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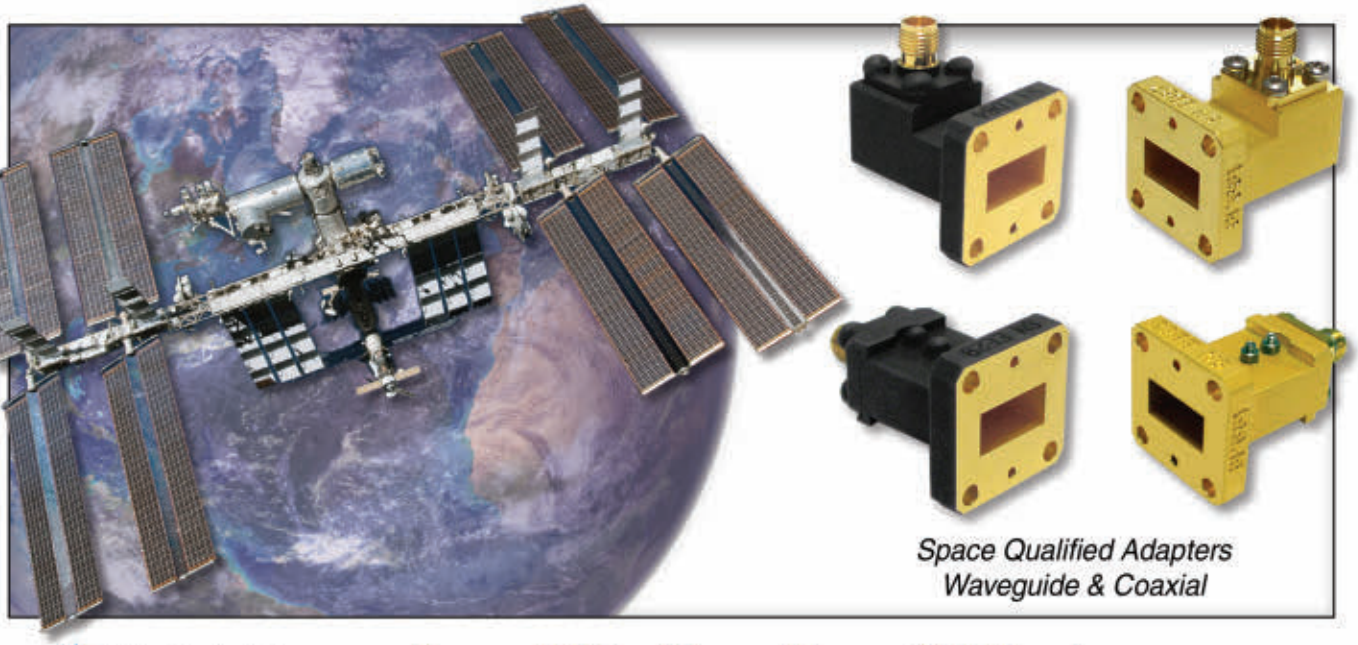

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Cables & Connectors Supplement

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2012 RF Connector and Cable Assembly Outlook

From its very beginning, the RF/microwave industry has understood that a good electrical connection between coaxial components, modules, subsystems and large platforms should not be taken for granted. Like high tech plumbers, our professional predecessors developed the coaxial cable and connector systems that allowed microwave signals to flow with minimal disruption and insertion loss through the modular electronic building blocks of today's communication, avionics, EW, radar, measurement, medical and industrial high frequency systems. In addition to addressing electrical performance, these manufacturers have also developed products that provide reliable and repeatable mechanical connections for all types of hostile operating environments and applications.

As modules and system technologies continue to evolve, so too does the state of interconnect technology. Similar to Moore's Law, these systems follow a universal trend toward miniaturization and added functionality, placing new demands on the interconnect design. Meanwhile, pressure to reduce costs combined with the availability of cheaper offshore labor is changing the manufacturing landscape and global supply chain. Cost, miniaturization and complexity are leading factors in a changing RF cable and connector market. In this special report, Microwave Journal examines these market and technology trends as well as some noteworthy developments among manufacturers.

RF CONNECTOR MARKET TRENDS

According to connector/cable industry analyst Bishop and Associates Inc., the global RF connector market is expected to reach nearly $3 billion in annual sales this year. This reflects a decade's worth of growth ranging from 8 to 11 percent per year. Seventy percent of RF connector sales are attributed to four major market sectors, namely communications, military, computers and industrial. These markets represent high volume consumer products as well as the high performance, low-volume/high-mix products required by aerospace and defense. Markets that are not traditionally associated with RF, such as transportation and medical applications are expected to show significant growth as wireless monitoring and machine-to-machine (M2M) becomes the norm.

Fleck Research estimates the North American connector market to be valued at $1.3 billion, compared to a $765 million connector market in China and a $650 million European connector market. The rest of the world makes up the remaining 10 percent (see ***Figure 1)***. Emerging markets such as China and India are the fastest growing with CAGRs well into the teens.

Each market has its own driving factors pushing RF connectors toward miniaturization

DAVID VYE
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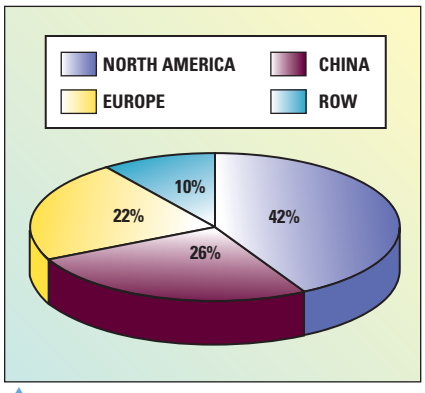

Fig. 1 Percentage of global RF connector sales in 2010, according to Fleck Research.

and increased bandwidths. Smaller connectors are critical to reducing the size of handhelds, tablets and the next generation of laptop computers such as Intel's recently announced Ultrabook. Miniaturization also helps lower the overall weight of RF systems in airborne applications, which is needed to reduce fuel consumption. Conserving fuel is especially critical for launching spacecraft and lengthening the mission time and range of next-generation UAVs, such as the smaller platforms slated to replace today's Predator force.

MIL/AERO

The military/aerospace market for cable assemblies represents approximately 11 percent of the worldwide market for all cable assemblies (including non-RF) at a value of $12.7 billion in 2010. In that year, China had the most growth, at 21 percent, and Japan had the least amount of growth at eight percent. The military and aerospace industry is a major source of technology development and jobs. Unlike other industries, the defense business depends critically on governments to be regulators, customers and investors. On average, over the last five years, governments worldwide have consistently spent 2.7 percent of their global gross domestic product on military expenditures.

In 2010, North America led connector sales to the military/aerospace sector with 47 percent of all worldwide defense end-market sales, according to research by Bishop and Associates. North America has consistently demonstrated strong connector sales to the aerospace/defense sector and enjoyed the second-largest year-to-year growth in 2010. According to the same report, China ranked behind Europe and Japan in overall connector sales to the military sector but exhibited the greatest growth over the previous year.

Much of China's military spending for connectors and cable assemblies remains invisible to the outside world, as products are produced in government-run factories and many of the components are not purchased on the open market. The information that is available points to a rapidly growing market that may open up to commercial competition in the near future. RF connectors manufactured in China for internal consumption and export include a variety of types (discussed later in this article) such as SMA, SSMA, SMB, SSMB, MMCX, SMP, SMZ, SMC, SA, BMA, BNC, TNC, N, K, F and SPC3.5. These commonly have nickel- or gold-plated contacts. Compact variants MMCX, SSMA and SSMB, and 1.9, 1.85 and 1 mm units are also popular targets by manufacturers in China because of the miniaturization trend in targeted applications.

Meanwhile, the U.S. military will keep its defense systems updated with the latest and greatest technology, i.e. smaller, lighter, faster and more mobile systems, by frequently replacing the electronic modules in its older airplanes that may have a service life of thirty years or more. Therefore, modules must be connectorized to support regular replacement. This approach drives the demand for both standard and customized connector solutions.

Unfortunately, a recent report from Fleck Research confirms the overall weakening of demand for military connectors in upcoming years. Former Defense Secretary Robert Gates initiated the rethinking of future DoD spending citing a shift in the U.S. military's global focus/priorities and in anticipation of funding cuts in an era of government austerity. As a result some new programs will be delayed or cancelled.

For the Marines, the F-35B Joint Strike fighter was threatened with a two-year delay. Recently, Defense Secretary Leon Panetta removed the F-35B model from its two-year "probation" a year ahead of schedule; this was only after its development was put back on track with two other F-35 models being developed for the U.S. Air Force and Navy. Still, the Marine Expeditionary Fighting (ship-to-shore) vehicle has been cancelled and the Army's SLAMRAAM surface-to-air missile and over-the-horizon launch platform have also been nixed.

Aerospace and defense analyst Rob Spingarn projects that spending cuts on defense could total approximately one-third of the total $2.4 trillion spending cuts over the next 10 years as outlined in the debt deal from this summer's debt ceiling fight between congress and the Obama administration. Spingarn believes that the majority of the DoD cuts are likely to be in procurement, starting in fiscal 2012 and 2013, with specific program cuts identified in early October 2011.

GOOD NEWS FOR DRONES

On the upside, Fleck Research considers the most significant factors governing future military connectivity include the federal government's mounting interest in the use of UAVs and the escalating challenges to competing with China as a formidable military power. This past summer, Sen. Kent Conrad (D - ND) told reporters for Avionics Intelligence that the number one request he has heard from combatant commanders in battlefield situations is for more unmanned aircraft. Moreover, the demand for drone-enabled surveillance has spread into other vertical segments such as law enforcement and border control.

Supplier	Total Sales in U.S. Dollars (billions)	Percent of Total Sales
UNITED STATES	170.764	39%
RUSSIA	81.059	18%
FRANCE	37.4	8%
UNITED KINGDOM	29.803	7%
CHINA	15.272	3%
GERMANY	22.807	5%
ITALY	15.134	3%
OTHER EUROPEAN	47.024	11%
OTHERS	23.654	5%

Notes: Percentages are rounded; each country shown as follows.
Developing Countries
Industrialized Countries

Fig. 2 Overall global arms exports in 2010.

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Although the U.S. Defense budget may be flat or down slightly year-over-year, the U.S. market for arms export is still strong. Responsible for nearly 40 percent of the total yearly global arms sales in 2010, the U.S. is by far the largest exporter of arms. According to a report on Conventional Arms Transfers to Developing Nations (Sept. 2011) by Richard Grimmett of Congressional Research Services, U.S. arms exports totaled $170.7 billion, followed by Russia ($81 billion), France ($37.4 billion), UK ($29.8 billion), Germany ($22.8 billion) and China ($15.3 billion) (see ***Figure 2***). Sale of advanced military hardware to areas such as the Middle East and Taiwan will help maintain the cable assembly market for mil/aero products through 2012.

Defense cuts have not affected the development and production of UAVs, with platforms that supposedly range from the size of a large insect, right up to that of a conventional fighter jet. For the period to 2015, it is projected that the market will have a 10 percent CAGR with the global market exceeding $94 billion by 2021 according to a Teal Group Corp. report from last March. Growth for RF connectors in UAV applications will likely track this 10 percent CAGR. In addition to offering ruggedness, performance and lower size/weight, RF connectors targeting use in UAV platforms will need to withstand altitudes up to 70,000 feet, temperatures from -60° to 75°C and frequencies up to 40 GHz.

SHIFTING SANDS IN THE MARKET

Who will benefit most from this demand? Each market has its own set of priorities dictated by a variety of factors. Pricing certainly drives a portion of many buying decisions and is forcing suppliers to lower their manufacturing costs as best they can. And yet, the true cost of using a particular vendor's connector or cable assembly includes additional considerations such as performance, quality, reliability, catalog (available products), on-time delivery, manufacturing capacity and the ability to successfully execute custom engineering in a timely manner.

