KEY KLIX

MERIDEN AMATEUR RADIO CLUB

1947 -- 2018

SPECIAL EDITION

SEPTEMBER # 2, 2018

OFFICIAL MAILING ADDRESS, MERIDEN AMATEUR RADIO CLUB, POB 583, MERIDEN CT 06450
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From the Editor:

This is a special edition of the Key Klix devoted to a unique and innovative antenna design by one of our members, Eric Knight KB1EHE. He has obtained patents on this design and a few variations of its construction and implementation. It has gained national notoriety when CQ magazine printed a five page article on the Sabertooth Antenna in the July Issue.

Eric is President of Remarkable Technologies Inc, please check out his website at www.remarkabletechnologies.com for a full description of his accomplishments. He will also be addressing the club in the near future on his space rocketry endeavors with Amateur radio .

Pursuant to an agreement with the Editor of CQ, W2VU Rich Moseson , that we would not reprint it until the August Issue is on the news stands, enclosed is the article in its entirety. We thank Rich W2VU and encourage our members to read and subscribe to CQ Magazine. I personally have been subscribing since the 1960's and like its down to earth approach to our hobby.

In regards to publishing a special edition of the Key Klix for this article, it is a practical decision for your Editor, as including a five page article would increase the size of a regular KK to 16 or more pages which means uploading this to the web on DSL would take a very long time (very very long time). Why not upgrade to COX high speed for the same price (initially)?? Well maybe in the future but for all the horror stories about internet service, DSL has been very Reliable at this QTH.. But maybe someday…??

Dave K1WJL

If you don't have room for a standard-length antenna, you might consider the wire-shortening technique described here by KB1EHE that can cut your antenna size in half without compromising performance.

The Sabertooth Wire: An Innovation in Antenna-Length Shortening

BY ERIC KNIGHT,* KB1EHE

In the century and a half since the discovery of radio-wave propagation for communications, countless antenna methods and designs have been developed. More recently, computer modeling has enabled significant advances in antenna designs and performance. But the tried-and-true wire-only antenna has had only modest advances in the past decades; for instance, dipoles are essentially the same as they were 50 years ago. And the 486/f formula has remained the bedrock of antenna-radiator length calculations and design. That is, until today.

It is pleasure to disclose to all of our fellow amateur radio colleagues the research that my colleague Rod Lane, N1FNE, and I have made over the last 10 years — resulting in a radiator-shortening method that does not require any external components, such as coils. With this method, antenna-radiator lengths can be easily shortened by up to 50% — or more — while maintaining high levels of transmitting and receiving efficiency.

