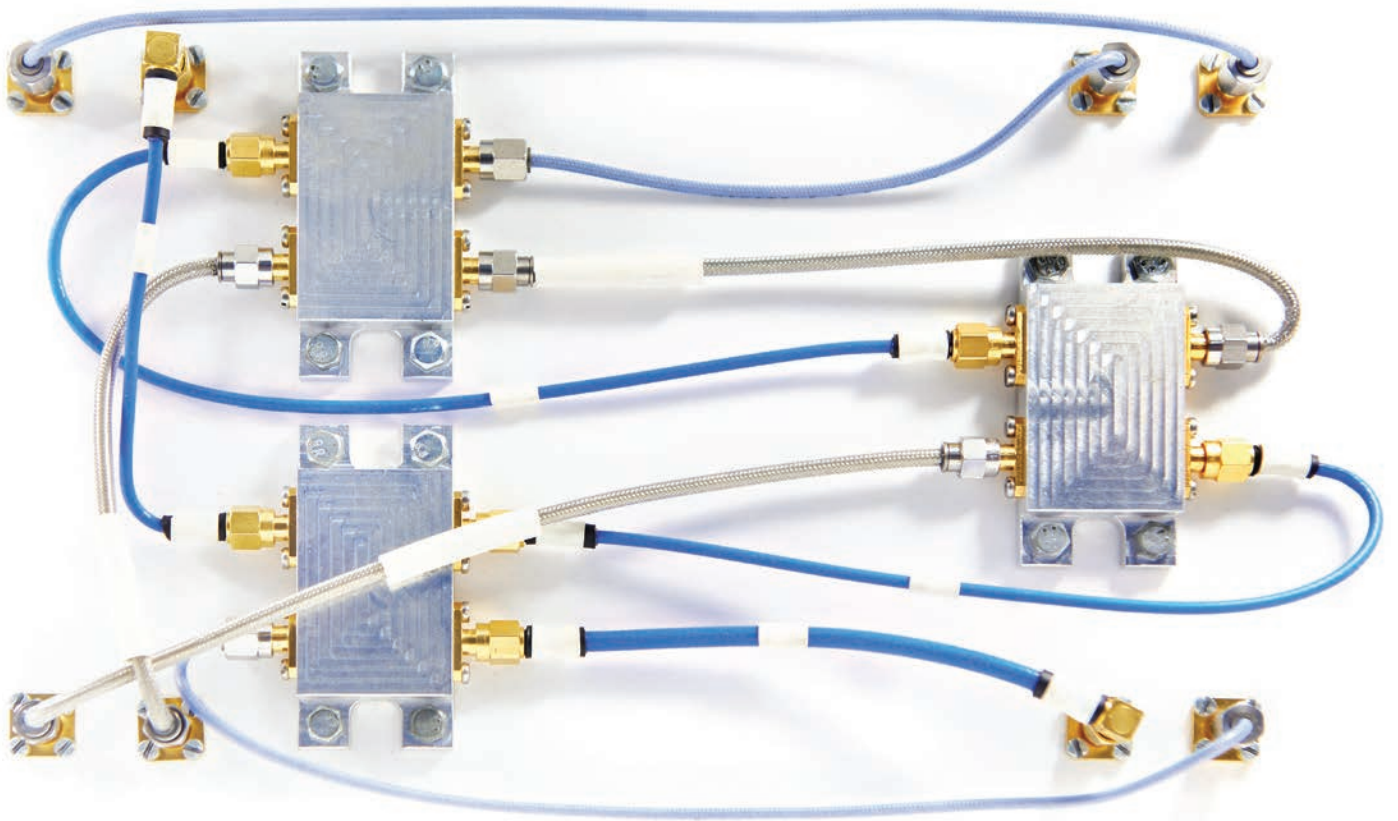




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RF & Microwave Cable Wire



ULBRICH CAPABILITY WHITEPAPER



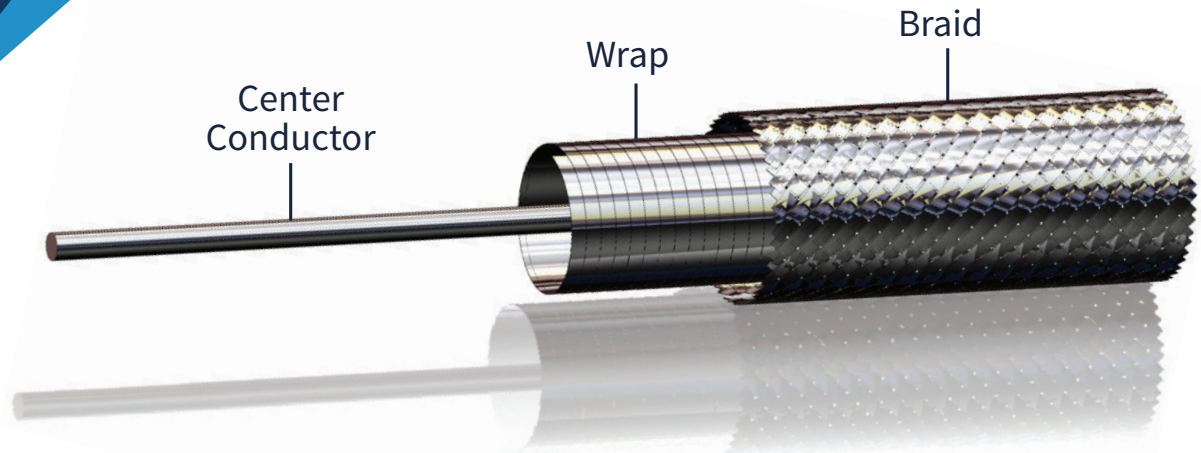


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CAPABILITY SHEET

High Performance RF Cable Materials



You have cable-making challenges.
We have **engineered wire solutions.**

Leading Supplier to the Microwave and RF Cable industry, Ulbrich is your source for a broad range of precision wires for your specialty cable requirements. Ulbrich's quality, technology and know-how will drive your performance higher.

- Customized Mechanical Properties
Enable Wrap Optimization
and Variability Control

- Consistent Performance
- Reduced VSWR Spikes
- Improved Flex Life
- High Aspect Ratio
- Higher Strength
- Lighter Weight



- 4-Axis FFT Analysis and Reporting
- Precision Drawing and Annealing
- In-Line Statistical Process Controls
Ensure High Cpk and Ppk Values
- In-House Silver Plating to Concise
Customer Requirements
- Special Alloys Available on Request
- ISO 9001:2008, ASTM B298 Compliant
- Global Manufacturing and Sales Reps

ULBRICH SPECIALTY WIRE PRODUCTS

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CENTER CONDUCTOR WIRE

MATERIALS & DIAMETERS AVAILABLE

Bare and Silver Plated Copper/Copper Alloy HSC 24
0.002" (0.05mm) to 0.294" (7.47mm) (44 AWG to 1 AWG)

Silver Plated Copper Clad Aluminum
0.005" (0.13mm) to 0.160" (4.06mm) (36 AWG to 6 AWG)

Silver Plated Copper Clad Steel
0.004" (0.1mm) to 0.060" (1.5mm) (38 AWG to 15 AWG)

PACKAGING

12" (305mm) Flange (D-50), 8" (203mm) Flange (D-25),
5" (127mm) Flange (D-5), 22" (559mm) Reel,
Other Sizes to Meet Customer Needs



HELICAL WRAP WIRE

ASPECT RATIOS

Up to 420:1

SIZE RANGES AVAILABLE

Thickness: 0.0005" (0.013mm) to 0.010" (0.25mm)
Width: 0.020" (0.5mm) to 0.325" (8.26mm)

MATERIALS AVAILABLE

Bare Copper and Silver Plated Copper (CD102, CD110),
Bare and Silver HSC 24 Alloy

PACKAGING

Available in Biconical or Straight Flanged Spools



BRAID WIRE

SIZE RANGES AVAILABLE

Thickness: 0.0007" (0.018mm) to 0.006" (0.152mm)
Width: 0.008" (0.2mm) to 0.150" (3.8mm)

MATERIALS AVAILABLE

Silver Plated Copper, Tin Plated Copper,
Bare Copper, Copper Alloys, HSC 24

PACKAGING

Wardwell/Hacoba, Steeger and
Other Specialty Bobbins



Ulbrich is the leading edge in conductor engineering; your development partner that can customize our support to your specific needs. This information may not be passed on to third parties without approval by Ulbrich Wire Group. All rights reserved. © 2022 Ulbrich Stainless Steels & Special Metals, Inc.



