Scotchlok™ UR2 Connector

Technical Report

July 2001
80-6104-1674-7-B

Contents:

1.0 Background

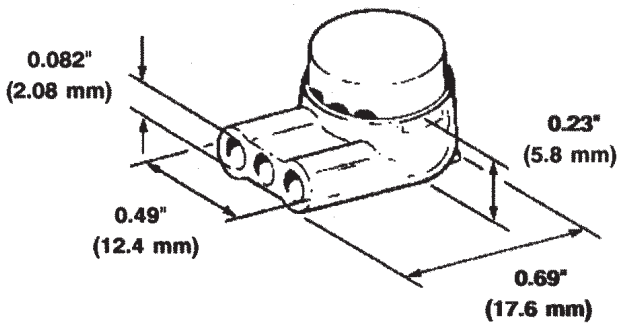
3M's first connector for telephony was the Scotchlok™ UR Connector. It was introduced in 1958. The UR Connector incorporated the original insulation displacement contact (IDC) housed in a polycarbonate body which contained a sealant for moisture protection. The reliability of the UR Connector has been confirmed by over 30 years of field service. Since the introduction of the UR Connector, an entire family of Scotchlok connectors has evolved, all based on the use of an insulation displacement contact which allows wires to be joined electrically without requirinq stripping of the wire insulation.

The UR Connector (more completely described in the next section) extends the capabilities of the UR Connector – long an industry standard for performing three-wire butt splices.

2.0 Description

The Scotchlok™ UR2 Connector is a butt-type connector which employs a specially designed insulation displacement contact. The contact, which is formed in a U shape, makes a double electrical connection to each wire. The UR2 Connector will accommodate any combination of three 19 to 26 AWG (0.9 to 0.4mm) copper wires from either filled or unfilled plastic insulated cable.

Scotchlok UR2 Connector Basic Properties



Physical:

Width	0.49 in. (12.4 mm)
Length	0.69 in. (17.6 mm)
Crimped Height	0.23 in. (5.8 mm)

Material Composition:

Connector Body	Polypropylene (Translucent)
Connector Cap	Polypropylene (Red)
Contact Element	Tin plated brass alloy
Moisture Sealant	Petroleum hydrocarbon base

Application:

Wire Configuration	Three-wire butt
Wire Range	19-26 AWG (0.9-0.4 mm) Filled or aircore PIC
Conductors	Solid copper only
Max. Insulation O.D.	0.082 in. (2.08 mm)

3.0 Test Program Interview

To predict the long-term performance reliability of the ScotchlokTM UR2 Connector, the connectors have been subjected to a number of tests which expose them to conditions more severe than anticipated in actual use. The tests are based upon telephone industry performance specifications and are believed to represent the most severe requirements of that industry.

The test conditions provide accelerated aging, allowing the prediction of the long-term performance within a relatively short time period. During the tests, such parameters as Connection Resistance, Insulation Resistance, Dielectric Strength and Physical Performance are monitored to determine the overall stability of the connectors.

4.0 Connection Stability Tests

Connection resistance is the parameter usually measured and considered indicative of contact performance. It is the change in connection resistance and its variability that provides insight as to the connector's electrical stability. Connection resistance for data and telecommunication circuits are measured based on ASTM B539-80, method C, Dry Circuit Testing. This test method sets maximum limits for voltage and current at 20 millivolts and 100 milliamperes respectively. This low level of electrical excitation is similar to actual in use conditions and is capable of detecting any resistive film that may have formed in the connection.

Tests involving the measurement of connection resistance and connection resistance change require that the samples be mounted on specially designed printed circuit (PC) boards which interface with 3M Telecom's computerized data acquisition system. All connection resistance measurements are made after the board mounted samples have reached thermal equilibrium in a regulated environmental chamber, controlled to 68 ± 0.9°F (20 ± 0.5°C). With this system, connection resistances can be measured to approximately 0.001 milliohm.

The resistance change of the connection must be small and randomly varied if the long-term reliability of the joint is to be assured. Random connection resistance changes remaining below 2.0 milliohms over the test period are generally considered acceptable as an indication of a stable electrical connection. Connection resistance changes greater than 20 milliohms are generally found to increase with time, eventually leading to service affecting instability, ultimately resulting in failure of the joint due to "high resistance opens".

4.01 Stress Relaxation

The Stress Relaxation Test subjects the UR2 Connector to an ambient temperature of 244°F (118°C for a period of 33 days. Following days 1, 2, 4, 8, 16 and 33 each sample is pulled momentarily with a 0.5 lb. (2.2 N) force. This mechanical disturbance is followed with connection resistance measurements.

This stress relaxation environment is intended to simulate the amount of relaxation which would occur at room temperature over an extended period of years. Connection resistance changes less than 2.0 milliohms are considered acceptable.

STRESS RELAXATION PERFORMANCE DATA
(Data in Milliohms)

Wire Configuration AWG (mm)	Connection Resistance Change		
	Average	Std. Dev.	Maximum
19 (0.9) -- 19 (0.9) -- 19 (0.9)	0.009	0.005	0.023
19 (0.9) -- 19 (0.9) -- 19 (0.9)	0.010	0.004	0.019
19 (0.9) -- 19 (0.9) -- No Wire	0.008	0.004	0.018
19 (0.9) -- No Wire -- 19 (0.9)	0.009	0.043	0.199
19 (0.9) -- 26 (0.4) -- 26 (0.4)	0.008	0.008	0.022
19 (0.9) -- 26 (0.4) -- 26 (0.4)	0.021	0.012	0.039
19 (0.9) -- 26 (0.4) -- 19 (0.9)	0.015	0.011	0.038
19 (0.9) -- 26 (0.4) -- 19 (0.9)	0.012	0.009	0.030
19 (0.9) -- 19 (0.9) -- 26 (0.4)	0.010	0.009	0.034
19 (0.9) -- 19 (0.9) -- 26 (0.4)	0.028	0.015	0.081
26 (0.4) -- 26 (0.4) -- 26 (0.4)	0.016	0.011	0.036
26 (0.4) -- 26 (0.4) -- 26 (0.4)	0.018	0.009	0.031
26 (0.4) -- 26 (0.4) -- No Wire	0.018	0.010	0.037
26 (0.4) -- No Wire -- 26 (0.4)	0.021	0.009	0.045

Note: Underlining indicates wires tested.

