Number 12 on your Feedback card

Using International 9096-IIA

Xtra-flex, low-loss coaxial cable.

by Steve Katz WB2WIK/6

My article called "The Hows and Whys of Coaxial Cable" in the May 1993 issue of *73* created a lot of reader response. Some readers asked about low-loss 50 ohm coax, which is more flexible and easier to use than the popular Belden 9913 but still has the same excellent electrical properties. I've been using Belden 9913 since its first appearance on the market about eight years ago and I've always had very pleasant results, although there are some caveats in the use of this air dielectric cable which I discussed in the May article.

I've searched for years for a suitable substitute for Belden 9913, not because I don't like the Belden product, but simply because it's not flexible enough for some applications. (The original 9913 has a #9 solid center conductor which makes the cable quite rigid.) In contacting the vendors of substitute cables, I found that most were not actual manufacturers, but rather distributors of wire and cable products who were very reluctant to reveal their sources of supply. Often these distributors have their own brand names imprinted on the cables they sell, giving the appearance that they actually have production operations. This is quite common in the wire and cable industry, and many "master distributors" like Alpha Wire Corporation (Elizabeth, New Jersey) have done business for many years and developed excellent reputations. Still, I've been reluctant to recommend distributors as product sources, feeling that if they don't manufacture the product, they have little or no control over it. Sure, we buy ham rigs, computers, TV sets and automobiles from distributors, but we know who made these items and we have the option of contacting the manufacturers directly for technical assistance, problem solving, and so forth, so we feel comfortable about our purchases.

Substitutes for 9913

I've tried products sold by a number of distributors and found some were better than others. I found at least one 9913 substitute, sold by an amateur product distributor who specializes in wire and cable, to be of such poor quality that I literally couldn't strip it. This cable's dielectric was so tightly bonded to its center conductor that it was nearly impossible to remove, but at the same time the dielectric was so poorly bonded to the aluminum-mylar film outer conductor that all attempts to remove the jacket resulted in pulling the dielectric and center conductor right out the end of the cable! This stuff was terrible.

"How does it work? In a word, 'great.' In two words, 'I'm impressed.'"

There's a brand-new product on the market from International Electronic Wire and Cable called 9096-IIA "Extra-Flex." This is another "9913 clone," but it's the best I've seen so far. It is similar to Belden 9913 (described in the sidebar), but instead of having a solid center conductor it has a 19-strand conductor of #9 overall gauge, which makes it very flexible and easy to use. The 9096 bends and flexes as easily as conventional RG8/U or RG213/U, but has far lower loss due to its construction and material content. 9096 has an outside diameter (o.d.) of 0.405" just like mil-standard RG213/U and will accept a standard "UHF" type PL-259 fitting; however, due to its oversized center conductor, it will not fit a standard UG21/U type "N" and must be fitted to a special type N, the kind sold for use with Belden 9913 (how convenient!). I took delivery of 500 feet of 9096 as soon as I heard about it, in part to lab test it but also to potentially use the new product to feed my recently installed 6 and 2 meter beam antennas.

How does it work? In a word, "great." In two words, "I'm impressed." Before installing the cable in my station, I measured its attenuation on the 28, 50, 144, 222, 440 and 1270 MHz bands, where it is most likely to be used in the average ham station. (Its low-loss characteristic would be almost wasted below 28 MHz, as conventional RG213/U is good enough for the majority of installations in the HF spectrum.) This data is shown in Table 1, which compares the loss of 9096 per 100 feet to the loss of conventional mil-standarcd RG213/U (which is the current successor to old-fashioned RG8/U). To make this measurement, I used all 500 feet of 9096 and installed type N connectors on both ends, then divided the measured loss by five to yield "loss per 100 feet." This is more accurate than measuring 100 feet, as it offers five times greater measurement resolution.

