SCOPE COMMUNICATIONS, INC.

Testing audited by

WireScope 155

Accuracy Analysis

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SCOPE COMMUNICATIONS, INC.

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This white paper presents the method and laboratory data used to determine the accuracy of the WireScope 155. The data collection has been performed in conformance with the draft TIA TSB-67 and has been independently audited by Inchcape Testing Services, ETL Testing Laboratories.

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Overview

Category 5 cabling is the key enabling technology for bringing high speed networking to the desktop. In order for installers and users of category 5 cabling plants to be sure that each cabling run can deliver high performance service, it is necessary to test cabling performance parameters in the field.

The draft TIA TSB-67 specification for field testing defines the required test functions, test configurations, and minimum tester accuracy necessary to reliably certify category 5 cabling in the field. TSB-67 defines two measurement accuracy levels and the instrument design parameters required to meet these overall measurement accuracy ranges. Annex A of the draft TSB-67 specification defines a mathematical model relating the overall accuracy of a field test instrument to measurable instrument error parameters. Using this model, it is therefore possible to obtain overall accuracy of a field tester from data which can be measured using laboratory equipment.

This article describes the application of the TSB-67 accuracy analysis to design qualification and production testing of the WireScope 155 field cable tester. Inchcape Testing Services, ETL Testing Laboratories audited the process of measurement and collection of the data presented in this analysis.

TIA TSB-67 Accuracy Evaluation Techniques

The TIA draft TSB-67 field tester specification defines several methods to verify the accuracy of field cable testers. The most critical of these is the error model technique defined in Annex A of the draft document. The Annex A error model technique must be used to verify compliance with the more stringent Level II accuracy requirements.

Other accuracy evaluation techniques provide varying degrees of “sanity checking” for the Annex A technique. Annex B of the draft document describes a technique for comparing field tester measurement data to corresponding data taken from laboratory grade network analyzers. Other sanity checking techniques are appropriate for field testing the cable tester to verify calibration and proper operation.

Annex A Error Model Method

Theory and Purpose

The technique described in Annex A of the draft TSB-67 document is intended to relate measurable error-contributing parameters to the resulting overall test instrument accuracy. The error model is intended as the reference technique for verifying compliance with the level I and level II overall instrument accuracy grades defined in the draft TSB-67 specification.

Instrument Error Parameters

Each of the error parameters defined below is an intrinsic characteristic of any field test instrument. Each error parameter impairs overall tester measurement accuracy through a different coupling mechanism and to a differing degree. The effects of each of these error parameters on overall accuracy varies with frequency and with the magnitude of the measured signals.

The following mathematical models presented in Annex A formalize the relationship between these various effects and the overall NEXT and attenuation accuracy:

$$NEXTAccuracy := |Ed| + 20 \cdot \log\left[1 + (|Er|)^2 + \sqrt{\left(\left|\frac{Ex}{A}\right|\right)^2 + \left(\left|\frac{En}{A}\right|\right)^2 + \left(\left|\frac{Sc \cdot Eb}{A}\right|\right)^2 + \left(\left|\frac{Sd \cdot Ec}{A}\right|\right)^2}\right]$$

$$AttAccuracy := |Ed| + 20 \cdot \log\left[1 + (|Er|)^2\right]$$

Ed, Er, Ex, En, Eb, Ec are error terms derived from the field tester parameters described below.

A is a term related to the absolute level of the measurement.

Sc and Sd are terms which model common mode to differential and differential to common mode coupling losses.

Figure 1. TSB-67 Annex A Accuracy Models for NEXT and Attenuation

Dynamic Accuracy

This parameter describes the accuracy of the core detector function within the field tester. This parameter is measured by comparing the output of the field tester's detector with a calibrated reference signal source. An ideal tester would have no dynamic accuracy error (0 dB). For a thorough analysis, this parameter should be measured at multiple frequencies over the operating frequency range and over an input signal level range which covers the instrument dynamic range.

Return Loss

Return loss represents the errors due to impedance mismatches between the field tester and the test load. An ideal tester would have infinitely high return loss (infinitely high dB value). This parameter should be measured at each pair when switched into transmit and receive circuits. This measurement should be made over the entire operating frequency range.

Residual NEXT

This term represents the measurement error due to the NEXT inherent in the field test apparatus. An ideal tester would have no residual NEXT (infinitely high dB value). This parameter should be measured for all six pair combinations over the entire operating frequency range.

Output Signal Balance

This term represents the error due to any imbalance in the differential test signals transmitted by the field tester. An ideal tester would have perfect balance(infinitely high dB value). This term should be measured for each pair over the entire operating frequency range.

Common Mode Rejection

This term represents the error contribution due to any failure of the test instrument to ignore common mode signals present on the tested cabling. An ideal tester would have perfect immunity from common mode signals (infinitely high dB value). This parameter should be measured for all pairs over the entire operating frequency range.

Random Noise Floor

The noise floor term defines the error contribution due to the proximity of any measured signal level to the background noise level in the test instrument. For signals which are close to the noise floor of the instrument, it becomes more difficult for the tester to distinguish the measured signal from the background noise. An ideal tester would have no background noise (infinitely high dB value). This parameter should be measured for all pairs over the entire operating frequency range.

Level II Accuracy Requirements

TSB-67 requires that level II testers meet both overall accuracy requirements and supplemental requirements for each of the six error parameters used in computing the overall NEXT and attenuation accuracy.

