Backstory: Storm-Test™ 50 GHz

The cable we designed to test our own cables with

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TELEDYNE
STORM MICROWAVE

The Cable we Designed to Test our own Cables With

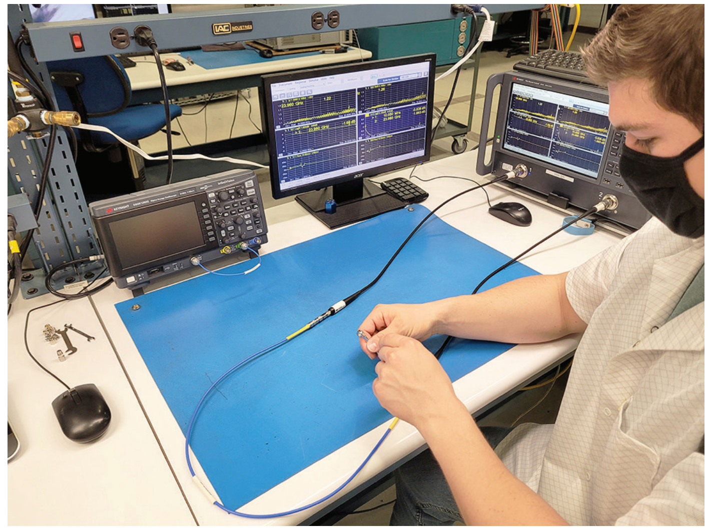
Like many of you, manufacturing of microwave components is our business, day-in, day-out. We make precise measurements to confirm the electrical performance of thousands of microwave cables every shift. We use Vector Network Analyzer (VNA) measurements to verify performance of our work-horse standard frequency cables, and also for our metrology-grade precision assemblies that either go to higher frequencies, or have more complex requirements such as precision phase and/or delay matching.

The Challenge

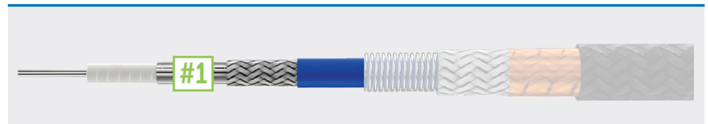
Being known for the quality and performance of our cables, we have to be able to produce them consistently, in high volume, and with high levels of repeatability. And, like any business, we want our production equipment to last as long as possible, despite the rigors of repeated human handling, constant motion, torquing, chafing and occasional accidental crushing. We want to keep our production costs as low as possible, while delivering product to some of the most demanding test and measurement, defense and space customers in the world. Meeting the challenge of extending the useful life of our production test cables at reasonable cost resulted in our new product, the Storm-Test™ cable series (50, 40 and 26.5 GHz).

A Solid Foundation

We make a wide variety of high quality 50Ω cables, including some of the most rugged armored cables available. However, a key requirement for our manufacturing environment is to retain flexibility as well as durability. We based the heart of the new cable on the technology underpinning our Phase Master product line, and the resulting construction is described below.