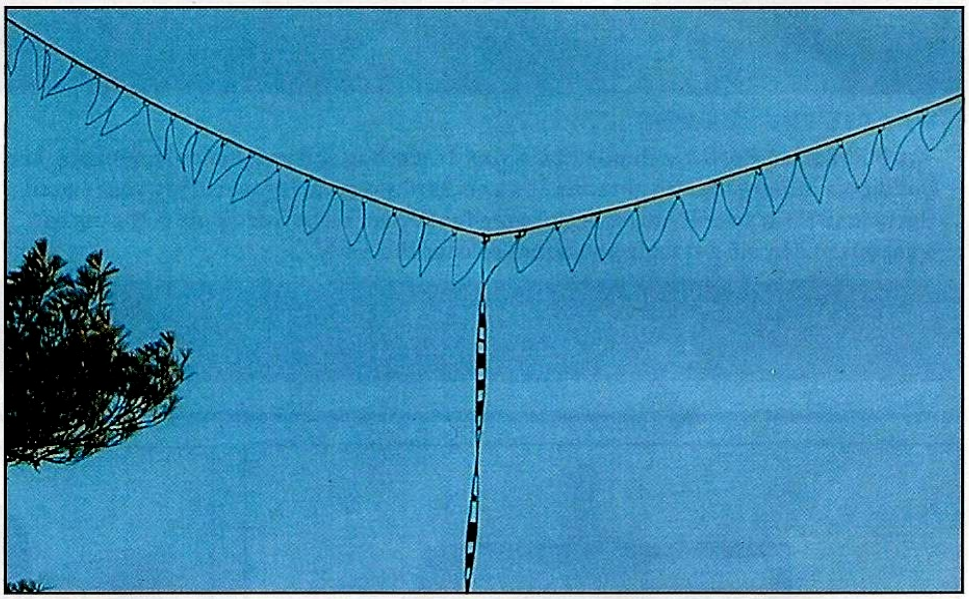


Photo A. One of the original designs constructed in 2010. It has survived multiple New England winters and is still in use at the author's QTH in Connecticut. The apexes of the wire are connected to the support rope with zip ties.

The resulting new wire technology is both patented (U.S. Patent 7,864,131) and patent-pending under an additional patent application recently submitted to the U.S. Patent and Trademark Office.

This article is not meant to be the be-all and end-all on this new radiator-shortening method. Our research and development work continues.

Discovery

In 2003, while on a flight to Europe, I was fidgeting with a twist tie. I looked down at the tray table at what my fingers had subconsciously made, and I spotted a couple of inches of zigzagged wire. I wondered, "How would a dipole antenna work if made this way?"

When I returned from travel, I spooled out 130 feet of 16 AWG antenna wire on my lawn. I then walked down the wire, crudely hand-zigzagging it into about 6-inch-tall equilateral-triangle waves. The resulting total end-to-end length was 50% less: 65 feet. I cut the zigzagged wire at the center and fed it with 50 feet of 450-ohm ladder line. I then used a length of polypropylene rope to "hang" it by the wire apexes, suspending it between two trees about 40 feet off the ground. Finally, I fired up the antenna from my shack with my Yaesu FT-857D, tuned with an MFJ-969 tuner.

I was surprised at how easily the antenna tuned up. But most importantly, I was stunned at the volume of contacts I was making with my CQs. I quickly set up an A/B switch between this new antenna any my trusty 130-foot, multi-band dipole, similarly fed with ladder line and supported 70 feet in the air in another part of my lot. The new antenna was as loud as my standard 130-footer. And when switching during QSOs, neither the hams on the other side of the QSOs nor I noticed any difference.

R&D and U.S. Patent

I contacted my long-time friend and ham radio buddy, Rod Lane, N1FNE, with my "discovery." He was as surprised and intrigued as I was with this new approach. Over the next few years, we dabbled with various constructions, including different ways to "hang" the wire from the support rope. We experimented with loops made of zip ties, directly threading the wire