The overall level II accuracy requirement for Basic Link testing is:

NEXT accuracy **1.6 dB**

Attenuation Accuracy **1.0 dB**

The minimum level II requirements for each of the Annex A error model parameters are:

Error Parameter	**@ 100 Mhz**	**As a function of frequency** (f, in Mhz)
Random Noise Floor	65 dB	65 - 15log(f/100) dB
Residual NEXT	55 dB	55 -15log(f/100) dB
Output Signal Balance	37 dB	37 - 15log(f/100) dB
Common Mode Rejection	37 dB	37 - 15log(f/100) dB
Dynamic Accuracy	0.75 dB	0.75 dB
Return Loss	15 dB	15 dB

Figure 2. TSB-67 Annex A Level II Error Parameter Minimum Requirements

Independent Confirmation of Measurements

TSB-67 Annex A states that filed test equipment manufacturers must design conformant equipment so that the error model analysis defined above can be performed by an independent organization for verification of instrument accuracy.

Furthermore, Annex A requires that conformant equipment be designed so that measurements (in particular NEXT) can be “sanity checked” in the field by transposing the transmitting and receiving pair assignments. When comparing two measurements of the same test link made before and after such a transmit/receive pair transposition , a user should not see a difference of more than twice the stated accuracy (2 x 1.6 = 3.2 dB for level II) between the results.

Annex A Error Model Analysis for WireScope155/DualRemote155

Measurement Conditions

All measurements were made using an automated instrumentation system. The lab instruments were controlled via HPIB and the Units Under Test (UUTs) were controlled via serial port. All the TSB-67 accuracy parameters were measured in the frequency band of 1 to 160 MHz.

Equipment used:

- HP 4195A Network / Spectrum Analyzer
- HP 11667A 50 ohm power splitter for the Network Analyzer
- HP 8656A Signal Generator
- Mini-Circuits directional coupler, ZDC-20-3
- PC with a CEC 488 HPIB interface adapter
- North Hills Baluns NH13734 and 0322BF -- 2 each
- Balance fixtures (figure 3) -- 1 for each pair
- IC socket adapter
- Through calibration plugs -- 3 plugs, 6 pair combinations
- 100 ohm terminator plug
- Coaxial and twisted pair cable adapters

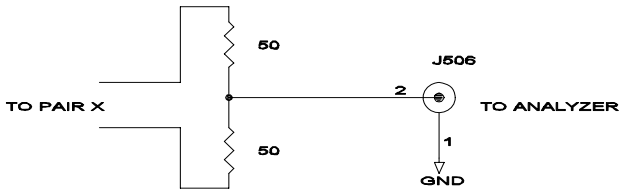


Figure 3. Balance fixture. This circuit is repeated for each pair. Coaxial cable is attached to the pair under test.

Test Connections Internal to the WireScope 155 / Dual Remote 155

Connections were made at the Transmitter and the Receiver circuits of the UUT as depicted by the block diagram below.

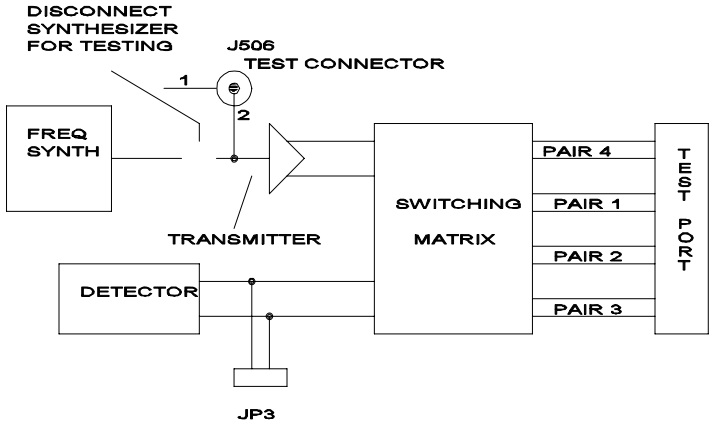


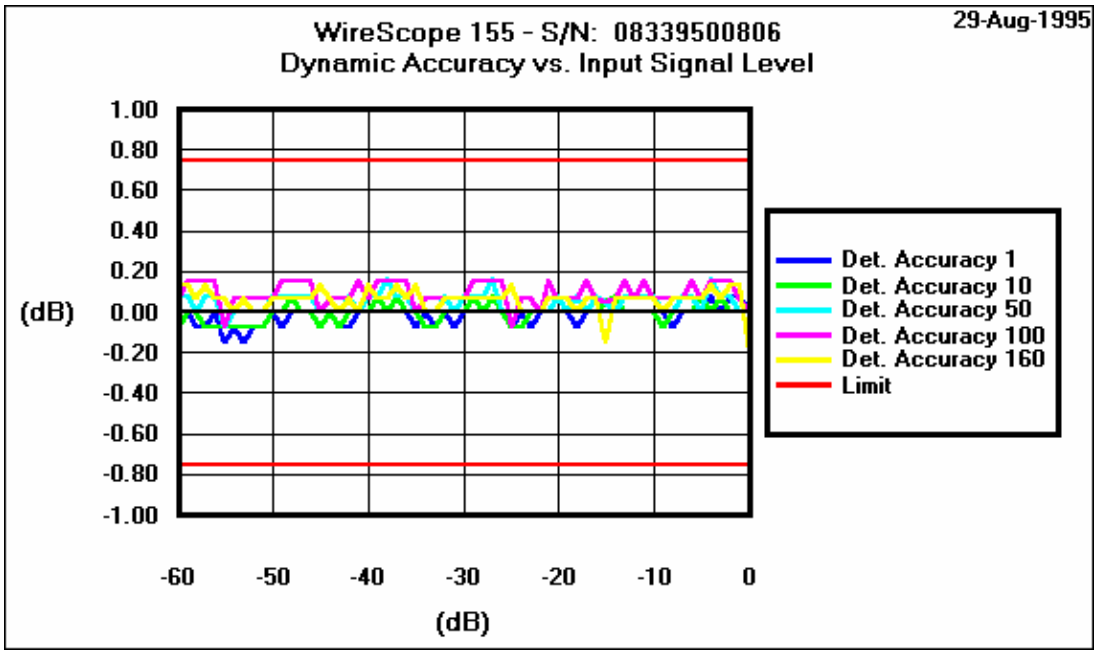
Figure 4. Block diagram of the WireScope 155 / Dual Remote 155 front end. Test connections are made at J506 and JP3

Typical Measured Instrument Parameter Data

The following figures describe the error parameter performance for one of the WireScopes measured in this analysis. Such a data set was taken for each of the units analyzed.