Literally thousands of companies manufacture RF connector and cable assemblies globally. Leading vendors do well in various connector/cable assembly markets according to how strongly they compete in any of these areas and how important that attribute is to a given market. Reputation and existing customer relationships, along with continued investment in R&D to improve performance, size and manufacturing should allow these companies to survive and expand. Strong brand awareness and a reputation for quality and reliability have considerable value in the interconnect component market today. As foreign competition heats up and lower priced products hit the market, brand loyalty may help leaders to retain customers and maintain margins.

Regular, in-depth conversations with end-customers are often required to ensure that product specs meet or exceed their needs. Developing clear two-way communication for product and service related support builds trust and ultimately improves the end product. As a result, many leaders are successful in getting their products "spec'd in" to OEM require-

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ments, which drives customer loyalty (by increasing switching costs) and allows for premium pricing relative to commodity products.

This dedicated in-house expertise has helped industry leaders expand their share within growing niches in the market. For example, companies focusing on the military and aerospace market have been able to develop long-term customer relationships with premium pricing arrangements. Industry specialization makes companies more attractive for take-over because specialization allows the new parent company to increase their exposure to specific end-customer markets. These acquisitions are often easier to integrate into the existing customer-based structure of the overall organization. As a result, premium valuations are frequently attached to any company targeted for a merger or acquisition if they have developed a clear specialization in the medical, military, aerospace and/or industrial markets.

▲ *Fig. 3 Cable assembly line in China (courtesy of Wellshow Technology Co.).*

Still, the manufacturing supply side has been undergoing some interesting shifts over the past few years. Firstly, components are increasingly being manufactured in places where the labor costs less than in the U.S. A number of leading manufacturers have developed offshore manufacturing capabilities in order to achieve significant cost savings, especially for high-volume production runs. Although many companies outsource these activities, many leaders own and operate manufacturing facilities in order to retain greater control over quality and production schedules (see ***Figure 3***).

As a result, electronic product manufacturing continued to migrate to China in 2011 despite recent increases in wages. One recent report indicated that average wages for Chinese workers will double by 2015. Therefore, the incentive for many U.S.-based companies to move into China is now focused more on being close to growth markets rather than low-cost manufacturing.

A second factor that may push development offshore is the DoD's effort to restrict the flow of bleeding-edge technologies. ITAR is hindering the ability of U.S. companies to compete globally. By restricting the counties to which U.S. manufacturers can sell their best technology, ITAR limits the ability of these suppliers to generate revenue through exports while encouraging foreign markets to develop these technologies independently. The proposed ITAR reforms may help alleviate some of these issues, but they appear to be far from getting approved in the near future.

In the last two decades, regional shifts in manufacturing has left voids in some basic areas, including master tool and die making, precision metal working and assembly as well

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as high-volume production, particularly in small, high-volume systems. This trend is unlikely to change as long as Western labor must compete with the work conditions, hours and wages that are only acceptable to a worker in an emerging market. In the short term, markets relying on high levels of performance and manufacturing achieved through sophisticated engineering and automation will favor domestic production. Long term domestic production is at risk unless this advantage is maintained or the global landscape changes (i.e. scarcity of materials, trade barriers, security restrictions, etc.). Arguably, China's competitive advantages are largely due to government subsidies, sparse regulation on the environmental impact of dirty manufacturing and most importantly – currency manipulation. The current political dialog of reinvesting in American manufacturing and skilled training comes at a critical time but will also require a tougher stance on global trade and manufacturing processes to be effective.

CABLE ASSEMBLY MANUFACTURING

The majority of system integrators have found it cost effective to shift their cable assembly design to specialized suppliers with established solution-oriented design, quality and manufacturing techniques. The given application will dictate whether the interconnect will be exposed to harsh outdoor conditions, require specific performance characteristics such as low passive intermodulation (PIM) and which cable type, i.e. hand-formable, semi-rigid or flexible is needed. Cable assembly houses also invest in the dedicated equipment necessary to produce high tolerance, reliable components, such as those shown in ***Figure 4***.

A typical coax cable assembly house will have a number of critical component dimensions measured and controlled through their own proprietary statistical process control program. Hipot and continuity testing along with visual inspection and gauge measurements are used to ensure that the process is in control. Typical in-house testing includes parameters such as VSWR, insertion loss, phase and delay measurements, as well as most standard mechanical and environmental tests (temperature range, humidity, vibration, shock and abrasion) as required by the standards called for by the given application.

Cable types and connectors have become rather specialized to meet the exact demands of how and where they intend to be used. For instance, test cables are designed for precision, flexibility and reliability over numerous mating/unmating cycles. One of the ways manufacturers address the wear and tear of high connection cycles is through improved surface plating of the connector. Although gold, silver and nickel are still widely used, proprietary platings have been developed by many manufacturers that combine these materials, as well as add additional materials to provide improved plating options.

One leading supplier offers a proprietary tri-metal plating solution containing copper, tin and zinc as an enhanced alternative to nickel/gold plating. The non-allergenic, nickel-free connector offers low-contact resistance, over 1000 mating cycles, and reasonable corrosion resistance. It is also non-magnetic, so its PIM characteristics are comparable to silver. For even more abrasion and corrosion resistance, a non-magnetic nickel-phosphorus base material with a thin plating of gold is also available. This product provides for twice as many mating cycles as components based on standard gold plating, as well as low and stable contact resistance and added protection against oxidation and corrosion.

RF assemblies are increasingly found in remote wireless monitoring systems from oil fields and factory floors to hospital medical equipment. There are RF assemblies in the medical field, both in general and disposable applications. The proliferation and ubiquity of wireless systems and their RF interconnects has led to concern over environmental impact. Legislation regarding end-of-life product recycling and additional safety requirements is having an impact on cable manufacturers. Industry standard RG-type PTFE/FEP cables are extremely resistant to decomposition. Regulations mandating that manufacturers recycle products at the end of their service life will eventually off-set the cost-saving benefits associated with the continued use of PTFE cable. PTFE cables also contain halogen, which gives off highly toxic and corrosive gases when ignited, creating major safety issues. In response, certain manufacturers are beginning to offer cable products that are halogen-free and composed of recyclable plastics that are not as resistant to decomposition as PTFE.

▲ *Fig. 4 CMC semi-automatic stripper assures quality with precision and stable tolerance control.*

CONNECTOR TYPES

RF connector types are segmented into primary families and sub-families, organized by size, frequency, coupling method and style. The frequency range of any connector is limited by the excitation of the first circular waveguide propagation mode in the coaxial structure. A decrease in the diameter of the outer conductor will result in an increase in the highest usable frequency. Filling the airspace with dielectric material in order to support the inner conductor will lower the highest usable frequency while also increasing the insertion loss.

Various connector types employ a range of mating technologies. The mating process typically changes the geometry of the mating surfaces and resistance loss at those interfaces as well as geometric changes, which result in variation of impedance and loss. This is an area where designers of high-precision connectors and cable assemblies focus their attention. Most connectors are designated as male or female depending on their internal structure. Many female connector types are designed with slotted fingers to accommodate tolerance variations of the mating male inner conductor. This design feature can reduce repeatability, introduce a small inductance and may eventually wear out after numerous re-connects.

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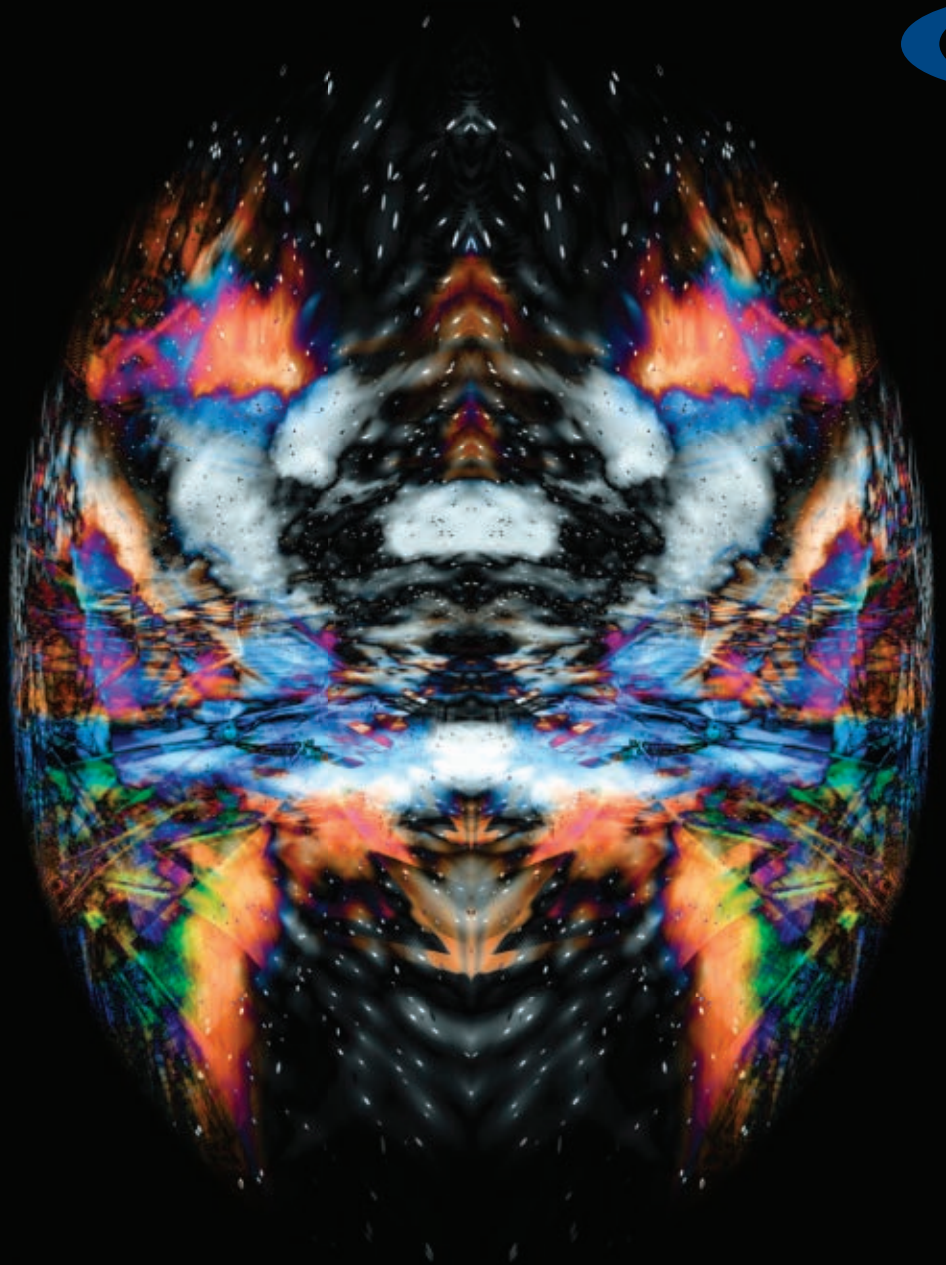

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Board-to-board connectors are commonly found among all the major markets and represent the fastest growing members of the connector family. One example is the notebook PC with built-in wireless card and multiple antennas. PC manufacturers are required to make their products field serviceable by designing them with replaceable screen and system boards. Board-to-board connectors allow these components to detach from each other. With thinner system packages and wide format screens, real estate is becoming a real challenge to connector suppliers. In addition, 802.11x devices operating at higher frequencies are driving the need for very small, high-performance interconnects as well as a rise in the number of multi-port coax solutions being offered on the market.

Many manufacturers are setting their sights on board-to-board connectors because of the variant's low production costs and wide use in wireless equipment, including base stations, remote radio heads (RRH) and GPS devices. Several foreign enterprises have launched MCX, MMBX, IMP and SMP series. The last is composed of two connectors placed on two PCBs or modules and an adapter. In the next three to five years, these three parts are forecast to merge, which will help lower outlay and raise precision levels. Local makers therefore expect RF connectors to replace coaxial cable assemblies in board-to-board applications gradually. The latter, however, will continue to be the primary choice in the external connections of communication, military and industrial equipment.