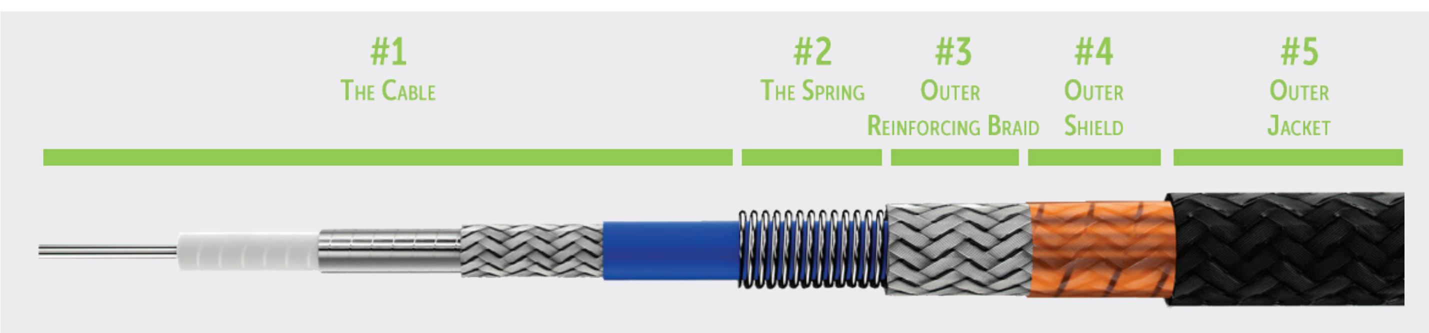


#1: The Cable

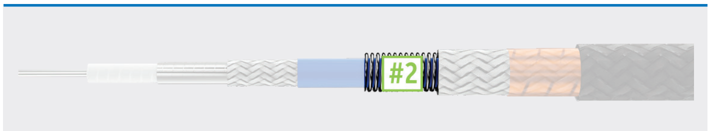


The heart of a VNA test lead is the 50Ω cable encased in the additional layers that provide protection, longevity, and stability. As Mil-Aero & commercial applications and the VNAs that support them typically come in 20, 40 and 50 GHz models, we decided that we needed to support all the permutations. By offering all the 3.5mm, 2.92mm and 2.4mm connector combinations plus a series of phase-matched adapter pairs, a single VNA can test any cable assembly configuration.

We decided to use a thoroughly vetted cable with years of use in airborne and land-based radars, satellites, and commercial applications. One important design choice was to keep as much flexibility as possible, which impacts the Velocity of Propagation (Vp). Normally the need for robustness would cause the use of lower Vp extruded solid PTFE dielectric (harder) rather than a higher Vp, softer dielectric. However, with the added layers of protection we were going to be adding, we decided that this presented minimal risk given the benefits of lower insertion loss and higher phase stability.



#2: The Spring



The inner spring that envelops the outer jacket of the core cable serves a variety of mechanical functions which in turn supports the electrical stability requirements. Using our factory as a typical example of a testing environment, the mechanical indignities a test lead endures are numerous:

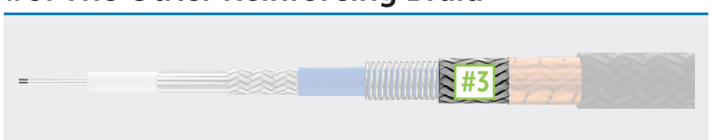
- Dropping heavy objects on the cable,
- Bending below the stated minimum, repeatedly
- Excessive movements just behind the connector as the result of constant positioning and re-positioning of Devices Under Test (DUTs) of various lengths and configurations,
- Torquing of the test lead (injurious to a helically wrapped cable) while connecting/dis-connecting the DUT.

First the material and gauge of the wire, plus coils per inch, were determined by an iterative process that involved the perceived stiffness by the test technician when flexing the test lead, any pinching of the underlaying cable when bent, and any digging into the underlaying cable when the cable is torqued clockwise.

Considerations for the spring material included:

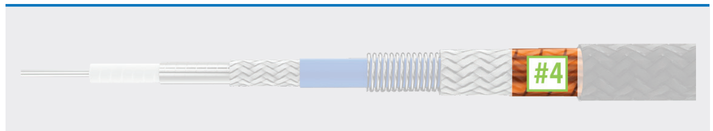
- Ductility
- Tensile strength
- Rigidity
- Malleability
- Manufacturability, since this was not purchasing in specific lengths as a "spring" but rather formed along with all the other layers in the manufacturing process.

#3: The Outer Reinforcing Braid



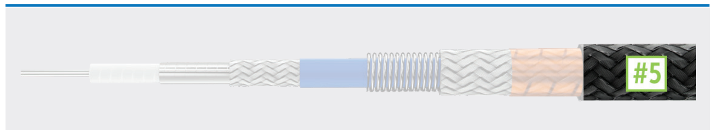
A braid's function is usually to provide extra tensile strength and RF shielding to the cable. However, in this instance the main function is slightly different, in aiding the positioning of the spring layer. For the spring to maintain its position along the cable – to not expand nor rotate when torsion is applied and to exert resistance to any crush forces – it must be prevented from bunching and shifting along the cable. The braid serves as a reinforcement mechanism to prevent such movement.