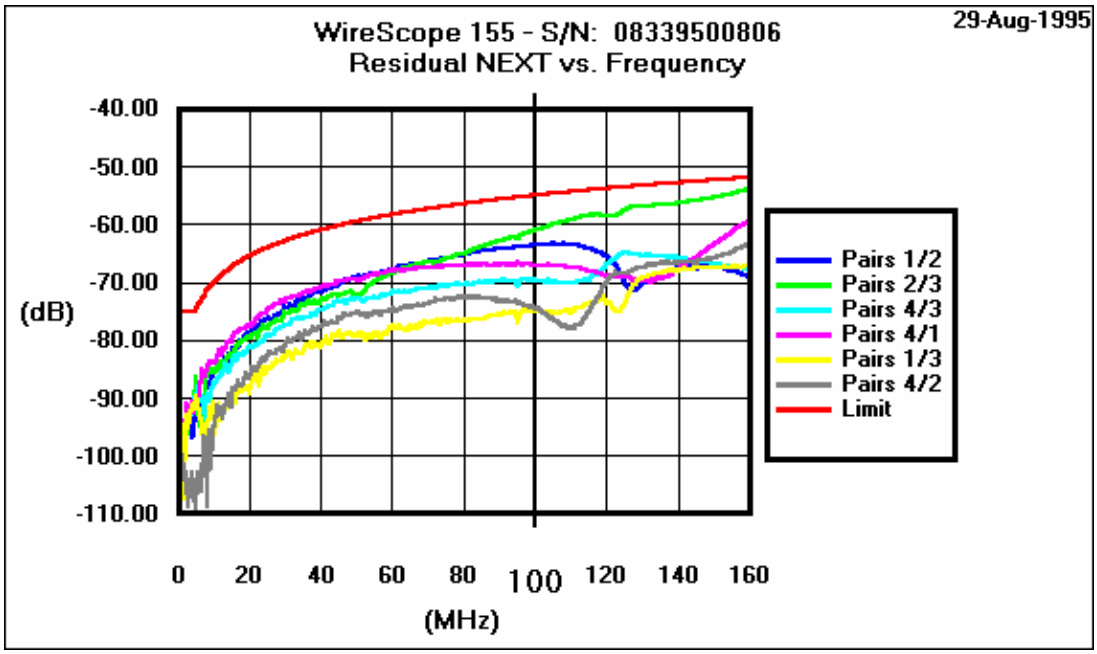
Dynamic Accuracy

Dynamic accuracy, measured at 1, 10, 50, 100 and 160 Mhz, is within ± 0.2 dB over the range of 60 dB.



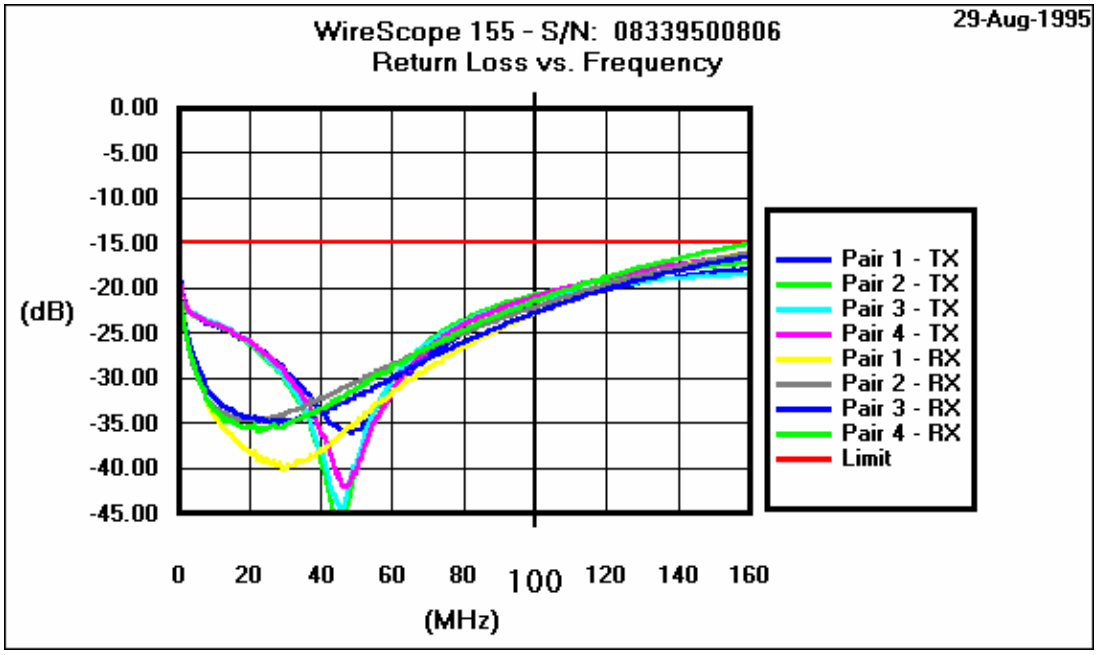
Residual NEXT

Worst case residual NEXT is better than 60 dB at 100 Mhz.



