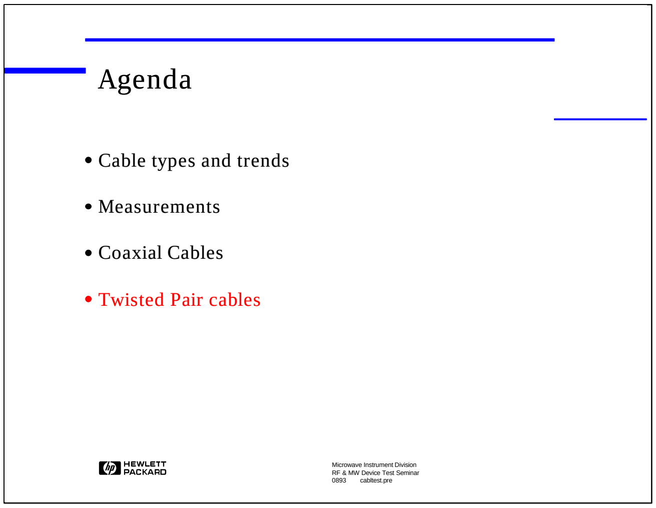
Connector and impedance mismatches, and other major anomalies may be ignored or bypassed with this gating.

The traces shown here illustrate the effects of time domain gating. The desired response is enclosed within the gates in the time domain display. The return loss data is modified to display only the signals selected in the time domain trace. This capability allows us to effectively remove undesirable reflections from the connector. We can then measure the cable and ignore the effects from the connector.

The upper trace shows the return loss measurement of two cables, one with reflections from a bad connector. By removing the reflections from the connector, the second trace reveals more detail about the cable reflections.

The first reflection in the time domain display , the connector, is gated out, i.e. the gate is set around all of the other reflections except the one from the connector.

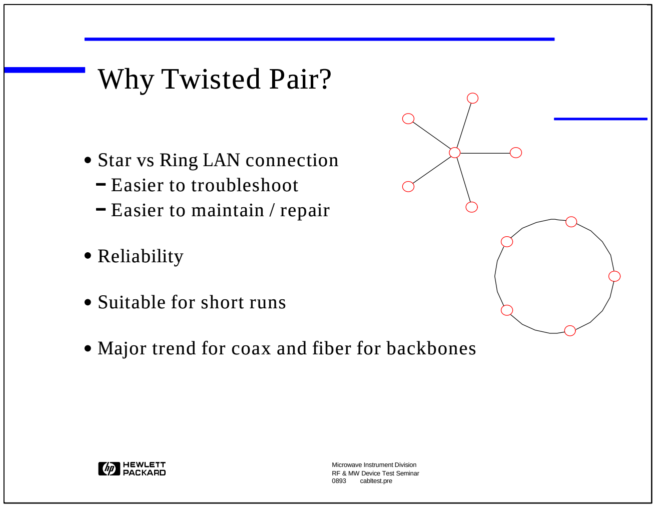
Slide #26



Let's now leave the coaxial cable discussion and examine the measurements which are performed on twisted pair cables and the techniques required to make those measurements.

This concludes the coaxial section. Questions or comments? Now on to twisted pairs. Breakpoint.

Slide #27



Twisted pair has become popular with the conversion from ring LAN configurations to the star configuration. Star configurations use twisted pairs for the shorter connections from the peripheral systems to the hubs.

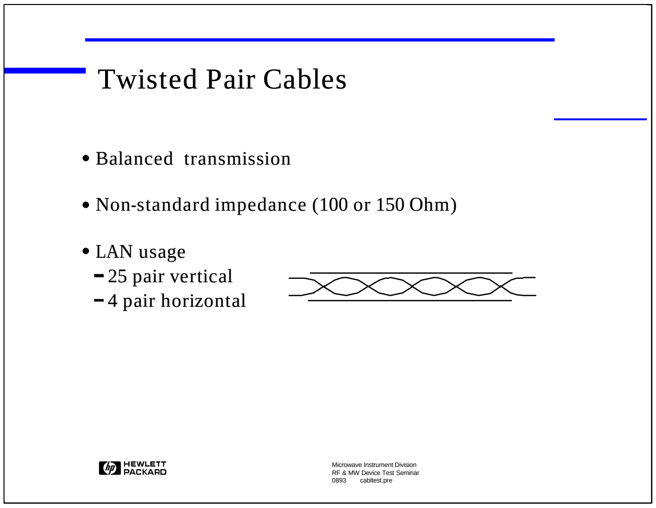
If a cable is damaged, or the connector torn off, only one system will fail rather than the entire ring of systems. It is easier to trace the location of the cable fault and correct it in this configuration.