* *email: <experiments@sabertoothwire.com>*

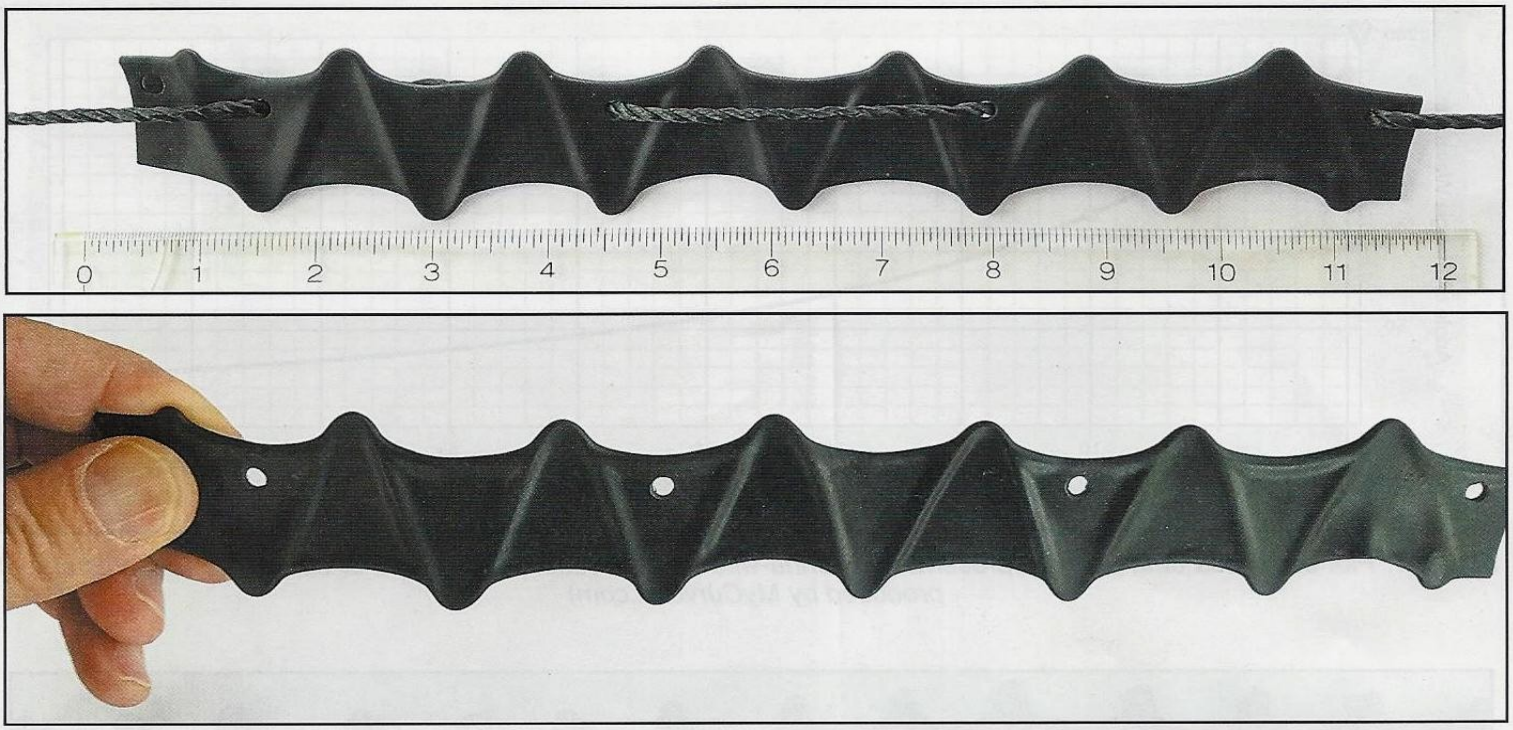


Photo B. Examples of "Sabertooth" wire made with heat-shrink tubing. The internal wire in these examples is 16 AWG solid copper. Inexpensive 100-foot spools of 30-mm I.D. polyolefin 2:1 heat shrink tubing can be found at various online suppliers.

apexes through the braids of the support rope, and other methods (*Photo A*). After compiling our years of construction and performance data, we filed for a U.S. patent in 2007 and the patent was granted in 2011. (See <https://bit.ly/2khkIMp>)

Continued Real-World Testing

After the patent was issued, we communicated our design to our ham radio colleagues through our local clubs and other contacts. We provided construction techniques and encouraged use and testing. Everyone who has deployed our antenna technique has found it to work as well as we have. It has been especially beneficial to hams who don't have property large enough to install full-size wire antennas.

User feedback and our own research delved us further into this "linear loading" method of antenna shortening. For a long time, hams have dabbled with wires that have twists, turns and folds. Our unique shortening method has been a hit for standard dipoles, end-feds, slopers, doublets, inverted vees, G5RVs, OCFs, long wires, wire verticals, wire beams, and more. It has been fun watching our fellow hams experiment with our technique.

Further Inspiration Strikes

Over the years, the only less-than-optimum feedback from colleagues has been in reference to the construction time. Admittedly, this approach takes more effort to build and deploy than simply stringing a straight piece of wire.