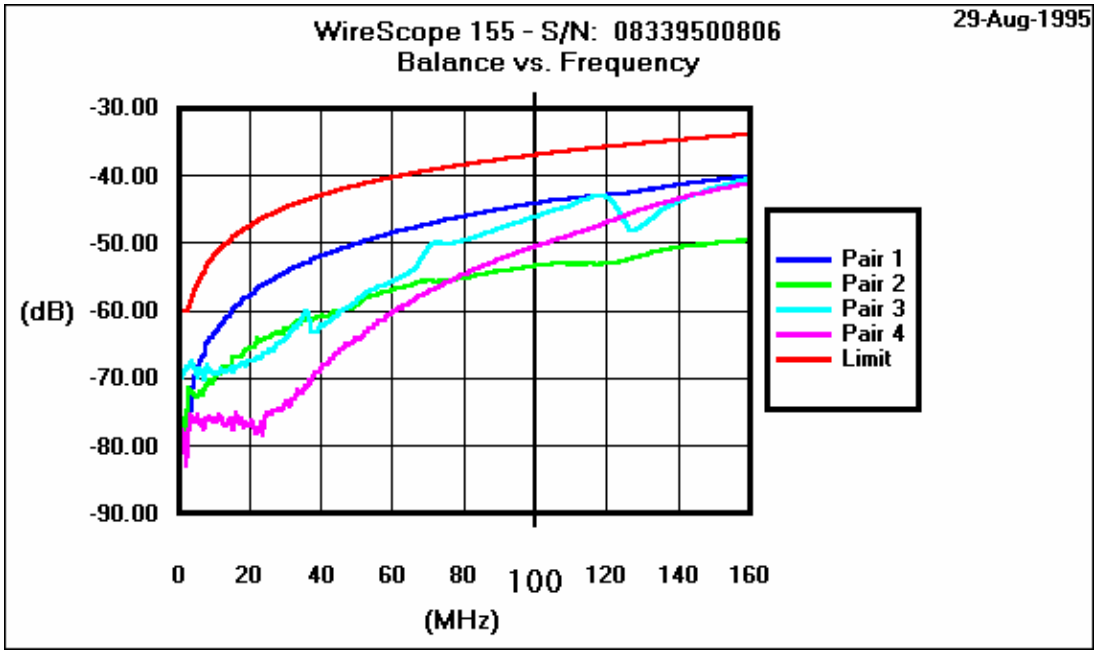
Return Loss

Worst case return loss, measured while each pair is switched into the Transmitter and then into the Receiver circuits, is better than 20 dB at 100 MHz.



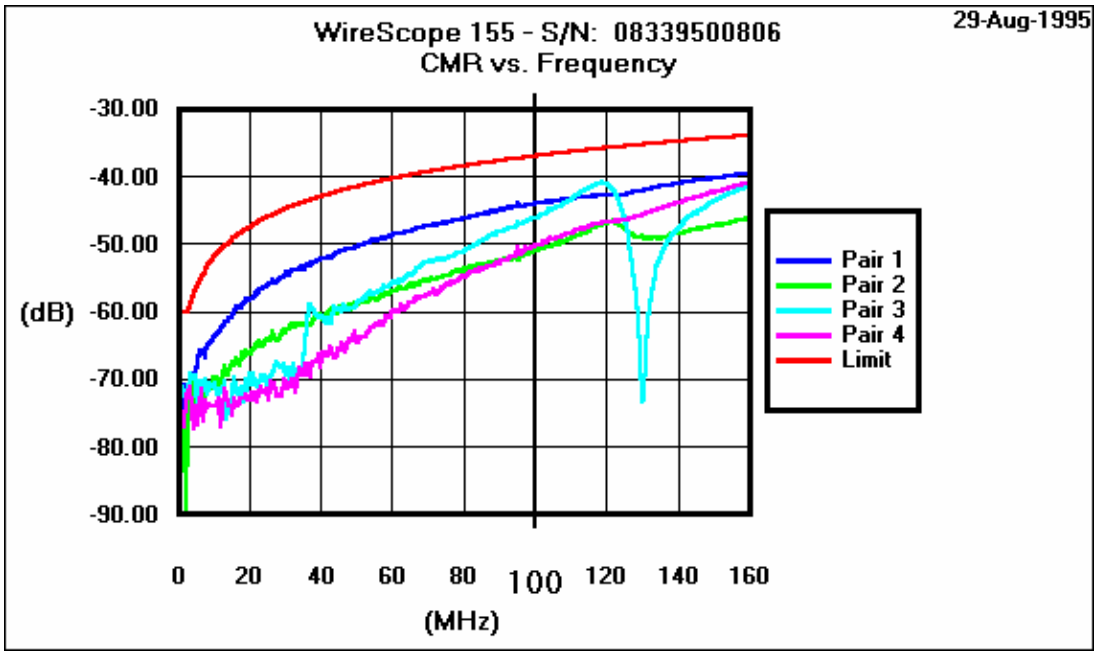
Output Signal Balance

Worst case output signal balance is better than 43 dB at 100 MHz.