Twisted pair is an economical solution for short runs of cable.

The major trend is to use coaxial LAN connections for the major interconnection between hubs or the backbone of the site installation. Fiber optic cable is also being used for this type of installation.

The choices are all data or digital format related, not the electrical properties of the cable. The communication techniques and connections are the deciding factor. Think of a string of Christmas tree lights. When the connections are broken or a bulb burns out, the lights all go out in a ring configuration and only one light goes out in the star configuration . Another comparison is to try to drive coax in parallel paths with multiple splitters, versus twisted pairs driven in parallel by connecting up to terminals. Multiple twisted pairs are much easier to connect and drive with data.

Slide #28



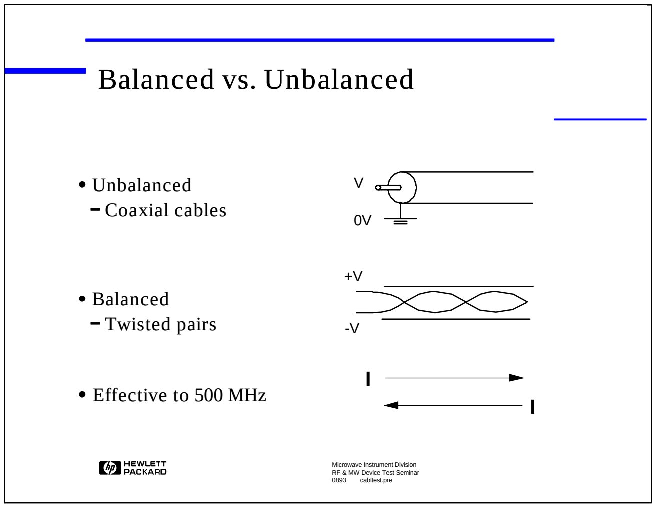
There are some difficulties associated with measuring twisted pair cables. The cables are used in a balanced configuration and require a balun device to interface with most standard test equipment.

Twisted pairs have an impedance other than 50 Ohms, usually 100 or 150 Ohms.

There are a lot of wires involved. A minimum of 4 pairs are used in a horizontal cable and as many as 25 pairs are contained in a backbone cable. Each of the pairs must be treated individually and as a group in the measurement. Each pair must be terminated to avoid influencing the measurements on the others.

Description of twisted pair cables used in LANs.

Slide #29



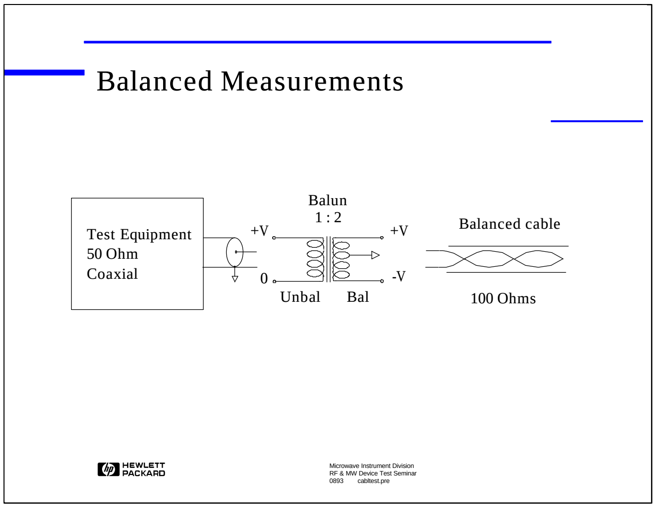
ERROR: Voltage is equal but opposite to ground at any point not zero or canceled. The current does cancels at any point across the pair.