One day, a couple of years ago, I was driving in my car, and — wham — not a car accident but an idea, dawned on me. I pulled my car to the side of the road and scribbled my thought on a notepad. My "ah-ha" was to encase the wire in a substrate — for instance, extruded like old-fashioned twin lead — so that the person building an antenna simply cuts off a length of this unique wire to create a dramatically shortened antenna. Like magic, a simple, single piece of wire would now perform like a wire twice its length. So, if someone wanted to get on the air on say, 160 meters, but didn't have the 250 feet to support a wire, he or she would now only need 125 feet. And because this shortened antenna would not require coils or other technology-based shortening tricks, the antenna's overall efficiency would remain unchanged.

To make a long story short, Rod and I experimented with ways to make this enhanced version of the innovation and then filed a new patent application. Based on our previous patent, and the even further novelty and unique characteristics of this new version, we're quite confident that another patent will be issued. In the meantime, we've come up with easy ways to make this new version, so other hams can give it a whirl.

How to Make our "Sabertooth" Wire

We have discovered an easy way to make durable variations of what we nicknamed "Sabertooth" wire. It consists of forming the zigzags in a length of wire, inserting the now-bent wire into an equal length of heat-shrink tubing, and heating up the shrink tubing with a heat gun. The result is wire (or a fully made antenna) that can be easily spooled up and deployed. We commonly punch holes along an edge that allows for easy support by common polymer rope; *Photo B (top)* shows the Sabertooth wire with 1/8-inch twisted polyester rope threaded through.

There are a variety of ways to bend the wire into the zigzag shape. One quick way is to wrap the wire around a long "form" of appropriate width — such as a metal yardstick. Then slide the wire off, open the coils lengthwise to create the appropriate triangle apex angle (see below for calculation details), and flatten the coils to create a continuous triangle wave of wire.

Another way to bend the wire into the appropriate zigzag shape is to create a zigzag wire guide made of common finishing nails on a plank of wood. By threading the wire through

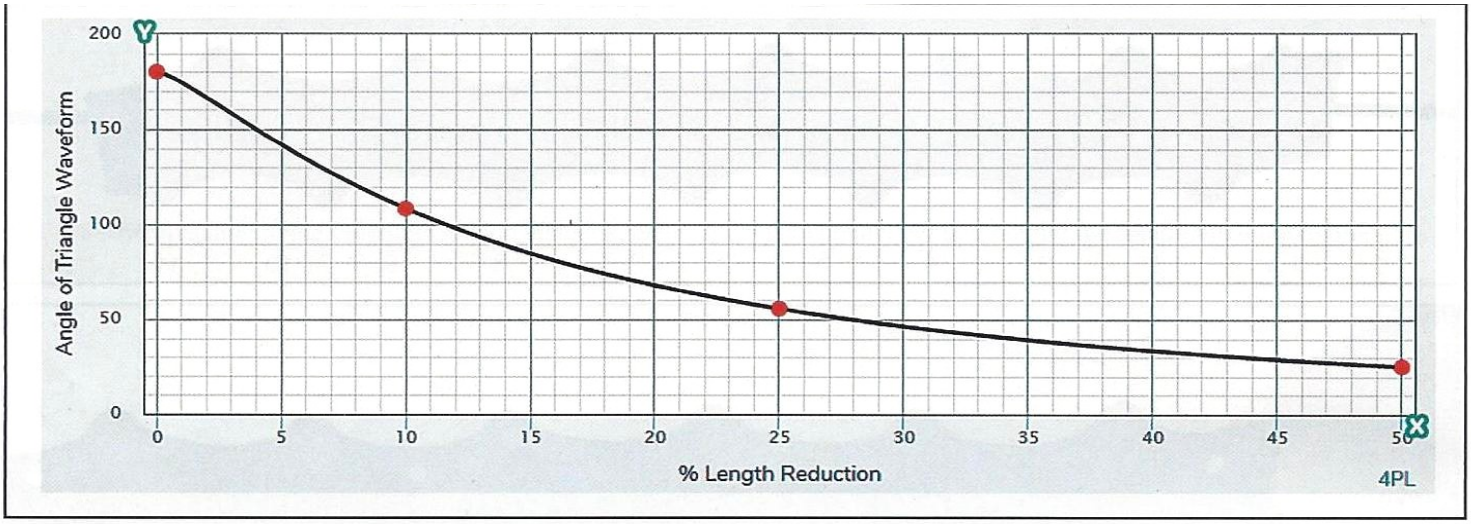


Figure 1. Plot of various data points representing antenna-wire length reduction vs. angle of waveform. (Graphic output produced by MyCurveFit.com)