9096 will handle the amateur legal power limit throughout the HF-VHF-UHF spectrum, although at very high ambient temper-

Continued on page 51

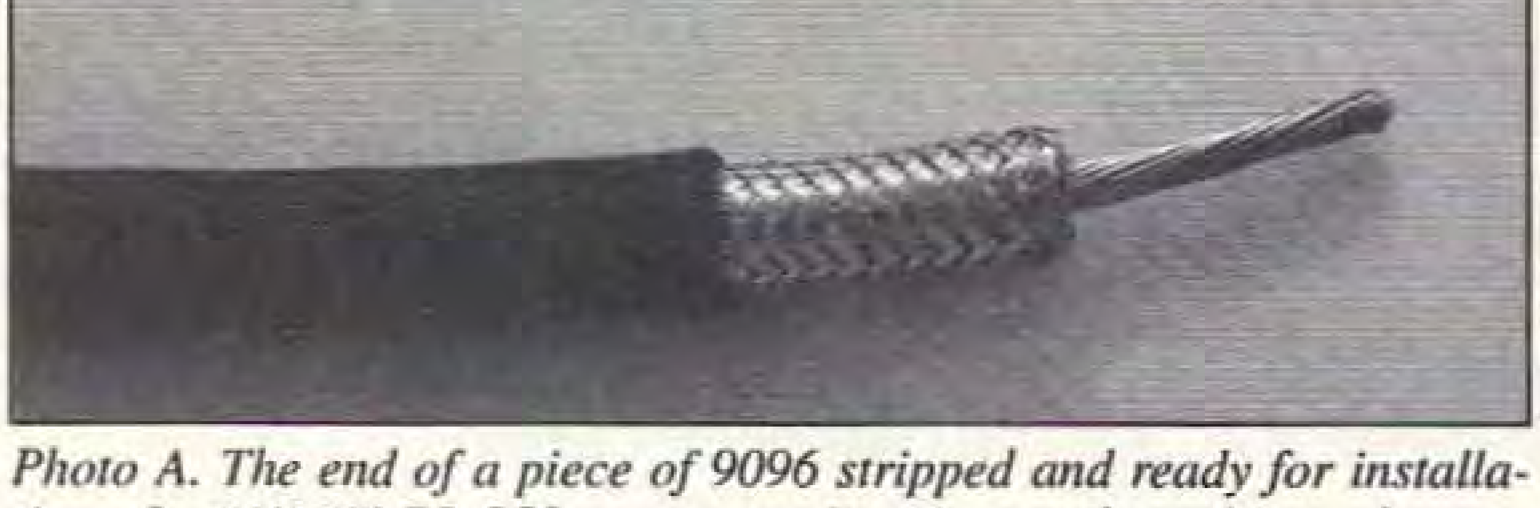

Photo A. The end of a piece of 9096 stripped and ready for installation of a "UHF" PL-259 connector. It strips easily and is a pleasure to work with: One razor blade and five seconds is all it takes to do this.

Photo B. A piece of 9096 with an end stripped and the tinned copper braid pulled back to reveal the aluminum-mylar film shield. You would not normally do this to install connectors. That #9 stranded center conductor is a healthy bunch of copper.

Using International 9096-IIA

Continued from page 48

atures or elevations it may require some derating. It features a type IIA polyvinylchloride (PVC) outer jacket material, which is tolerant to ultraviolet (UV) radiation and therefore requires no protection from the sun, unlike some commercial coaxial cables which can contaminate with UV radiation.

Since cable is a pretty simple product which is most readily assessed for attenuation and ease of use (and most other parameters are not terribly significant), I cannot report a great deal more about the merits of the new International product. It works, it works well, and is a suitable replacement for Belden 9913 for those situations requiring greater mechanical flexibility. Because 9096 is 100% shielded like the semi-rigid "hardline" cables are, it would lend itself well to repeater installations where single-shielded cables don't perform, due to RF leakage and noise generation caused by the braided outer conductor. See the sidebar for more details on construction of International 9096.

Now would be a good time to point out some of the limitations of helical dielectric cables including 9096:

1. This cable is flexible enough to be routed nearly anywhere, but great care must be exercised in its handling due to its internal construction. *Do not*: step on it; use nylon or metal cable ties or clamps to affix it to supports; "kink" it; bend and re-bend it back and forth at the same spot; make any bend of less than 4" internal radius, and if you make such a tight bend, be sure to do it only once in that spot; or place mechanical stress on it at any point where it makes a bend or is affixed to a support. (This is a lot of "do nots" but they are all important, and reasonably easy to follow.)