In a normal coaxial measurement , the signal is referenced to the shield or ground. There is a center conductor which is centered in a dielectric cylinder and surrounded by a shield layer on the outside of the cylinder.

Balanced transmission is accomplished with an equal and opposite current flowing through the pair. The voltage potential is between pairs, not referenced to ground. Each line of the pair is equal and opposite in voltage with respect to each other. At any instant in time, the current and voltage will cancel out at a point.

Description of balanced operation. There is an error in the handout, in the last sentence.

Slide #30

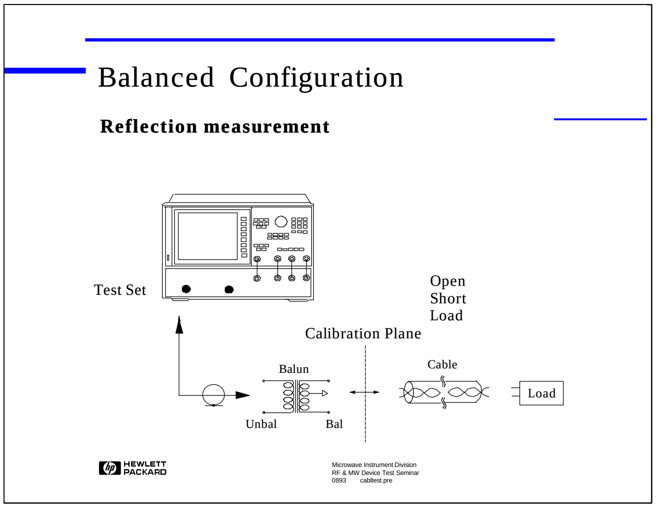


This illustration shows a balun transformer being used to convert a 50 ohm single ended signal to a 100 ohm balanced twisted pair. Connectors are also required to make the connections with the balun and the source. The balanced end is usually a set of terminal posts.

Care should be taken in choosing the connectors as they will affect the measurement of the pair. As the frequency increases, the choice of connectors and balun configuration becomes more critical.

The balun is used to perform the impedance transformation as well as balance the twisted pair. No ground needs to be used in the coaxial connection. Introduce the balun concept. Balun selection criteria is discussed in a couple of slides.

Slide #31



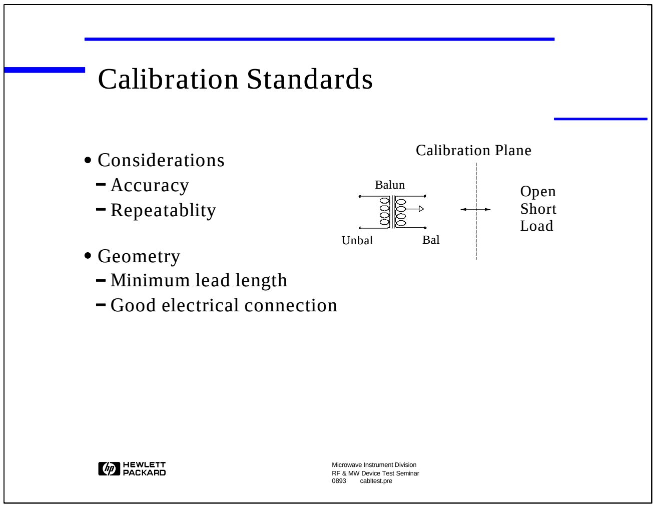
This is the setup to measure the return loss of a twisted pair.

The test port of the test set is connected to the 50 ohm side of the balun. A calibration or reference plane is established on the output side of the balun. This port is calibrated with a short, open and a load to match the balun. The associated errors of the output port and the balun are characterized with the calibration and removed from the measurement data.

The twisted pair is then connected to the balun and terminated with the load. The measurement is then performed and the data interpreted as in an unbalanced coaxial system.

