CommScope Smooth-Wall Transmission Line System Survives Extreme Testing Without Secondary Waterproofing

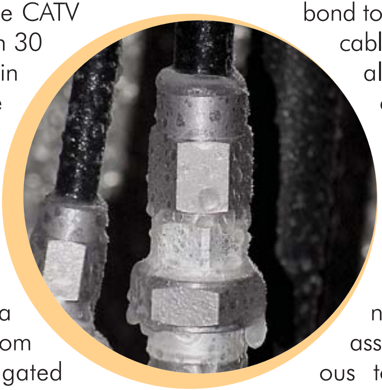
Over the last seven years, the wireless industry has installed over 24 million feet of CommScope smooth-wall cable, including more than 2 million connectors. Many of the locations are in the harshest climates in the world. Yet, not a single cable or connection has failed when installed properly. This fact has led many in the industry to wonder just what it would take to push the smooth-wall cable to the breaking point.

In 2004, a major infrastructure vendor challenged CommScope engineers to subject their smooth-wall cable assembly to the most extreme environmental tests ever developed. The battery of tests, devised by a joint team of OEM and CommScope engineers, included the following extreme testing: extreme thermal cycling and icing, monsoon-like rainfall and thermal stress cycling with the cable assembly having a damaged outer jacket.

During the tests, every effort was made, every measure taken, to force the smooth-wall cable assembly to fail. In the end, however, the tests failed to push the CommScope Transmission System to the breaking point.

New Smooth-Wall Technology Makes A Big Impression

In 1998, CommScope Wireless introduced a smooth-wall coaxial cable assembly into the wireless market. Similar cable and connector assemblies have been used in the CATV industry for more than 30 years and deployed in over 90% of the broadband networks throughout the world. For wireless transmission line applications, however, the smooth wall cable was seen as a radical departure from the standard corrugated copper assemblies typically used in the wireless industry.



The cable itself features a triple-bonded configuration in which a solid center conductor is physically bonded to a closed cell foam dielectric. The dielectric, in turn, is bonded to a smooth, outer conductor. The outer conductor shares a physical bond to the polyethylene sheath. The cable is manufactured with either aluminum or copper outer conductors.

The smooth-wall, non-corrugated structure also enables more accurate and consistent termination. As a result, CommScope engineers claim that the entire assemblies are virtually impervious to environmental conditions such as water migration, humidity, and thermal cycling.

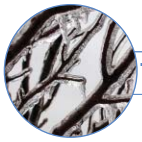
Prior to its introduction the CommScope smooth-wall cable assemblies easily passed the standard battery of industry-accepted tests such as IEC's IP68. More important, however, is the product's performance in the field. In the last seven years, the wireless industry has installed more than 24 million feet of the CommScope smooth wall cable and connector assemblies. CommScope Transmission Line Systems are located in many of the most severe environmental conditions throughout the world. In that time, not a single assembly has failed when installed properly.

When compared to similar corrugated assemblies, whose failure rates reach as high as 25%, the performance and reliability of the CommScope smooth wall cable assemblies is an anomaly. (For details, see article CommScope® *Smooth-Wall Replacing Corrugated As Cable Of Choice)*

Challenging the Results

In 2004, CommScope presented its smooth-wall cable technology to engineers of a prominent wireless infrastructure vendor. After several presentations during which test data and anecdotal evidence were presented, the vendor’s engineers remained skeptical that any cable assembly could be as durable as the field and lab results indicated. When asked what it would take to convince them, the engineers suggested a series of tests designed to go beyond the most extreme environmental conditions and find a weakness that traditional testing would not expose.

The test development team consisted of engineers from the vendor and CommScope. The team decided to test CommScope's smooth-wall 50-ohm aluminum-based cable; thereby challenging CommScope's claim that aluminum is as effective as the industry standard copper-based cable. Other decisions, as described in this paper, were also made in an attempt to stack the odds against the success of the CommScope cable assembly. The tests were conducted at CommScope's facilities and the vendor had unrestricted access to all phases of the tests and the resulting data.