STANDARD CLASS

The Type N connector was originally designed in the 1940s for military systems operating below 5 GHz. Most sources attribute the "N" designation to an RF engineer from Bell Labs named Paul Neil. Subsequent improvements to its design have pushed the mode-free performance up to 18 GHz. The "Bayonet Neil-Concelman" commonly known as the BNC was originally designed for military use but has gained wide acceptance in video and RF applications to 2 GHz. A threaded version known as the TNC helped resolve the connector's leakage and geometric stability problems, allowing the TNC to be used up to 12 GHz. The 7/16 DIN is a high-power 50 Ω connector originally developed by Spinner. This relatively new connector is growing in popularity especially in wireless applications including cellular towers. This connector, which is plated in silver or gold, performs up to 7.5 GHz.

SUB-MINIATURE CLASS

The SMA (Subminiature A) connector was designed by Bendix Scintilla Corp. and Omni-Spectra Corp. as the OSM connector, and is one of the most commonly used RF/microwave connectors. This connector is often used with semi-rigid cables, which are connected infrequently. In contrast, the subminiature B (SMB) snap-mount connectors are rated to 4 GHz but usable up to 10 GHz for applications requiring easy and fast connect/disconnect operations. Its mechanical design leads to poor electrical performance especially for low noise applications. The SMC is a threaded type connector that is ideal for size constraints and in the case where a threaded solution is viable.

MICRO-MINIATURE CLASS

Smaller versions of the SMA include the Sub-SMA or SSMA and OSSM types. At 70 percent the size of an SMA, these connectors are typically rated up to 26 GHz, but special high-performance versions are available with mode-free performance up to 40 GHz. Other snap-on types include the MCX family (MCX and MMCX), which are rated to 6 GHz. These connectors are 70 percent and 50 percent the size of an SMB connector, respectively, offering about

Family classification varies, but some commonly recognized groupings and connector types include:

Standard Coax
- N Type, HN (high voltage N type) – screw-on, up to 11 GHz
- SHV, BNC HT, MQ HT, THT-20 – high voltage
- C/SC Type, bayonet coupling, high power, up to 11 GHz
- 7/16 DIN – screw on, high power, low PIM, up to 8 GHz

Miniature Coax
- BNC, mini-BNC, TNC, bayonet coupling, mil, RF and video apps, up to 4 GHz
- UHF, Miniature UHF, M-Type – screw-on, up to 1 GHz
- Dezifix (Rohde & Schwarz)
- GR874 (General Radio)
- LC

Sub-Miniature Coax
- SMB – snap-on, up to 4 GHz
- SMC – #10-32 screw-on, up to 10 GHz
- FME – screw-on, easy connect, up to 3 GHz
- SMA including variants:
  - 3.5 and 2.92 mm connectors, which cross-mate with SMA
  - 2.4, 1.85 and 1.0 mm connectors, which do not cross-mate with SMA
- FAKRA – snap-lock, automotive RF, up to 4 GHz
- SMZ connector - System 43 (BT43 and High Density HD43) for use in DDF
- MHV/SHV

Micro-miniature types
- OSMT/SSMT – surface-mount, 3 mm height profile, up to 6 GHz
- MCX, OCX – snap-on, up to 6 GHz
- MMCX – micro-mini snap-on, board-to-board or cable, up to 6 GHz
- QSL – low profile, ruggedized for wireless, multiple ports, up to 6 GHz
- OSMM – smaller than SSMA, higher order moding is over 450 GHz
- SMP/SMPM – push-on, performance up to 40 GHz
- SSMA – smaller version of SMA, up top 40 GHz

Ultra-miniature Coax
- IMP – press-on, low cost, board-to-board
- MMT – snap-on, low profile SMT, up to 8 GHz
- MMS – snap-on, low profile SMT, WLAN and GPD handhelds, up to 6 GHz
- UMP – press-on, secure, board-to-peripheral, up to 6 GHz
- U.FL/IPX/IPEX/IPAX/MHF/AMC – WiFi antenna to Mini-PCI board, up to 6 GHz

Precision types
- APC-7 – 7 mm sexless, low reflection for test/meas. applications, up to 18 GHz
- Higher frequency versions with dimensions 1.0 mm (110 GHz), 2.4 mm (50 GHz), 2.9 mm (40 GHz), 3.5 mm (26.5 GHz)

Quick-lock connectors
- QMA, Mini-QMA – designed to replace SMA (18 GHz)
- QN (QL-N), SnapN, HPQN – designed to replace low power N type (11 GHz)
- WQMA – Waterproof version of QMA

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the same number of reliable reconnects (~ 500).

PRECISION CLASS

This class of connectors is used most often in a test environment where accurate and repeatable measurements are required. One well known type is the sexless APC-7 originally designed by Amphenol. Amphenol's APC was the first instrument-grade coaxial connector series to achieve repeatable TE_{11} mode resonance-free signal transmission from DC to 50 GHz with a minimum return loss of 26 dB. These 50 W connectors were designed primarily for use in test and measurement equipment where reliable performance is critical for repeated connect/disconnect cycles. The "Precision SMA" connector was designed by Wiltron (now Anritsu), another test and measurement manufacturer. The two basic geometries are the 3.5 mm/Wiltron WSMA and the 2.92 mm/Wiltron K.

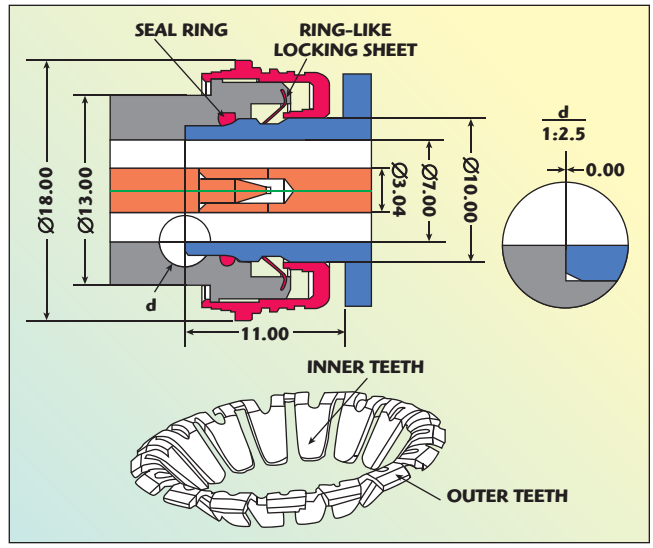

Fig. 5 Cross section of HPQN type quick lock RF connector mechanical design and locking ring.

QUICK LOCK

This connector family was created by the Quick Lock Formula Alliance (QFL), which consists of leading connector manufacturers. Available since 2003, these quick-connect RF connectors were designed to replace the widely used SMA connectors and Type N connectors in cases where the connection/disconnect operation need to be faster and easier by eliminating the need for a torque wrench. In the case of QMA, its basic structural parameters and electronic performance are very close to that of the original SMA connector making it backward compatible with this design.

Variations on a QL N-type connector include the NQ, SnapN and HPQN. The QN designed originally between 2002 and 2004 eliminated the threaded coupling with a snap-in retention and an integrated sealing ring. Unfortunately, clearance between the contact surfaces of the outer conductors leads to instability and potential discontinuity of characteristic impedances. Because of this deficiency, the SnapN design placed a spring at the rear of the outer conductor of the plug rather than between the contact surfaces of the connector's two outer conductors. While improving the performance, the elasticity of the spring made the connector performance susceptible to external forces such as heavy cable swing. The HPQN designed in 2007 improves on this design through the use of a ring-like locking washer, which is fixed in the plug and locks the mating slope of the jack (see ***Figure 5***).

SUMMARY

The HPQN connector represents one example of the ongoing efforts to develop new designs and manufacturing processes to deliver higher performance, lower cost, ease-of-use and a variety of other specific attributes targeting the increasingly specialized requirements for high frequency interconnect technology. The overall market is going at a steady clip of about 8 to 10 percent per year for the past decade, tracking the growth of its leading markets, namely computers, telecommunications, aerospace/defense and industrial. As market competition continues to drive design improvements, connector, cable and cable assembly manufacturers will strive to innovate with new and evolving products. These companies help keep the wireless world connected. ■

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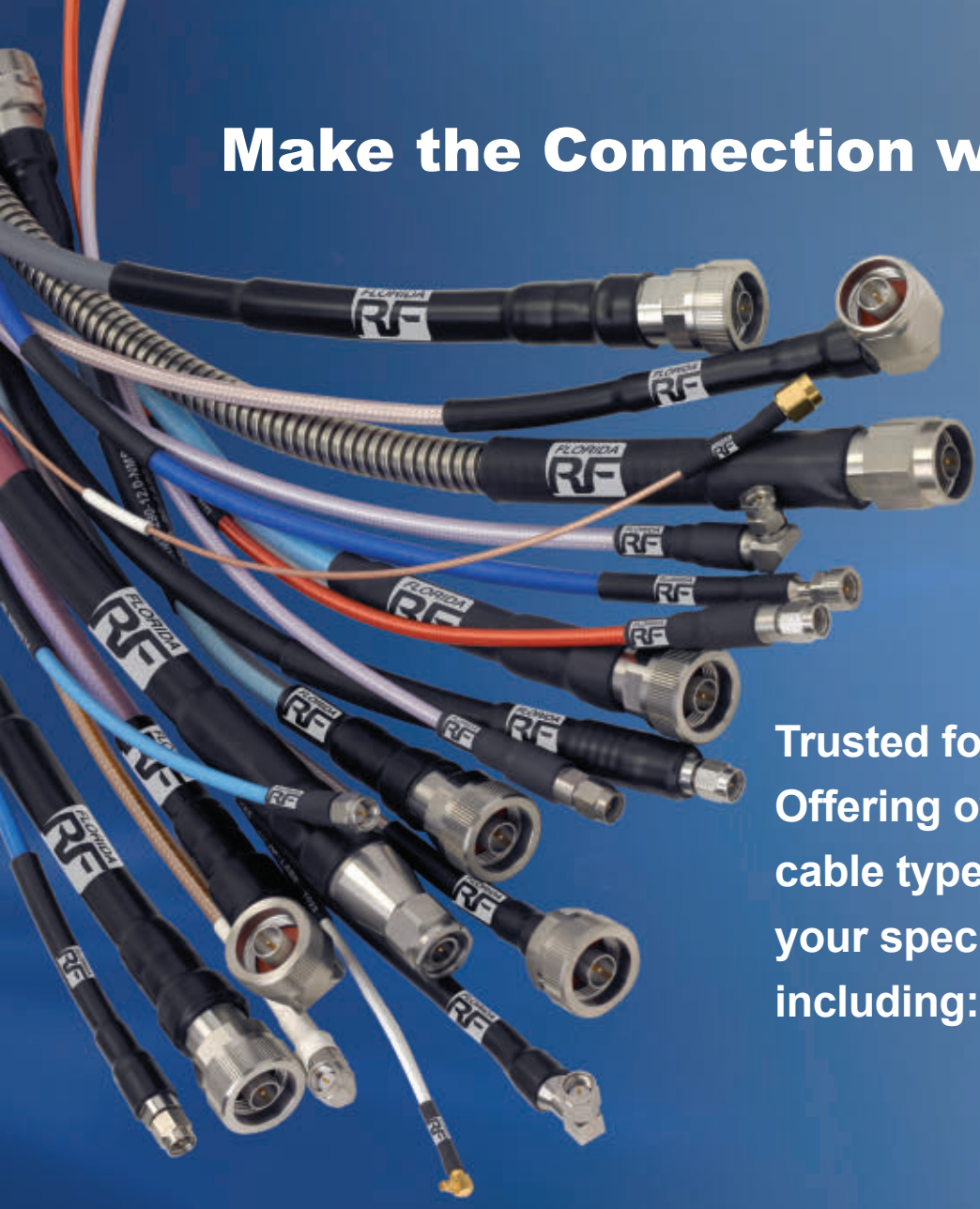

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The Importance of Knowing Your Cable Constraints

The cost of failure in many of today's electrical applications dictates the need for highly reliable RF/microwave cable assemblies — whether failure translates to lost revenue, production downtime, or customer safety. Using ruggedized assemblies has become one of the most common solutions for preserving reliable performance. However, having a ruggedized RF/microwave cable assembly does not necessarily mean the assembly needs to be over-engineered; it simply needs to be properly designed to ensure it is appropriate for the intended use. Understanding the constraints of your application and the environment in which it will be used can ensure that the RF/microwave cable assembly will be properly engineered to provide precise and repeatable measurements with stable electrical performance for your application. Challenges during installation, usage considerations and constraints of the physical environment all affect a cable's performance.