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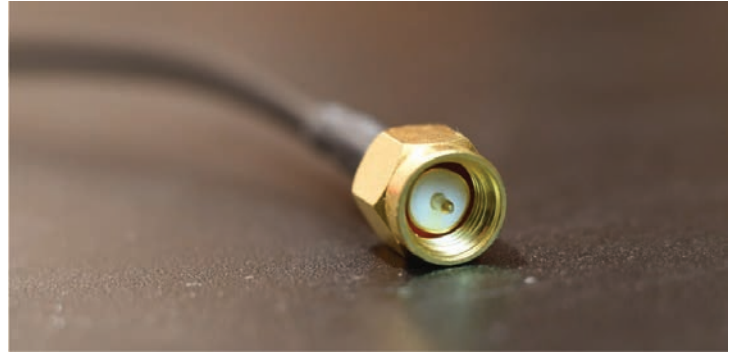
Evolving Wire Specifications to Improve RF & Microwave Cable Performance

Developing the best possible helical wrap, braid, and center conductor products require an understanding of the role each plays in the assembled cable. Each component serves its function & therefore has characteristics that are most important to the success of the final cable. A common issue that can arise is the unwritten rules that must be met, especially with helical wrap wires. The solution for this breaks down into two parts, which are valuable to know for RF Cable manufacturers because it'll help expedite the improvement of these wires' performance.

First, reverse engineering, both good and bad samples, to identify the characteristic that likely needs control for the cable's success is an excellent place to start. After this, providing samples that represent changes that should be made to improve the performance of the overall system will be instrumental. If the samples are successful, then the data is used to write specifications to capture this critical detail.

Over time, once one problem has been settled, other issues are sometimes identified, and the exercise must be repeated with changes made to a new process parameter. Recently, the marketplace has begun to see a push for improvements in helical wrap wires that will allow cables to increase in bandwidth and overall length. There are two categories these generally fall into.

The first would be improving Fast Fourier Transformation (FFT) limits for better Voltage Standing Wave Ratio (VSWR) performance. The second would be changing mechanical properties, so the wire can better handle the wrapping process and avoid increases in resistance after undergoing any type of motion.



WHAT IS FFT?

The Fourier Transform is a mathematical operation that changes the domain (x-axis) of a signal from time to frequency. The latter is particularly useful for decomposing a signal consisting of multiple pure frequencies. You can probably already tell that the FFT is a rather complicated algorithm. The Fourier Transform is a method for representing an irregular signal — such as the voltage fluctuations in the wire between an output device and an input device — as a combination of pure frequencies. Fast Fourier Transform is one of the most important algorithms in the information sciences and essential for ensuring performance in precision RF Cable wire manufacturing.

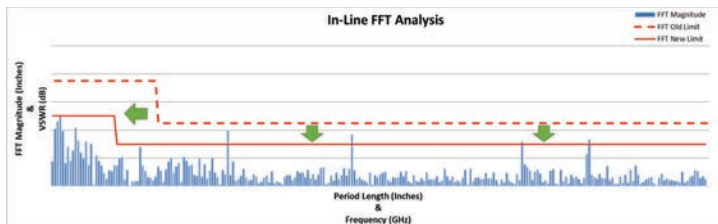
It is critical because when producing data cables, any irregularities such as variations of diameter, eccentricity, and capacitance pose a risk for data transmission in the final cable product. Understanding how the precision metals used to make RF Cable play into the entire production process is very beneficial in producing a cable that will perform as intended.

The production of RF Cables begins with the production of the different items that make up the cable, such as the various wires that are needed to make it.

INTRODUCING VSWR

You might be asking, wait, "what is VSWR?" VSWR is the ratio of the maximum voltage to the minimum voltage in standing wave pattern along the length of a transmission line structure & is used to measure differences in impedance. It is very similar to Structural Return Loss. These terms describe the uniformity of a cable's impedance along its length related to reflected energy. The difference between VSWR and SRL is essentially a difference in how reflected energy is measured. For the purposes of this article, we will focus on VSWR at the material level for high-performance cable manufacturing.

As the demands for higher performance cables permeate information sciences & technologies, so does the demand for the precision wire which are free of irregularities that can disrupt the signal transfer across long lengths of cable. In a perfect system, 100% of the RF power would transmit through a lossless line, uninterrupted. By reducing VSWR, cable manufacturers can reduce reflections and lower the impedance between components. This achievement starts with engineered materials, wire, manufactured to best-in-class standards using cutting edge technology, minimizing imperfections that result in signal loss. Managing VSWR levels by dialing in FFT during the manufacturing of RF cable raw materials is essential to achieving predictable, high performance RF Cable.



This is an example of the FFT used during production. The period length on the x-axis correlates with the frequency on VSWR plots and the FFT magnitude on the y-axis correlates with the decibel level on VSWR plots. It also shows how FFT limits might need to be tightened to compensate for changes in bandwidth or new VSWR requirements such as lower decibel limits.

IMPROVING FFT LIMITS FOR BETTER VSWR PERFORMANCE

The best RF wire manufacturers have systems in place for measuring FFTs (Fast Fourier Transformations) on dimensional data during production which allows for the ability to make improvements in VSWR performance, for wrap wire applications. This technological capability enables the ability to measure width and thickness FFTs for repeating periods down to 0.1" or up to 1000" in length.

By imposing limits over the live FFT graph, a production operator can be informed if there is a machine issue causing a repeating pattern that will show up in a VSWR plot. Varying limit levels can be applied to FFT magnitudes, depending upon the cable design and required VSWR limits. Occasionally the limit level chosen at the beginning of development appears adequate because no issues arise in the first cables assembled. As production increases, the magnitude of the FFT spikes can vary inside the initial limit from batch to batch. When this happens, VSWR plots from these batches of wire can be compared to FFT plots to determine the need for a tighter FFT limit.

Such iterations could require manufacturing process adjustments, which could potentially have unforeseen consequences on other properties in the wire, and consequently in the cable. Collaborative technical dialogue between the wire and cable engineers provides the best opportunity to optimize all wire & cable production processes to achieve the best possible characteristics in the cable. If an adjustment to the wire process is required, it is prudent to produce a small sample spool of wire with the proposed changes; which the cable maker can test under engineering supervision. Once the desired results are confirmed, the revised wire specification and the process moves into mass production.

HOW PRECISE MECHANICAL PROPERTY CONTROL CAN AID MICRO-BENDING OF HELICAL WRAP WIRE

Changing mechanical properties can also improve the performance of helical wrap wire. This has less to do with VSWR performance and more to do with how the wire itself handles the wrapping process. The thickness of these wires tends to be on the order of 0.002" (0.050mm) and is being wrapped around diameters around the order of 0.020" (0.50mm). Because of the small orders of magnitude involved here, the wrapping of a shield wire around a dielectric could be categorized as micro-bending process.

Micro-bending refers to thin foils being formed around tight radii. The behaviors observed during micro-bending don't follow classic formability laws associated with sheet metals. In this realm, the ratio of grains per unit thickness of foil begins to dictate the behavior of the material during forming. For these reasons, the process of helically wrapping the shielding or wrap wire around the dielectric qualifies as micro-bending.

To achieve the unique microstructure (micro-temper) optimal for the cable, the wire maker needs to develop an appropriate thermal treatment process. The etching of copper grains can sometimes be more of an art than a science, so it is unfortunately not a reliable means to write a specification. Fortunately, each of these unique microstructures has a unique set of mechanical properties that can be used to efficiently ensure the heat-treated (annealed) wire has the appropriate micro-temper.

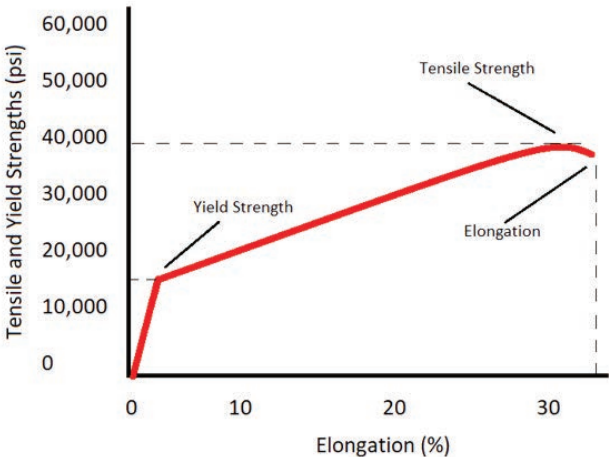
CD-102 Micro-Temper	
Property	Soft
Tensile	38,000 psi
Yield	17,000 psi
Elongation	32%

The graph on the right plots a typical stress-strain curve from pure copper in its soft condition.