The balun is added and the reflection measurement is performed as before. Calibration removes the measurement errors associated with the balun and system. This is true only when the twisted pair impedance does not vary. Below 1 MHz, the impedance varies widely and can cancel out any calibration.

Slide #32

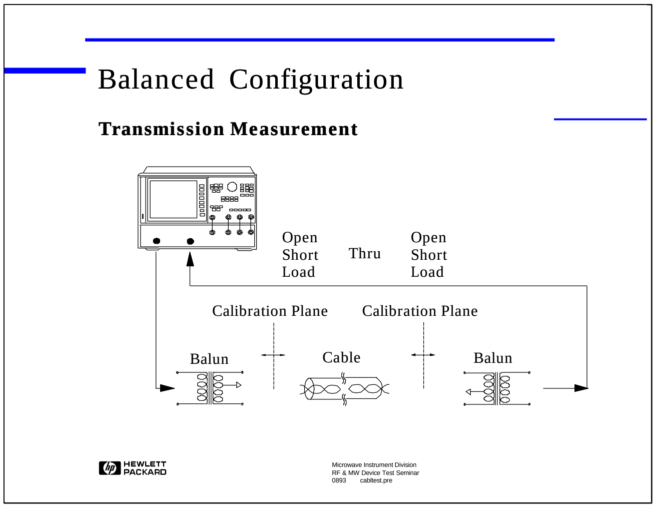


Calibration standards must be chosen carefully as the accuracy of the calibration and measurement depend upon them. A good electrical connection with the test connectors is most important for all three standards. The short and open may be just that, open terminals and a piece of wire or copper sheet. The load should be measured carefully to provide the exact resistance , i.e. a 1% resistor reflects a 1% accuracy in the measurement.

Lead length does not become a factor until the lengths approach a significant portion of the wavelengths of the frequencies being measured. With 500 MHz as the upper limit of the testing, carefully shortened leads are the only consideration. This would not be the case at 5 GHz! Use a connector that is reasonable for the cable being tested and build a set of standards using the same connector. Avoid using alligator clips and long test leads!

Balun calibration standards do not exist and must be created for the measurement setup and fixturing. Build connectors and standards with the care required to reflect your measurement needs. It's not difficult to generate an acceptable set of standards.

Slide #33

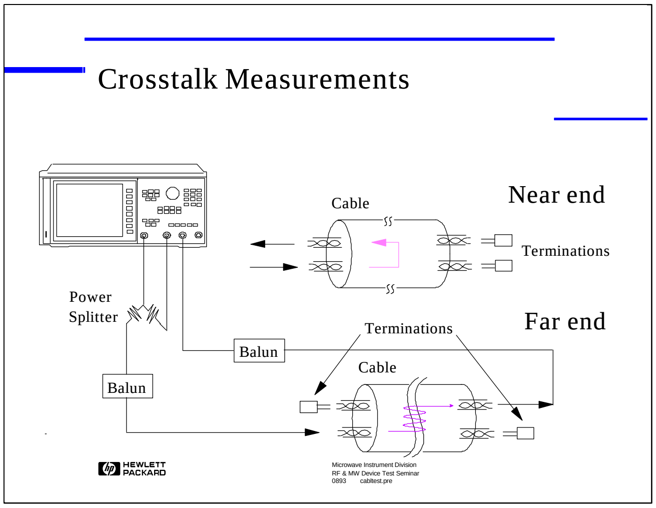


Add another balun and a 2-port cal to perform a transmission measurement. The calibration plane is set at the end of the cable.

To perform a transmission measurement requires high dynamic range in the measurement system and a receiver port that is balanced as well. A second balun is used as a termination for the twisted pair and is connected to the input port for the analyzer. A second calibration plane is established for the analyzer input which removes the systematic errors from the measurement. This configuration allows both a transmission and reflection measurement.

A thru connection must be added to the calibration standards. This would usually be a representative short length of the cable pair being tested.