Test #1: Extreme Thermal Cycling and Icing

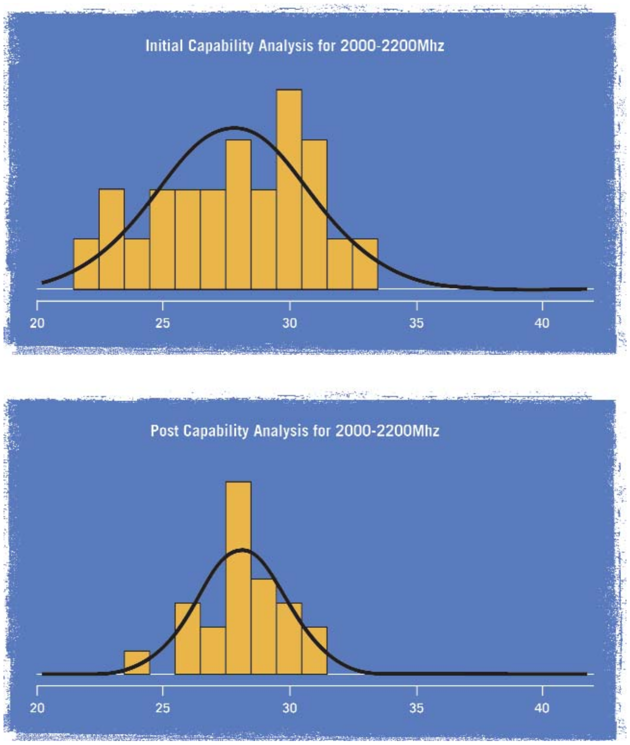
The most extensive and heavily controlled test involved prolonged and extreme thermal cycling in addition to heavy icing. The tests involved four groups of 24 CommScope FXL aluminum smooth-wall cable assemblies. Each assembly consisted of a 2-foot section of 50-ohm main line transmission cable connected on either end to two 2-foot long jumper cables. The free ends of the jumper cables were then terminated and fitted with connectors and connected to the test equipment.

The preparation of the samples, however, did not take place in the lab under ideal conditions. In an attempt to duplicate extreme environmental conditions, the technicians were required to prepare the cable ends and connect the assemblies in a thermal chamber where temperatures were held steady at -30°C (-22°F). Even with heavy gloves and appropriate clothing, the maximum length of time an individual technician could endure such conditions was 10 to 15 minutes. During that time, each technician prepared and connected eight cable assemblies.

To further induce failure, the test team prepared the assemblies without the benefit of any secondary waterproofing. While this is contrary to standard industry practice, vendor engineers were eager to challenge CommScope's claim that, when prepared and connected properly, the smooth-wall cable assembly requires no secondary waterproofing.

Once connected, the assemblies were allowed to return to room temperature. After the temperature had stabilized at 20°C (68°F), each assembly was tested for Return Loss and DTF (Distance to Fault). (See diagram 1)

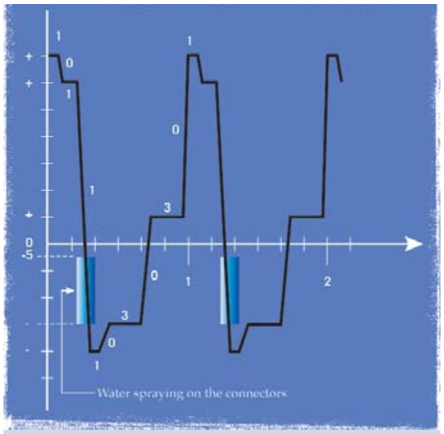
Diagram 1 Side-by-side comparison of pre-and-post test analysis



After benchmarking, the 24 samples were returned to the thermal chamber and subjected to prolonged extreme thermal cycling (See diagram 2). Each cycle ranged from -40°C (-40°F) to 60°C (140°F) and lasted approximately 12 hours. During the cycle, the temperature was held at the highest and lowest point for sixty minutes.

As the temperature passed from -5°C (23°F) to -40°C (-40°F) during each cooling cycle technicians entered the chamber to spray a cold water mist directly onto the cable-connector assembly. Numerous cold-water mist applications were made during each cycle in an attempt to build up an ice coating of at least 1/16 inch (1.6mm) thick. The ice layer remained for three hours as the temperature rose slightly to -30°C (-22°F). After three hours, the temperature began to rise past the freezing point and the water had a chance to migrate into any openings within the cable-connector interface that may have formed during the severe thermal contraction and expansion. The chamber was also programmed so that the temperature rose and fell rapidly in order to apply as much stress on the cable-connector assemblies as possible.

Diagram 2 Thermocycling profile



After 28 continuous cycles lasting 336 hours, the test was completed.

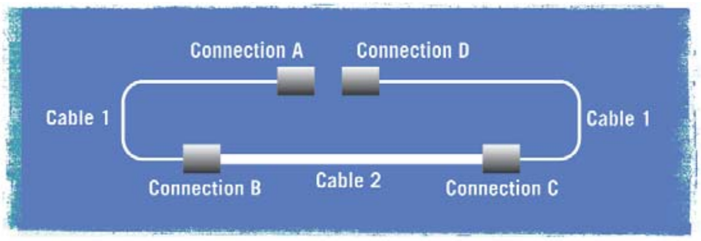
Test Fixture Samples

Test #1 Results:

At the completion of the final cycle of environmental tests, each assembly was tested once again for Return Loss and DTF (Distance to Fault).
(See Diagram 1)
Of the 138 individual cable/connector assemblies (four groups of 24 samples), only one assembly showed signs of degradation. When studying this assembly, only one failed connector was found. The failed connection involved a 3/8-inch connector, the smallest size used in the tests. Closer analysis of the failed connector assembly revealed a damaged o-ring caused when a technician, working with heavy, bulky gloves in sub-zero temperatures, failed to connect the assembly properly. Considering the extreme conditions, the fact that only one assembly failed speaks not only to the integrity of the technology but to the ease and simplicity of the installation.