UNDERSTANDING MICRO-TEMPERS FOR CABLE APPLICATIONS

Many times, specifications determine the temper of a wire by the elongation of the wire. Some cable manufacturers find softer wire better handles their wrapping process, but that elongation alone will not guarantee success from batch to batch. Cable manufacturers should realize that softness is not the only thing to consider, and there are other mechanical properties that better predict how the material will respond when it is wrapped. To help show the difference in mechanical properties of different micro-temper, and how they impact the wire during wrapping, please see the illustration below showing the stress-strain curve from a tensile test of pure copper in the "Soft" condition and the resulting properties in the table to its left.

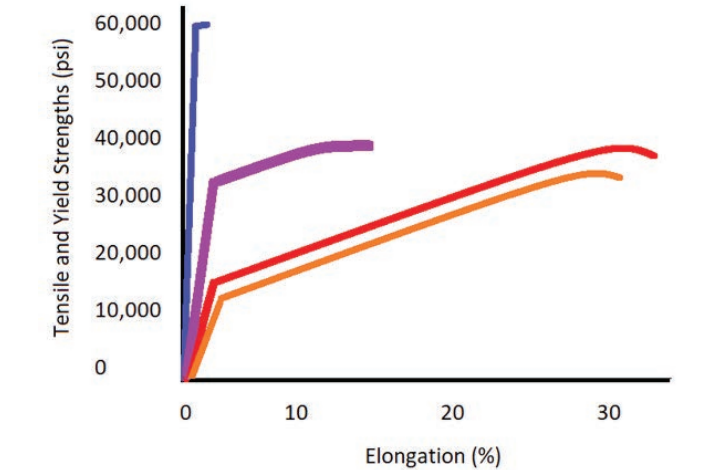
The elongation is determined by how far the material stretches before it breaks. The reason this may not accurately describe the wire's behavior during wrapping is that the wire is not being pushed to complete failure. Tensile strength describes the stress the material must undergo to reach its maximum elongation at failure, so this also fails to describe the material's behavior under wrapping tension. The yield strength, however, occurs at about half of the applied force of the tensile strength and 1% elongation. When yield strength is crossed during a tensile test, it means that the wire has shifted from elastic to plastic deformation.



UNDERSTANDING MICRO-TEMPERS FOR CABLE APPLICATIONS CONTINUED

Elastic deformation means that enough stress has been applied to the wire to make it slightly elongate but it will return to its original length if the stress is relieved. Plastic deformation means that enough stress has been applied for the wire to elongate past the point at which it can return to its original length if the stress is relieved.

Let's imagine a case where the stress applied exceeds the yield strength (stress of 20,000psi) and the wire plastically deforms. If we find where the stress-strain curve of the "Soft" micro-temper reaches 20,000psi, and look down at the x-axis we see elongation of 10%, so we know 20,000 psi is applied the wire will elongate from 10" in length to 11" and will stay at 11" in length when let go. For cable makers struggling to have helical wrap wire that is soft enough based only upon the elongation measurement, an "Extra Soft" micro-temper could help. By reducing the yield strength of the wire, the wire will require less tension during wrapping to undergo the same amount of deformation. This does come at a slight cost to the tensile and elongation, but that should not be of concern if the wire is not pushed to the point of failure.



CD-102 Micro-Tempers				
Property	Hard	Tough	Soft	Extra Soft
Tensile	55,000 MIN	35,000 – 50,000	32,000 – 42,000	30,000 – 40,000
Yield	50,000 MIN	25,000 – 40,000	15,000 – 20,000	10,000 – 15,000
Elongation	2% MAX	6% – 25%	25% MIN	20% MIN

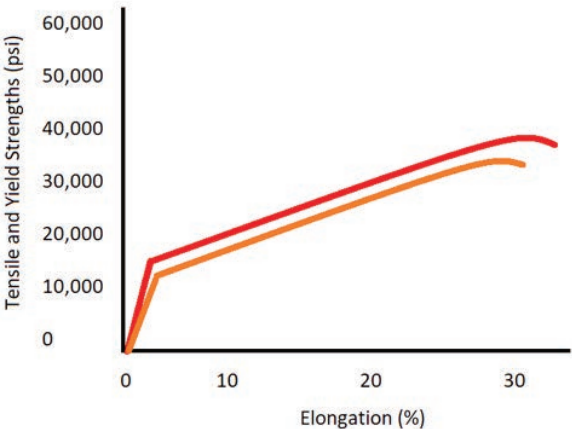
This set of plots above compares the hard, tough, soft, and extra-soft tempers' stress-strain curves.

A "Tough" micro-temper has a much higher yield strength than is typically found in annealed copper. While the overall tensile strength is slightly higher as well, the nearly 2x normal yield strength value is what is truly unique. This means that a stress that would break a standard annealed copper wire won't even permanently deform wires annealed to this micro-temper.

Again, there is always a give and take when changing mechanical properties & the "Tough" wire usually has around 15% elongation. But we know that high strength copper alloys used in some cable applications only have around 8% elongation, and that renders them soft enough to survive their handling in the machine.

While it doesn't have quite the yield strength of "Soft" high strength copper alloy, one advantage the "Tough" wire has is no conductivity loss since it is still a pure copper alloy. When comparing stress-strain curves as well as properties, you can see that it falls right between the traditional "Hard" and "Soft" conditions.

The "Tough" micro-temper could be ideal for applications where increased tension helps with cable performance yet traditional copper tempers cannot hold up under these tensions.



CD-102 Micro-Tempers		
Property	Soft	Extra Soft
Tensile	38,000 psi	32,000
Yield	17,000 psi	13,000
Elongation	32%	30%

Shown above is stress-strain curves comparing pure copper in soft and extra-soft tempers.

WORK COLLABORATIVELY WITH A WIRE PARTNER TO UNLOCK YOUR CABLE'S TRUE POTENTIAL

High-performance cable producers would be well served to partner with a technically competent wire supplier, such as Ulbrich Specialty Wire Products, who can help enable the best possible performance in their cables. The wire producer needs to be able to measure and control a variety of subtle variables. These variables, once understood, can be written into specifications that result in performance gains in the assembled cable. When the wire & cable makers work together, these characteristics are captured so that manufacturing time and purchasing funds are not wasted on defective cables. The wire producer can become an integral part of the cable development team. There is not a one size fits all solution for developing cable wires. Some problems that arise when moving to full-scale production can only be solved by a joint effort between the wire and cable engineers.

At Ulbrich, we understand how critical it is for cable manufacturers to provide the physical & mechanical properties of their cable materials. However, there is a distinct lack of detailed specifications capturing such properties, and that lack impacts helical wrap wires and center conductors more than any other components. Fast Fourier Transfer (FFT) limits are usually not provided for the helical wrap wire, despite their relationship to VSWR in the finished cable. Moreover, mechanical properties are usually defined so broadly that there are issues with “in-spec” material causing the cable to fail from batch to batch. To educate cable manufacturers, product engineers, students and other industry professionals on this importance, we sponsored a live webinar to discuss these concerns. Check out the free on-demand recording below to gain virtual access to the industry's leading wire supplier for microwaves and RF cable materials!

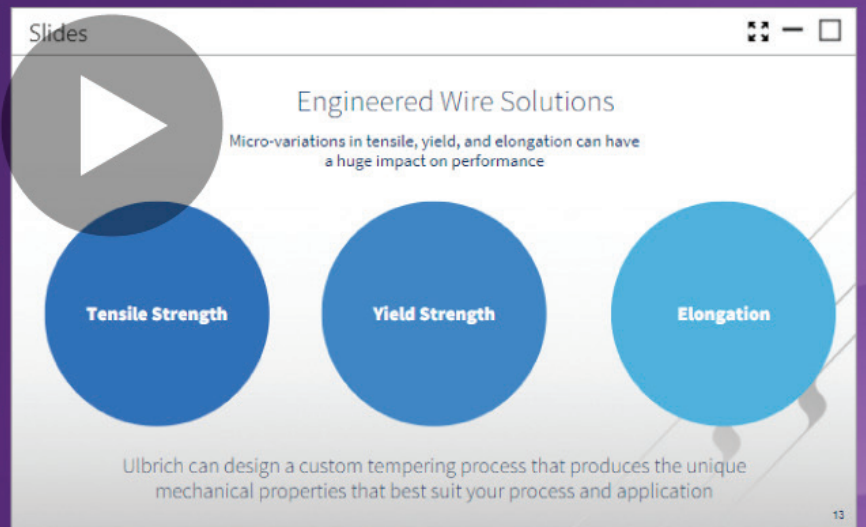
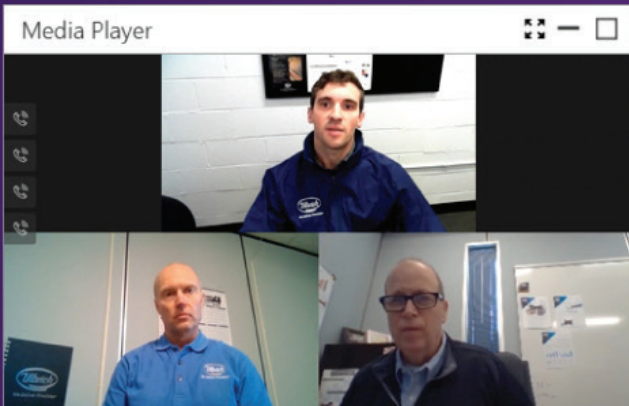
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Microwaves&RF



AVAILABLE ON DEMAND!