Slide #34



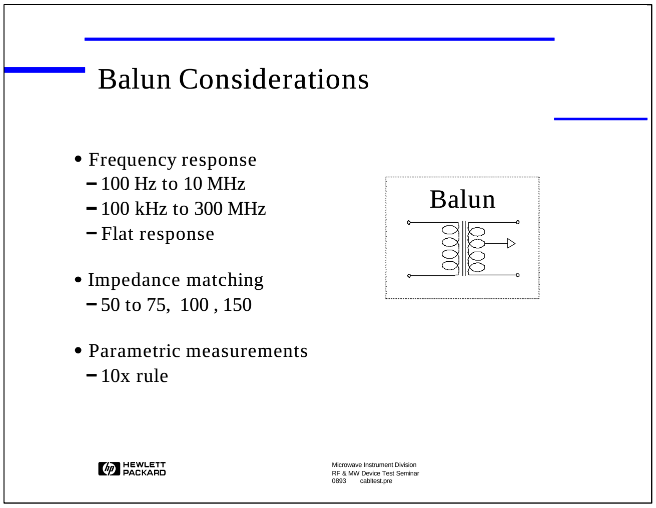
Crosstalk measurements are made between pairs of pairs. One pair is energized and the other pair is examined for signals present. Baluns are required as in the transmission measurements. Note that a power splitter may be used in place of the test set for this measurement. However, a test set would also work correctly.

Two different tests are illustrated here, a near end and a far end crosstalk measurement. The near end refers to the location of the measurement on the receiving pair.

While the crosstalk tests are being performed, all of the other pairs within the cable must be terminated in a characteristic load

Crosstalk measurements are extremely important to LAN applications . Crosstalk interference is defined when the induced signal levels from another pair mix with the desired signals and eventually cause disruption of transmission. This is a complicated measurement with lots of data taking and comparisons between pairs as well as switching and terminating.

Slide #35



Baluns perform the impedance transformation and the balanced line output very well, but there are some considerations in selecting them for your measurement.

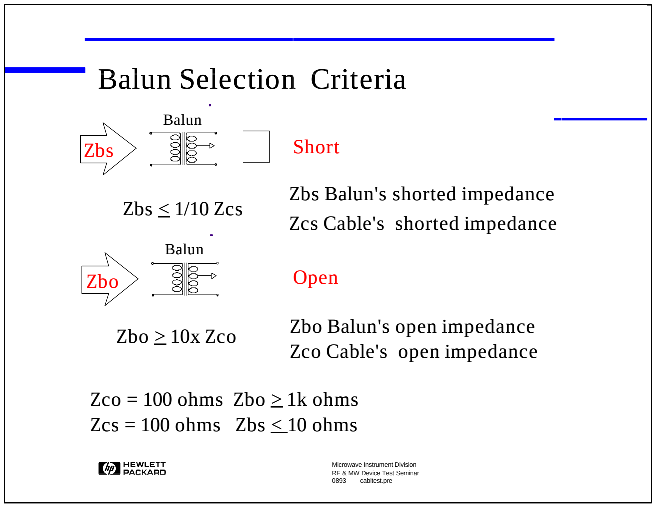
There are two different types of transformers associated with baluns, low frequency and high frequency. Both are fairly wideband, but over different frequency ranges. The balun should have a flat frequency response, or 3 dB bandwidth, greater than the frequency range of testing.

Impedance matching is usually available in a ratio or for typical impedances, such as 50, 75 or 100 ohms.

Be careful when making physical measurements that the balun is not affecting your measurements. A general rule is to use baluns whose impedance is at least ten times larger than the largest value of the cable or ten times smaller that smallest of the cable values that you are trying to measure. Let's examine this rule in more detail in the next slide.

North Hills has 13 different impedance choices with differing bandwidths and HP has 2 different models. The references section lists the model numbers and information. Baluns can be purchased as self-contained components or as pulse transformers, wire would around coils.

Slide #36



Measure the open and short-circuit impedance of the balun and observe the ten times rule. The short-circuit impedance of the balun should be as low as possible, at least 1/10 or less than the impedance of the cable being measured. The open circuit impedance of the balun must be at least ten times the maximum value of impedance of the cable.