An example of the sample schematic is illustrated in Diagram 3.

Diagram 3 Sample schematic and description



Sample #	Connection A	Cable 1	Connection B	Cable 2	Connection C	Cable 3	Connection D
1	540ADM	FXL540	1070540ATSBN	FXL1070	1070540ATSBN	FXL540	540ADF
2	540ADM	FXL540	1070ADF/540ADM	FXL1070	1070ADF/540ADM	FXL540	540ADF
3	SFXADM	SFX500	1070ADF/SFXADM	CR1070	1070ADF/SFXADM	SFX500	SFXADF
4	SFXADM	SFX500	1070ADF/SFXADM	FXL1070	1070ADF/SFXADM	SFX500	SFXADF

Test #2: Extreme Rain Simulation

The second test involved subjecting the assemblies to monsoon-like conditions that prevail in many parts of the world. With water migration as a major cause of transmission line failure, the vendor required that the test conditions far exceed anything that may occur in temperate regions.

Technicians prepared 96 individual cable/connector assemblies (eight groups of 4 samples) identical to those used in the extreme thermal cycling and icing tests. The assemblies were prepared in a thermal chamber at -15°C (5°F). To encourage failure, no secondary waterproofing was applied to any sample. In one-third of these samples, each connector was hand-tightened only. While installation guidelines require wrenches for final tightening, installers may overlook tool tightening in the field. The test team wanted to know what the outcome might be if connectors were only hand-tightened.

The test team conducted pre-test benchmarking as before. The samples were then placed in the test chamber where multiple showerheads were situated a few inches away from the assemblies and aimed directly on the cable-connector junction. Water spray from the showerheads exposed the cable-connector assemblies to the equivalent of 27 inches of rain.

The samples were then immediately subjected to thermal cycling during which temperatures ranged from -20°C (-4°F) to 27°C (80.6°F). When the temperature dropped to the freezing point, the samples were sprayed with a cold-water mist to build an ice layer. As the ice melted, the water had the opportunity to migrate into any gaps between the cable-connector interface that may have developed. Each cycle lasted 6 hours. The test concluded at the end of 8 cycles; at which time, the assemblies underwent post-test electrical analysis.

Text #2 Results:

Of the 32 individual cable-connector assemblies in the eight test samples, not a single connection failed.

Test 3: Extreme Thermal Stress Cycling:

A key to a transmission cable's durability and value is how it performs if the protective polyethylene jacket is abraded, cut or torn. The inherent design of corrugated copper cable allows gaps between the outer conductor and polyethylene jacket that encourage water migration and ultimately leads to failure. This final test was designed to challenge CommScope's assertion that the adhesive bond between the jacket and the outer conductor protects the smooth-wall cable from water migration if the outer jacket is damaged or torn. Prior to the test 10 aluminum cable-connector assemblies were prepared as before at room temperature. Each assembly was electrically tested for return loss and passive inter-modulation.

Removed portion of cables polyethylene jacket.

After benchmarking, technicians removed a portion of the cable's polyethylene jacket, directly behind the connector, from five of the samples. All ten samples were then placed in the thermal chamber where the relative humidity was raised to 80%. The samples were thermal cycled from -40°C (-40°F) to 50°C (122°F). Each cycle lasted two hours with this portion of the test involving six cycles.

After the first phase of thermal cycling, the ten samples with the damaged polyethylene jacket were removed from the thermal chamber and subjected to IP68 water immersion testing for 24-hours.

The ten samples were removed from the water, dried then re-tested for return loss and passive intermodulation.

Text #3 Results:

Of the ten samples, consisting of 20 connector/cable interfaces, not one showed signs of electrical degradation.

Conclusion:

In the field, it is unlikely that a wireless transmission cable system will be subjected to the extreme environmental conditions and installation hardships experienced by the CommScope System during these tests. The value of such tests is what they show in terms of the robust quality and reliability of the smooth-wall cable system.

Under extreme environmental conditions, the CommScope cable and connector system has demonstrated, to the satisfaction of one of its most demanding customers, the ability to support the long-term reliability needs of today's wireless networks. Additionally, these tests prove that the CommScope System is reliable even without the benefit of secondary weatherproofing.

This type of evidence further substantiates CommScope's belief that the smooth-wall cable and connector design indeed delivers the lowest life cycle cost in the industry.

CommScope is committed to Manufacturing Excellence in all aspects of its operations. Our policy is to design, manufacture and deliver products and services which conform to specifications and satisfy customer requirements and expectations in every way.