INSTALLATION CONSTRAINTS

Where and how the RF/microwave cable assembly will be installed has a direct impact on the long-term reliability of the cable. Understanding the installation process can help determine which materials are best for the assembly's construction. For example, if the assembly must be routed through a tight space, size and durability should be evaluated. If the assembly will be pulled through a conduit, the cable's outer jacket also needs to be abrasion-resistant. And, if the assembly needs to be twisted so it can be routed around other equipment, it needs to be very flexible with a small bend radius. All of these situations mean that the cable's construction needs to withstand the installation and protect the conductors during use (see ***Figure 1***).

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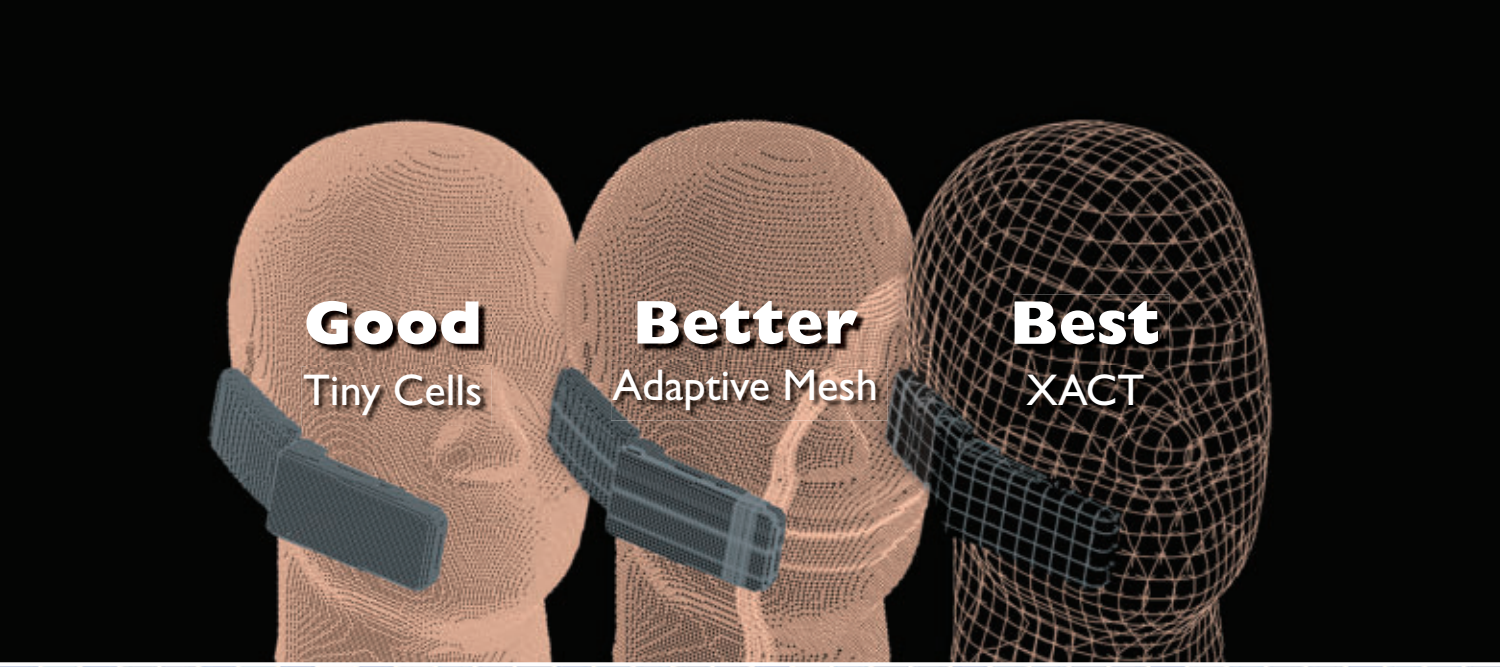

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If the distance between the two connection points for the cable assembly is very short, signal reflection and voltage standing wave ratio (VSWR) can have an adverse effect on the measurement accuracy. Adding a service loop in the cable can allow more flexibility and help eliminate length tolerance issues.

Fig. 1 The tight spaces and routing challenges of installation in an aircraft can easily compromise the performance of RF/microwave cable assemblies.

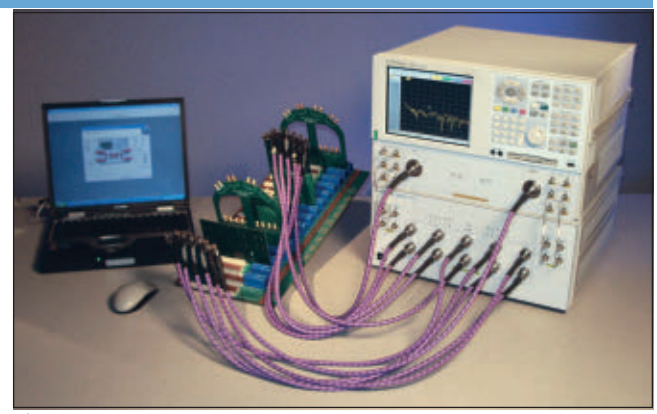

Fig. 2 In a laboratory environment, RF/microwave cable assemblies are frequently bent, twisted and pulled, which can affect the precision and repeatability of measurements (courtesy of Agilent Technologies).

USAGE CONSIDERATIONS

How the RF/microwave cable assembly will be used is another important aspect to consider when selecting the right cable. Like the installation process, the application for which the assembly is intended often defines the type of materials used in the assembly's construction as well as its performance requirements.

Cable Handling: The first, and probably foremost, consideration is whether the cable will be left in place once it is installed or whether it will be handled frequently. When the cable is connected to equipment handled manually, it is much more likely to experience flexure, and frequent flexing can potentially affect the precision and repeatability of measurements. An operator can kink, pinch, or crush a cable by stepping on it, rolling over it, or wrapping it around a piece of portable equipment during transport. Therefore, tensile strength is essential in overcoming mechanical stress on the cable. Externally ruggedized cables cannot always withstand this type of torque. However, internally ruggedized cables can improve phase and amplitude stability with flexure because they are crush-resistant and maintain excellent tensile strength even at a small bend radius (see ***Figure 2***).

Another consideration for cables that are frequently handled is whether they will be used in a high-throughput application. These applications require frequent attaching and detaching of the cable from the device under test (DUT). Assemblies engineered for this type of application should reduce the need for frequent recalibration and time-consuming troubleshooting due to testing errors. Selecting a reliable RF/microwave cable assembly with a quick-turn connector can also increase throughput by eliminating the need for a torque wrench.

Size Constraints Versus Insertion Loss: For applications that require RF/microwave cable assemblies, insertion loss is usually a critical performance specification. For some applications, the size of the cable assembly is also important, and there can be a trade-off between insertion loss and cable length or diameter. With RF/microwave cable assemblies, loss is directly related to cable diameter. An application may have a specific loss target as well as an overall cable diameter target; however, in some instances, the maximum diameter target could prevent the loss requirement from being met. The combination of longer distance and loss target may mean that the cable needs a larger diameter. In aerospace systems, for example, engineers often specify a maximum cable diameter because smaller cables mean less weight. Reducing the weight of a cable assembly may compromise its durability and electrical performance with use. Choosing a high-quality cable with a lower dielectric constant will translate to a lower loss for a given diameter. However, it is important to focus on the dielectric constant of the finished cable assembly rather than that of the raw materials.

Phase or Time-Delay Matching: RF/microwave cable assemblies may require phase or time-delay matching to ensure that every cable within a set has its time delay or phase length within a specified tolerance range. This type of matching can be either absolute (i.e., one or more assemblies having a specific time delay or phase length target value plus/minus the tolerance) or relative (i.e., a set of assemblies with time delay or phase length within a specified match window). Phase-matched assemblies are usually used in applications with phase-array radar, differential signaling and power combining. For applications that require phase or time-delay matching, it is critical to select a cable assembly that is also phase-stable over flexure so that performance is maintained.

Power Handling at Frequency of Interest: Assemblies are usually specified with an adequate margin of safety to ensure that they can handle the maximum amount of power at the desired frequency range. However, environmental conditions, such as high temperatures, vacuum, humidity, etc., can affect the power requirements. A cable assembly dissipates heat energy using three mechanisms: conduction, convection and radiation. Temperature or pressure changes directly affect the cable's ability to reduce heat by convection, with a vacuum completely eliminating it. This leaves only conduction through the outer braid and center conductor of the cable assembly and radiation as alternative mechanisms. One of the consequences of these environmental conditions is thermal breakdown caused by heating within the cable and connector due to power dissipation. To understand power handling challenges, it is necessary to understand temperature and pressure requirements as well as the continuous average power value at a specific frequency being put to the cable.

For power handling at certain frequencies, the type of connector used with the RF/microwave cable assembly is

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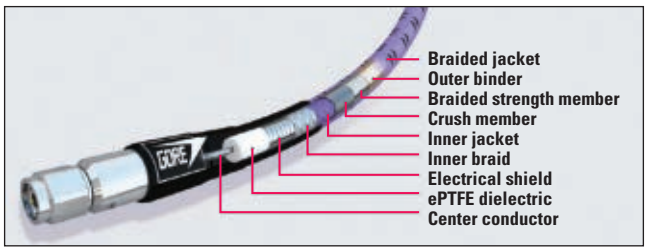

Fig. 3 RF/microwave cables with robust shielding at the outer conductor can minimize crosstalk and electromagnetic interference.

also important. Like cable assemblies, connectors are rated based on how they handle power as a function of frequency. Charts are available that detail the power handling capability of various connectors. In addition, since high amounts of power under certain conditions may generate a significant amount of heat, the type of solder used for terminating the connectors should also be considered.

THE PHYSICAL ENVIRONMENT

The physical environments in which RF/microwave assemblies are being used today are becoming more challenging. Assemblies are being exposed to such conditions as extreme temperatures, vibration and constant electromagnetic interference (EMI). These environmental challenges vary significantly, depending on the application. For example, a cable assembly used in a controlled-environment laboratory encounters very different environmental conditions from one analyzing flight data in an aircraft. Like all constraints, the impact of these environmental challenges can be minimized by selecting a RF/microwave cable assembly engineered to withstand them.

Temperature and Pressure: Temperature and pressure variations can affect a RF/microwave assembly's VSWR and insertion loss performance. High temperatures increase insertion loss, while low temperatures reduce insertion loss. This is due to thermal effects and their impact on electron activity. VSWR can be altered by physical changes in the assembly as a result of expansion and contraction due to temperature change.

Temperature changes can also affect phase length. As the temperature approaches an extreme, the electrical length will change; if it does not change at the same rate as the temperature when returning to normal (a state known as hysteresis), it is very difficult to apply error-correction techniques to the signal.

Temperature and pressure can also affect the cable's durability. Low temperatures can make cable materials brittle, and high temperatures cause them to become very soft. Vacuum leaches oils and additives out of certain materials, which could have an adverse effect on a cleanroom manufacturing process.

Vibration: Whether used on a manufacturing floor or in an aircraft, RF/microwave cable assemblies can be exposed to significant shaking and vibration. Phase and amplitude stability during flexure and shake need to be evaluated for any assemblies that will be used in these types of environments. Utilizing a high-quality cable that is phase- and amplitude-stable will provide more precise and repeatable results by preserving the integrity of the signal.

Electromagnetic Interference (EMI): Today's electronic equipment is increasingly complex, with many electrical subsystems generating their own signals, all of which can interfere with the performance of a RF/microwave cable assembly. In addition, assemblies are also being used in environments where high-voltage signals are continually being transmitted. For example, portable test analyzers with RF/microwave assemblies are used in the telecommunication industry to test the performance of cell tower antennas with constant interference that could compromise the integrity of the test measurements. Choosing a cable with robust shielding at the outer conductor will minimize any possibilities of cross-talk or EMI (see ***Figure 3***).