2. When installing a "UHF" type PL-259 connector, use a lot of heat applied for a brief period of time to get the solder to flow into the connector body holes (for braid connection), rather than a small amount of heat applied for a long period of time. Using a 260 watt soldering gun and soldering all the holes in just a few seconds is much better than using a 100 watt gun and taking 30 seconds to accomplish the task. During and for about five minutes after the connector soldering operation, do not move the cable at or near the soldered connector. Leave it alone so the dielectric can re-form to its intended state and establish a good insulator between the inner and outer conductors of the cable near the connector, or you risk a short-circuit.

3. If you need to affix the cable to a "hard" support such as an antenna boom or mast, tower leg, tower cable standoff arm or whatever, do not use many layers of overlapping vinyl tape pulled tight around the cable and its support—you'll short-circuit the cable at this spot. Instead, use many loosely-wrapped spiral-wound layers of tape, spread over several inches of cable and support. This will be just as strong and place much less stress on the cable.

Photo C. A piece of 9096 cut away (sectioned) to reveal its internal construction. If you look closely you can see the spiral turns of polyethylene dielectric, with 1/2" air spaces between them.

4. When "rolling out" the cable for use, *do not* uncoil a bunch of cable and let it lay around on the ground or roof and pull on a free end. This will surely cause destructive "kinks" in the cable. Instead, free up just one coil of cable to connect that free end to your antenna (or whatever), then gently and carefully unroll the cable using a hand-over-hand technique to roll the cable, allowing it to uncoil one turn at a time. If you see a "kink" form, flop the entire roll of cable over in the appropriate direction to "unkink" it, and then continue unrolling. With practice, you won't get any kinks at all. It helps a lot to have the cable wound on a wooden spool, so you can use a piece of 1-1/2" pipe inserted all the way through the spool to create a "handle" on each end. You can hold the pipe ends like handles, and just walk with the spool, allowing it to gently unspool itself. This way, no kinks will form and the whole process is not tiring at all.

"This is a lot of 'do nots' but they are all important, and reasonably easy to follow."

5. When making bends in the 9096, make them as gradually as possible, preferably 9" or greater in radius. I've experimented with this cable to determine it will accommodate a 4" radius bend, just once. If such a small radius bend is "un-bent" and bent again in the same place, it can create an internal short circuit in the cable. When making a "rotor loop" of cable to route around a rotator, make the loop as large as possible, but be sure that it won't snag on guy wires, clamps or other supporting mechanisms as the rotator turns.

If these precautions are followed, the cable will serve you well. Note that all these caveats apply to *any* helical-dielectric cable with air between the turns (9913 included), not just International 9096; the only difference is 9096 is so flexible that it is deceiving—it bends easily, but too much bending can destroy it.

Short Circuits

If you install a long section of 9096 and find that you've created a short circuit in the cable, you may be able to determine where the short is, so the whole length won't require replacement. Surely any point along the cable where it may have kinked and a kink's been "pulled out" during installation would be highly suspect. Also, any point where the cable makes a bend and that point is taped or otherwise affixed to a supporting structure would be suspect, as well.

If you inspect the line and can find no visible clue as to why the cable shorted, try using a high-quality directional wattmeter in the shack and transmitting into the cable on the highest frequency you can generate. Record both forward and reflected power readings. If they are both equal, the short circuit is very close to your transmitter. If the reflected power is considerably lower than forward, the short is farther away. If the short were all the way up at the antenna end, then the reflected power reading would

Continued on page 54

Frequency	Attenuation in dB/100 feet	
	9096	RG213/U
28 MHz	0.65 dB	1.20 dB
50 MHz	0.82 dB	1.62 dB
144 MHz	1.35 dB	2.40 dB
222 MHz	1.76 dB	3.78 dB
440 MHz	2.60 dB	5.71 dB
1270 MHz	5.13 dB	10.87 dB

Notes: Data from measurements taken by WB2WIK 7/93 on 500-ft. lengths of each cable type shown. No data taken for 903 MHz as transmitter was unavailable. Extrapolation indicates that at 903 MHz, 9096's loss would be approximately 4.0 dB, and RG213/U's would be 8.7 dB. 9096 may not support use above 2 GHz due to minor inconsistencies in center conductor spacing resulting from the use of soft materials. I recommend only "sweep-tested" cables above 2 GHz.

Table 1. Attenuation per 100 feet vs. operating frequency, International 9096 and MIL-STD RG213/U.

Using International 9096-IIA

Continued from page 51

be equal to forward power generated, minus two times the loss of the cable.