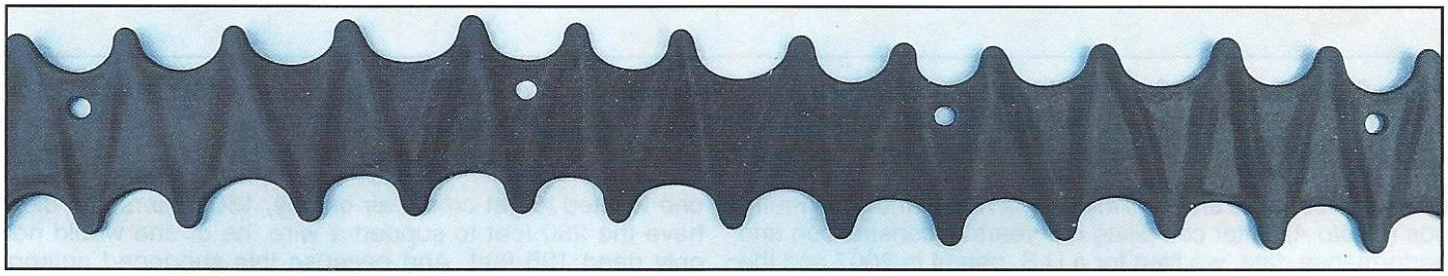


Photo C. An example of Sabertooth wire made with 25-degree wire angles. This version provides 50% end-to-end antenna-wire shortening.

this form, you can quickly create a few feet at a time of angled wire. The resulting wire zigzag is perfectly flat.

Would you like a super-quick version for Field Day? Or a temporary stealth version that could be deployed anywhere? Instead of using heat-shrink tubing, just sandwich the zigzagged wire between two layers of ordinary clear packing tape. It won't have UV resistance or weather durability, so it's not a long-term solution. But it will deliver the 50% shortening effect and play well. NOTE: This method would work for extended periods of time as an attic antenna where you're not exposing the construction to sunlight and weather.

We're also looking into other construction methods, such as polymer extrusion (similar to twin lead and its polyethylene sheath) as well as directly molding it in a polymer. We're also examining various techniques for bonding and laminating wire between layers of UV-resistant non-conductive film. Our most-recent patent application encompasses a broad swath of wire-encased and wire-carrier derivatives and options.

What's the Formula?

You may be wondering about the angle at which should the wire be zigzagged and how wide the triangle wave should be. Good questions — as these have been at the heart of our decade-long research.

Over the years, we have experimented with dozens of designs, angles, wire types, and bonding materials. After hoisting a design variant into the air, we would connect the endpoint of the feedline to an antenna analyzer (such as an MFJ-259C) to see the frequency at which the antenna would resonate. Over countless tests, we've made a number of important discoveries.

The most important discovery: The percentage of linear compression does not change linearly with decreasing wave angle (see *Figure 1*). So, a special non-linear equation had to be developed to fit the data.

Another discovery: The height of the waveform is not a major factor on the overall shortening effect. We have successfully experimented with all sorts of wave widths (peak-to-peak heights), with the most typically tested being between 1 inch and 6 inches.

Another consideration, and somewhat expected: It is important to factor in the dielectric used to contain the waveform. We all know that dipoles made with insulated wire can be made a bit shorter than the classic 468/f formula would indicate, due to the insulation's effect on the wire's velocity factor. The same effect occurs with this new zigzagged antenna wire.

If you'd like to experiment with this new wire, we would suggest starting with a triangle waveform that has a peak-to-peak height of 1.5 inches. As far as the internal angle, it depends largely on the amount of antenna shortening you require.