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Extremeflex™ Aluminum

Coaxial Cable:
Dissimilar Metals Engineering Analysis

Executive Summary

For decades, design engineers in most industries have opted for aluminum over copper in the design of sophisticated transmission systems. In addition to being lighter, more flexible, and less expensive than traditional copper, aluminum is, pound for pound, twice as conductive as copper[1]. In fact, 90% of today's high-voltage transmission lines use aluminum conductors[2] and 99% of all CATV cables are aluminum.

Now, engineers at CommScope have introduced an aluminum-based transmission cable into the wireless industry. Known as Extremeflex, it represents the next generation of CommScope's smooth-wall cable technology, first introduced with the company's Cell Reach line of cables. Today, the smooth-wall technology is used by eight of the ten largest wireless providers. Despite the success of Cell Reach, concerns continue to linger about the use of aluminum in wireless applications.

This report discusses the various concerns. Further, it demonstrates, through laboratory testing, field trials and application analysis, that Extremeflex performs as well as the leading corrugated copper product, while delivering the added benefits of aluminum.

Historical Use Of Aluminum In Transmission Cable Applications

Since its commercial introduction in the 1880s aluminum continues to be one of the most valuable and versatile commercial metals. Weighing in at just 1.172 pounds per square inch per linear foot, it is among the lightest commercially suitable metals, one-third the weight of copper[1]. With an electrical resistance of 13.36 microhms per square inch per foot[1], its mass conductivity is twice that of copper. It is also highly resistant to corrosion due to the formation of a self-protecting oxide coating. These properties, combined with an extremely high tensile strength (24,000 pounds per square inch[1]), and tremendous flexibility have made aluminum the material of choice for many transmission systems.

One of the first major markets for aluminum was wiring for the burgeoning electricity industry. By the end of 1898, the Pittsburgh Reduction Company (later Alcoa) had sales commitments for 1.3 million pounds of aluminum wire[2].

From that point forward, wide-scale commercial production of aluminum and the electrification of the United States developed side-by-side. Today, aluminum is used in 90% of America's power lines[2]. Aluminum first appeared as part of a coaxial cable system in the late 1960s. Because it offered a significant reduction in cost as compared to copper with no drawbacks in performance it quickly began displacing copper coax as the primary transmission cable. Today an estimated 5 billion feet, representing 99% of all CATV cable is aluminum.

The wireless industry is now ready for the same transition. Since the first wireless networks appeared in the 70s, corrugated copper has been the standard cabling material. This was largely due to copper's successful application in the early telephone microwave systems. However, in recent years, network engineers appear more open than ever to significant design changes in transmission systems.

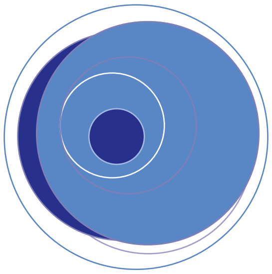
Seven years ago, CommScope engineers introduced Cell Reach®, a unique copper smooth-wall cable that represents a significant departure from traditional corrugated cable. With its ability to greatly reduce water migration and corrosion, the most common cause of cable failure, the new design has been widely embraced and is now employed by eight of the top ten wireless operators.

As a follow up to the success of its Cell Reach product, CommScope has introduced a smooth-wall aluminum cable known as Extremeflex™. The design, based on the Cell Reach® cable, replaces the copper outer conductor with an aluminum outer conductor. Including the smooth-wall design, it is nearly identical to cable used in more than one million miles of CATV Broadband networks throughout the world. The most noticeable difference is the 50-ohm center conductor instead of the standard 75-ohm center conductor used for broadband cable.

While the use of aluminum is accepted and preferred in the CATV industry, it represents a significant change for wireless network engineers who have relied on copper-based cables since the development of the first wireless networks in the early 70s.

On the one hand, engineers argue that the use of dissimilar metals in the cable assembly (aluminum cables and brass connectors) leaves it overly susceptible to galvanic corrosion. At the same time, they are concerned that when attached to a steel tower, the differing coefficients of thermal expansion will place too high a strain on the cable, resulting in the physical distortion of the cable.

The remainder of this paper addresses each of these issues and shows how it has been possible to design around these phenomenon.



Myth #1 | Susceptibility to Corrosion Due To Dissimilar Metals

One of the questions about the aluminum cable in the wireless arena has been the concern that aluminum tends to be more susceptible to corrosion. The process, known as galvanic corrosion, occurs when dissimilar metals are connected in the presence of an electrolyte. The electrons flow between the two metals causing the more chemically active metal, in this case aluminum, to corrode[3]. The same is true of any structure made of dissimilar or identical metals, including copper.