Abrasion and Cut-Through: In addition to being a consideration during the installation process, abrasion and cut-through are constraints that can be found in many environments — aircraft applications, handheld analyzers used in the field, portable equipment around which the assembly is wrapped during transport, etc. Some jacketing materials, such as polyurethane and engineered fluoropolymers, are more abrasion-resistant and durable than others, so potential exposure to abrasive surfaces should be considered when designing a cable assembly for a specific application.

VERIFYING PERFORMANCE

Because precise and repeatable measurements are so important with RF/microwave cable assemblies, it is important to discuss with the manufacturer what types of performance testing have been done on the assembly. Mechanical tests — such as a flex test with repeated bending of 180 degrees or more, or the pull test to simulate use as a tether — can verify the assembly's electrical performance while it is operating under conditions such as crushing, abrasion, potential cut-through and continuous flexing. During these tests, insertion loss and VSWR should be evaluated.

The cable's electrical performance should also be measured while simulating the physical environment in which it will operate — conditions such as temperature, altitude, pressure and vibration. For example, it is important to monitor impedance during altitude change, mechanical shock and vibration tests. By adding a clamp force during a temperature cycling test, the cable assembly's dielectric withstanding voltage can be monitored to see how the jacket and conductor change. After the cable is put through substantive mechanical and environmental tests, the manufacturer should again verify that the electrical performance, dielectric and jacket materials remain stable within the requirements of the application.

CONCLUSION

RF/microwave cable assemblies need to be engineered to withstand demanding applications in which precise and repeatable measurements are essential. Understanding the constraints of an application and the environment in which the RF/microwave cable assembly will be used can ensure that it will be properly engineered to provide consistent, repeatable measurements with stable electrical performance for that application. And performance testing can ensure that the cable will maintain reliable performance. The proper cable assembly can save time and money over the life of the equipment because it can reduce equipment downtime, eliminate cable failure and increase service life. ■

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Case Study: Using Electromagnetic Simulation to Ensure EMC Compliance

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As they have grown the business, differentiating themselves from the competition has become an important goal. To accomplish this, KEC is developing further expertise in the area of electromagnetic simulation of the harness systems. By modeling and simulating customers' designs, KEC can identify problems early in the process and recommend corrections before the EMC certification stage. This enables customers to avoid costly mistakes and pass certification testing on the first try.

THE CHALLENGE

When researching potential unmet needs in their target markets, KEC's team focused on the challenges their customers faced during EMC testing and certification. In addition to the demanding requirements of the defense and aerospace markets, international legislation has created rigorous specifications that challenge many other industries such as telecommunications, railroad and computing.

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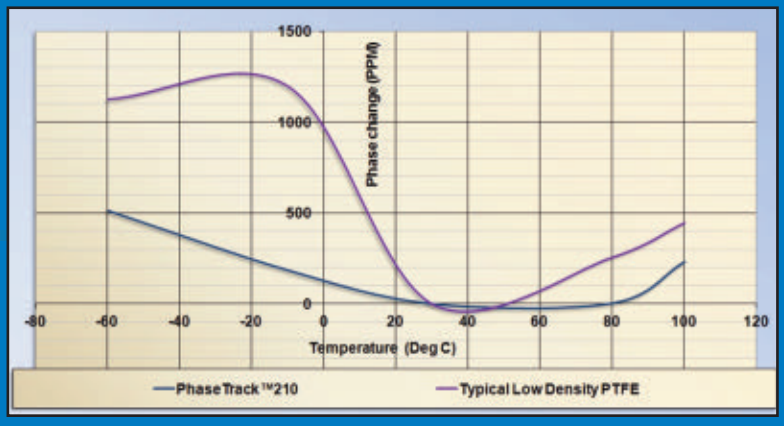

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the harness system is in compliance before integrating it into their designs and installing it into their equipment. KEC recognized that providing simulated results early in the design stage could greatly assist their customers. It also happened to be a unique technology that was not being offered by anyone else.

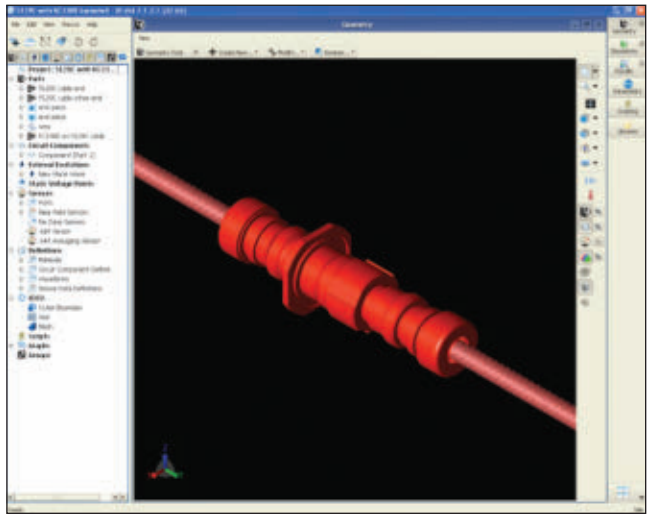

Fig. 1 Geometry for cable harness test.

David Dyson, chairman at KEC, said, "We realized that we could provide a more complete solution for customers by testing the harness system first using EM simulation. The simulations demonstrate how the shielding protects the wiring and signals from RF fields, allowing us to pinpoint weaknesses if they exist. We can then help the customer to redesign until the simulation results are satisfactory. The goal is to pass the certification the first time."

In order to implement their strategy, KEC's next step was to shop for an EM simulation tool that they could use on their own to model and simulate the harness systems. KEC approached various providers of EM simulation software and decided on Remcom's full-wave 3D EM solver.

Simon Ireland, design and development engineer at KEC, said, "We chose XFdtd because the product is so easy to use. The XF7 interface is intuitive, making it simple to set up complex problems."

Several different applications were tested, based on some key customers' specific projects. One project included both commercial and academic problems. From the academic side, a series of dipole antennas and other textbook type simulations were examined in order to compare the simulation outputs with theoretical solutions. From the practical/commercial side, a series of test harnesses were manufactured and put through EMC testing. Simulations of these test harnesses were then performed to compare the simulation outputs with real world problems (see ***Figure 1***).

Another scenario examined the design of a folded metal backshell as an alternative to castings for low production runs. KEC had to design the metal folds in such a way that would allow the backshell to fit together, and there were several ways in which this could be achieved. By simulating the different options in XF7, a measureable difference was seen, enabling the team to choose the best design option (see ***Figure 2***).

"Remcom impressed us with their software, specifically the ease of use, but also with the support received during the product trial," Ireland said. "Remcom engineers provided very detailed responses to any questions I had, and I usually received a reply within a day of sending my email."

RESULTS AND SUMMARY

A few select customers are currently working with KEC to use their problems as a testing ground for the new service. The team is refining the simulation process for these customers' specific applications and comparing the simulated results with the actual equipment being tested. Response is proving extremely positive, and KEC will soon be offering the service as part of their regular product line.

"There are many benefits to including EM simulation in the typical cable harness design process that reach beyond the added value to our customers," Dyson said. "In the EMC interconnect arena, the usefulness of EM simulation is just being discovered.

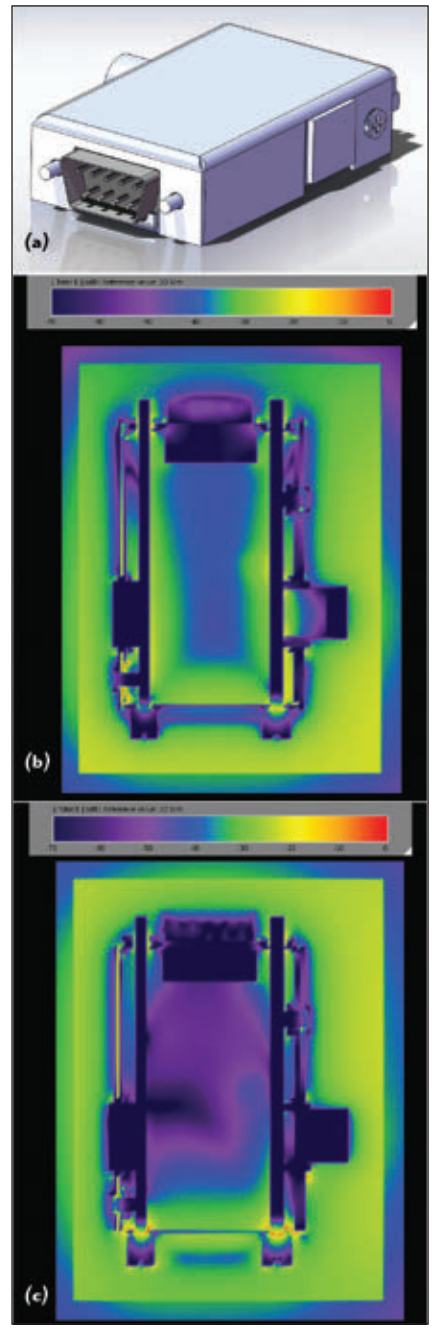

Fig. 2 Design of folded metal backshell (a), analysis of first configuration (b) and analysis of second configuration (c).

It is our hope that by demonstrating the value of in-situ testing before proceeding to EMC trials, we will be at the forefront of wider industry adoption." ■

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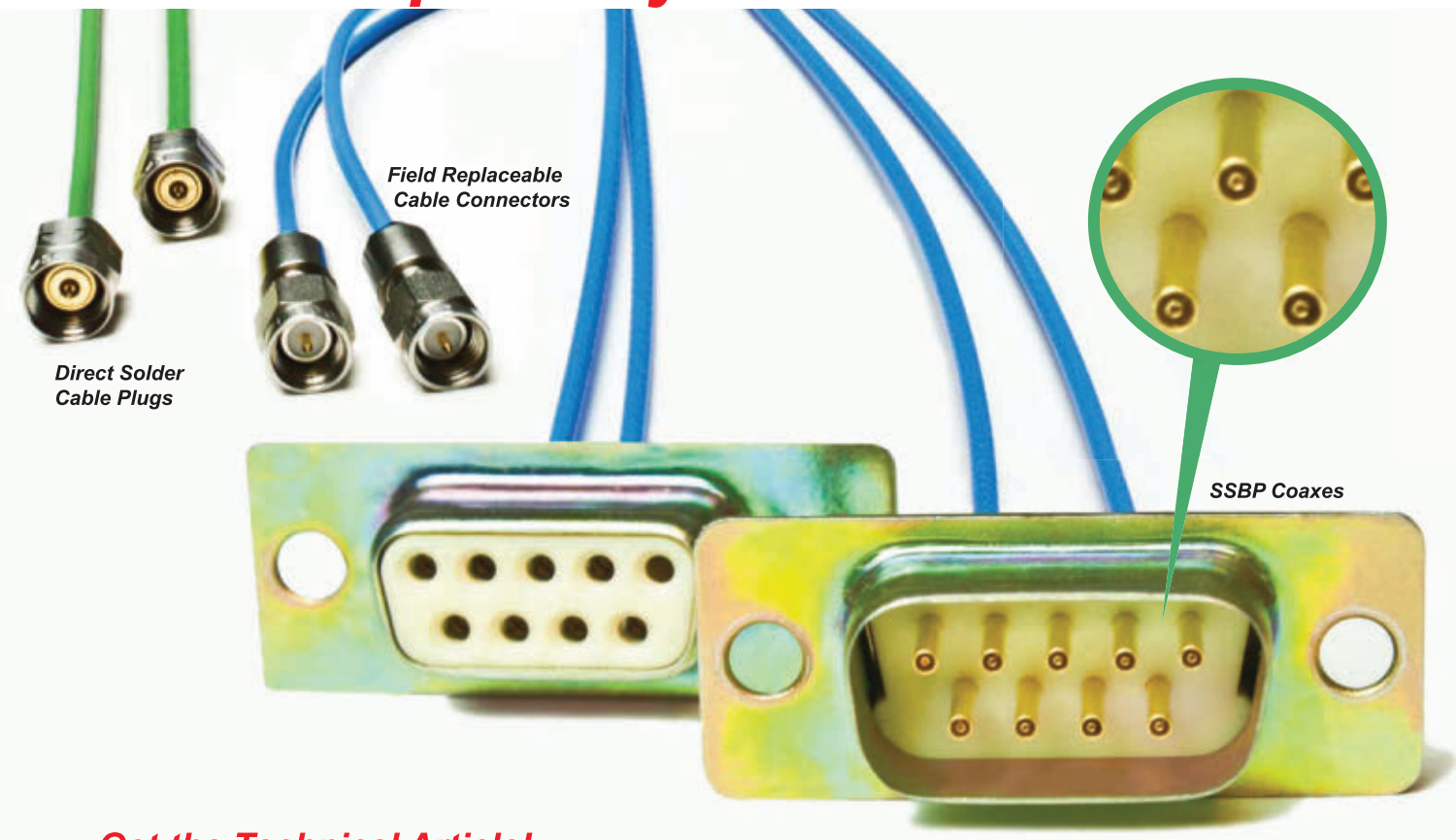

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What's All This PIM Stuff Anyways?