4.02 Temperature Cycle

The temperature Cycle Test subjects the UR2 Connector to 1024 two-hour temperature cycles from -40°F to 140°F (-40°C to 60°C) with one-half hour dwells at the end point temperatures. The temperature cycles shall have an average rate of change of 360°F (182°C) per hour between temperature extremes.

At designated intervals, connection resistance measurements are taken and compared with the initial connection resistance values, allowing determination of connection resistance change. Connection resistance changes less than 2.0 milliohms are considered acceptable.

TEMPERATURE CYCLE PERFORMANCE DATA
(Data in Milliohms)

Wire Configuration AWG (mm)	Connection Resistance Change		
	Average	Std. Dev.	Maximum
19 (0.9) -- 19 (0.9) -- 19 (0.9)	0.028	0.028	0.035
19 (0.9) -- 19 (0.9) -- 19 (0.9)	0.029	0.018	0.079
19 (0.9) -- 19 (0.9) -- No Wire	0.018	0.012	0.034
19 (0.9) -- No Wire -- 19 (0.9)	0.016	0.016	0.088
19 (0.9) -- 26 (0.4) -- 26 (0.4)	0.015	0.008	0.034
19 (0.9) -- 26 (0.4) -- 26 (0.4)	0.020	0.012	0.047
19 (0.9) -- 26 (0.4) -- 19 (0.9)	0.024	0.012	0.042
19 (0.9) -- 26 (0.4) -- 19 (0.9)	0.017	0.009	0.037
19 (0.9) -- 19 (0.9) -- 26 (0.4)	0.021	0.012	0.035
19 (0.9) -- 19 (0.9) -- 26 (0.4)	0.040	0.023	0.059
26 (0.4) -- 26 (0.4) -- 26 (0.4)	0.030	0.011	0.044
26 (0.4) -- 26 (0.4) -- 26 (0.4)	0.028	0.011	0.043
26 (0.4) -- 26 (0.4) -- No Wire	0.027	0.010	0.044
26 (0.4) -- No Wire -- 26 (0.4)	0.022	0.014	0.058

Note: Underlining indicates wires tested.

4.03 Temperature Cycle with High Humidity

Scotchlok™ UR2 Connectors were subjected to 300 12-hour cycles between temperatures of 40°F (4°C) and 140°F (60°C) at 95% Relative Humidity, with a 3-hour minimum dwell at each temperature extreme. This 150-day test evaluates connection integrity in high humidity conditions with temperature cycling. Connection resistance changes less than 2.0 milliohms are considered acceptable.

TEMPERATURE CYCLE WITH HIGH HUMIDITY
(Data in Milliohms)

Wire Configuration AWG (mm)	Connection Resistance Change		
	Average	Std. Dev.	Maximum
19 (0.9) -- 19 (0.9) -- No Wire	0.010	0.006	0.021
19 (0.9) -- No Wire -- 19 (0.9)	0.008	0.011	0.035
19 (0.9) -- 26 (0.4) -- No Wire	0.006	0.007	0.031
19 (0.9) -- No Wire -- 26 (0.4)	0.023	0.021	0.076
26 (0.4) -- 26 (0.4) -- No Wire	0.017	0.014	0.051
26 (0.4) -- No Wire -- 26 (0.4)	0.016	0.024	0.081

4.04 Vibration

In this test, samples were subjected to 20 minutes of vibration in each of three mutually perpendicular planes. The vibration is a harmonic motion with an amplitude of 0.06 in. (1.5 mm) cycling from 10 to 55 Hertz in one minute.

The samples were monitored during this test for opens in circuit continuity of 10 microseconds (10×10^{-6} sec) or longer. Any loss in circuit continuity or change in connection resistance greater than 2.0 milliohms would constitute a failure.

VIBRATION TEST
(Data in Milliohms)

Wire Configuration AWG (mm)	Connection Resistance Change		
	Average	Std. Dev.	Maximum
19 (0.9) -- 19 (0.9) -- 19 (0.9)	0.040	0.020	0.045
19 (0.9) -- 19 (0.9) -- 19 (0.9)	0.030	0.019	0.047
19 (0.9) -- 19 (0.9) -- No Wire	0.016	0.012	0.034
19 (0.9) -- No Wire -- 19 (0.9)	0.008	0.004	0.034
19 (0.9) -- 26 (0.4) -- 26 (0.4)	0.043	0.022	0.051
19 (0.9) -- 26 (0.4) -- 26 (0.4)	-0.027	0.015	-0.040
19 (0.9) -- 19 (0.9) -- 26 (0.4)	0.039	0.022	0.049
19 (0.9) -- 19 (0.9) -- 26 (0.4)	0.053	0.030	0.089
26 (0.4) -- 26 (0.4) -- 26 (0.4)	-0.048	0.034	-0.088
26 (0.4) -- 26 (0.4) -- 26 (0.4)	-0.005	0.078	-0.139
26 (0.4) -- 26 (0.4) -- No Wire	-0.034	0.032	-0.066
26 (0.4) -- No Wire -- 26 (0.4)	0.069	0.035	0.082

Note: Underlining indicates wires tested.

4.05 Salt Fog

Scotchlok™ UR2 Connectors were subjected to salt fog exposure, per ASTM B117, for a period of 48 hours. Connection resistance measurements were made before and after the exposure, to determine the resistance change as a result of the salt for exposure. Resistance changes of less than 2.0 milliohms are considered acceptable.