The key to preventing corrosion within the cable, therefore, is not in the type of metal used but in being able to prevent water from entering the cable and acting as an electrolyte. Without water there can be no corrosion[4].

CommScope engineers understood this concept 30 years ago when designing CATV cables and applied it seven years ago when they began developing the smooth-wall design found in CommScope's Cell Reach copper cables. The design is fully bonded. The waterproof outer layer is fully bonded to the shielding layer that shares a full physical bond with the dialectic foam layer, which in turn, is fully bonded to the center conductor. The closed cell structure of the dielectric foam adds yet another level of protection against water migration. One of the key benefits of the design is that it ensures a weatherproof connection between cable and connectors; where corrosion is most likely to begin.

In a field test conducted through a major U.S. carrier, from 1996 to 2002, 278 sites were up-fitted with the CommScope smooth-wall Cell Reach copper cable. Six and half years after installing the first smooth-wall assembly, not a single cable-related failure has been reported.[5] Previous to the field trial, the carrier had reported a 16% failure rate in its corrugated cables due to water ingress, which causes corrosion. Secondly, they experienced a 23% failure in corrugated jumpers due to water ingress, which causes corrosion.[5] Water ingress is the cause of failure, not the use of dissimilar metals.

The Extremeflex, aluminum smooth-wall cable represents the next step in the evolution of the smooth-wall technology. It incorporates lightweight, highly flexible aluminum in place of copper. By eliminating water from the system, CommScope engineers have developed a system that is corrosion resistant.

Aluminum and Copper Smooth-Wall Cable Versus Corrugated Copper in Accelerated Life Testing

To test the electrical performance and corrosion resistance of the Extremeflex smooth-wall aluminum cable, CommScope engineers subjected it to intense temperature cycling and prolonged exposure to highly corrosive salt fog. This accelerated life test, also known as military standard 202F, compared the Cell Reach smooth-wall copper cable, Extremeflex smooth-wall aluminum cable and a leading corrugated copper cable.

Identical lengths of cable were connectorized on both ends using the manufacturer's recommended procedures. No secondary waterproofing such as tape or shrink tubing was added. Engineers then recorded baseline measurements for return loss, distance to fault, and passive intermodulation. The cable assemblies were then subjected to eight thermal cycles, from -40 to +170 C. During each cycle the temperature was held at the highest and lowest extremes for four hours. Thermal cycling was immediately followed by exposure to a 5% salt fog for 48 hours. Return loss, distance to fault and passive intermodulation readings were taken at the end of each full cycle. The process was continuously repeated eight times for a total of 64 cycles.

The following tables list the results from just one of several accelerated lifecycle tests. This specific test compared 7/8" Cell reach, Extremeflex and corrugated copper cables.

Notes:

1) The accuracy of the test method and set up is no better than +- 1 dB.
2) The aluminum cable used in this test is the first prototype design. These samples had not been optimized and the SRL data is lower/worse than production cable. Production cable typically has return loss values of 28-30 dB.
3) The pertinent information for this test is the change in the test sample measured value from the initial test to the end of the test at 64 cycles.
4) Comparisons of actual measurement levels are not indicative of the results we are testing. Only changes over the test period are pertinent. See table 3.
5) Trained engineers professionally installed all connectors under laboratory conditions.
6) Look for changes between initial test and after 64 thermal and salt spray tests.

Table 1 | Initial Test Results (See Notes pg. 4)

	Return Loss .80-1.00 GHz	Return Loss 1.7-2.11 GHz	Return Loss 2.3-2.7 GHz	Return Loss 0.05-5.0 GHz	DTF 1.8-2.0 GHz	PIM
Corrugated Copper	32 dB	32 dB	28 dB	18 dB	39/39 dB	126 dBm
Corrugated Copper	35 dB	29 dB	32 dB	21 dB	41/39 dB	131 dBm
Corrugated Copper	35 dB	30 dB	29 dB	20 dB	38/39 dB	127 dBm
Corrugated Copper	35 dB	30 dB	31dB	21 dB	38/40 dB	117 dBm
Corrugated Copper	33 dB	28 dB	28 dB	20 dB	35/41 dB	130 dBm
Average	34 dB	30 dB	30 dB	20 dB	38/40 dB	126 dBm
Smooth-wall Copper	37 dB	36 dB	35 dB	21 dB	44/49 dB	126 dBm
Smooth-wall Copper	38 dB	33 dB	32 dB	22 dB	44/45 dB	129 dBm
Smooth-wall Copper	37 dB	32 dB	33 dB	21 dB	44/41 dB	129dBm
Smooth-wall Copper	37 dB	33 dB	33 dB	21 dB	42/45 dB	129 dBm
Smooth-wall Copper	37 dB	32 dB	31 dB	22 dB	43/44 dB	129 dBm
Average	37 dB	33 dB	33 dB	21 dB	43/45 dB	128 dBm
Smooth-wall Aluminum	33 dB	27 dB	26dB	22 dB	36/39 dB	117 dBm
Smooth-wall Aluminum	33 dB	27 dB	26 dB	21 dB	36/38 dB	133 dBm
Smooth-wall Aluminum	34 dB	25 dB	25 dB	22 dB	36/38 dB	118 dBm
Smooth-wall Aluminum	32 dB	27 dB	26 dB	20 dB	36/38dB	119 dBm
Smooth-wall Aluminum	32dB	27 dB	26 dB	21dB	36/38 dB	126 dBm
Smooth-wall Aluminum	34 dB	26dB	25 dB	22 dB	36/38 dB	126 dBm
Smooth-wall Aluminum	31 dB	28 dB	26 dB	21 dB	36/38 dB	129 dBm
Smooth-wall Aluminum	32 dB	27 dB	27 dB	22 dB	36/39 dB	131 dBm
Smooth-wall Aluminum	33 dB	25 dB	24 dB	21 dB	36/36 dB	125 dBm
Smooth-wall Aluminum	32 dB	28 dB	27 dB	22 dB	36/38 dB	127 dBm
Average	33 dB	26 dB	26 dB	21 dB	36/38 dB	125 dBm
Std Deviation	1	1	1	0.6	0.3/1	5
Specification	26 dB	26 dB	NA	NA	34 dB	112 dBm