The following non-linear formula will give you a reasonable approximation for typical gauges of antenna wire and encapsulating the zigzagged wire in either shrink tubing or sandwiched between two layers of clear packing tape. The X variable is your target shortening percentage. For instance, swap out the X with 50 if you'd like the end-to-end

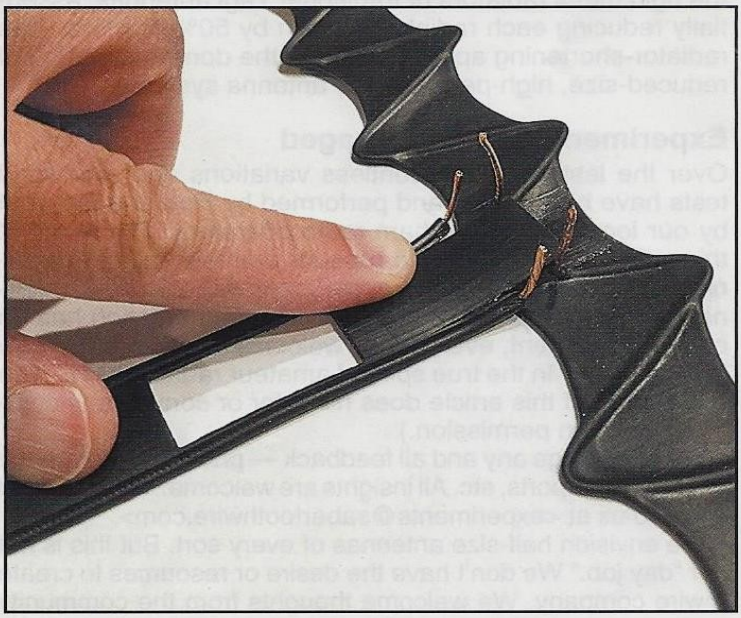


Photo D. Easy feedline attachment. Just splice in.

antenna wire length to be 50% shorter than you would get with 468/f.

[(-7.469441) + ((180 - (-7.469441))]/
[1 + ((X/14.59603)^1.266242)]

You can save your fingers a bunch of calculator keystrokes by simply copying this formula (with your target shortening percentage substituted for X) into a Google search box. Google will spit out the number that will be your target for the wire angle. In the case of 50%, you'll get a wire angle of 25.1° (*Photo C*).

Given that there are various types of shrink tubing material (most commonly polyolefin and PVC) and various types of packing tape (polyester, acrylic, polyimide, etc.), the referenced formula should be a generic starting point for anyone's experimentation.

No Tension on the Internal Wire

In most traditional wire antennas, the wire itself is a structural component, with significant linear tension placed on the wire elements. Over time, the wire can stretch and break. In contrast, with Sabertooth wire, the wire element is encased in a protective sheath (heat-shrink tubing, etc.). Because there is no tension on the wire itself, small gauge wire — much thinner than is typically used for antennas — can be used. We've even performed testing with "magnet wire" versions of Sabertooth wire. Of course, the gauge of the internal wire needs to be proportional to the output of the transmitter for a proper margin of power-handling capability.

Additionally, by being sealed within the polymer sheath, the wire is not directly exposed to the elements and as a result, little to no corrosion occurs, providing enhanced durability.

Feedline Attachment

We have discovered a variety of easy ways to attach various feedlines. Most of the time, we just snip into the sheath, strip back the polymer, and directly attach the feedline. In *Photo D*, we are attaching 450-ohm ladder line to Sabertooth wire after peeling back a portion of the shrink-tube sheath.

Heil Sound Introduces BM-17 at Hamvention

Heil Sound has introduced a new lightweight headset designed for emcomm hams who volunteer for emcomm duties. It is available as either a single-side or dual-side model. In addition, to accommodate different radio setups, the BM-17 is available with either a BM-17-Dynamic element or a BM-17-iC electret element.