SALT FOG PERFORMANCE DATA
(Data in Milliohms)

Wire Configuration AWG (mm)	Connection Resistance Change		
	Average	Std. Dev.	Maximum
19(0.9) -- 19(0.9) -- No Wire	-0.003	0.003	.003
19(0.9) -- No Wire -- 19(0.9)	0.002	0.012	0.045
19(0.9) -- 26(0.4) -- No Wire	-0.003	0.005	0.011
19(0.9) -- No Wire -- 26(0.4)	-0.002	0.006	0.013
26(0.4) -- 26(0.4) -- No Wire	0.000	0.006	0.018
26(0.4) -- No Wire -- 26(0.4)	-0.017	0.020	0.004

5.0 Dielectric Strength

High dielectric strength prevents connector damage which could result from temporary high voltage conditions caused by lightning strikes or a power line cross.

5.01 Dielectric Strength (Wet)

Scotchlok™ UR2 Connectors were immersed in a 5% (by weight) salt water solution. A copper electrode was also immersed in the water. Voltage between the Scotchlok UR2 Connector and the copper electrode was increased at 500 VRMS per second until breakdown occurred or 8 kV was reached. Breakdown voltages above 2.5 kV are considered acceptable.

DIELECTRIC STRENGTH PERFORMANCE DATA

Wire Configuration AWG (mm)	Minimum Breakdown Voltage
19 (0.9) -- 19 (0.9) -- 19 (0.9)	8.0 kV
19 (0.9) -- 26 (0.4) -- 26 (0.4)	No Breakdown
19 (0.9) -- No Wire -- 26 (0.4)	7.4 kV
26 (0.4) -- 26 (0.4) -- 26 (0.4)	7.7 kV

6.0 Insulation Resistance

High connector insulation resistance is needed in order to minimize noise pick-up (i.e. crosstalk) and signal loss. Readings were taken prior, during and after exposure to the test condition at 250 volts D.C.

6.01 Water Immersion

The UR2 Connectors were immersed in water to a depth of 6 in. (15.2 cm) for a period of 7 days. Throughout the test, 48 volts D.C. was maintained between the tip and ring connectors. Insulation resistance measurements between each connector and the water were made (at 250 volts D.C.). The targeted performance requirements are the following: Not more than 10% of insulation values can be below one megohm (1 x 10^6 ohms); Not more than 25% can be below 100 megohms (1 x 10^8 ohms).

DATA FOLLOWING 7 DAYS WATER IMMERSION

Wire Configuration AWG (mm)	Insulation Resistance (Data in Ohms) Average	Minimum	% < 10^6	% < 10^8
19 (0.9) -- 19 (0.9) -- No Wire	4.51 x 10^{11}	1.51 x 10^6	0	5
19 (0.9) -- No Wire -- 19 (0.9)	8.35 x 10^{14}	1.46 x 10^{11}	0	0
19 (0.9) -- 26 (0.4) -- No Wire	4.78 x 10^{11}	2.32 x 10^{11}	0	0
19 (0.9) -- No Wire -- 26 (0.4)	3.14 x 10^{11}	1.42 x 10^{11}	0	0
26 (0.4) -- 26 (0.4) -- No Wire	4.93 x 10^{11}	2.36 x 10^{11}	0	0
26 (0.4) -- No Wire -- 26 (0.4)	3.01 x 10^{11}	1.43 x 10^{11}	0	0

6.02 Temperature Cycling with High Humidity

Test samples of Scotchlok™ UR2 Connector were subjected to 300 12-hour tempeature cycles between 40˚F (4˚C) and 140˚F (60˚C) at 95% Relative Humidity, with a 3-hour minimum dwell at each temperature extreme. During aging conditions samples had 48 volts D.C. applied between tip and ring connectors.

This 150-day test evaluates insulation and dielectric integity in high humidity conditions with temperature cycling. The targeted performance is for all the readings to be greater than 100 megohms (1×10^8 ohms)

DATA FOLLOWING 150 HIGH HUMIDITY CYCLES

	Insulation Resistance (Data in Ohms)			
Wire Configuration AWG (mm)	**Average at 140˚F**	**Minimum at 140˚F**	**Average at 140˚F**	**Minimum at 140˚F**
19 (0.9) -- 19 (0.9) -- No Wire	2.66×10^{11}	9.38×10^{10}	2.62×10^{11}	9.23×10^{10}
19 (0.9) -- No Wire -- 19 (0.9)	1.70×10^{11}	6.17×10^{10}	1.72×10^{11}	6.08×10^{10}
19 (0.9) -- 26 (0.4) -- No Wire	1.80×10^{11}	6.34×10^{10}	1.61×10^{11}	5.63×10^{10}
19 (0.9) -- No Wire -- 26 (0.4)	2.62×10^{11}	9.76×10^{10}	2.50×10^{11}	8.89×10^{10}
26 (0.4) -- 26 (0.4) -- No Wire	2.76×10^{11}	9.17×10^{10}	2.77×10^{11}	8.91×10^{10}
26 (0.4) -- No Wire -- 26 (0.4)	1.72×10^{11}	6.10×10^{10}	1.83×10^{11}	6.40×10^{10}

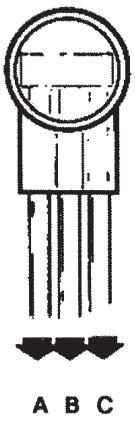
7.0 Physical Tests

Three physical tests are used to evaluate the connector's ability to withstand the physical handling and abuse associated with normal field use. The tests are Tensile Strength, Wire Torsion and Wire Bending.

7.01 Tensile Strength

Both control wires and wires spliced with unfilled UR2 (UR2-D) Connectors were tested for tensile strength. measurements were made with a cross-head speed of 1.0 in/min. (25.4 mm/min).

This test evaluates the wire tensile strength after inserting into a "U-contact" relative to the control wires. Tensile strengths which exceed 85% of the strength of the original unspliced wire are considered acceptable.