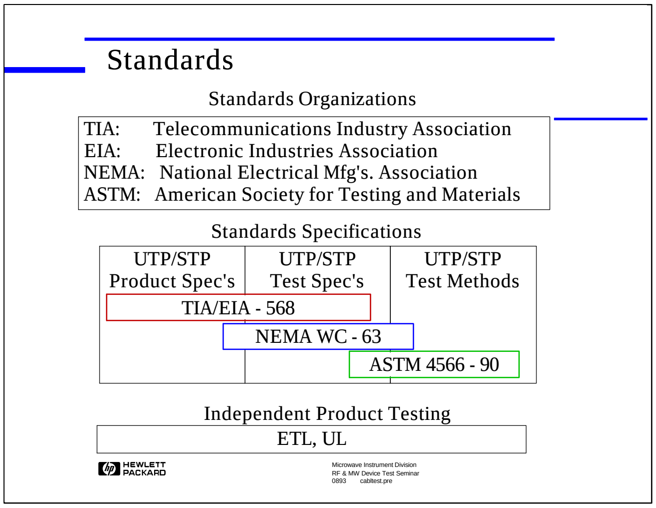
The balun impedance must be ten times greater or ten time less than the values you are trying to measure. By observing this rule, you are eliminating the effects of the balun impedance on the measurement. However, a ratio of ten still yields a 20% error in the measurement.

For example, if you are measuring a cable which has an impedance of 100 Ohms, you should choose a balun that has an open-circuit impedance of at least 1 k Ohm and a short-circuit impedance of less than 10 Ohms.

How do you measure the open and shorted impedance? Why, with our analyzers!

ERROR: last sentence. An error ratio of ten, 20 dB, still yields a 1 d

Slide #37



Standards have been defined for the manufacture of twisted pair cable and measurement of the associated parameters. Here are a number of the current standards that must be observed and their relationship to each other. A number of measurements are required to meet these standards.

Note that the NEMA specifications specify the entire range of product specifications, test specifications and the test methods. Both STP, (Shielded Twisted Pair), and UTP, (Unshielded Twisted Pair) are included in the specifications.

This table illustrates that there are standards in existence which are continually evolving and in transition. There isn't time to explain them. The latest proposal, June 93 , for TIA/EIA has some interesting new measurements, such as power sum. Each of the lines in the crosstalk measurement must be measured against all the others and then the results combined mathematically for a worst case condition. The new trends only lead more toward automation and fixturing for the measurements.

STP Shielded Twisted Pair
UTP Un-shielded Twisted Pair

Slide #38

Test Requirements

	100 Ω UTP Levels 3 - 5	150 Ω UTP Type A	100 Ω UTP
DC Resistance	✓	✓	✓
DC Resistance Unbalance	✓	✓	✓
Mutual Capacitance	✓		✓
Capacitance Unbalance	✓	✓	✓
Characteristic Impedance	✓	✓	✓
Balanced Attenuation	✓	✓	✓
Near End Crosstalk	✓	✓	✓
Structural Return Loss	✓		✓
Common Mode Attenuation		✓	
Core Shield Resistance			✓

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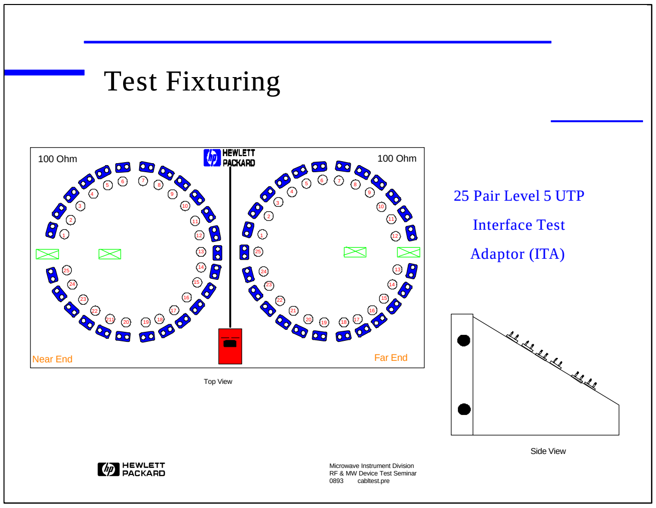
Microwave Instrument Division
RF & MW Device Test Seminar
0893 cabltest.pre

This table shows the series of tests that must be performed to certify that a cable meets the standards. Note the mix of physical parameters, twisted pair and swept frequency measurements.