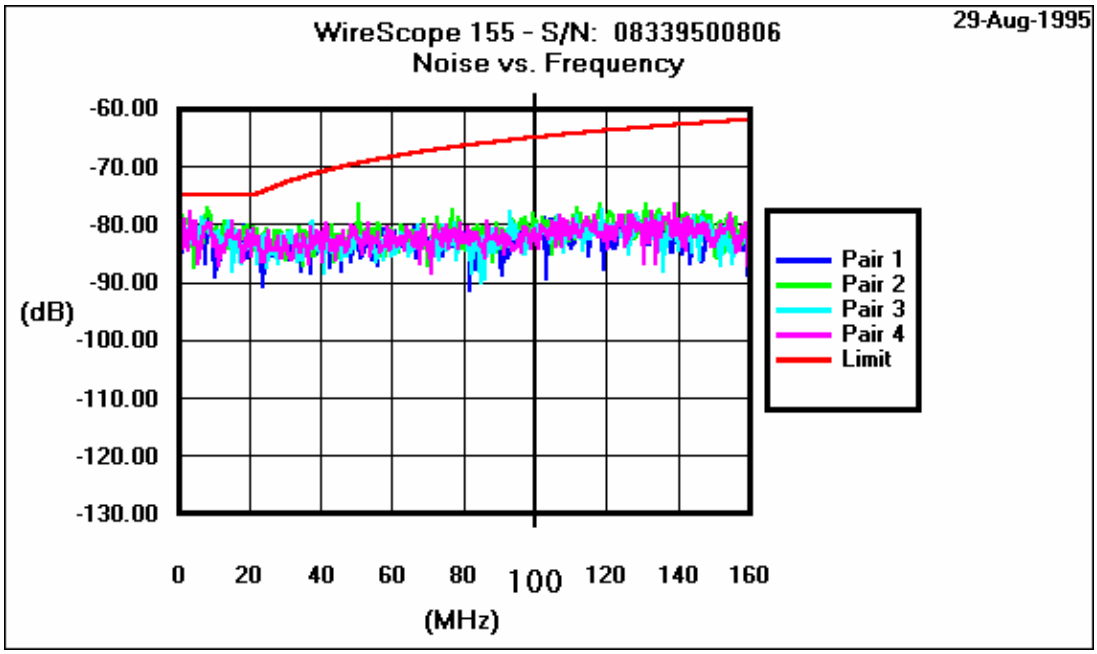
Common Mode Rejection

Worst case common mode rejection is better than 43 dB at 100 MHz.



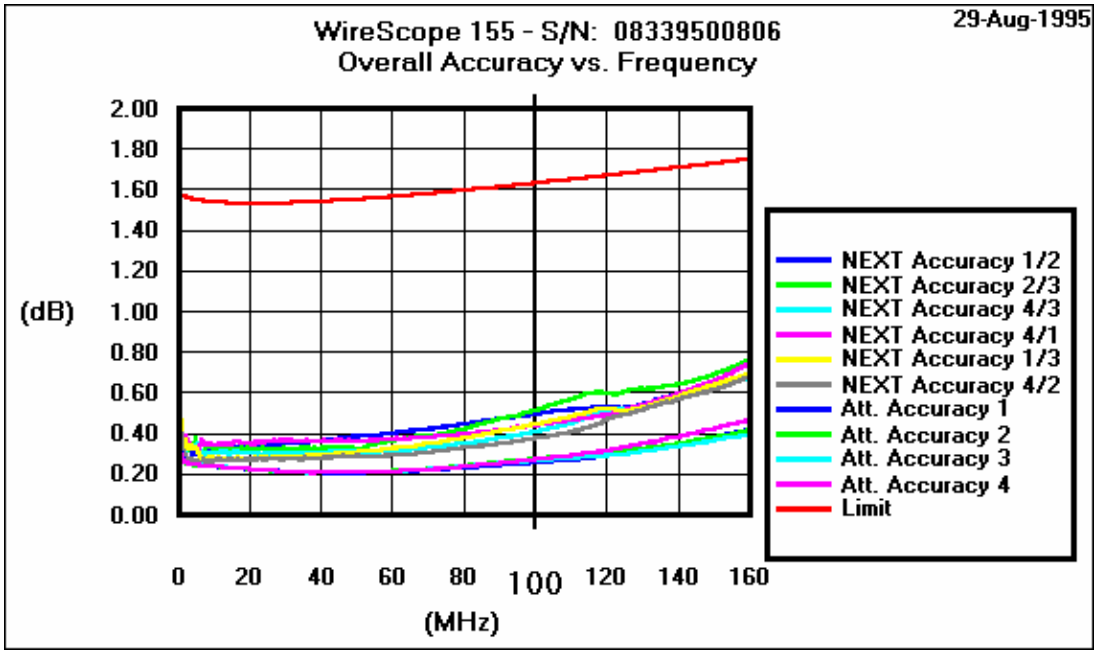
Random Noise

Random Noise is below the noise floor of the HP analyzer.



Overall NEXT and Attenuation Accuracy

The testing of ten WireScope 155 and Dual Remote 155 instrument circuit assemblies was audited by Inchcape Testing Services, ETL Testing Laboratories. Overall NEXT and attenuation accuracy was computed for each instrument using the error model equation in Annex A of TSB-67. The overall NEXT accuracy was computed for 6 pair combinations. The attenuation accuracy was computed for 4 pairs. The plots below show an example of the 6 NEXT and 4 attenuation accuracy curves plotted for each UUT over the frequency band of 1 to 160 Mhz.



Data Analysis

The measurements taken during the audit by Inchcape Testing Services, ETL Testing Laboratories were used to determine overall NEXT and attenuation accuracy for each pair and pair combination of the ten units tested. The test data and some statistical data analysis for these units are presented below.