Wireless network operators upgrading to next generation systems such as LTE must ensure low passive intermodulation (PIM) in order to achieve bandwidth optimization and maximum Quality of Service (QoS). PIM represents third-order mixing products (in-band) generated by two distinct frequencies co-located within a system. These "ghost" signals act as interference for the cellular receiver and consume system capacity as well as causing false phone calls.

PIM can be caused by a number of characteristics, including the effects of corona generation, current saturation and the nonlinear characteristics of certain materials, all of which can be introduced by the cable assemblies used to interconnect the network's modules and components for effective signal flow.

Specific connector design features are meant to lower PIM. For instance, connectors designed for high RF power levels typically employ chamfered transitions to avoid localized ionization. To further minimize PIM, mating conductive surfaces should have smooth surface finishes at all component and connector/cable transitions, with optimum mating force maintained between conductive surfaces. Hard versus soft materials within press fits and the use of strong wiping action between mating center contacts can mechanically break down oxide layers and generate a clean conductive path, also helping to minimize the generation of PIM.

A new white paper from San-tron discusses the causes of PIM and its impact on next generation wireless networks as well as the design features in the company's eSeries connector products designed to mitigate PIM and is available on the Microwave Journal website at www.mwjournal.com/SantronPIM.

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Quick Test adapters, also commonly referred to as push-on adapters, quick connect adapters, quick-lock adapters and snap-on adapters, have been used by the microwave industry for years at low frequencies. While adding a level of convenience not found in traditional RF connectors, these adapters suffered from a degraded electrical performance, poor repeatability and reduced life. As such, adapters of this type were often avoided by those seeking a reliable connection.

In response to customer demands for high-frequency, extremely repeatable, long life precision push-on adapters, Maury Microwave invented the precision push-on/pull-off 3.5 mm adapter, the QT3.5mm™. The QT3.5mm is a patented design, based on Maury's metrology and precision adapter technology and is compatible with SMA, 3.5 and 2.92 mm connectors. The QT3.5mm is available in four configurations: no nut, 3/8" diameter nut, 9/16" diameter nut and guide sleeve.

Fig. 1 No nut quick-test adapter.

NO NUT

The no nut quick-test adapter (see ***Figure 1***) enables push-on/pull-off operation and allows for a full 360 degree rotation after connection is made, greatly increasing the flexibility of installations. With a rated life of over 3000 connect/disconnect cycles, the no nut QT3.5mm maintains a S-parameter repeatability of over 40 dB.

3/8" AND 9/16" DIAMETER NUT

The 3/8" and 9/16" diameter nut quick-test adapters (see ***Figure 2***) not only act as quick-test adapters with push-on/pull-off operation, but also have the increased accuracy of a threaded connection. With only a 1.5-turn rotation, the threaded nut will engage and prevent accidental slippage during use. Machined wrench flats allow the use of torque wrenches for metrology and calibration applications. With a rated life of over 3000 connect/disconnect cycles, the 3/8" and 9/16" diameter nut QT3.5mm maintains a S-parameter repeatability of over 50 dB when hand- or wrench-torqued.

GUIDE SLEEVE

The no nut quick-test adapter allows for a full 360 degree rotation after connection is made, greatly increasing the flexibility of installations. The additional guide sleeve (see ***Figure 3***) enables self-alignment making it ideal for automated test stations. With a rated life of over 3000 connect/disconnect cycles, the no nut guide-sleeve QT3.5mm maintains a S-parameter repeatability of over 40 dB.

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▲ *Fig. 2 3/8" and 9/16" diameter nut quick-test adapters.*

▲ *Fig. 3 No nut quick-test adapter with guide sleeve.*

AVAILABLE MODELS

No nut, 3/8" diameter-nut, 9/16" diameter-nut and guide-sleeve models are available to adapt with Type-N connectors to 18 GHz, 7 mm connectors to 18 GHz and 3.5 mm connectors to 26 GHz with excellent insertion loss and VSWR. Ruggedized 3.5 and 2.4 mm NMD options are also available for use on test ports (see ***Table 1***).

INDEPENDENT TEST RESULTS

Independent testing was carried out on the 8006Q1 QT3.5mm guide sleeve adapter at 3000 connect/disconnect cycles. While rated with a re-

TABLE 1

AVAILABLE MODELS FOR QT3.5MM LINE

Model	Adapts		
	Side A	Side B	
8006B1	QT3.5mm™ (m) with no nut	7mm	
8006B11	QT3.5mm™ (m) with 3/8" diameter nut		
8006B21	QT3.5mm™ (m) with 9/16" diameter nut		
8006C1	QT3.5mm™ (m) with no nut	NMD3.5mm (f)	
8006C11	QT3.5mm™ (m) with 3/8" diameter nut		
8006C21	QT3.5mm™ (m) with 9/16" diameter nut		
8006E1	QT3.5mm™ (m) with no nut	3.5mm (f)	
8006E11	QT3.5mm™ (m) with 3/8" diameter nut		
8006E21	QT3.5mm™ (m) with 9/16" diameter nut		
8006F1	QT3.5mm™ (m) with no nut	3.5mm (m)	
8006F11	QT3.5mm™ (m) with 3/8" diameter nut		
8006F21	QT3.5mm™ (m) with 9/16" diameter nut		
8006G1	QT3.5mm™ (m) with no nut	Type N (f)	
8006G11	QT3.5mm™ (m) with 3/8" diameter nut		
8006G21	QT3.5mm™ (m) with 9/16" diameter nut		
8006H1	QT3.5mm™ (m) with no nut	Type N (m)	
8006H11	QT3.5mm™ (m) with 3/8" diameter nut		
8006H21	QT3.5mm™ (m) with 9/16" diameter nut		
8006K1	QT3.5mm™ (m) with no nut	NMD2.4mm (f)	
8006K11	QT3.5mm™ (m) with 3/8" diameter nut		
8006K21	QT3.5mm™ (m) with 9/16" diameter nut		
8006Q1	QT3.5mm™ (m) guide sleeve	3.5mm (f)	

[1] *Slightly reduced VSWR specs to 34 GHz.*

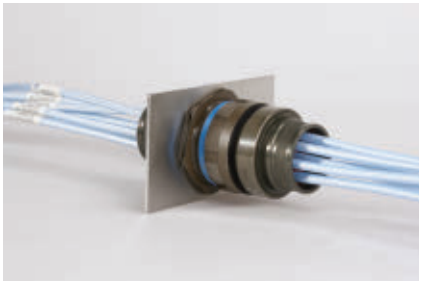
turn loss repeatability of better than 40 dB without use of a torque nut or wrench, independent testing proved a repeatability better than 56 dB to 10 GHz, 49 dB to 20 GHz and 47 dB to 26.5 GHz after 3000 connect/disconnect cycles. Similar results surpassing rated specifications were achieved for insertion loss magnitude repeatability, with a low variance of 0.03 dB to 10 GHz, 0.04 dB to 20 GHz and 0.06 dB to 26.5 GHz after 3000 connect/disconnect cycles, without use of a torque nut or wrench. As with magnitude, insertion loss phase repeatability surpassed specifications with a low variance of only 0.16 degrees to 10 GHz, 0.31 degrees to 20 GHz and 0.45 degrees to 26.5 GHz after 3000 connect/disconnect cycles, without use of a torque nut or wrench. Maximum life was noted as 10,000 connect/disconnect cycles.

INDUSTRY USE/APPLICATIONS

The convenient push-on/pull-off connector offers excellent repeatability, a long operating lifespan and increased throughput (up to 10× faster than mate-torque-demate) making it ideal for use in high volume test/production environments such as those found in component manufacturers (filters, attenuators, cables, couplers, etc) and those testing device assemblies in high volume (cell phones, radios, medical RF devices, etc). Commercial and military field operations can also benefit from a push-on/pull-off connector where using a torque wrench might not be convenient or even possible.

Maury Microwave,
Ontario, CA
(909) 987-4715,
www.maurymw.com.

Frequency Range (GHz)	Maximum VSWR (GHz)
DC to 18.0	DC to 4.0 ≤ 1.04 4.0 to 18.0 ≤ 1.08
DC to 26.5[1]	DC to 16.0 ≤ 1.08 16.0 to 26.5 ≤ 1.12
DC to 26.5[1]	DC to 16.0 ≤ 1.05 16.0 to 26.5 ≤ 1.08
DC to 26.5[1]	DC to 16.0 ≤ 1.05 16.0 to 26.5 ≤ 1.08
DC to 18.0	DC to 4.0 ≤ 1.05 4.0 to 18.0 ≤ 1.08
DC to 18.0	DC to 14.0 ≤ 1.05 4.0 to 18.0 ≤ 1.08
DC to 26.5[1]	DC to 16.0 ≤ 1.08 16.0 to 26.5 ≤ 1.12
DC to 26.5[1]	DC to 16.0 ≤ 1.05 16.0 to 26.5 ≤ 1.08



Multiport Connectors for Harsh Environments

Durability and high performance of components are key factors that determine the functionality of the overall installation. Often, connectors, cables and harnessing are mounted in hard to reach areas, making replacement or troubleshooting difficult and costly. Also, in rough and harsh environments connectors and cables will be charged to the limit, so any unwanted signal interruption will result in high repair costs. To address these issues HUBER+SUHNER is able to design and produce customized RF cable assemblies.

MULTICONNECTIONS

The series offers the facility to connect and disconnect microwave cables in one single activity rather than mating every single contact individually. Thus, these robust, compact, lightweight multiport connectors not only provide a high performance connection but also save space and time, resulting in reduced costs.

Due to its design and size, the series is particularly suitable for use in confined spaces; ***Figure 1*** shows the connectors used in a communication center of sensors. Installation is also simplified by the fact that intelligent mechanical coding on the MIL-DTL-38999 connectors eliminates any confusion.

HARSH ENVIRONMENTS

The multiconnectors have an aluminum alloy shell and olive green cadmium plating, and can withstand 500 mating/demating operations. Their durability and high performance means that they are particularly suitable for harsh environments. They are moisture proof, waterproof and robust enough to withstand a high level of vibration.

The MIL-DTL-38999 connectors are available with either four or eight coaxial connections and are particularly equipped for heavy and long usage. They are designed for communication terminals and testing systems in dirty, oily and dynamic environments with significant temperature changes. The multiport connectors address a temperature range of -65° to 175°C, with mated connectors meeting the altitude immersion requirements of MIL-C-38999.