Again, just to show examples of the types of tests that are specified. Point out the mix of the three types of measurements.

Slide #39



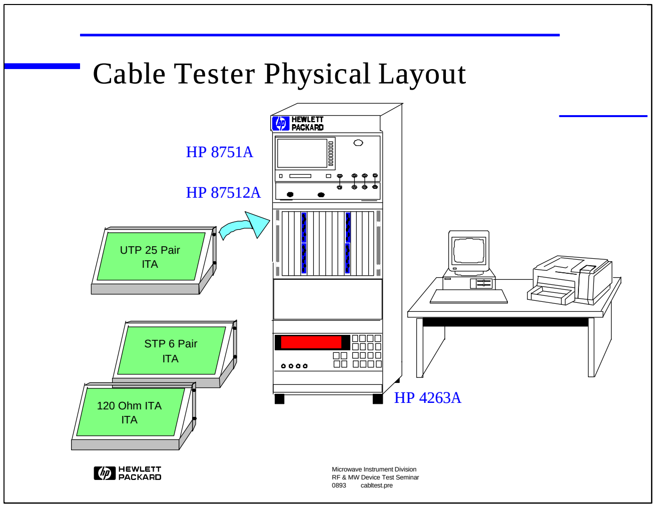
A large number of connections must be made with baluns and the loads for the cables not being tested as well as the pair(s) being measured. Here is the test fixture layout for a 25 pair backbone LAN cable.

Each terminal pair has an associated balun and load. Switching and termination of the pairs is controlled by a large switch matrix which connects the desired pair to an LCR meter or a network analyzer for performing the desired tests.

A circular layout geometry is desired to allow uniformity of the cable pair lengths and the stripped pairs for insertion into the fixture. Note there is a near end and a far end set of terminals.

This is an example of a proposed test fixture to connect the pairs to a switch matrix for testing, This layout allows equal lengths of pairs from the cable to the fixture.

Slide #40



The test rack is shown here to illustrate the test equipment required and the cable connection and fixturing. A PC is used to control the operation and provide a data base of test results. Test that might require weeks manually can be accomplished in a matter of hours.

An HP 8751 network analyzer and an HP 4263 RLC meter are the test instruments in the system.

This is a proposed system that the Application Center in Burlington, MA is planning to build. Four manufacturers have anted up $150K and only one more is needed. Have the *<u>salesman</u>* *contact Pete Johnson if there is any interest from a customer in purchasing or specifying a system.*

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System Engineering Business Unit
Hewlett-Packard Co.
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Burlington, MA 01803
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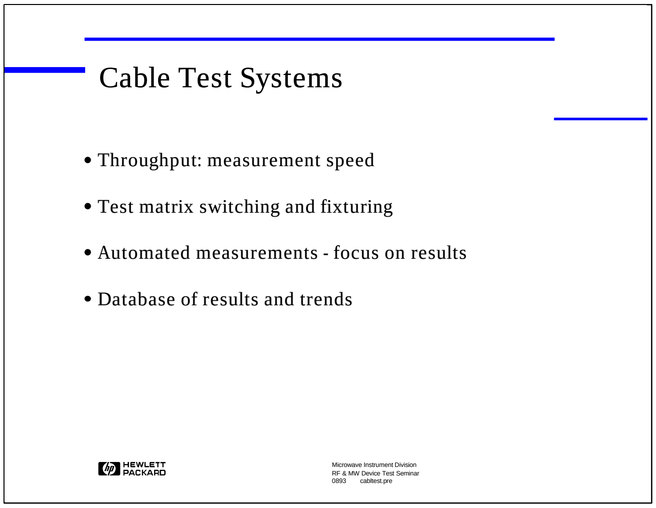
Slide #41



Manufacturers of twisted pair cable will require an automated solution for testing their products to the industry standards.