Understanding Materials' Impact on Performance of Helical Wrap-Wire Cabling





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ULBRICH SPECIALTY WIRE PRODUCTS

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CAPABILITY SHEET

Ulbrich CCS & SPCCS

Copper Clad Steel

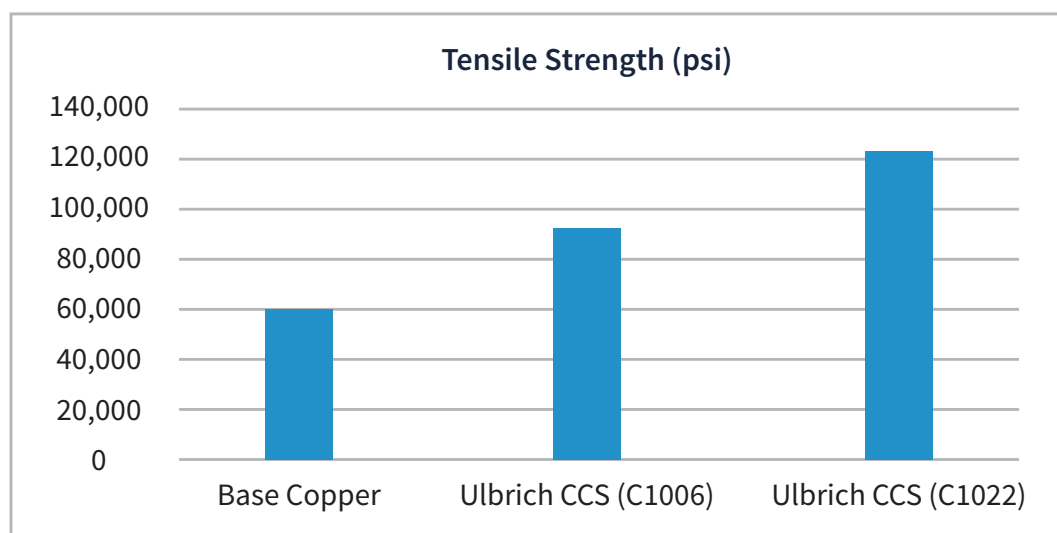
Precision Drawn, Rolled and Plated Ulbrich Materials

Applications: Wrap, Braid and Center Conductor materials for RF and Microwave Cables

Ulbrich is committed to delivering high precision products, now with the added benefit of bi-metal construction for high strength applications. SPCCS can be manufactured into both round and flat sizes comparable to other copper products.

Strength Plus Conductivity: Ulbrich CSS & SPCCS is a stronger alternative to pure copper while retaining desirable electrical properties. This material is ideal for applications where a stronger material is needed without the increase costs of some of the other “high-strength” copper alloys. A graph is included below showing the difference in tensile strength between pure copper, copper clad steel and high strength copper alloy round wires.

Reference ASTM B501, ASTM B452, and other Standards



Available Forms

- Round and Flat
- Bare and Silver Plated
- Single and Multi-end

Size Ranges

Diameter: 0.004" to 0.060"

Thickness: 0.001" to 0.010"

Width: 0.010" to 0.030"

10:1 Width to Thickness Ratio

Property	Copper Wire	Ulbrich CCS (C1006)	Ulbrich CCS (C1022)
Tensile (psi)	60,300	94,100	123,000
Yield (psi)	59,300	84,300	108,300
Electrical Conductivity IACS	100%	40%	40%



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CAPABILITY SHEET

Ulbrich Lite Weight CCA & SPCCA Copper Clad Aluminum

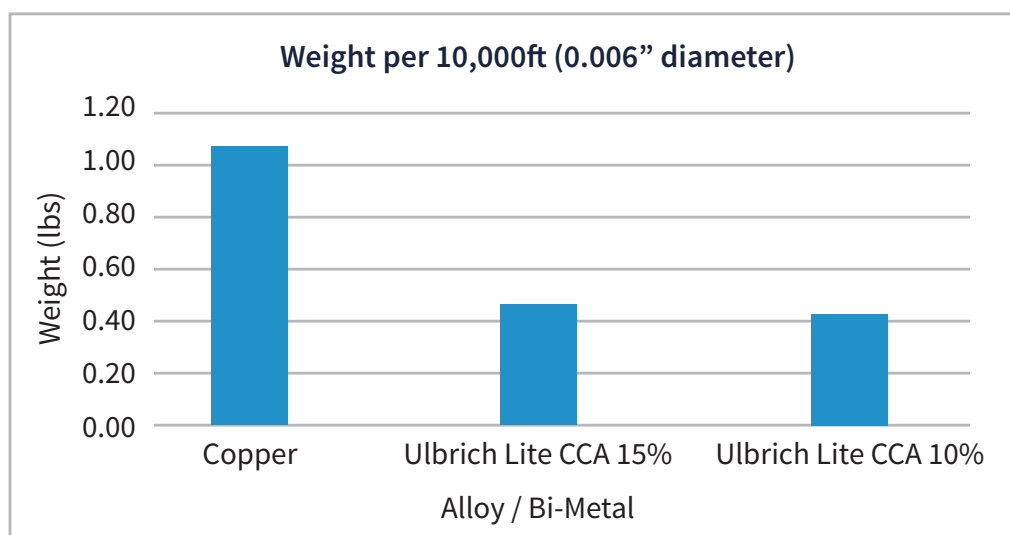
Precision Drawn, Rolled and Plated Ulbrich Lite Weight Materials

Applications: Center Conductor and Braid materials for RF and Microwave Cables

Ulbrich is committed to delivering high precision products, now with the added benefit of large weight savings for your critical applications. SPCCA can be manufactured into both round and flat sizes comparable to other copper products.

Weight Savings Plus Conductivity: This lighter alternative to pure copper has an approximate weight savings of 70% to copper while retaining desirable electrical properties. This material is ideal for aerospace, military, satellite & other weight conscious applications. To demonstrate the weight saving potential, the graph below shows the difference in weight between a pure copper round wire and that same length and size wire made of copper clad aluminum.

Reference ASTM B566, and other Standards



Before Plating



After Plating



Rolled Side



Rolled Edge



Available Forms

- Round and Flat
- Bare and Silver Plated
- Single and Multi-end

Size Ranges

Diameter: 0.005" to 0.160"
Thickness: 0.0025" to 0.010"
Width: 0.015" to 0.100"
 10:1 Width to Thickness Ratio

Property	Copper Wire	Ulbrich Lite CCA 15%	Ulbrich Lite CCA 10%
Density [lb/in ³]	0.324	0.131	0.12
Electrical Conductivity IACS	100%	64.42%	62.85%
Electrical Resistivity [Ohms m]	1.68 x 10 ⁻⁸	2.67 x 10 ⁻⁸	2.74 x 10 ⁻⁸



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Ulbrich is the leading edge in conductor engineering; your development partner that can customize our support to your specific RF & Microwave cable needs.