HUBER+SUHNER AG
Herisau, Switzerland

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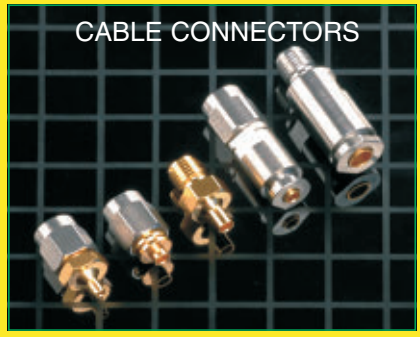

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2.4mm	**DC-50 GHz**	**3.5mm**	**DC-34 GHz**	**SSMA**	**DC-40 GHz**

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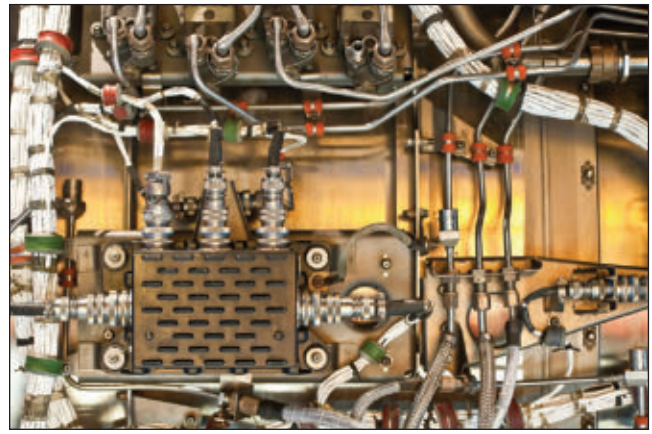

Fig. 1 MULTIPORT MIL-DTL-38999 connectors are suited to confined spaces such as this communication center of sensors.

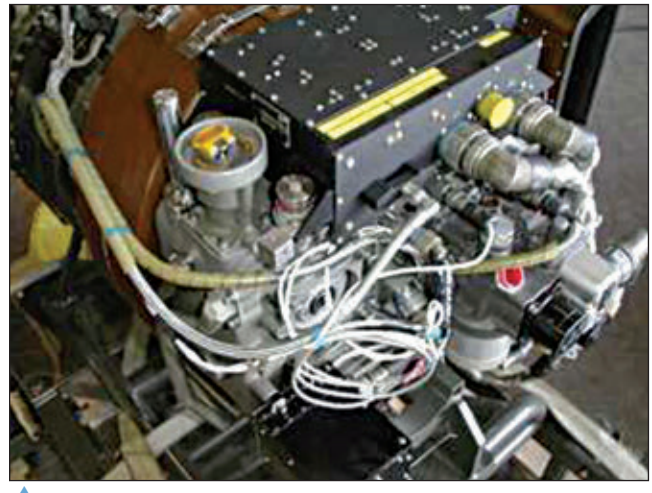

Fig. 2 The multiport connectors can withstand aharsh environments and vibrations enabling them to be used for landing gear.

They can be used for railway, aviation, defence, industrial technologies, onboard communications and radar for the transmission of RF signals for fast analog and digital signals. They are suitable for all types of rail and road vehicles, aircraft (***Figure 2*** shows their use for landing gear), ships, tanks and industrial applications.

The MULTIPORT MIL-DTL-38999 series of connectors offers easy quick and safe connection via one compact, robust multiport connector that can be fitted into confined spaces. The series is particularly suitable for harsh environments and for a wide range of applications.

They are compact, lightweight, robust and resistant to vibration. The connectors can operate over a wide temperature change and exhibit a high resistance to dust, water and high humidity. All of which make the series a cost-effective, time-saving option for installation engineers.

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New Strain Relief Extends Cable Assembly Life

Teledyne Storm Products–Microwave has developed an improved strain relief that significantly extends the life of cable assemblies used in test applications requiring frequent flexure behind the connector. Hard-To-Hurt™ strain relief technology was developed in response to a common industry problem: early failure in cables with "standard" strain reliefs when repeatedly flexed behind the connector.

Since no industry-standard flexure test exists, Storm developed an accelerated life test to evaluate strain relief designs using a cable flexing device capable of testing up to six cables simultaneously. Connectors are held static while the flexer deflects the cable behind the connectors 30° to the right and 30° to the left. An integrated counter tracks the number of cycles (± 30° per cycle) that the cables have been flexed (see video on the company's website).

During flexing, the cables are connected to a network analyzer and monitored for insertion loss and VSWR. Every 1000 flexures, the movement is stopped, and each cable's performance is measured and recorded to determine when a cable starts to develop instability. Flexing is continued until cables fail to meet insertion loss or VSWR requirements. To establish a baseline, Storm evaluated cable assemblies with standard strain reliefs, and then alternate designs and materials were evaluated until the Hard-To-Hurt design was selected.

Available on two of Storm's most popular test cables, True Blue® 205 and Accu-Test® 200, Hard-To-Hurt technology increases their flex life by nearly four times over standard strain relief.

Teledyne Storm Products, Woodridge, IL, www.teledynestorm.com/microwave.

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Quick-Lock Test Cable Mates with SMA Connector

The Mini-Circuits QBL Series Coaxial Cables include a Quick-Lock connector that mates securely with a standard female SMA connector with a simple sliding lock feature. These cables are ideal for use in test lab applications, with superior strain relief for lasting durability and flexibility for tight access locations. The FEP jacket supports operation to 105°C and protects a double shielded cable construction for minimum signal leakage.

The Quick-Lock system is as simple as push, slide and click to make a repeatable RF connection. The unique design of the QBL Quick-Lock connector mates directly with a standard female SMA connector, with a contact and guide structure that makes a secure connection to 18 GHz.

Supporting 25 dB return loss at 6 GHz and 19 dB up to 18 GHz, the QBL Series is ideally suited for testing a wide range of RF equipment while minimizing measurement degradation due to the effects of VSWR interactions. Capable of withstanding RF power of 270 W at 1 GHz and 47 W at 18 GHz (at sea level). The QBL Series is a great fit for a wide variety of test and installation applications operating from DC to 18 GHz.

Tested without performance degradation to over 20,000 flex cycles (flexed to stress both the cable and strain relief), the QBL Series is ideal for a wide variety of test applications. Typical applications include high volume production test stations, research and development labs, environmental and temperature test chambers, replacement for OEM test port cables, field RF testing and cellular infrastructure site testing.

VENDORVIEW

Mini-Circuits, Brooklyn, NY (718) 934-4500, www.minicircuits.com.

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Over-the-Air (OTA) Signal Challenges and Implications - Recommendation for LTE RAN

Protocols used by LTE networks to leverage MIMO technologies are significantly impacted by correlation and thus by the channel models under which they are tested or emulated. Over-the-Air testing with a Base Station Analyzer can determine how the MIMO Transmitters are functioning, map the downlink coverage or look for co-channel interference. This Forum provides an understanding of over-the-air, multi-path signal challenges and considerations for end-to-end testing.

Wednesday May 9, 2012
10:30 AM – 12:30 PM

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MIMO OTA Measurements – The Next Generation Platform for Wireless Testing

Extensive efforts are underway to standardize on a next generation platform for performance testing of wireless devices, taking into account LTE, A-GPS, uncertainty budgets and use of head/hand phantoms. This Forum provides an understanding of system performance and presents the core elements - such as the chamber, software and instrumentation - that facilitate systematic and repeatable measurements of MIMO devices.

Thursday May 10, 2012
12:30 PM – 2:30 PM

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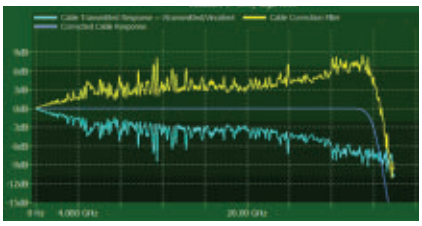

Why Engineers Ignore Cable Loss

Companies spend large amounts of money on test and measurement equipment. One of the largest purchases for high speed designers is a real time oscilloscope. As is the case with most instruments, oscilloscope vendors charge a premium for cutting edge bandwidths. Companies are willing to pay this premium to be able to know with certainty that the device they are testing is being represented properly by the oscilloscope. An oscilloscope with too little bandwidth will under report rise times and in many cases, over report jitter. This leads to eroding electrical margins and increasing costs and time to market for a project and design. The benefit of higher margins makes the bandwidth premium a worthwhile investment.

Despite its cost, an oscilloscope is only part of the entire measurement system and precious measurement system bandwidth can be lost through other links in the channel system. One potential bandwidth bottle neck includes the cabling and adapters. Despite this, the characteristics of such adapters tend to be ignored. Compared to the price of an oscilloscope, the cost of a cable is very minor. Yet cables can wreak havoc on any measurement system. Beyond losing the biggest portion of the investment (the bandwidth) because of cable loss, precious margins are now lost as well. Amplifying the problem, companies now use more links in their measurement channels including switches (to measure multiple channels), adaptors and fixtures. Similar frequency responses potentially could be found in each one of these components, all causing erosion of crucial margins and potentially wasting hundreds of thousands of dollars. Yet the underlying theme is that the loss is largely ignored.

Agilent Technologies has published an article covering cable loss and how to adjust for it. It is available on the Microwave Journal website at www.mwjournal.com/AgilentCableLoss.

VENDORVIEW

Agilent Technologies Inc., Santa Clara, CA (800) 829-4444 www.agilent.com.

High-Performance Surge Arresters

Frontlynk has developed a family of surge arresters that are designed to protect sensitive electronic facilities such as base stations or outdoor antennas from lightning damage and current surges. As well as solid surge arresters, the family includes a system whereby the surge of electric current enters the arrester and is diverted though a gas-tube to earth, thus protecting valued components throughout the system. The incorporation of a replaceable gas-tube into the design of specific arresters means that only a small component needs to be replaced rather than the complete arrester, offering an economic and green alternative.

The family includes a range of surge arresters, including the N type and also the 7/16 series, which can be used for higher voltage equipment such as base stations. Each surge arrester, irrespective of its design, comprises three in-series adapters: Plug-to-Plug, Plug-to-Jack and Jack-to-Jack. The company also offers the facility to modify the design in accordance with customer needs.

To optimize the performance and reduce the loss the company divides the surge arresters into two, according to the operating frequency: 0 to 3 GHz and 2 to 6 GHz. Both frequency ranges have a 50 Ω impedance, surge capability of 8/20 µs 1 time 20 kA and breakdown voltage (±20 percent) of 90, 230 and 350 V. The 0 to 3 GHz surge arrester has a maximum VSWR of 1.2 and a maximum insertion loss of 0.3 dB, while the 2 to 6 GHz surge arrester has a maximum VSWR of 1.3 and a maximum insertion loss of 0.5 dB.

Signal loss is not an issue and customers can select the specific arrester to suit the requirements of their particular systems. Importantly, the surge arresters are waterproof, meeting the environmental requirements of IP67, which, due to its special design, also applies to the gas-tube replacement version.

Frontlynk Technologies Inc., Tainan City, Taiwan +8866-356-2626, info@frontlynk.com, www.frontlynk.com.

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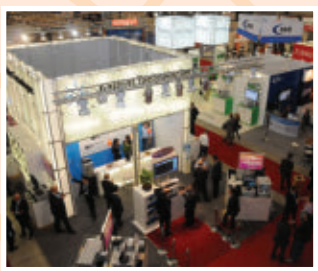

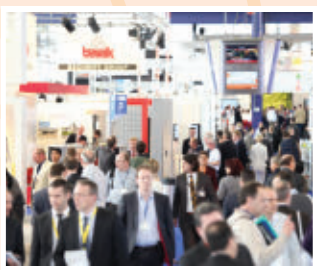

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Lightweight Space Savings Interconnect

ITT Corp. has developed a rugged, lightweight, "no-profile" interconnect system designed specifically for wearable and portable military equipment used in modern warfare. The Nemesis Series Space Saver connector is a compact, lightweight solution that not only saves weight, but also helps effectively shrink the overall size of portable equipment.

The advanced Nemesis Series Space Saver connector system utilizes canted spring technology to provide blind mating and quick snap-on/rip-away coupling to prevent military personnel from being endangered should a cable snag. Other design considerations include the use of ribbed overmolding for secure grip under difficult conditions.

Extremely rugged and with a high degree of sealing, the Nemesis Series Space Saver connector is designed to withstand harsh conditions in the field and features an anti-reflective RoHS-compliant salt-spray resistant plating that is guaranteed for 500 hours.

The Nemesis Series Space Saver has superior EMI performance to ensure the integrity of high frequency signals, as well as pogo pin contact technology for enhanced contact durability. Its canted spring technology provides full 360-degree EMI protection.