Table 2 Test Results After 64 Thermal Cycles And Salt (See Notes pg. 4)

	Return Loss .80-1.00 GHz	Return Loss 1.7-2.11 GHz	Return Loss 2.3-2.7 GHz	Return Loss 0.05-5.0 GHz	DTF1 .8-2.0 GHz	PIM
Corrugated Copper	35 dB	30 dB	29 dB	22 dB	39/37 dB	115 dBm
Corrugated Copper	34dB	28 dB	29 dB	24 dB	38/36 dB	115 dBm
Corrugated Copper	34 dB	28 dB	27 dB	21 dB	36/38 dB	117 dBm
Corrugated Copper	34 dB	28 dB	28 dB	24 dB	37/37 dB	121 dBm
Corrugated Copper	33 dB	27 dB	27 dB	22 dB	34/38 dB	115 dBm
Average	34 dB	28 dB	28 dB	22 dB	37/37 dB	117 dBm
Smooth-wall Copper	36 dB	42.0 dB	41 dB	22 dB	42/52. dB	123 dBm
Smooth-wall Copper	37 dB	36 dB	36 dB	23 dB	44/39 dB	118 dBm
Smooth-wall Copper	37 dB	36 dB	37 dB	22 dB	44/45 dB	116 dBm
Smooth-wall Copper	36 dB	37 dB	36 dB	22 dB	42/48 dB	116 dBm
Smooth-wall Copper	35 dB	36 dB	33 dB	23 dB	44/48 dB	125 dBm
Average	36 dB	38 dB	37 dB	23 dB	43/46 dB	120 dBm
Smooth-wall Aluminum	32 dB	24 dB	26 dB	22 dB	35/32 dB	119 dBm
Smooth-wall Aluminum	31 dB	25 dB	27 dB	22 dB	33/37 dB	118 dBm
Smooth-wall Aluminum	30 dB	24 dB	26 dB	23 dB	35/32 dB	119 dBm
Smooth-wall Aluminum	35 dB	23 dB	26 dB	21 dB	35/33 dB	119 dBm
Smooth-wall Aluminum	32 dB	25 dB	27 dB	22 dB	33/37 dB	114 dBm
Smooth-wall Aluminum	30 dB	24 dB	26 dB	23 dB	33/35 dB	119 dBm
Smooth-wall Aluminum	31 dB	24 dB	26 dB	22 dB	33/34 dB	112 dBm
Smooth-wall Aluminum	33 dB	24 dB	28 dB	22 dB	32/38 dB	128 dBm
Smooth-wall Aluminum	31 dB	23 dB	24 dB	23 dB	31/34 dB	123 dBm
Smooth-wall Aluminum	32 dB	23 dB	24 dB	20 dB	34/35 dB	120 dBm
Average	32 dB	24 dB	26 dB	22 dB	33/35 dB	119 dBm
Std Deviation	1	1	1	1	1/2	4
Specification	26dB	26 dB	NA	NA	34 dB	112 dBm

Table 3 Summary changes from Table I (initial test) to Table II (end test).