Dual Remote S/N: 08339500507

NEXT Accuracy, dB (at 100, 160 MHz)		Atten. Accuracy, dB (at 100, 160 MHz)	
Pairs 1/2	0.498, 0.767	Pair 1	0.242, 0.372
Pairs 2/3	0.502, 0.781	Pair 2	0.249, 0.348
Pairs 4/3	0.396, 0.663	Pair 3	0.276, 0.398
Pairs 4/1	0.501, 0.766	Pair 4	0.272, 0.448
Pairs 1/3	0.482, 0.780		
Pairs 4/2	0.407, 0.701		

WireScope S/N: 08339500506

NEXT Accuracy, dB (at 100, 160 MHz)		Atten. Accuracy, dB (at 100, 160 MHz)	
Pairs 1/2	0.443, 0.603	Pair 1	0.241, 0.365
Pairs 2/3	0.522, 0.814	Pair 2	0.255, 0.356
Pairs 4/3	0.421, 0.707	Pair 3	0.258, 0.374
Pairs 4/1	0.443, 0.697	Pair 4	0.275, 0.446
Pairs 1/3	0.396, 0.647		
Pairs 4/2	0.404, 0.708		

Dual Remote #08339500707

NEXT Accuracy, dB (at 100, 160 MHz)		Atten. Accuracy, dB (at 100, 160 MHz)	
Pairs 1/2	0.497, 0.718	Pair 1	0.262, 0.407
Pairs 2/3	0.496, 0.738	Pair 2	0.260, 0.373
Pairs 4/3	0.461, 0.777	Pair 3	0.266, 0.388
Pairs 4/1	0.566, 0.866	Pair 4	0.265, 0.422
Pairs 1/3	0.501, 0.769		
Pairs 4/2	0.423, 0.726		

WireScope S/N: 08339500606

NEXT Accuracy, dB (at 100, 160 MHz)		Atten. Accuracy, dB (at 100, 160 MHz)	
Pairs 1/2	0.401, 0.524	Pair 1	0.247, 0.374
Pairs 2/3	0.495, 0.770	Pair 2	0.258, 0.367
Pairs 4/3	0.438, 0.703	Pair 3	0.264, 0.383
Pairs 4/1	0.487, 0.728	Pair 4	0.278, 0.450
Pairs 1/3	0.360, 0.588		
Pairs 4/2	0.431, 0.693		

Dual Remote S/N: 08339500807

NEXT Accuracy, dB (at 100, 160 MHz)		Atten. Accuracy, dB (at 100, 160 MHz)	
Pairs 1/2	0.428, 0.624	Pair 1	0.261, 0.418
Pairs 2/3	0.485, 0.734	Pair 2	0.253, 0.367
Pairs 4/3	0.453, 0.763	Pair 3	0.251, 0.368
Pairs 4/1	0.463, 0.770	Pair 4	0.272, 0.458
Pairs 1/3	0.422, 0.628		
Pairs 4/2	0.427, 0.750		

WireScope S/N: 08339500706

NEXT Accuracy, dB (at 100, 160 MHz)		Atten. Accuracy, dB (at 100, 160 MHz)	
Pairs 1/2	0.460, 0.637	Pair 1	0.265, 0.414
Pairs 2/3	0.496, 0.791	Pair 2	0.274, 0.399
Pairs 4/3	0.430, 0.735	Pair 3	0.280, 0.408
Pairs 4/1	0.467, 0.803	Pair 4	0.282, 0.458
Pairs 1/3	0.411, 0.642		
Pairs 4/2	0.423, 0.750		

Dual Remote S/N: 08339500907

NEXT Accuracy, dB (at 100, 160 MHz)		Atten. Accuracy, dB (at 100, 160 MHz)	
Pairs 1/2	0.410, 0.622	Pair 1	0.259, 0.402
Pairs 2/3	0.506, 0.797	Pair 2	0.268, 0.394
Pairs 4/3	0.403, 0.648	Pair 3	0.257, 0.377
Pairs 4/1	0.438, 0.687	Pair 4	0.272, 0.457
Pairs 1/3	0.374, 0.579		
Pairs 4/2	0.398, 0.670		

WireScope S/N: 08339500806

NEXT Accuracy, dB (at 100, 160 MHz)		Atten. Accuracy, dB (at 100, 160 MHz)	
Pairs 1/2	0.460, 0.637	Pair 1	0.265, 0.414
Pairs 2/3	0.496, 0.791	Pair 2	0.274, 0.399
Pairs 4/3	0.430, 0.735	Pair 3	0.280, 0.408
Pairs 4/1	0.467, 0.803	Pair 4	0.282, 0.458
Pairs 1/3	0.411, 0.642		
Pairs 4/2	0.423, 0.750		

Dual Remote S/N: 083395001007

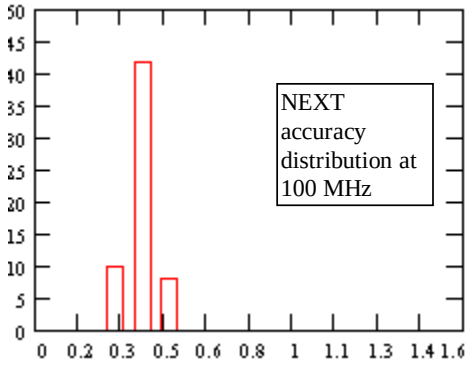
NEXT Accuracy, dB (at 100, 160 MHz)		Atten. Accuracy, dB (at 100, 160 MHz)	
Pairs 1/2	0.386, 0.591	Pair 1	0.252 0.396
Pairs 2/3	0.476, 0.741	Pair 2	0.265, 0.402
Pairs 4/3	0.454, 0.779	Pair 3	0.256, 0.381
Pairs 4/1	0.507, 0.811	Pair 4	0.269, 0.458
Pairs 1/3	0.389, 0.607		
Pairs 4/2	0.425, 0.765		

WireScope S/N: 08339500907

NEXT Accuracy, dB (at 100, 160 MHz)		Atten. Accuracy, dB (at 100, 160 MHz)	
Pairs 1/2	0.464, 0.634	Pair 1	0.254, 0.394
Pairs 2/3	0.516, 0.805	Pair 2	0.261, 0.385
Pairs 4/3	0.386, 0.671	Pair 3	0.259, 0.371
Pairs 4/1	0.433, 0.707	Pair 4	0.272, 0.444
Pairs 1/3	0.383, 0.609		
Pairs 4/2	0.387, 0.690		