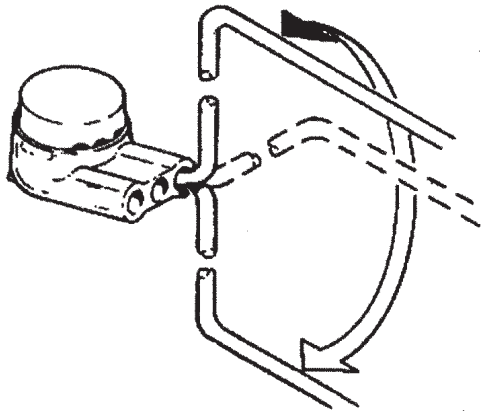


TENSILE STRENGTH PERFORMANCE DATA

Wire Configuration AWG (mm)	Average Percent of Wire Strength		
	Wire A	Wire B	Wire C
19 (0.9) -- 19 (0.9) -- 19 (0.9)	96	86	86
19 (0.9) -- 26 (0.4) -- 26 (0.4)	98	96	99
19 (0.9) -- 19 (0.9) -- 26 (0.4)	96	86	97
26 (0.4) -- 26 (0.4) -- 26 (0.4)	97	96	97
26 (0.4) -- 19 (0.9) -- 26 (0.4)	97	98	98

7.02 Wire Torsion

For this test, the wires from each sample were bent 90 degrees against the connector body (in the plane of the wire port axes). From this position, using a conductor crank arm of 2 in. (50.8 mm), the conductor was rotated 10 times to each side. During the Wire torsion Test, the connectors were monitored for circuit discontinuities.



This test evaluates the wire connection and strain relief when conductors are subjected to a torsional twist. Targeted performance is 10 rotations without a circuit discontinuity of greater than 10 microseconds (10 x 10^{-6} sec.) or a break in the wire.

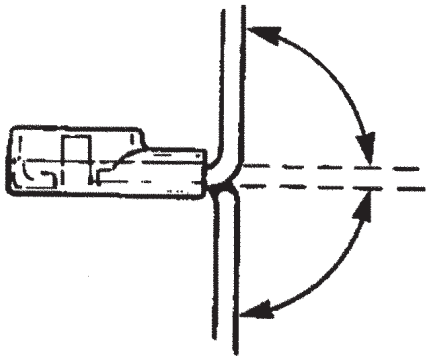
Connectors which can survive 10 torsional cranks as described above are considered acceptable.

WIRE TORSION TEST PERFORMANCE DATA

Wire Configuration AWG (mm)	No. Rotations to Each Side	Circuit Discontinuities	Comments
19 (0.9) -- 19 (0.9) -- 19 (0.9)	10	None	No wire breakage or slipping in contact
19 (0.9) -- 26 (0.4) -- 26 (0.4)	10	None	No wire breakage or slipping in contact
19 (0.9) -- 19 (0.9) -- 26 (0.4)	10	None	No wire breakage or slipping in contact
26 (0.4) -- 26 (0.4) -- 26 (0.4)	10	None	No wire breakage or slipping in contact
26 (0.4) -- 19 (0.9) -- 26 (0.4)	10	None	No wire breakage or slipping in contact

7.03 Wire Bending

Using a conductor bending arm of 2 in. (50.8 mm), the conductors were bent 90 degrees toward each side 10 times with all motion remaining in the same plane (no torsional rotation). During the Wire Bending Test, the connectors were monitored for circuit discontinuities.



This test evaluates the wire connection and strain relief when conductors are subjected to bending. Targeted performance is 10 bends without a circuit discontinuity of greater than 10 microseconds (10 x 10^{-6} sec.) or a break in the wire.

Connectors which can survive 10 bends as described above are considered acceptable.

WIRE BENDING TEST PERFORMANCE DATA

Wire Configuration AWG (mm)	No. Bends to Each Side	Circuit Discontinuities	Comments
19 (0.9) -- 19 (0.9) -- 19 (0.9)	10	None	No wire breakage or slipping in contact
19 (0.9) -- 26 (0.4) -- 26 (0.4)	10	None	No wire breakage or slipping in contact
19 (0.9) -- 19 (0.9) -- 26 (0.4)	10	None	No wire breakage or slipping in contact
26 (0.4) -- 26 (0.4) -- 26 (0.4)	10	None	No wire breakage or slipping in contact
26 (0.4) -- 19 (0.9) -- 26 (0.4)	10	None	No wire breakage or slipping in contact

8.0 Frequency Performance

Connector performance was evaluated per ANSI/EIA/TIA standard 568 A, Oct. 1995, section 10.4.4, Category 5, which applies to connecting hardware for 100 ohm UTP cable whose transmission characteristics are specified up to 100MHz. That document details the attenuation, NEXT, and return loss test procedures and requirements for testing of connector performance.

For the following three tests, four pairs of UR2 connectors were fixtured in close proximity, top to bottom, to simulate a four-pair connector or to approximate a closely bundled group of individual connectors.

8.01 Attenuation

Attenuation is a measure of signal power loss due to the connecting hardware and is derived from swept frequency voltage measurements on short lengths of 100 ohm twisted pair test leads before and after inserting the connectors on test.

For attenuation measurement, connector samples were prepared using small lengths of Category 5 wire terminated with contact pins on both sides of the connector pair on test. The insertion loss due to the connectors was measured by inserting the connectors on test between two baluns in a set-up for insertion loss/attenuation measurement. The set-up was calibrated using full two port calibration prior to connecting the connectors on test.