	Return Loss .80-1.00 GHz	Return Loss 1.7-2.11 GHz	Return Loss 2.3-2.7 GHz	Return Loss 0.05-5.0 GHz	DTF 1.8-2.0 GHz	PIM
ΔVXL5	0.2 dB	1.7 dB	1.7 dB	2.6 dB	1.4/2.5 dB	9.4 dBm
ΔCR1070	1.2 dB	4.2 dB	3.8 dB	1.4 dB	0.4/1.8 dB	8.8 dBm
ΔFXV700PE	1.0 dB	2.5 dB	0.1 dB	0.6 dB	2.6/3.3 dB	6.1 dBm

The results indicate that the aluminum cables perform as well as copper cables in how they change over time and respond to adverse environmental conditions. Additional tests on various sizes of cable and varying production runs of aluminum cable yielded comparable results. These findings support the hypothesis that, without an electrolyte, galvanic corrosion becomes a non-issue even in the presence of dissimilar metals.

Myth #2 The Effects of Thermal Expansion And Contraction Within The Transmission System

Another concern about aluminum cable is the constant thermal expansion and contraction of aluminum when attached to structures of different materials. At issue is the thermal co-efficient of expansion: a measure of the dimensional change of a material due to a change in temperature. This coefficient is commonly expressed in terms of centimeter per centimeter per degree Celsius or inch per inch per degree fahrenheit[6]. For reference, the following thermal coefficients of expansion may be useful.

Steel:	0.0000063
Copper:	0.0000094
Aluminum:	0.000013

For decades, engineers have used expansion joints in buildings, highways, etc. to compensate for expansion and contraction in structures that are subject to temperature change. The same holds true for transmission systems. CATV lines are installed with an excess of several feet of cable at each pole. During the cold winter months, the lines absorb the excess as the cable contracts. In the hot summer months, the cable expands under the heat and the lines relax, as it were. Without the ability to draw on this "reservoir" the cable would come under intense strain as it contracted.

When the aluminum or copper cable is attached to a steel tower there is also the additional concern due to the different thermal coefficients of expansion. If each component is not allowed to move freely a strain develops which can be destructive if the strain exceeds the strength of either of the component materials. In addition to the temperature change, coefficients of expansion, and component materials, length is a major defining condition because it effectively increases the strain.

In order to avoid the potentially harmful effects of differential coefficients of expansion, each material must be allowed to expand and contract at its own rate, without attempting to constrain one by the other. In the case of a copper cable installed on a steel tower, the cable must be allowed to move differentially to the tower. In the case of corrugated cables, some expansion benefit may be derived from the corrugation. However, even in the case of the Cell Reach smooth wall cable, the years of experience have shown that the cable / tower system design allows the differential movement to take place without damage to the cable. How does this happen?

Had the transmission cable been completely fixed to the tower, the concerns may be valid. However, this is not the case. In the typical tower installation the ends of the cable are not affixed to the steel tower but are, in effect, floating with respect to the tower. The cable is held loosely in place along its length with hangers or other hardware. The expansion and contraction of the cable is accommodated by very small movements in the hangers or by the ability of the hanger to move with respect to the tower structure. As the cable makes its turn at the top and at the bottom of the structure the bend in the cable forms a natural expansion and contraction joint, which compensates for movement during the seasonal temperature changes.

The ability of the system to accommodate the length change may be better understood by calculating the potential change in the length of each material and evaluating the difference. The following calculations represent approximations only. The actual degree of contraction and expansion will vary based one the precise design and composition of the tower and cable as well as the fluctuation in temperature.

Example Of Thermal Expansion

Example of a 150 foot tower:

Steel - .0113 in/degree °F
Copper - .016 in/degree °F
Aluminum - .023 in/degree °F

In the case of a test site in Utah, we have temperature changes between -20 °F and 100 °F (a 120 °F change). In the worst case scenario, we would have the following change in length if there were a simultaneous change in weather (using the formula DL =aL1DT):

Δ**L** = Change in Length
α = Thermal Coefficient of Expansion
L_1 = Initial Length
Δ**T** = Change In Temperature

At 150 Foot:

Steel- 1.356"
Copper- 1.92"
Aluminum- 2.76"