#4: The Outer Shield



These outer layers work in concert with each other to maintain the mechanical and electrical properties of the inner coaxial cable. Specifically, here braid-bunching is mitigated since the outer jacket is woven rather than employing an extruded solid barrier. The shield also serves as a vapor barrier.

#5: The Outer Jacket

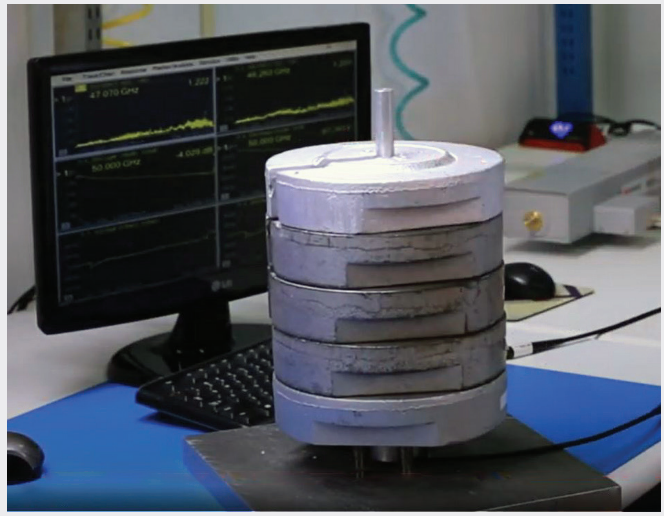


In a factory setting, these cables are in constant motion, being dragged along a test bench and sometimes getting snagged on a calibration kit or a DUT. A specific design choice was to use an outer braid material made of FEP as opposed to coated Nomex, thereby increasing the jacket's resistance to fraying over time. Another challenge for the outer jacket with constant use is that the back of the connector can act as a dull cutting force; over time this frequently results in damage to the internal layers of the cable. A 3D printed boot at the back of the connector limits movement and therefore limits any damage caused by this movement.

So, Did it Work?

We were aiming for a product which exhibited robustness, phase stability, repeatability and long useful life. It was designed and then refined in an active manufacturing facility, testing hundreds of DUTs on tens of VNAs in a single day, and whose beta testing reflected the most rigorous scenarios. The test lead integrity was constantly measured to monitor the electrical performance since this was an active manufacturing facility where accurate test results were critical to our customers. Unsurprisingly, the end results of the theoretical design, lab-based confirmation of requirements and the practical production-based usage-refinement-repeat methodology, is a VNA test lead that can be used on the total range of applications needed, providing consistent, stable and repeatable results.

Part of our standard suite of development tests involves placing a new cable design into a test fixture and loading weights onto it, as shown in the example at right where a 100 lb. stack is being applied.