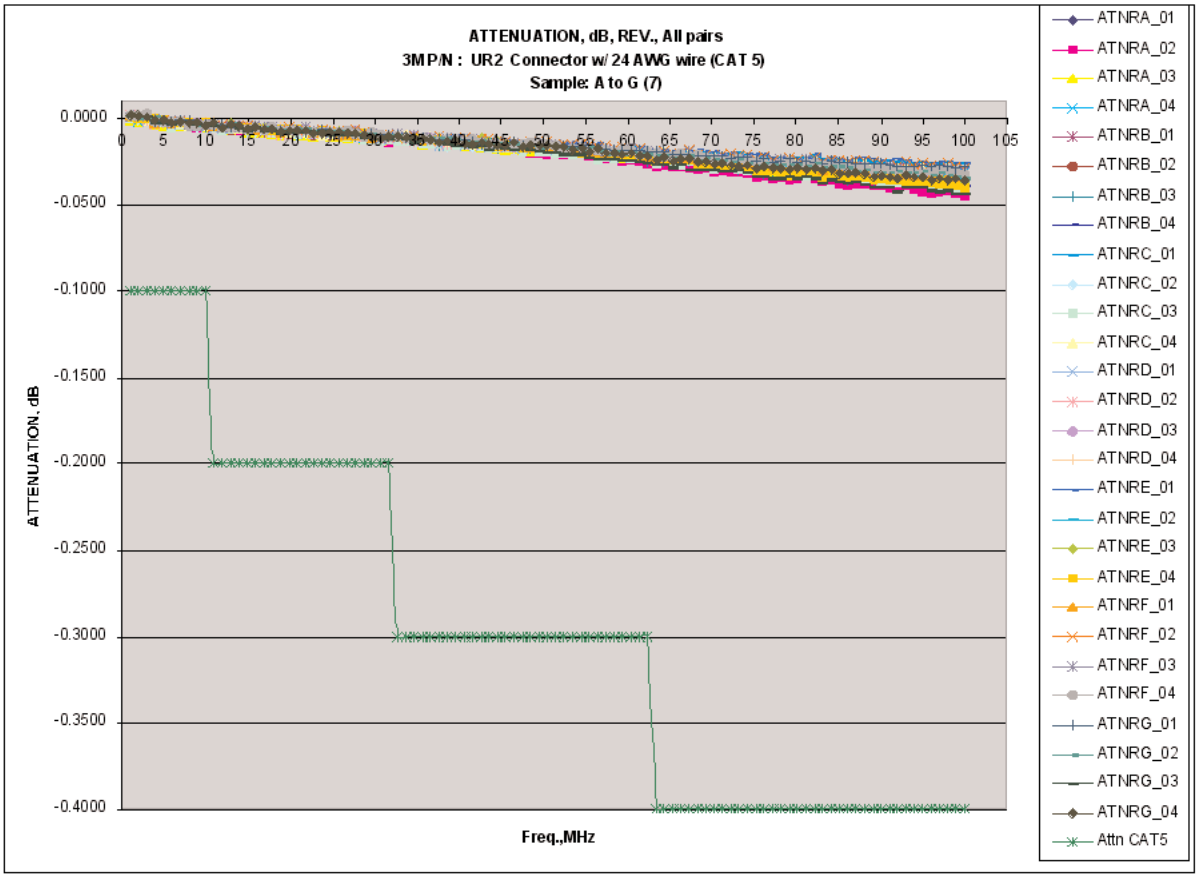
Equipment:

- H.P. Network Analyzer Model 8753D/E with
- North Hills balun Model 0322BF for 1MHZ to 100MHz (Category 5 freq. band measurement) and
- North Hills balun Model 0320BF for 30KHz-30MHz (for xDSL freq. band measurement)

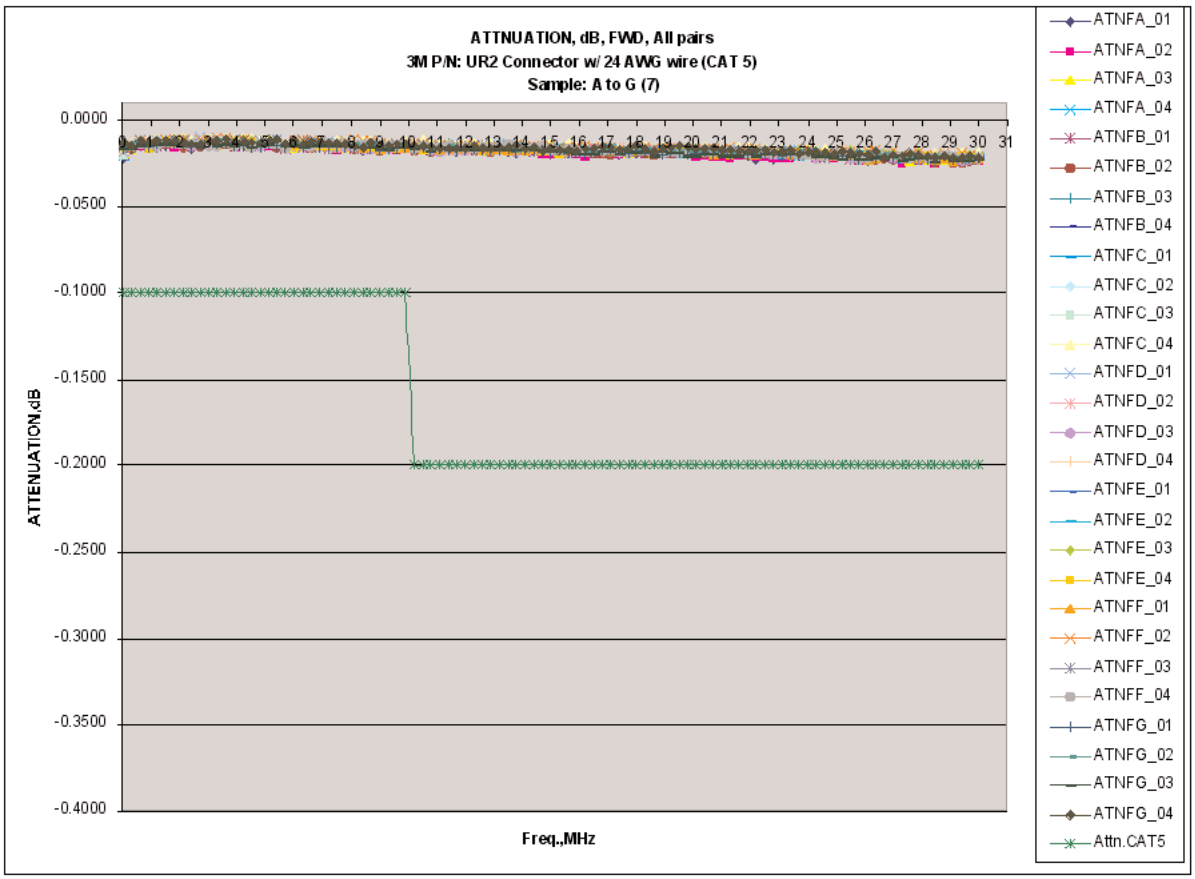
Frequency (MHz)	Category 5 Attenuation (dB)
1.0	≤ - 0.1
4.0	≤ - 0.1
8.0	≤ - 0.1
10.0	≤ - 0.1
16.0	≤ - 0.2
20.0	≤ - 0.2
25.0	≤ - 0.2
31.25	≤ - 0.2
62.5	≤ - 0.3
100.0	≤ - 0.4

Results:

The results below show that the measured connector complies with Category 5 requirements.