The distribution plots of the NEXT and attenuation accuracy performance are presented below. The statistical sample for the distribution plots consists of the NEXT and attenuation accuracy figures listed in the tables above. This sample includes:

- NEXT accuracy for 60 NEXT pair combinations (6 pair combinations x 10 units)
- Attenuation accuracy for 40 pairs (4 pairs x 10 units)



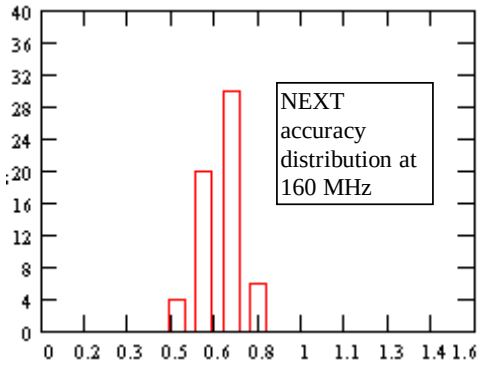


Figure 5. Distribution of overall NEXT accuracy. The x-scale is the accuracy in dB. The y-scale is the number of occurrences of the accuracy on the x scale. Predominantly, the NEXT accuracy at 100 Mhz is below 0.5 dB and the accuracy at 160 Mhz is concentrated around 0.7 dB.

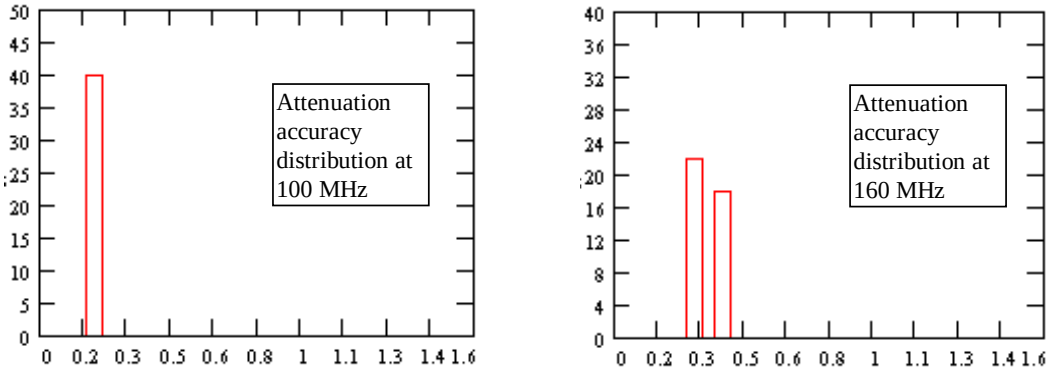


Figure 6. Distribution of overall attenuation accuracy. The x-scale is the accuracy in dB. The y-scale is the number of occurrences of the accuracy on the x scale. Predominantly, the attenuation accuracy at 100 Mhz is below 0.3 dB and the accuracy at 160 Mhz is between 0.3 and 0.4 dB.

Test of Measurement Precision and Repeatability

To demonstrate the measurement precision of the ten units, a cable was measured (from the same end) by each WireScope and Dual Remote in the test sample. At the far end, each pair of the cable was differentially terminated with 100 ohm resistor. The figure below shows a screen from ScopeData Windows utility with the uploaded NEXT plots from all the units tested. The ten NEXT plots are virtually indistinguishable from one another, indicating the superior accuracy of the instruments under test.

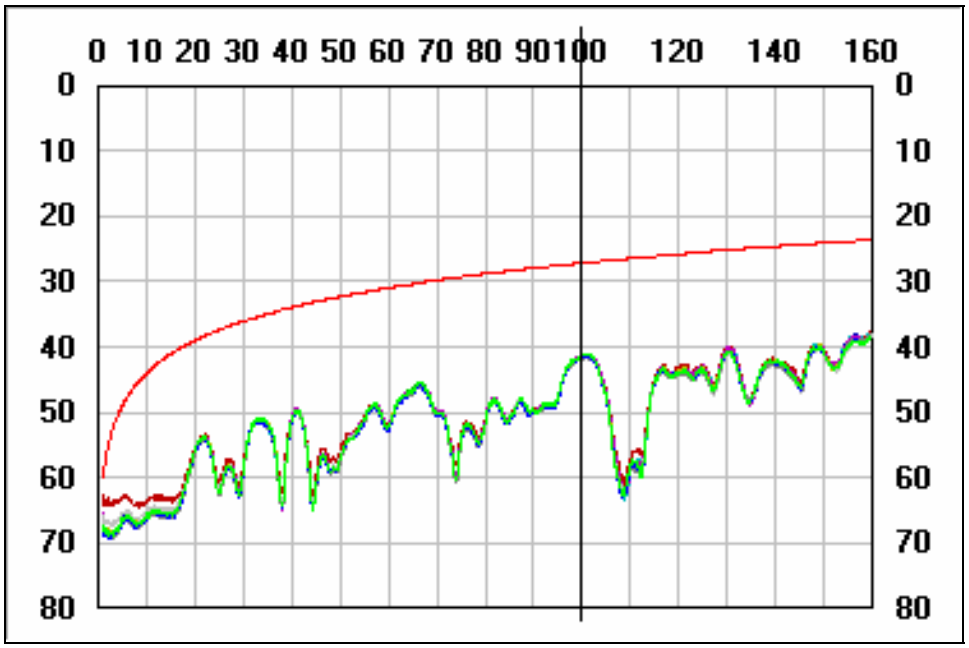


Figure 6. NEXT plots uploaded into ScopeData Windows utility from the ten units under test.