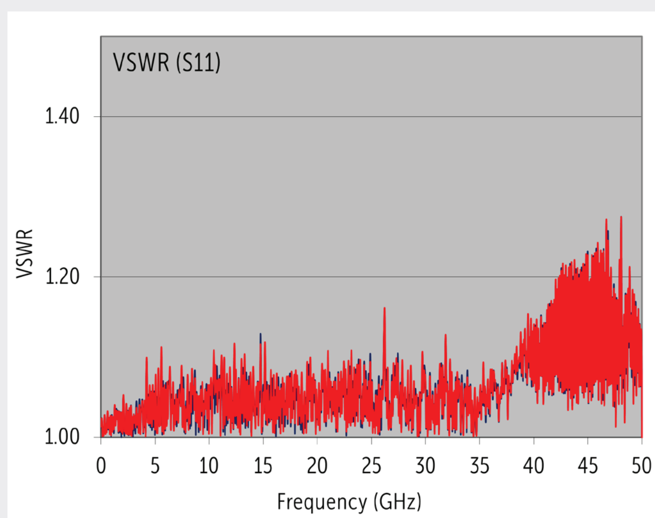
Cable Cruelty by Car

However, to demonstrate the ruggedness of our new Storm-Test cable series design a little more graphically, we decided to treat these cables much more harshly than the treatment they received on the production floor. We subjected the cable to the weight of a car by running one over back and forth 10 times, measuring the electrical performance up to 50 GHz before and after.

In the charts that follow, the blue trace is the initial state and the red trace shows the performance of the cable after being run over by the car 10 times.

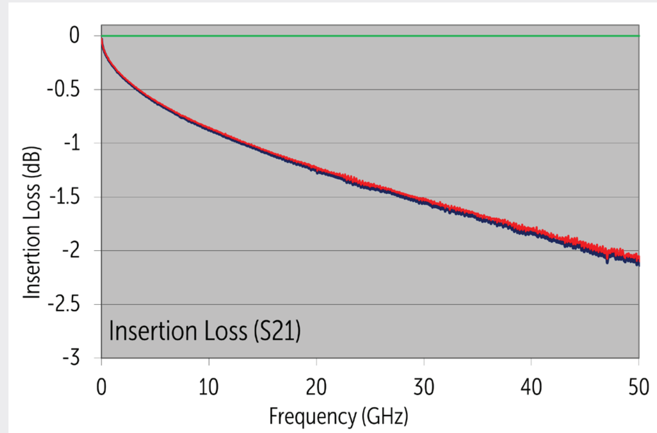
VSWR

From a VSWR perspective, although most of values overlap each other, you can see little shifting of the chart after being run over 10 times. From 0.1 to 26.5 GHz the average degradation afterwards was 0.2% with a peak degradation of 0.4% at 26.2 GHz. From 26.5 to 50 GHz the average degradation was 0.09% and at 48.08 GHz there was a slight improvement of 0.01%.



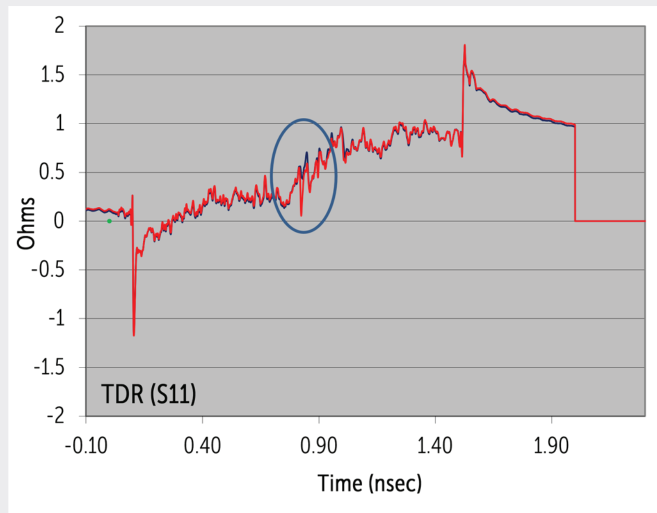
Insertion Loss

There is no change in Insertion Loss (IL) after being run over repeatedly as shown by how the blue trace (before) and red trace (after) curves overlap.



TDR

Time Domain Reflectometry (TDR) shows changes to impedance over the length of the cable and would tend to highlight where along the length of the cable any damage might have occurred. As can be seen from the plot below, the traces overlay almost exactly, except at about the mid-point (circled) where this rather extreme crushing was inflicted with minimal impact to the performance.