Category 5 Freq. Band, 1MHZ to 100MHz Measurement



xDSL Freq. Band 30KHz to 30 MHz Measurement

8.02 NEXT

NEXT (near end crosstalk) loss is a measure of signal coupling from one circuit to another and is derived from swept frequency voltage measurements on short lengths of 100 ohm twisted pair test leads terminated to the connector under test. A balanced input signal is applied to a disturbing pair of the connector while the induced signal on the disturbed pair is measured at the near-end of the test leads.

For NEXT measurement, connector samples were prepared using small lengths of Category 5 wire. One side (near end) of the first of the four pairs of connectors was terminated with contact pins and the other side was terminated using 100 ohm SMT resistors. NEXT measurements were made from the contact pin side between pairs 1-2, pairs 1-3, pairs 1-4, pairs 2-3, pairs 2-4, & pairs 3-4. The set-up was calibrated using full two port calibration prior to connecting the connectors on test.

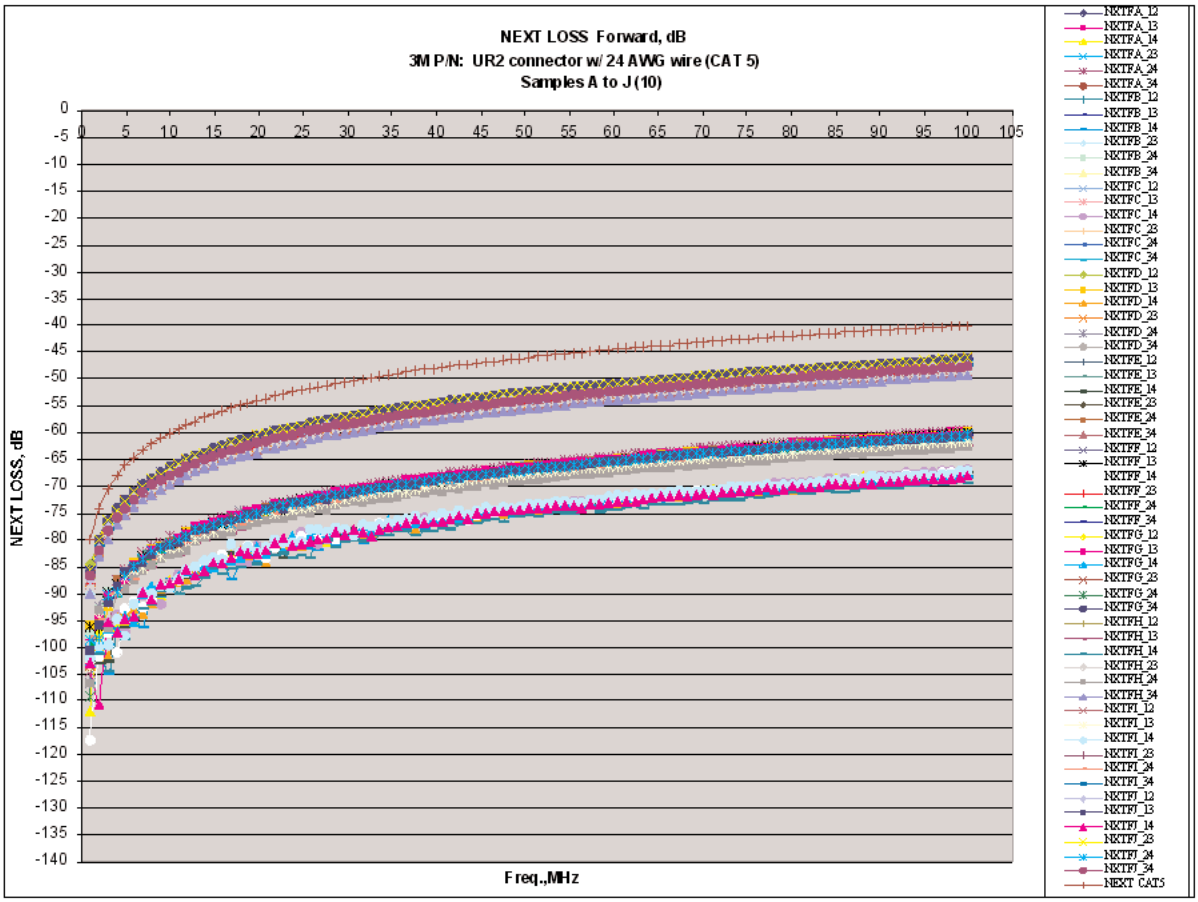
Equipment:

- H.P. Network Analyzer Model 8753D/E with
- North Hills balun Model 0322BF for 1MHZ to 100MHz (Category 5 freq. band measurement) and
- North Hills balun Model 0320BF for 30KHz-30MHz (for xDSL freq. band measurement)