Say you're using 100 watts of power at 144 MHz, and 100 feet of 9096 cable. You know you have a short somewhere, but don't know where. You transmit into the cable and measure 100 watts forward power and 70 watts reflected power. You refer to Table 1 of this article to determine that 9096's loss per 100 feet at 2 meters is 1.35 dB. This means its "round-trip" loss for a signal generated by your transmitter, reflected back from the far end of the cable and back down to your wattmeter, is 2.7 dB. Thus, if the short-circuit were right at your antenna, 100 feet "down the line," you'd measure 2.7 dB less reflected power than forward power. 100 watts minus 2.7 dB is 53.7 watts. So, if your short circuit were at the antenna, you should measure 53.7 reflected power. But you didn't; you measured 70 watts, which means the short circuit is closer to your transmitter than 100 feet. 70 watts is 1.55 dB less than 100 watts, so the short circuit is "1.55 dB away." 1.55 dB divided by two is 0.775 dB. 0.775 divided by 1.35 dB (the loss for 100 feet of cable) is 0.574. This would place the short-circuit at about 57.4 feet from your transmitter.

This method of establishing where a short circuit in coaxial cable is located is a bit crude, as it relies heavily on the accuracy of your directional wattmeter, published data regarding line losses, and so forth. But it's better than nothing, and is probably about 90% accurate. Thus, if you were to cut your cable about three feet before and after the 57.4-foot point (that is, cut it at 54 feet and 61 feet from the transmitter end) and check the section of cable you've cut out of the line, there is a fair assurance that the short circuit would be located in that section. Not foolproof, but, again, better than no system at all. A more accurate assessment could be made using a time-domain reflectometer (TDR), but not many

What makes 9096 different from ordinary RG213/U (the successor to old-fashioned RG8/U) coaxial cable?

Instead of using a solid polyethylene dielectric and a #13 gauge center conductor as in RG213/U, 9096 uses instead a dielectric which is mostly air and a center conductor of #9 gauge. To hold the center conductor in place, securely centered between the cylindrical "sides" of the outer conductor, RG213/U uses solid polyethylene, a good dielectric material; 9096 uses instead a thin spiral of polyethylene with large air spaces between the turns of the spiral. This is called a "helical" dielectric, because its construction resembles a helix. The helix turns occur at 1/2" spacing in 9096, which is about as far apart as they can be without risking a short circuit at every bend in the cable. The closer together the helix turns are, the more mechanically robust the cable will be, but closer spacing will increase the cable's dielectric constant, slow down its velocity of propagation factor, and increase the cable's transmission losses. The farther apart the turns are, the more mechanically fragile the cable will be, but farther spacing will reduce the cable's dielectric constant, speed up its velocity of propagation, and decrease the cable's transmission losses. This is a trade-off, and International made an intelligent choice by using 1/2" spacing. It's a good compromise between attenuation and usability.

Because the dielectric constant is so much lower with this construction, 9096 can use a much larger center conductor diameter without decreasing the cables nominal impedance. 9096 is a 50 ohm impedance cable that uses a huge center conductor (19 strands of #21 copper wire) to decrease ohmic and "skin effect" losses and reduce attenuation. Popular "9913" cable, introduced by Belden in the mid-1980s and copied by many, is very similar in construction but uses a solid #9 center conductor, making it more difficult to flex. International calls its 9096 "Extra-Flex" and they're not kidding—it is very flexible indeed.

Another difference between 9096 and normal military cable types like RG213/U is the construction of the outer conductor. RG213/U uses braided copper, tightly woven to provide 95% to 97% coverage of the dielectric. This is good, low-loss material that has sufficient shielding for most applications, but it is not "100% shielded." Even RG214/U, which uses two silver-plated copper woven braids, is not "100% shielded," although it is about 99%. International 9096 uses two outer conductors and provides truly "100% shielding." The innermost of the conductors is an aluminum-mylar film which completely covers the dielectric and provides 100% shielding. However, it would be impossible to solder or clamp to this shield, as it is thin and fragile like household aluminum foil and aluminum is not readily soldered with standard materials. So, over the aluminum-mylar film is a tinned copper braid which offers about 95% coverage. This tinned copper braid is very strong and can be readily soldered to a PL-259 or clamped in a type N connector, just as one would do for the mil-standard cables.