Accuracy and Quality Assurance

Testing Unit Accuracy in Production

In order to assure that all WireScope 155 units exhibit consistent accuracy performance when leaving the factory, an automated system has been developed to test each production unit in the manner described in this article. A personal computer running custom Scope production software controls a NIST-traceable HP4195A spectrum/network analyzer which measures the TSB-67 error model parameters for each production unit. The Scope production software automatically logs all accuracy data for each unit (referenced by serial number). A complete accuracy report is available for each unit shipped.

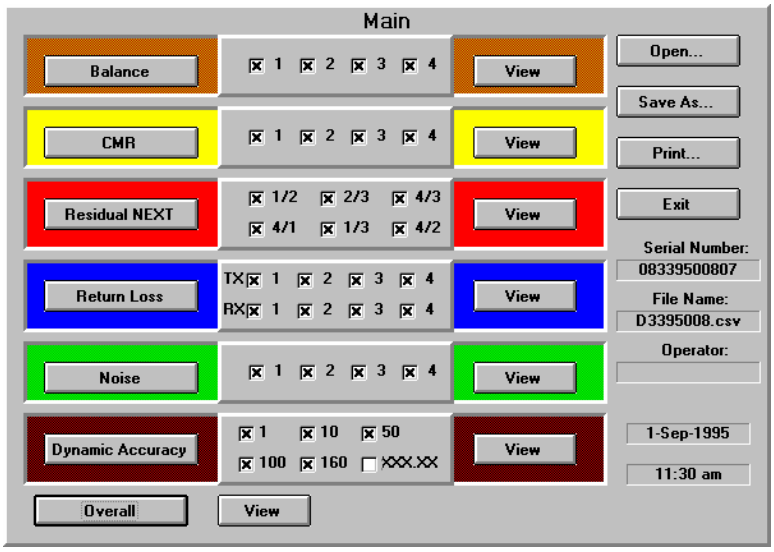


Figure 7. Scope Production Test Software Control Screen

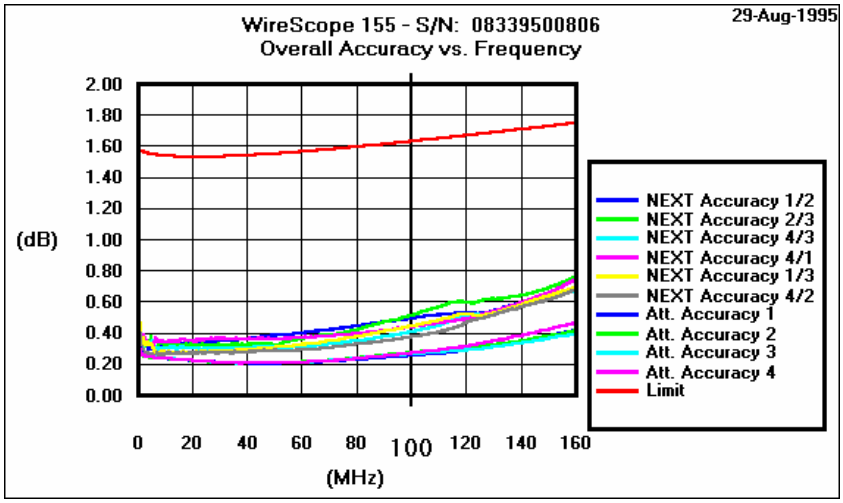
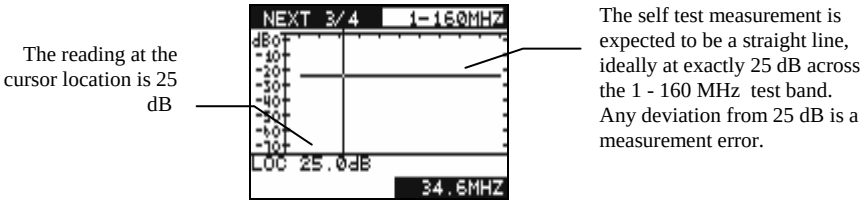


Figure 8. Sample Overall Accuracy Plot from Production Test Report

Field "Sanity Check" for Tester Accuracy

A self test probe (Scope Part number 450-0015) is available for sanity checking the performance of the WireScope 155 in the field. This probe provides a flat attenuated loopback path that can be used to verify the WireScope's measurement accuracy against a known reference.



Self test measurement using the self test probe which produces a flat attenuation of 25 dB.

Any deviation from the expected attenuation is a measurement error and should be within the specified accuracy of the WireScope 155 (i.e. +/- 1 dB, with an allowance for a small error in the self test plug itself).

Measurements of the self test probe can be run before and after a transposition of transmit/receive pair assignments to verify that both results match closely enough to satisfy the field sanity check requirements defined in Annex A of TSB-67.

Conclusions

WireScope 155 is 3 Times More Accurate than the Level II Requirement! With typical NEXT accuracy of 0.5 dB at 100 Mhz, WireScope 155 is three times more accurate than the TSB-67 level II requirement (1.6 dB). Typical attenuation accuracy of 0.3 dB is also more than three times the level II requirement (1.0 dB).

WireScope 155 Maintains Superior Accuracy to 160 Mhz. Even at 160 Mhz, WireScope 155 has typical NEXT accuracy of 0.8 dB, more than twice as accurate as the TSB-67 level II limit.

Independently Audited Accuracy Analysis. Inchcape - ETL, a respected testing laboratory, has independently audited the data collection process used to determine the accuracy of the WireScope 155.

100% Quality Assurance. Scope-developed software allows 100% automated production testing which includes full TSB-67 Annex A error model data collection and analysis. Every unit has a traceable accuracy report which can be inspected if ever there is a question about measurement accuracy.

Contacts For Further Information

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