CAPABILITY SHEET

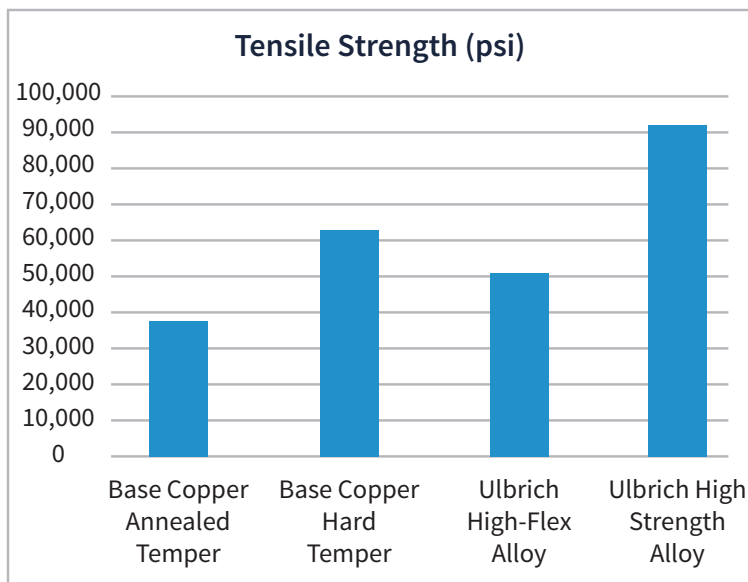
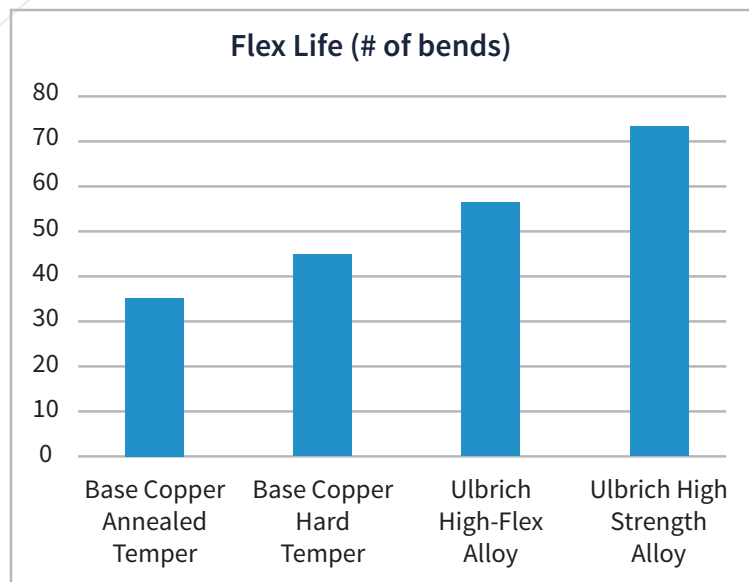
Ulbrich Specialty Alloys

Ulbrich High-Flex and High Strength RoHS Alloys

Applications: Braid and Center Conductor materials for RF and Microwave Cables

Ulbrich is committed to delivering high precision products, now with alternate copper alloys that can provide improved flex life and material strength. These materials are well suited for flat or round braid applications where a high-flex life is needed.

Flex Life and Strength: The addition of alloying agents can help improve the overall strength and flex life when compared to the base copper (C102) materials with a minimal loss of conductivity. Comparison data of measured flex life and tensile strength are shown below.



Property	Base Copper Annealed Temper	Base Copper Hard Temper	Ulbrich High-Flex Alloy	Ulbrich High Strength Alloy
Flex Life (# of bends)	35	45	56	73
Tensile Strength (psi)	37,500	63,000	51,000	92,400
Yield Strength (psi)	18,000	60,000	42,000	90,700
Elongation (%)	30	2	10	2
Conductivity (IACS%)	100	97	98	76



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HSC-24 CAPABILITY SHEET

High Strength Copper Alloy 24

Markets: RF & Microwave, Aerospace, Medical, Robotics, Electronics



Stronger Materials For Your Demanding Cable Applications

- **High Performance**
ASTM B624 compliant, HSC-24 offers a min tensile strength of 414 MPa (60 ksi), elongation of 6%, and conductivity in excess of 85% IACS.
- **Excellent Plating Ability**
Thanks to their smooth surface, HSC-24 wires are highly suitable for metal plating.
- **High Processability**
Based on our extensive experience in developing copper alloys, Ulbrich is continuously optimizing our in-house manufacturing to deliver products with excellent breakage ratios.
- **Softening Resistance**
The HSC-24 alloy retains its properties and hardness when exposed to high operating temperatures.
- **RoHS and REACH Compliance**
HSC-24 complies to all contemporary standards and directives concerning hazardous products. It does not contain cadmium or elements that are hazardous for the environment.
- **High Flex-Life**
Alloy HSC-24 is suitable for applications subject to significant mechanical stress, offering approximately 9 times the flex-life of Cu-ETP round wires.
- **Consistent Quality**
The stability of our copper alloy casting process results in consistent quality and product characteristics, always in compliance with industry standards.
- **Global Manufacturing and Sales Reps**

ULBRICH SPECIALTY WIRE PRODUCTS

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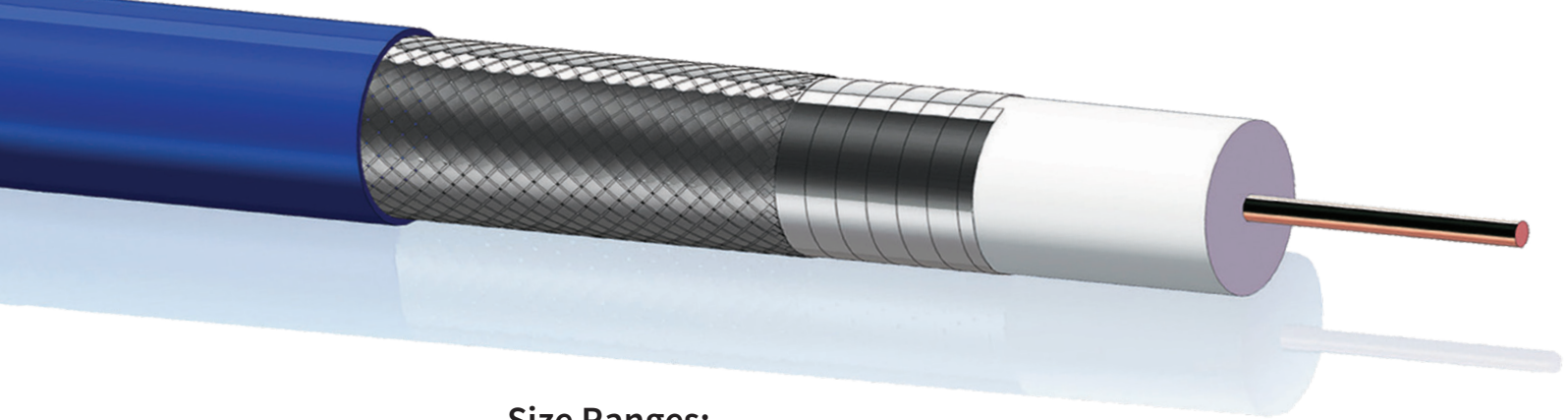
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austria@ulbrich.com



BRAID

Size Ranges:

• Round:	0.002" to 0.010"	0.05mm to 0.25mm
• Thickness:	0.0007" to 0.006"	0.02mm to 0.15mm
• Width:	0.008" to 0.150"	0.2mm to 3.8 mm

• Packaging:

- Wardwell/Hacoba
- Steeger
- Other Specialty Bobbins



HELICAL WRAP

Size Ranges:

• Thickness:	0.0007" to 0.010"	0.02mm to 0.25mm
• Width:	0.008" to 0.150"	0.2mm to 3.8 mm

• Aspect Ratio: Up to 200:1

• Packaging:

- Biconical
- Straight Flanged Spools



CENTER CONDUCTOR

Size Ranges:

• 0.002" to 0.102" (44 AWG to 10 AWG)	0.05mm to 2.59mm
---------------------------------------	------------------

• Packaging:

- D-50 Flange - 12" (305mm)
- D-25 Flange - 8" (203mm)
- D-5 Flange - 5" (127mm)
- Reel 22" (559mm)
- Other Sizes to Meet Customer Needs



Cost & Price Factors for RF Cable Wire

HOW MUCH DOES HIGH-PERFORMANCE RF CABLE WIRE COST?

One of the questions any metal purchaser is going to ask when researching material options is, "what is the price of silver-plated copper, high-strength copper, or copper-clad wire for RF cable conductors?"

At Ulbrich, we've answered this question thousands of times over the years, and these days, hundreds of prospective metal buyers will ask us for quotes or estimates every year -- and many folks will raise the question in the first few minutes of our conversations.

We get it.

As a professional buyer, you're working with a limited budget to buy all the materials you're charged with purchasing. Your goal is, at least partially, to help your company to manufacture its goods economically and maximize its profitability, and lower scrap rate. The cost of materials from all sources, lead times, plus metals at time of shipment, and surcharge are just a small collection of things you're thinking about as you purchase metal and go about your day. This is without mentioning how you need to ensure that you have enough material to satisfy your production schedule.

The job of a materials purchaser certainly wasn't made any easier over the last 12 months, either. With most metals shooting up in price, "metals charges" nearing all-time highs, and lead times breathing down the neck of a calendar year.

So, how much does conductor materials such as flat or round silver-plated copper wire cost? What's the going rate for copper-clad aluminum wire? Well, like many other metals used for manufacturing, the answer is: it depends.