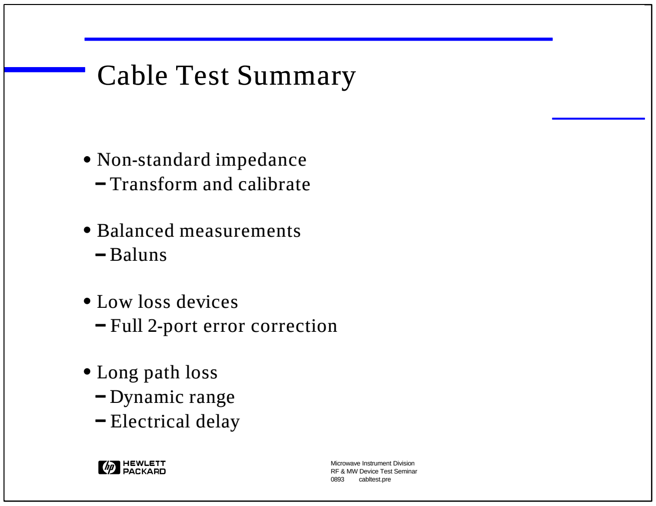
This test system must provide a large matrix for switching
test instruments, loads and baluns for the cable pairs.

Automation will provide a consistent measurement with accurate results. Much of the tedium of the measurement is reduced and the operator can focus on the test results, instead of which pair is being tested.

The volume of data acquired and analyzed for each test cable is quite large. Maintaining a data base of results to verify the quality of the manufacturing process requires a data processing solution that can be provided by HP.

The proposed test system features big increases in testing throughput and data documentation. Tests that can take a week to perform can be accomplished in a few hours. Imagine all the connections and terminations that have to be made and changed for each test.

Slide #42



Cable testing and measurement provides a number of challenges that we discussed in this section.

Non-standard impedances may be measured in a calibrated environment.

Baluns can provide the test interface to twisted pair measurements

Cables as low loss devices require a full 2-port 12-term error correction to remove the effects of impedance mismatch with the test ports. These can be a large source of error in low loss measurements.

The long path loss associated with testing cable requires a test system with a high dynamic range, at least ten dB greater than the expected result. Electrical delay, the time for the signal to travel through the cable, may cause measurement problems in long cables. Slow the sweep down to compensate for the delay.

Summary of the section. Briefly remind the customers of the solutions for each major problem. Questions if time?

References

Hewlett-Packard Company, *Vector Seminar*, Vector Measurements of High Frequency Networks
(HP publication number 5958-0387).

Hewlett-Packard Company, *Scalar Seminar*, Scalar Network Measurements (HP publication number 5954-1586).

Society of Cable Television Engineers Engineering committee, Interface procedures subcommittee recommended practices and test methods for the CATV Industry, IPS-TP-007 Preliminary test method for Structural Return Loss.

Application Notes

Measuring the Impedance of Balanced Cables, Application Note 339-4 (HP publication number 5950-2918).

Measuring Cable Parameters, Application Note 380-2 (HP Literature number 5950-2399).

Balanced Cable Measurement with an Impedance Analyzer / LCR Meter / Network Analyzer, Application Note 346-2 (HP Literature number 5091-4480).

Video Tapes

Balanced Cable Measurement,
(HP Part number 90468T).

Baluns

Hewlett-Packard Company

Model No.	Impedance	Freq. Range	Connectors
16316A	50 : 100	100 Hz - 10 MHz	BNC - BPs
16317A	50 : 600	100 Hz - 10 MHz	BNC - BPs

North Hills Electronics

Model No.	Impedance	Freq. Range	Connectors
0101BB	50 : 75	0.1 - 125 MHz	BNC - lugs
0300BB	50 : 100	0.1 - 100 MHz	BNC - lugs
0400BB	50 :150	0.1 - 100 MHz	BNC - lugs

And a wide assortment of other configurations

North Hills Electronics A Porta Systems Company
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Tel. 516-682-7740 FAX 516-682-7704