"In essence, I'm giving up 1.8 dB on 2 meters at a cost savings of more than $400!"

So, although the outer diameter of 9096 is 0.405" just like RG213/U, its use of a largely air dielectric and an oversized center conductor allows it to have substantially less attenuation. Whether you'll notice the lower loss depends on what frequency you operate and how much cable you use. I would not recommend it for runs of less than 100 feet on frequencies below 28 MHz, as the difference in loss will be impossible to detect. But if you use 100 feet or more at frequencies of 144 MHz or higher, you *will* notice an improvement in station performance. If you refer to Table 1, you'll see that 9096 has less loss per 100 feet length (as compared with RG213/U) by about 1 dB on 2 meters, about 2 dB on 222 MHz, 3 dB on 440 MHz, etc. As you can see, the higher the frequency used, the more notable the improvement will be if you use 9096 instead of solid-dielectric cables.

The difference will also be more notable when long transmission lines must be used. For example, in my station, I need 250 feet of coax to feed my 2 meter beam, and another 250 feet to feed my 6 meter beam, since they are both located on a tower that is 200 feet behind my home. By using 9096 instead of RG213/U, I've saved about 2.5 dB in feedline loss on 2 meters—definitely a worthwhile improvement. I could save another 1.8 dB or so if I changed from 9096 to 7/8" "hardline" (solid-conductor, rigid cable), but at *very* significant expense. The 9096 costs about as much as good-quality RG213/U, but 7/8" "hardline" retails for about $2 per foot, plus its connectors can cost another $40 each or so. In essence, I'm giving up 1.8 dB on 2 meters at a cost savings of more than $400! But my first 2.5 dB station improvement came from using 9096, at an added cost of literally nothing! Each of us has our own sense of values, but for the $400+ I'm saving by not using 7/8" coax, I could take my family on a short vacation.

The only trade-off in using 9096 instead of RG213/U is that the International product—like all helical-dielectric "soft" cables—is more fragile, and more care must be used in handling and installation. If you choose to use it, and I recommend you do if it will improve your station performance at no added cost to you, just be *careful*. If you handle the cable as though it were a crate of fresh eggs it will serve you well.

hams have access to this piece of laboratory equipment.

I offer advice on all this because it is possible that many users of 9096 and similarly constructed cables will create a short circuit during installation, especially if the cable isn't handled with care. With experience and repeated use, you'll find 9096 is great stuff and short circuits will be avoided.

International 9096 is available from many wire and cable retailers. Look for those distributors who specifically advertise "9096-IIA Extra-Flex" rather than just "flexible 9913 type" cables, to be sure you're getting the product described here. It retails for about the same price as Belden 9913 or standard RG213/U (in the 69¢ per foot range for 100-foot lengths), making it a very attractive deal for those wishing to use flexible but low-loss coax. When you order, be sure to request a copy of International's 10-year warranty. Distributors should have no difficulty providing you with a copy of this document. 73

More About 9096

International Electronic Wire & Cable offers their 9096 and other products for sale through franchised distributors. For technical information, they may be contacted directly at 89-1/2 O'Leary Drive, Bensenville IL 60106. Their 10-year warranty on 9096-IIA states, ". . . cable is warranted against defects in material or workmanship for 10 years from date of purchase. Any defective footage will be replaced free of charge when shipped pre-paid with proof of purchase to (their address). This warranty does not apply to damage resulting from accident or misuse. Liability is limited to replacement only and does not include installation."

9096-IIA is rated by the manufacturer as follows:

Dielectric strength	3000 VDC (equivalent to 2121 Vrms AC, which would be 89,973 watts!)
Capacitance	24 pF/foot
Impedance	50 ohms
Velocity factor	84% (important to know in the design of phasing lines or transformers)
DC resistance	0.95 ohms/1000 feet
Attenuation	0.9 dB/100 feet at 50 MHz
	1.4 dB/100 feet at 100 MHz
	1.8 dB/100 feet at 200 MHz
	2.6 dB/100 feet at 400 MHz
	4.2 dB/100 feet at 900 MHz
	4.5 dB/100 feet at 1000 MHz

(Note: Attenuation ratings differ from actual test data taken by this author as shown in Table I, but not by very much. I measured the cable to be better than its ratings on all frequencies below 1000 MHz.)