One of the most critical mistakes a materials purchaser for RF cable applications can make is not taking the time to properly research the best options in wire suppliers as it pertains to their unique needs. The truth is that the price of wire can fluctuate based on many variables. Throughout this article, we'll discuss the factors that cause the cost of metal wire needed to make RF cables go up or down.



COMMODITY MARKET ADDS VARIABILITY TO THE COST OF RAW AND ENGINEERED MATERIALS USED TO PRODUCE RF CABLE

Many of the materials used to make RF Cables are affected by fluctuations in the commodity markets such as silver and copper. Prices of iron ore, copper, silver, and other commodities have been volatile around the world in part due to the pandemic. Silver is integral to numerous B2B and B2C products from aerospace RF Cable to photography, jewelry, and coins.

These materials' high electrical conductivity and silver's durability give these metals industrial and technological applications, with almost every computer, mobile phone, aircraft, and appliance containing silver and copper. The market prices for these materials can cause the cost of both silver and copper wire to move up or down for manufacturing buyers.

Similarly, much like what we've all experienced during the pandemic period, supply chain issues can have downstream effects on the price of all types of raw materials used to produce RF Cables. From metals to plastics or ceramics, the availability of materials within the supply chain can cause prices to move up or down depending on the current economic environment. It is even more important for buyers to choose wire producers with extensive relationships with many supply sources in times like these. These manufacturers should also have contingencies in place in case of upstream production interruptions or supply chain issues for acquiring the materials their customers need.



HIGH ORDER VOLUMES LOWER THE COST OF SILVER-PLATED COPPER AND COPPER-CLAD ALUMINUM OR STAINLESS WIRE

It will not surprise most RF industry buyers that order volume has an inverse relationship with silver and copper wire price. The more wire you intend to purchase, the lower price you will pay for fabricating a given length or unit of weight of that wire.

However, in addition to this – within the wire & cable marketplace itself, there is another typical distinction that comes with order volumes which impact the cost of materials. Typically when you see lower prices within the overall marketplace for high volume items, you're looking at wire being purchased in tonnage. These large quantities or large orders are often produced to broad material requirements accompanied by very, very competitive pricing in part because of economies of scale, but also because the type of wire being purchased in those quantities is more than likely to be a wire with a low-to-mid-range performance which is used in applications which are not demanding in regards to the material's mechanical, electrical, or signal-bearing properties.

This type of wire is used to make cables for mainstream, top of the bell curve, purposes ranging from networking ethernet cables to RF cables used in commercial aircraft where the cables are massively mass-produced and dimensional, weight, and signal properties are not highly critical.

Conversely, lower volume orders tend to be associated with the fabrication price of silver-plated copper or copper-clad materials going up. This principle applies to smaller wire orders for applications where precision is non-critical but is embodied by wire used in critical and demanding applications. In these applications where performance, dimensional and mechanical uniformity, and other characteristics throughout the length of the wire are critical, order volumes tend to be lower because of how custom the product needs to be and the fidelity and niche usage of the material. Manufacturers seeking higher performance wire for applications in outer space, for example, or for use in R&D or cutting edge early production applications can expect the price of their materials to be much higher due to many factors, including volume.

PERFORMANCE & ENGINEERING DEMANDS CAN EFFECT PRICES FOR RF CABLE WIRES

Inquiry 1: .002" x .040" SPC Wire Qty: 75lbs

Inquiry 2: .002" x .040" SPC Wire Qty: 75lbs

These two inquiries for silver-plated copper wire may look identical in terms of thickness and width but one of these items may come with a cost of over 10X the other. But why? The answer is that highly engineered product pricing is typically not directly based on cost. Instead, it's based on value added to the wire through highly engineered production variables such as being manufactured to extremely tight tolerances in terms of, plating thickness, electrical properties, and/or mechanical properties, etc. As a result of the intensive engineering used to produce the material with exacting precision, the value shows itself in product consistency, reliability, performance, uniformity, and repeatability.

How Lower Performance Needs Reduce Prices

Suppose performance is not critical for your application. In that case, the price of silver-plated copper wire, copper-clad aluminum, or copper-clad steel wire will typically be lower than a higher performance wire because it won't have the rigorous requirements attached to its consistency and characteristics. This wire may not be produced using multiple passes through a wire rolling mill at all. Instead, it may be run through once at high speed, reducing its thickness substantially in one go, and that will be enough. Because the need for fine-tuning the characteristics of the wire through multiple passes, small reductions, and constant measurement are not required when the only critical aspects are the wire's thickness and width, not dimensional or mechanical stability.

How Higher Performance Needs Increase Price

The wire used to produce cables that meet the high-performance demands of critical applications such as aerospace, defense, and testing, requires significantly more engineering to create. The wire used for these applications will be highly customized; manufactured to the unique requirements of the buyer using technologically advanced equipment and highly trained personnel.

Producers of high-performance wire for RF Cable manufacturing, such as silver-plated copper wire or copper-clad steel wire, often go so far as to monitor the dimensional consistency of their tooling, using advanced testing equipment. These measures ensure that tooling isn't introducing variability to the product's critical & precise characteristics. The time, equipment, quality, and consistency of the raw materials and level of engineering support needed and supplied by a wire manufacturer who produces a more highly engineered precision product will be much more significant – which results in higher prices. It also goes without saying that because this is a more highly engineered wire, the scrap rate for the buyer will be reduced because there is no performance variation leading to higher output rates.



MECHANICAL PROPERTY REQUIREMENTS CAN MAKE THE PRICE OF WIRE GO UP

Your needs regarding the mechanical properties of the wire you buy to produce RF Cable also have a reasonable impact on the price. The more properties you require the manufacturer to hold to a specific value or range causes the price of the wire to go up. This is because of the engineering involved in balancing & holding the various properties throughout the dimensions of the wire. There is more work, and therefore more value introduced as more properties are specified as being critical. With that said, there is extreme upside for procurement teams to specify these properties. By identifying multiple properties such as tensile, yield, and elongation – or by working with their wire producer to define them, a buyer will benefit from highly consistent material optimized for their specific use case, manufacturing equipment, and needs.

On the flip side, less demanding applications, where manufacturing equipment and processes are deployed that do not have the burden of outputting extremely high performance cable do not need to worry so much about micro-managing the precise mechanical properties of the wire they use to make their wares. This helps procurement teams buying this type of RF cable wire to keep cost and price lower and gives them access to purchasing wire in large quantities economically.

WHAT OTHER FACTORS CAUSE THE PRICE OF COPPER WIRE TO BE HIGHER OR LOWER?

Plating Thickness

When buying silver-plated copper wire for your RF Cable production needs, the silver content and silver plating thickness play a part in driving the price of the wire up or down. Many buyers assume that the material is plated after rolling or drawing as the last operation in wire production, but this is not always the case.

Plating sometimes comes before rolling, and in other cases it is done after the wire is at or near its final thickness & width – it depends on many factors we won't go into, and sometimes varies from manufacturer to manufacturer as well. The thickness of the plating and silver content of the finished product impacts pricing regardless.

Merely specifying the silver thickness or silver content required often has an impact on price. Suppose your application demands a specialized plating thickness within a tight tolerance of variability throughout the length of the wire in order to meet your spec. In that case, the price of that wire will go up due to the precision needed. This also requires you to seek out a manufacturer who possesses the specialized tools and expertise needed to produce the wire with that level of accuracy and consistency.

There are other ways that the silver-plating thickness may impact price. For example, the specification you're working with may indicate that you need a silver thickness of 40 microinches to meet your spec. Still, suppose you're encountering issues in terms of signal loss in the final product. In that case, you may need to consult with a wire manufacturer with expertise in metallurgy who can analyze your unique manufacturing processes & equipment.

The plating thickness or some other property required by your spec may not be sufficient or may be incompatible to some extent with your operations. The wire producer may recommend evolving your internal spec to 60 microinches min or even 80 because that additional silver can improve the overall signal transmission of the cable. This leads to an improved signal carriage, reduced signal loss, and ultimately enhances the signal's speed. However, increasing the thickness of the silver will increase the cost of your silver-plated copper material.