Military personnel often carry in excess of 95 pounds of wearable equipment on long and arduous missions, so reducing this weight burden is now a top priority of defense departments. The "no-profile" connectors utilize ITT's proven Pogo Pin/Pad and breakaway technologies, which are designed to increase the maximum number of mating cycles, while enabling the connectors to be cleaned in the field.

Maximum current rating for the Nemesis Series Space Saver connector is 2 A, and the voltage rating is 50 V with a minimum insulation resistance of 5000 MΩ. The Nemesis Series Space Saver connector features an operating temperature ranging from –40° to +100°C with a life span of more than 2500 cycles. Applications include portable computers, weapons, vision systems, headsets, radios, GPS equipment and headsets.

ITT Interconnect Solutions,
White Plains, NY,
www.ittcannon.com.

Cost-Effective SMA Family

TE Connectivity has released its next generation of RF products – the KOAXXA RF interconnects product family. The redesigned SMA family offers RF connectors with customizable designs, faster lead times and compelling pricing. While the traditional RF interconnects are still available and very well suited for their applications, the KOAXXA RF interconnects meet the market's need for cost-effective RF connectivity with reduced sensitivity to future material and labor appreciation.

KOAXXA RF products supplement traditional RF connectors by providing alternative connectors designed for the right performance at a competitive price. The new SMA connectors are redeveloped as an extendable product platform for large-scale manufacturing and assembly automation. This enables mass customization and reduces lead time and sensitivity to rising material and labor costs.

To combat material headwinds, the new KOAXXA connector family design reduces material consumption and waste. Advanced plating puts the precious metals only where needed: selective tin plating in the solder region promotes easy soldering and selective gold in the contact region offers the performance and durability needed to meet industry standards. The product leverages TE's global standardized manufacturing footprint, allowing KOAXXA RF interconnects to meet global demands quickly.

As the first offering of the KOAXXA RF interconnects product family, the SMA product line is offered in the most popular configurations with frequency ranges and durability to help meet the market's needs. These include: PCB straight and right-angle board mounts; cable plugs and jacks with a variety of flexible, semi-rigid and conformable cable types; and panel mount. Additional SMA configurations are planned for subsequent release.

KOAXXA SMA connectors are designed to be fully compatible with IEC-169-15 interface standards and are qualified per the EIA-364 test standard.

TE Connectivity,
Berwyn, PA,
www.koaxxa.com.

eLEARNING center

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Presented by: Mini-Circuits
Live webcast: 3/13/12, 11:00 AM ET

Using Highly Integrated RF ICs to Optimize Your Infrastructure and PTP Designs
Presented by: Richardson RFPD/Analog Devices
Live webcast: 3/28/12, 11:00 AM ET

Besser Training Series
LTE Overview
Sponsored by: AWR and Anritsu
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Live webcast: 3/8/12, 2:00 PM ET

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RF Power Amplifier Design Series: Part 2: End-to-End Design and Simulation of Handset PA Modules
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Network Analysis
Basics of RF Amplifier Test with the Vector Network Analyzer
Live webcast: 3/13/12, 1:00 PM ET

Pulsed IV Measurement with PNA-X
Live webcast: 3/27/12, 1:00 PM ET

Wireless Communications Series
IEEE 802.11ad PHY Layer Testing
Live webcast: 3/8/12, 1:00 PM ET

Aerospace/Defense Series
RF Streaming, Analysis and Playback in Aerospace & Defense Applications
Live webcast: 3/15/12, 1:00 PM ET

LTE Series
It's Time for TD-LTE
Live webcast: 3/22/12, 1:00 PM ET

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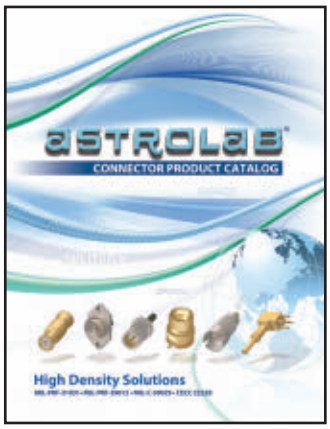


Product Catalog

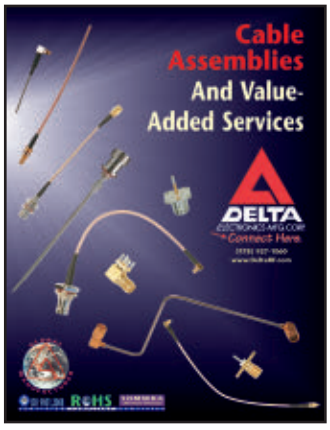
This catalog features the company's SMPM-T, the smallest threaded open source connector on the market offering unprecedented electrical and mechanical performance advantages. The catalog also showcases Astrolab's wide selection of SMP, BMZ, BMA, MCX and SMPM blind-mate connectors and coaxial contact product lines.

Astrolab Inc.,
Warren, NJ (732) 560-3800, www.astrolab.com.

Phase Adjusters

Check out Carlisle Interconnect Technologies latest sales sheet on its line of highly phase stable, low VSWR, precision phase shifters designed for high performance military communications (phased array antennas) and commercial applications. A precision mechanical movement provides continuously varying phase shifts, while maintaining a 50 Ohm impedance over the entire frequency range.

Carlisle Interconnect Technologies,
Cerritos, CA (866) 282-4708, www.carlisleit.com.



Product Brochure

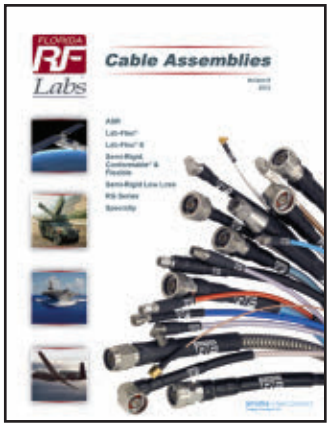
To assist customers who have a need to streamline their supply chain and logistics, Delta Electronics Manufacturing now offers a broad range of coaxial cable assemblies and other connector-related, value-added component subassemblies. Delta's cable assemblies, incorporating flexible, semi-rigid and hand-formable cables, range in size from micro-miniature to large, high-power types. They cover the spectrum of market needs from high volume, low cost assemblies to high performance, low volume categories.

Delta Electronics Manufacturing Corp.,
Beverly, MA (978) 927-1060, www.deltarf.com.

Product Catalog

Emerson Connectivity Solutions announces the latest version of the Trompeter catalog featuring products that align with military, aerospace, broadcast and telecommunications markets. Trompeter also offers a complete solution for any interconnect requirement, from standard to custom. Trompeter provides products that continually deliver the highest quality signal integrity for the most demanding applications.

Emerson Connectivity Solutions,
Bannockburn, IL (847) 739-0300,
www.emersonconnectivity.com.



Product Catalog

VENDORVIEW

Florida RF Labs is a leader in the design and manufacture of high reliability microwave coaxial cable assemblies. This new catalog highlights the company's growing line of Lab-Flex® products and introduces its new line of Lab-Flex® S and ASR precision test port assemblies. The company also offers a full line of semi-rigid, semi-flexible and cost-effective flexible solutions.

Florida RF Labs,
Stuart, FL (772) 286-9300, www.emc-rflabs.com.

Product Catalog

This 204-page catalog covers the entire Maury Metrology-Grade Precision Calibration Standards product line, including coaxial and waveguide VNA calibration kits, opens, shorts, loads, coaxial adapters, waveguide-to-coaxial adapters, coaxial connectors and cables, connector gage kits, torque wrenches and manual tuners. It is available in the original 2006 printed edition, and as a revised and updated 2010 PDF edition that can be downloaded from the Maury website at: www.maurymw.com.

Maury Microwave Corp.,
Ontario, CA (909) 987-4715, www.maurymw.com.

Product Catalog

MIcable Inc. is a designer and manufacturer of high-performance microwave coaxial cable assemblies for a variety of applications, including DC to 40 GHz test flexible cable assemblies, conformable cable assemblies and semi-rigid cable assemblies. In addition, the company designs and produces various precise coaxial stainless and copper connectors. Custom designed assemblies are also available. MIcable is your quality fast and low cost solution. Please e-mail sales@micable.cn.

MIcable Inc.,
Fuzhou, Fujian, China +86-591-87382855, www.micable.cn.

IF/RF Microwave Signal Processing Components Guide

VENDORVIEW

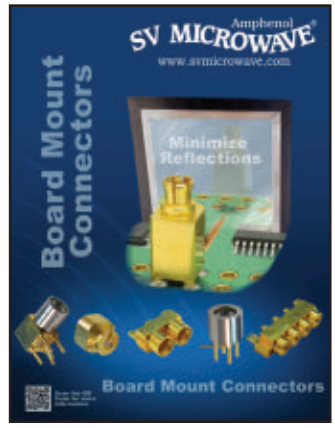
Mini-Circuits' new 164-page catalog includes over 750 new products and is the industry's most comprehensive listing of RF/IF and microwave components and subsystems with more than 4100 products and over 25 product lines, including state-of-the-art amplifiers, mixers, VCOs, synthesizers, filters, test accessories and USB Power Sensors. Mini-Circuits' website provides additional data, application notes, design tools and its powerful YONI search engine, which searches actual test data on over thousands of units.

Mini-Circuits,
Brooklyn, NY (718) 934-4500, www.minicircuits.com.

Technical Paper

Southwest Microwave's technical paper "Optimizing Test Boards for 50 GHz End Launch Connectors" provides insights and guidelines to help assure the best transition using Southwest's end launch coaxial connectors to grounded coplanar waveguide and microstrip PCB lines. Via placement, line spacing and taper are discussed and concludes with a loss comparison between GCPW and microstrip. Southwest Microwave is a performance leader in microwave and millimeter coaxial interconnects by providing low VSWR, insertion loss and RF leakage.

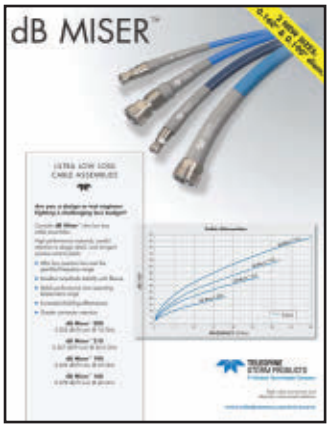
Southwest Microwave Inc.,
Tempe, AZ (480) 783-0201, www.southwestmicrowave.com.



Board Mount Connectors

SV Microwave introduces its next generation of push-on interconnects including single-port and multiport SMP, SMPM and SMPS edge launch, board mount and thru-hole connectors. They are ideal for high density applications. Additionally, the company offers custom PCB footprint design services, enabling the optimization of connector to PCB transitions through software simulation.

SV Microwave,
West Palm Beach, FL (561) 840-1800, www.svmicrowave.com.



Product Brochure

This expanded brochure introduces two new cables in the dB Miser™ line of ultra low loss assemblies: A 0.160" diam. cable (0.678 dB/ft nom. @ 40 GHz) and a 0.190" diam. cable (0.496 dB/ft nom @ 32 GHz), as well as new connector offerings. The clear choice for engineers facing challenging system gain or signal-to-noise requirements, dB Miser™ cables also exhibit excellent amplitude stability with flexure, stable performance over temperature, and exceptional connector retention.

Teledyne Storm,
Woodridge, IL (630) 754-3300, www.teledynestorm.com.

RF and Microwave Interconnects

TRU Corp. has created a short form capability catalog that outlines a wide variety of RF and microwave interconnect solutions. The catalog utilizes easy to use matrices to specify TRU brand cable and connector interface options for general purpose, commercial wireless and high performance test cable assemblies. A complete outline of RF receptacle design options as well as a full range of precision test and quick change adapters are included. This capability catalog discusses additional application driven design capabilities available from TRU Corp.

TRU Corp.,
Peabody, MA (978) 532-0775, www.trucorporation.com.

Cables & Connectors Supplement

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- **Phase Adjusters** - Our family of precision coaxial phase adjusters is ideally suited for Electronically Scanned Arrays (ESAs) and other military and space applications.
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For more information visit
www.CarlisleIT.com
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