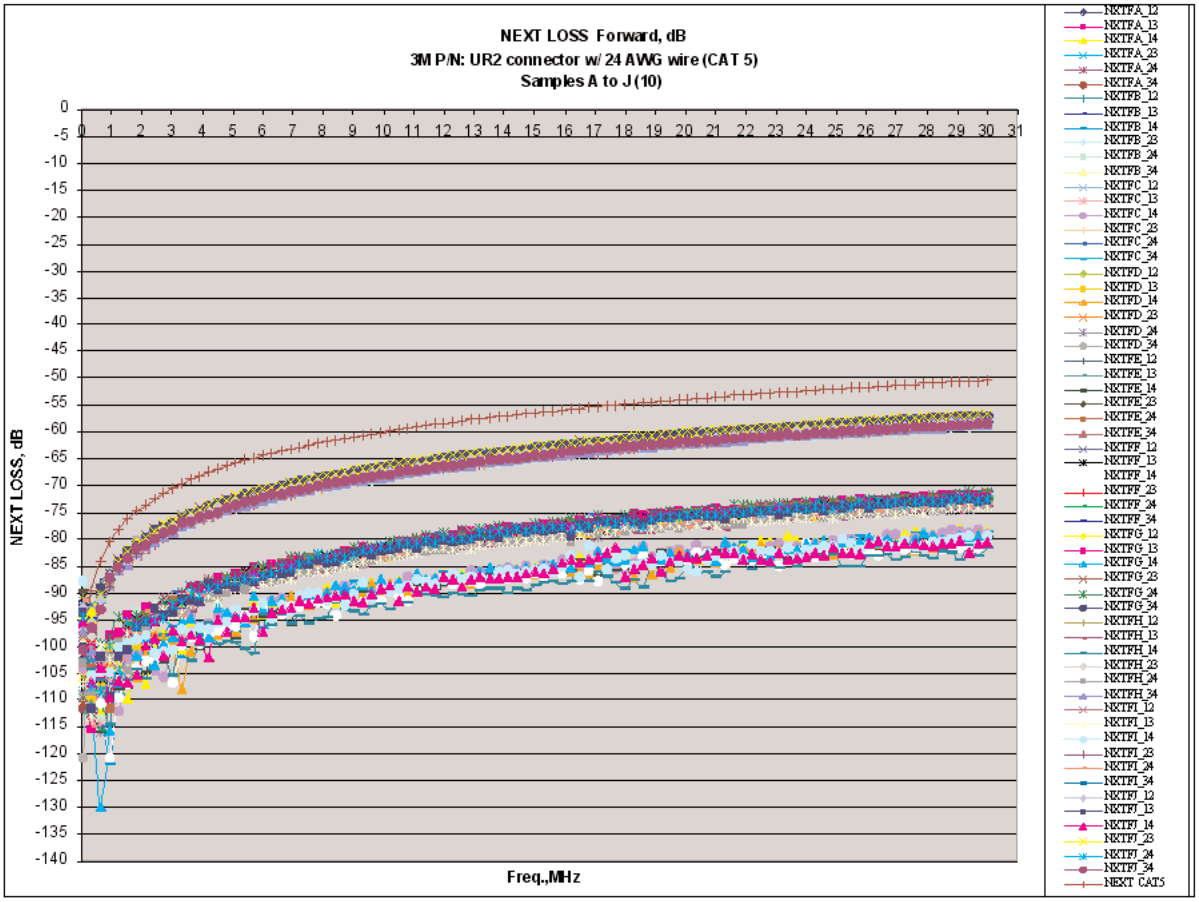
Frequency (MHz)	Category 5 NEXT (dB)
1.0	- 65
4.0	- 65
8.0	- 62
10.0	- 60
16.0	- 56
20.0	- 54
25.0	- 52
31.25	- 50
62.5	- 44
100.0	- 40

Results:

The results below show that the measured connector complies with Category 5 requirements.



Category 5 Freq. Band, 1MHZ to 100MHz Measurement



xDSL Freq. Band 30KHz to 30 MHz Measurement

8.03 Return Loss

Connector return loss is a measure of the degree of impedance matching between cable and connector and is derived from swept frequency voltage measurements on short lengths of 100 ohm twisted pair test leads before and after inserting the connector under test. A balanced input signal is applied to a connector while signals that are reflected back due to impedance discontinuities are measured at the same port from which the signal is applied.

For return loss measurement, connector samples were prepared using small lengths of Category 5 wire. One side of the connector pair on test was terminated with contact pins and the other side was terminated using a 100 ohm SMT resistor. Return loss measurements were performed by connecting each pair of contact pins to the balun. The set-up was calibrated using full two port calibration prior to connection of the connectors on test.

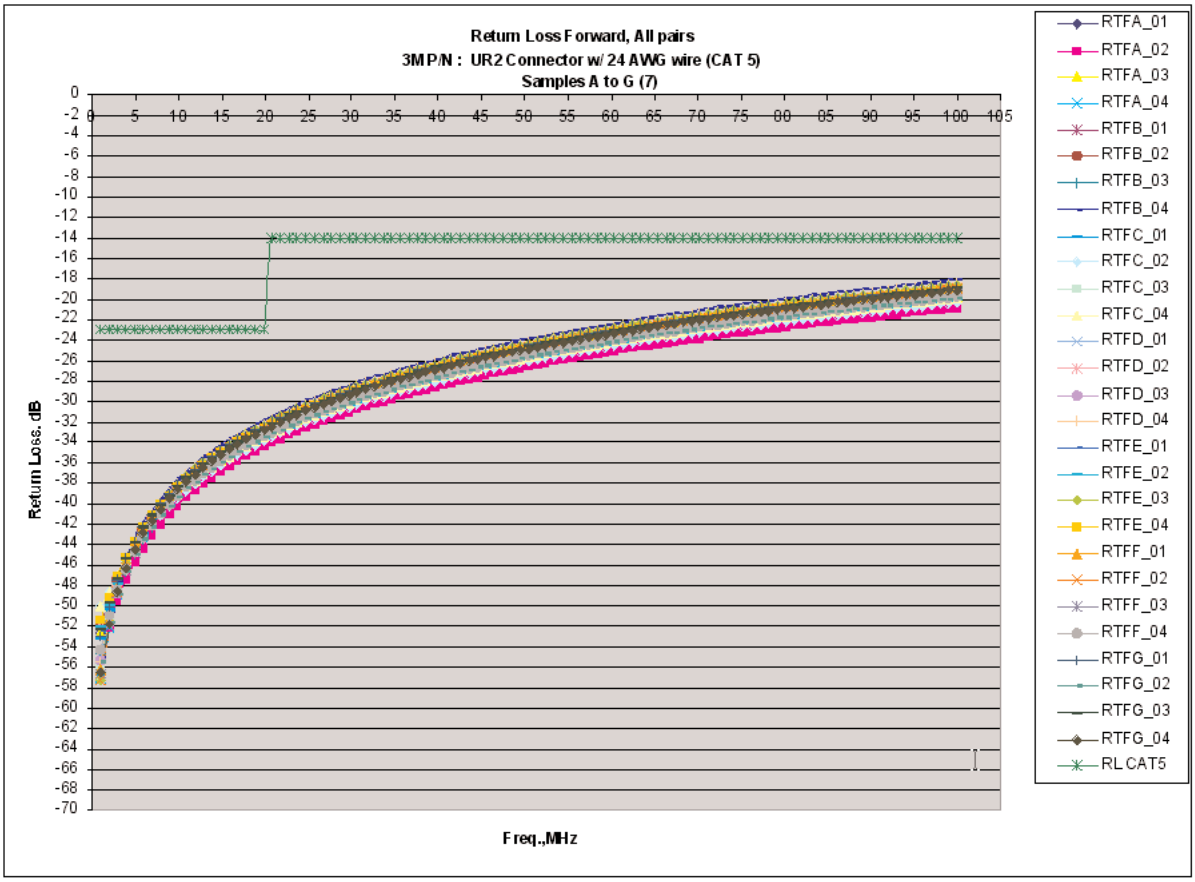
Equipment:

- H.P. Network Analyzer Model 8753D/E with
- North Hills balun Model 0322BF for 1MHZ to 100MHz (Category 5 freq. band measurement) and
- North Hills balun Model 0320BF for 30KHz-30MHz (for xDSL freq. band measurement)

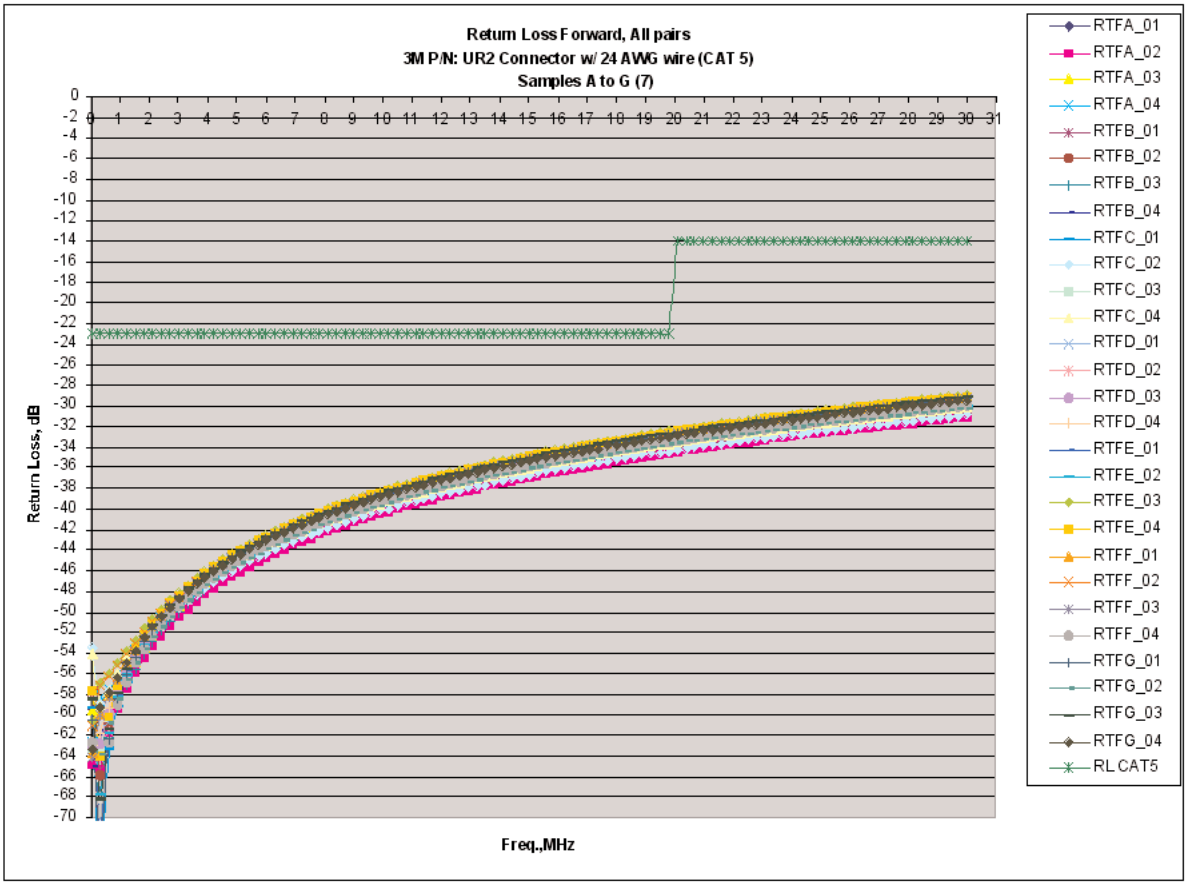
Frequency (MHz)	Category 5 Return Loss (dB)
1.0	≥ 23
4.0	≥ 23
8.0	≥ 23
10.0	≥ 23
16.0	≥ 23
20.0	≥ 23
25.0	≥ 14
31.25	≥ 14
62.5	≥ 14
100.0	≥ 14

Results:

The results below show that the measured connector complies with Category 5 requirements.



Category 5 Freq. Band, 1MHZ to 100MHz Measurement



xDSL Freq. Band 30KHz to 30 MHz Measurement

9.0 Conclusions

The Scotchlok™ UR2 Connector successfully met or exceeded all test requirements.

For information concerning specific agency approvals, please contact your 3M Telecom Access Products Division representative.

3M

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