CONTINUATION OF OTHER FACTORS THAT CAUSE THE PRICE OF COPPER WIRE TO INCREASE

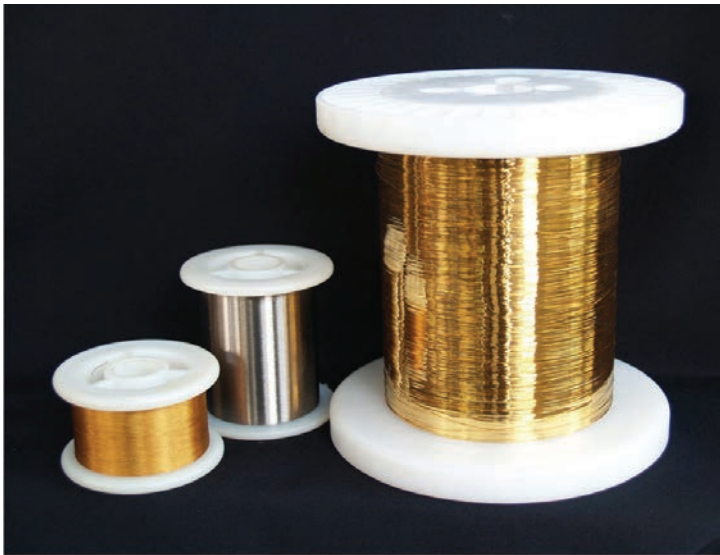
Aspect Ratio

The relationship between the thickness and the width of the wire can cause the price of copper clad aluminum, steel, or silver-plated copper to increase or decrease. The aspect ratio between thickness and width of the wire can influence prices an RF Cable buyer will experience.

Different aspect ratios increase the amount of cold work required to produce the finished wire product. The cold work, as well as the other precision factors detailed throughout the article can cause the price of these wires to be higher.

Suppose your application doesn't demand high aspect ratio wire, and instead utilizes a more standard width to thickness ratio. In that case, this will cause the price of your wire to be lower than a higher aspect ratio wire of a similar configuration.

When you need difficult aspect ratios and tolerances get tighter, the price of that material will be higher. A pricier wire is produced using more operations, at slower speeds, and utilizes more advanced equipment and people to make.



Alloy Requirements

This is likely unsurprising to most buyers, but different alloys have different costs associated with them. Standard 110 ETP (Electro tough pitch) is typically lower priced than the more pure 102 oxygen-free copper. Other alloys that are usually priced higher are other non-standard materials that have certain properties imbued into them that result in higher performance, such as copper-clad aluminum or copper-clad steel. These specialty clad wires are typically more costly than standard copper wire or silver-plated copper for many reasons, including the difficulty of acquiring these alloys and the high level of technical expertise required to process them. Specialty alloys such as these are typically more challenging to manufacture, have lower availability in the marketplace, and this will usually show up in the material's price.

Suppose your RF Cable application doesn't have specialized demands pertaining to the alloy used, and you can get away with a standard commodity copper material. In that case, the price of your wire material will be considerably lower.



Fast Fourier Transform (FFT) Requirements

Recently, the marketplace has begun to see a push for improvements in helical wrap wires that will allow cables to increase in bandwidth and overall length. The prevailing solution for this problem is by improving FFT for better VSWR (Voltage Standing Wave Ratio) performance. This is something you will surely look to improving if you often encounter failure or undesirable performance results from your finished product.

Fast Fourier Transform is one of the most important algorithms in the information sciences and essential for ensuring performance in precision RF Cable wire manufacturing. Wire manufacturers such as Ulbrich Specialty Wire Products monitor FFT like it's our Coinbase account looking for any irregularities such as variations of diameter, eccentricity, and capacitance pose a risk for data transmission in the final cable product.

This is high-tech stuff we're talking about here and cable producers or assemblers who absolutely cannot have signal loss issues should look to partner with wire manufacturers who have expertise in rolling wire and drawing with optimal VSWR. Consider the big picture as well, as your current wire suppliers may be doing some FFT measurement, there are challenges to trying to pick up FFT variation on something that's very thin. You may need to diversify your supply base to include a partner capable of measuring Fast Fourier Transform data at extremely high resolution in order to identify the root cause of your signal challenges and make micro-adjustments inline as the wire is being rolled in order to achieve your desired result.



The demands placed on high performance cables these days are getting more extreme, requiring unprecedented levels of precisions. Higher frequencies and longer link cables are becoming more prevalent in the world today, which is another contributing factor.

Lower priced wire is probably not even being measured for FFT. Logically, this means that wire which is produced with minimizing signal loss and optimizing FFT for VSWR performance results in higher costs to the buyer. If you need high performance, and consistency, however, this increase is a small price to pay.

In contrast to wire monitored and optimized for FFT performance, lower priced RF Cable materials are usually just produced to a thickness and width and a plus or minus tolerance. If this is the case for your company, and the specification you're working with, then you will experience lower prices than a higher performance wire where signal consistency and higher frequency are absolutely critical.

IN THE END, THE PRICE OF WIRE FOR RF CABLE PRODUCTION DEPENDS ON MANY VARIABLES

Ultimately, the price of your engineered wire materials will depend on the final cable you're producing, as well as the unique needs of your business, engineers, customers, and the equipment used to assemble your final product.

Some RF cable manufacturers will be great fits for a standard wire product due to their needs and specific end use application not requiring extreme performance or highly customized attributes. Others, such as those manufacturing cables used in lab test & measure equipment, space exploration, or military applications need their wires to have highly specific properties and/or require highly precise dimensional consistency. It may seem cliché, but the best way to get pricing for the material you need is to contact a wire manufacturer like Ulbrich and have a conversation about the cables you're producing, including materials, performance characteristics the cable needs to exhibit, and the conditions of end-use. Only then will you have a clear understanding of what is needed to meet your requirements and product goals.

Ulbrich Specialty Wire Products is a leader in producing wire materials within the RF Cable space that adhere to, and oftentimes exceed, the requirements set by the most rigorous and demanding specifications. Our state of the art wire manufacturing facility located in SC has served this market for many years, and employs some of the most sophisticated engineers in the country who help our customers meet the challenges they face every day in producing high performance RF & Microwave wire cables.

Click on the video recording below to watch our product managers and technical team guide viewers through the issues they are facing and explain what capabilities are within Ulbrich's means to address those issues during a live Q&A.

We'd love to hear more about the issues you are encountering when it comes to optimizing your cable's signal bearing properties and producing high frequency, high performance RF Cables. Reach out today and speak to one of our highly skilled engineers about your critical application.

Ulbrich is your development partner for specialized wire products used in RF and high performance cables.



HIGH PERFORMANCE
Center Conductor



PRECISION ENGINEERED
Flat Wrap Wire



ROUND & FLAT
Braid Wire

Q&A: How to Go Beyond Industry Specs to Meet Next-Generation RF Cable Material Requirements

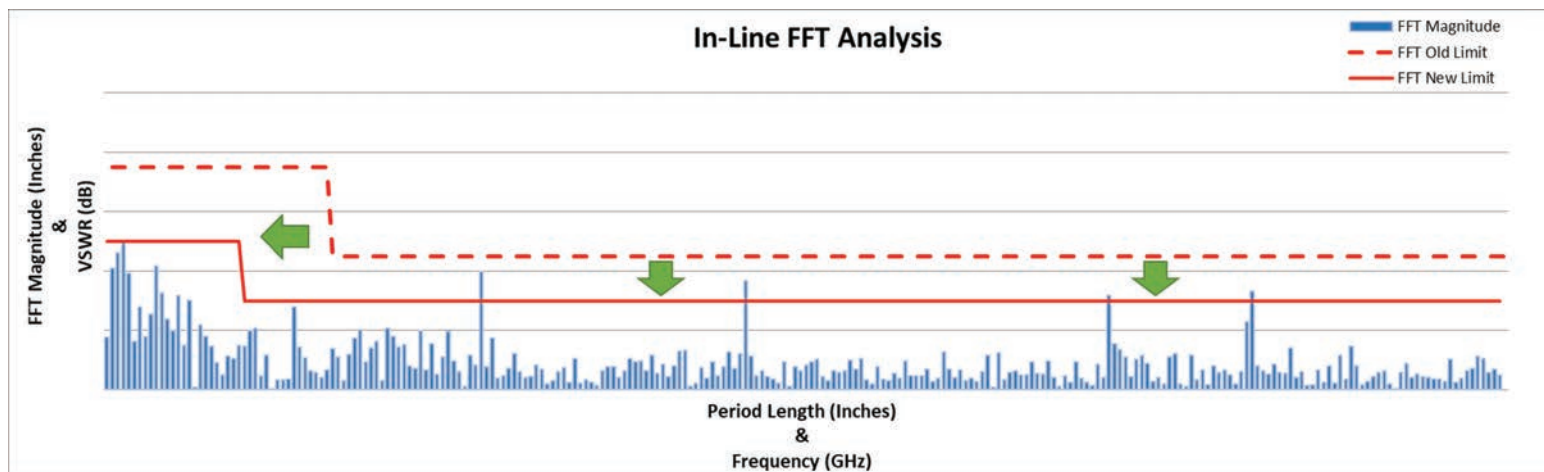
The following questions are frequently asked by customers looking to optimize the performance of their cables.