The speakers used in the BM-17 have a frequency response of 200 Hz - 5 kHz with very low distortion. The ear pads are replaceable acoustic foam.

The BM-17-Dynamic headset uses the BM-D dynamic element designed specifically for communications use. This 500-ohm dynamic element will work on most amateur radio rigs requiring a Low-Z input impedance (usually between 150 ohms and 4k ohms). Radios requiring a high impedance input of 10k to 30k ohms will require the use of an XT-1 impedance matching transformer. The BM-17-Dynamic has an operating frequency response of 120 Hz - 10 kHz.

The BM-17-iC headset, using Heil's iC electret element, was created for use with ICOM radios. This element must be paired with the AD-1-iC (included) or AD-1- iCM adapter. The iC adapters have no internal DC blocking capacitor so bias voltage can be passed, allowing the iC electret element to operate. The iC element has an operating frequency response of 35 Hz – 12 kHz.

The microphone audio for the BM-17 series terminates into a 1/8-inch mono plug while the headphone terminates into a 1/8-inch stereo plug (1/8-inch to 1/4-inch adapter included).

The boom is designed to be extremely flexible and is swivel-mounted to the headphone speaker for optimal positioning in any situation.

The use of the AD-1 series mic adapters allows simple interface with popular transceiver inputs. The adapter is 6-8 inches long and has a 1/8-inch female input jack for the headset microphone while the 1/4-inch female that exits the adapter is the PTT (push to talk) line for the Heil foot switch or hand switch. The 1/8- or 1/4-inch stereo plug goes into the headphone jack on the transceiver front panel.

The BM-17 line of headsets is available now with a suggested retail price of $127 for the BM-17 Dual Dynamic, $107 for the BM-17 Single Dynamic, $150 for the BM-17 Dual iC, and $130 for the BM-17 Single iC. For more information, contact Heil Sound Ltd., 5800 N. Illinois St., Fairview Heights, IL 62208. Phone: (618) 257-3000. Website: <www.heilsound.com>.

We simply solder the bare ends together, and then environmentally protect the connections with wire nuts, tape, or shrink tubing.

No Feed-Point Insulator or End Insulators Needed

As Sabertooth wire is supported along its edge by a non-conductive carrier rope, no end insulators are needed to isolate the radiator from the carrying line. Similarly, as described above, the feedline can be directly attached to Sabertooth wire — eliminating the need for a traditional feedpoint insulator, such as a center insulator with a dipole.

Potential for Less Overall Copper

Because smaller gauges of internal wire may be used, it is possible to produce variations of Sabertooth wire with reduced amounts of total copper. But, as in any antenna wire or element, there are tradeoffs with power handling and tuning bandwidth as conductors decrease in diameter.

An added benefit to the extra total lengths of wire that comprises any Sabertooth wire construction appears to be received-signal enhancements. With more total wire in the air, users have anecdotally noted improvements on the reception facet of antenna use. However, we have not yet done any scientific investigations into RF reception properties or performance.

Also Applicable to Non-Wire Antennas, Such as Beams

It's important to note that this novel shortening method is not limited to wires, but can be applied to any RF radiator. For instance, the triangle-wave pattern could be incorporated into the rigid metal radiators of traditional Yagi antennas, essentially reducing each radiator's length by 50% or more. This radiator-shortening approach opens the door to a myriad of reduced-size, high-performance antenna systems.

Experimentation Encouraged

Over the last decade, countless variations and real-world tests have been made and performed by Rod and me, and by our local network of ham radio operators. The intent of this article is to provide the broader amateur radio community with the opportunity to experiment with this new antenna-wire technology. As long as the experimentation has no commercial intent, everyone is welcome to explore the new technology — in the true spirit of amateur radio. (NOTE: The publication of this article does not infer or convey any commercialization permission.)

We encourage any and all feedback — photos, performance data, on-air reports, etc. All insights are welcome. You can send email to us at <experiments@sabertoothwire.com>.