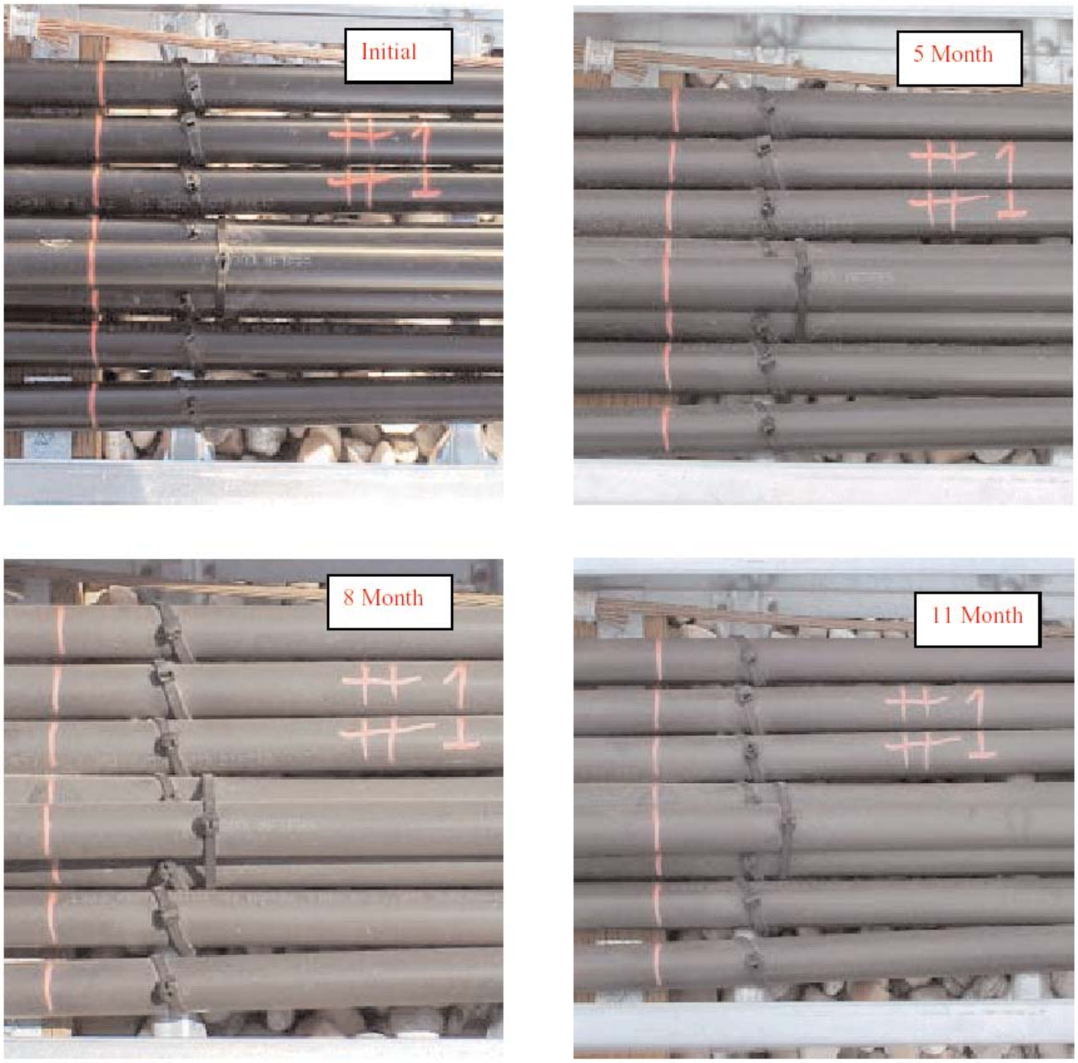
Field Tests Yield Positive Results For Using Aluminum Smooth Wall Cable and Connectors On Wireless Transmission Line Systems

To test its performance in the field, engineers selected a cellular site on the coast of Brazil. The site was chosen on the high failure rate of traditional corrugated cables due to galvanic corrosion. The trial began in 2000 and involved installation of 7/8" Extremeflex aluminum cable. After three years, not one single performance problem has occurred.

A second, more detailed trial took place in Utah and involved Extremeflex cable situated on an exposed rooftop. The site experiences temperature swings from -20 F to +100 F and is exposed directly to all the elements.

When the site was erected, engineers recorded baseline measurements for the cable/connector system to be compared with subsequent findings. Engineers also photographed the installation providing a visual comparison of the effect of thermal contraction and expansion. Since then, they have returned at one-, five-, eight-, and eleven-month intervals with additional visits planned at 18 and 24 months. (See site photos on following page)

During each visit engineers documented the cable assembly's electrical performance and photographed it in order to compare it to previous findings. To date no change in performance, dimensional measurements, or photographic evidence has been detected.



Cable Markings #1

These pictures show the aluminum cable fastened to the steel trays at various chronological times over a one-year period.

CONCLUSION

Based on the laboratory and field test results, the Extremeflex aluminum smooth-wall cable offers all the electrical performance of copper cables. With the performance requirements satisfied, engineers can now turn their attention to the ancillary benefits of the aluminum smooth-wall cable.

In addressing the major concerns regarding the use of aluminum in transmission cables, we have not even touched upon the various benefits that aluminum offers.The fact that aluminum is one-third the weight of copper reduces the effects of tower loading and the overall strains on the cable during long runs. Aluminum also holds its shape better than corrugated copper, placing less internal stress on the cable where severe bends are required. Finally, aluminum may offer potential cost-savings compared to corrugated cable. The added benefits of greater flexibility, lighter weight, and cost savings provide a compelling argument for the new technology.

As the technologies driving the wireless industry continue to accelerate and applications continue to converge, it is precisely this willingness to embrace new designs and materials that will determine the degree to which wireless lives up to its potential.

Sources

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