HOW DOES SWITCHING HELICAL WRAP WIRE MATERIAL FROM SPC TO ALUMINUM ALLOY AFFECT COAX ATTENUATION? ASSUMING EVERYTHING ELSE IS LEFT UNCHANGED.

It's unclear whether the material change itself affects attenuation in the assembled cables. That said, we can hold copper-clad aluminum products to similar FFT limits (from a dimensional standpoint) as traditional copper wrap wires. This indicates that (assuming everything else is left unchanged), the switch shouldn't introduce irregularities that will disrupt data transmission.

UNDER WHAT SPECIFIC PROCESS CONDITIONS OR MATERIAL PROPERTIES IS FFT APPLIED?

FFT Measurements are only performed on the wire's physical dimensions. Thickness and width are first checked while the rolling process is being set up to ensure the machine is in its optimal condition. FFTs are then rechecked at spooling to ensure dimensions remained consistent throughout the entire run.



This is an example of the FFT used during production. The period length on the x-axis correlates with frequency on VSWR plots and the FFT magnitude on the y-axis correlates with decibel level on VSWR plots. It also shows how FFT limits might need to be tightened to compensate for changes in bandwidth or new VSWR requirements such as lower decibel limits.

DO YOU OFFER STRANDED CONDUCTORS AND IS FFT ANALYSIS AVAILABLE FOR THEM?

Ulbrich has recently begun a partnership with a company that can strand our wire. While FFTs have not yet been performed on stranded conductors, our gauging and FFT analysis program could possibly be adapted to look for repeating patterns in conductor lengths of interest.

WHAT FREQUENCY RANGE SEEMS MOST COMMON FOR FFT ISSUES? FOR EXAMPLE, DO FFT ISSUES EVER OCCUR ABOVE 20 GHZ OR HIGHER?

This will be different for different cable assemblies based upon cable diameter, wrap wire overlap, etc. but we are typically monitoring FFT spikes in the 1"-30" length along the wire. We're working towards measuring down to wire lengths as small as 0.1" to cover even the highest frequencies.

DO YOU PERFORM FFT ON ROUND WIRE DRAWING?

Yes, we can perform FFT analysis on round wire drawing. We have typically provided this for center conductor applications. To establish the appropriate setting in the program, we would need to know some additional cable parameters.

WHAT ROLE DO LUBRICANTS PLAY IN THE PROCESS AND FINAL PRODUCT?

Lubrication is used in rolling and drawing round wires using cold work. They aid in lowering friction, heat dissipation, tool wear, and surface finish. It's important to note that these lubricants must be free of silicon, which can compromise signal transfer in the finished RF cable.

Ulbrich uses engineered lubricants compatible with the specific metals being produced including silver-plated copper and bare coppers. We filter our lubricants to micron levels to remove metal fines. In some cases, lubricants may be applied during the final winding. This is common when manufacturing braid wires. At Ulbrich, we use a "vanishing oil" called Isopar that can be used by itself or mixed with prescribed blends of mineral oil to apply evenly to the braid wire surface. This provides a smooth releasing agent during the dynamic motions required in braiding.

CAN TIGHTER SPECS THAN ATSM B298 BE CREATED?

Yes, we can create tighter specs than what is included in ASTM B298. We would need to see exactly what changes to ASTM B298 are being proposed but as long as we have the processing capability to meet the new spec, we are open to writing a customer-specific spec for your precise needs.

CAN WE GET GRADE 40 AND GRADE 30 COPPER-CLAD STEEL?

We commonly carry two grades of copper-clad steel, both with 40% IACS Alloy W40C06 would be for lower strength applications and we also carry W40C22 for higher strength applications. While we do not carry 30% IACS copper-clad steel, it is available to us through our supply chain.

IS IT RECOMMENDED TO USE LUBE FOR A HELICALLY-WRAPPED APPLICATION? WHAT LUBES AND MIXTURES ARE AVAILABLE?

Lubricants are typically only used on braid wires. However, the same application technique could be used on wrap wires. Ulbrich typically uses Isopar with anywhere from 0-10% mineral oils mixed in. If a customer has another lubricant they are interested in, we would be glad to discuss using that as well.

WHAT SORT OF INSPECTION METHODS ARE USED TO GUARANTEE A PROPER WRAP IN THE PACKAGE SPOOL TO PREVENT WRINKLES?

Wrinkles in the material can be managed with proper spooling settings. It's almost important that the spool itself is dimensionally solid and sound. To prevent wrinkles, our operators look for a level wind across the traverse without "build up" or "drop off" at the flange. We write specific spooling parameters into the process instructions for each part to ensure product consistency.

If you have further questions, don't hesitate to contact us. We're more than happy to share our expertise!



We Deliver Precision®

ULBRICH.COM

CAPABILITY SHEET

Innovative Leadership in Aerospace RF Cable Wire

AS COMMERCIAL AND DEFENSE AVIATION ADVANCES, SO DOES ULBRICH'S ABILITY TO PROVIDE LIGHT WEIGHT AND HIGH STRENGTH MATERIAL THAT ALLOWS PLANES TO FLY MORE EFFICIENTLY THAN EVER.

MATERIALS THAT WILL WITHSTAND HOTTER TEMPERATURES

To meet these temperature demands, Ulbrich offers heat-resistant super alloys (HRSAs), including bi-metals:

- Silver Plated Copper Clad Aluminum
- Silver Plated Copper Clad Steel
- Titanium and Nickel Alloys



CONTINUOUS PURSUIT OF INNOVATION

We're on top of the latest trends, processes and industry-specific requirements. Our light weight materials offer increased strength & corrosion resistance.

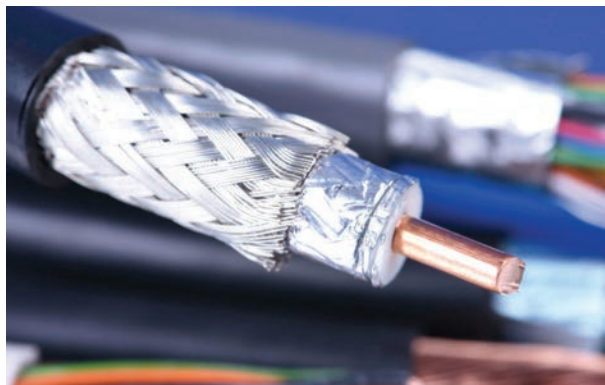
NO MARGIN FOR ERROR

At 35,000 feet, every detail matters. From material selection to manufacturing and everything in between, we're dedicated to precision.



Precision Products & Alloys for Electronics

WE'RE ALWAYS LOOKING FOR WAYS TO INNOVATE AND IMPROVE UPON ELECTRONIC DEVICES



In addition to our state-of-the-art capabilities in rolling, slitting, and annealing, Ulbrich is continuously testing, researching, and analyzing alloys and their chemical and mechanical properties to maximize performance potential. What does this mean for you? It means when you partner with Ulbrich, you not only get the best of the best in personnel, process, and product—you also get a promise of a team that truly cares about making your electronic device as consistently successful and effective as possible.

GLOBAL REPRESENTATION WITH SERVICE & DISTRIBUTION CENTERS LOCATED WORLDWIDE

Ulbrich Stainless Steels & Special Metals, Inc., is a family owned company in its fourth generation of leadership. Established in 1924, Ulbrich has become a critical supplier of stainless steels and special metals to the RF & Microwave Cable Industry. During this time, we have participated in the development and manufacturing of hundreds of innovative high tech electronic applications. With industry leading Dimensional Control, real time gauging and Statistical Process Control (SPC), a large variety of specialty alloys, and the best customer service available, we strive to produce and distribute the highest quality materials to you. Ulbrich is comprised of a series of manufacturing divisions that supply specialty strip and foil, as well as precision flat, fine, round, plated and shaped wire, all with local management and all designed to provide custom metal products to satisfy the needs of original equipment manufacturers.

YOU HAVE IDEAS. WE HAVE RESOURCES. PARTNER WITH LEADING EXPERTS.

With Ulbrich's world-class Development Innovation Team, you can gain access to product specialists and quality metallurgists, each with expertise that is best-suited for your unique raw material needs. Our team can deliver custom material solutions to maximize the performance of your application. Talk to a specialist today to learn about what finishes, edge capabilities, mechanical properties, packaging and lengths we can offer for your application! Learn more about our Development Partnership online at www.ulbrich.com/company/development-partnership

Contact Ulbrich For Your RF & Microwave Cable Wire Needs!

info@ulbrich.com | **800-243-1676**

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