The Bottom Line

On a more practical level, we use Storm-Test 50 GHz cables for all of our manufacturing test VNA measurements and have been delighted with the results. Like us, customer feedback is that they have found the cables to last significantly longer than cables from our competitors, saving them, and us, considerable time and money. **We know you can trust the Storm-Test™ Cable Series – we do.**

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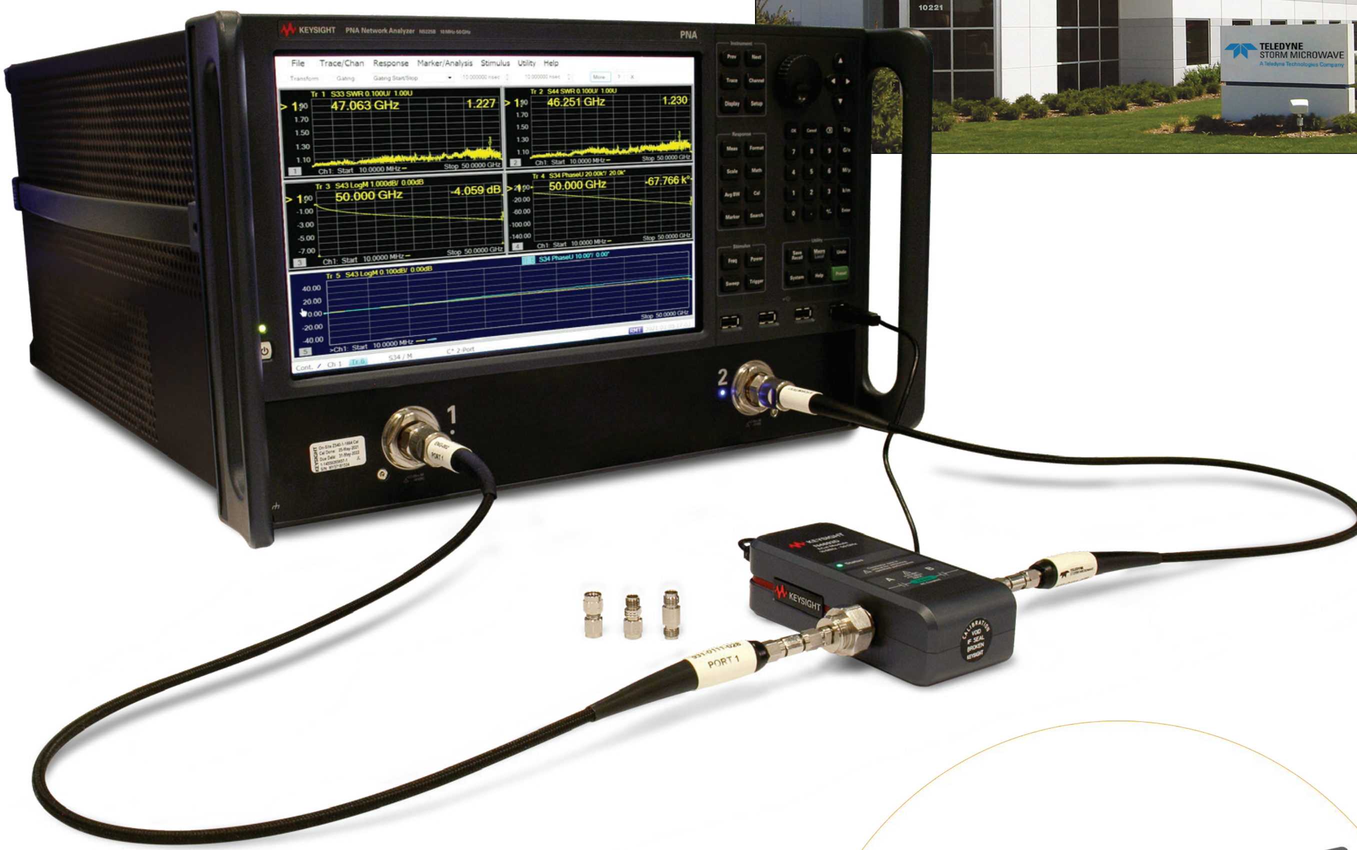

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