We envision half-size antennas of every sort. But this is not our "day job." We don't have the desire or resources to create a wire company. We welcome thoughts from the community on how to scale this up so that hams everywhere could take advantage of this new antenna-shortening method. To help, we have discovered a variety of techniques to efficiently make the zigzag wire pattern in unlimited lengths, such as this method publicly circulating on YouTube: <https://bit.ly/2khPxRf>. If you have production thoughts or interests, send us a note at <manufacturing@sabertoothwire.com>.

We feel we've just scratched the surface of this antenna-shortening innovation. We welcome hams around the world to do what we all enjoy: Tinker, experiment, learn, and have fun!

Additional comments from Eric KB1EHE

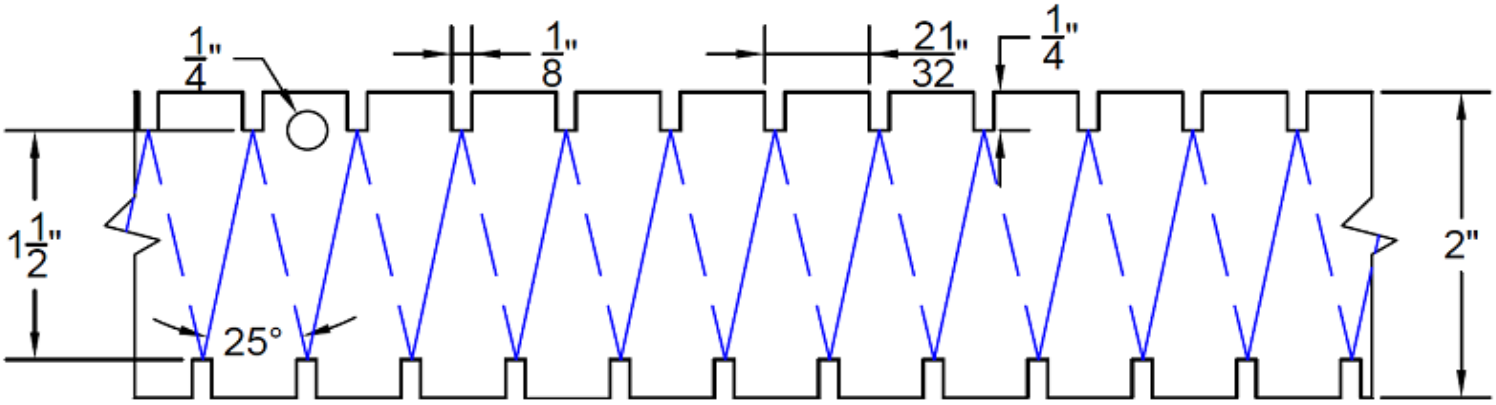
Recently , while lacing up my running shoes, an inventor's ah-ha hit me: It dawned on me, as an additional "Sabertooth" product, that I could create a polymer wire carrier version that would allow anyone to quickly thread his / her own wire into the proper angle on this carrier. It could be extruded from a material like polyethylene -- the same material as ladder line and old-fashioned twin lead.

I brainstormed the idea with my friend and colleague, Rod Lane N1FNE, and we came up with a variety of approaches and designs that would do the trick. On September 10th, we filed a new patent application on these approaches. That gives us one granted patent and two pending patents for this innovation.

As I mentioned, we devised a variety of polymer carriers of various configurations. Below is just one of them. In this version, a person would just wind the wire around the continuous polymer strip of appropriate length (say 30 - 40 feet) and -- voila -- instant Sabertooth wire.

(Note that the 25-degree wire angle delivers an approximate 50% end-to-end shortening effect with many types of wire.) You'll also see a 1/4" hole indicated. That hole would occur every foot, so that a user could easily "hang" the completed Sabertooth wire between supports by threading a support line through the repeating holes.

We're now in the process of trying to find a polymer-extrusion company that could make this pattern. Does anyone know of any Connecticut company that would like to make thousands of feet of this unique product? The goal is to commercialize it to bring this product to hams everywhere! I'm open to any and all ideas. Thanks! 73, Eric KB1EHE



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