DUMMY LOAD OR ANTENNA?

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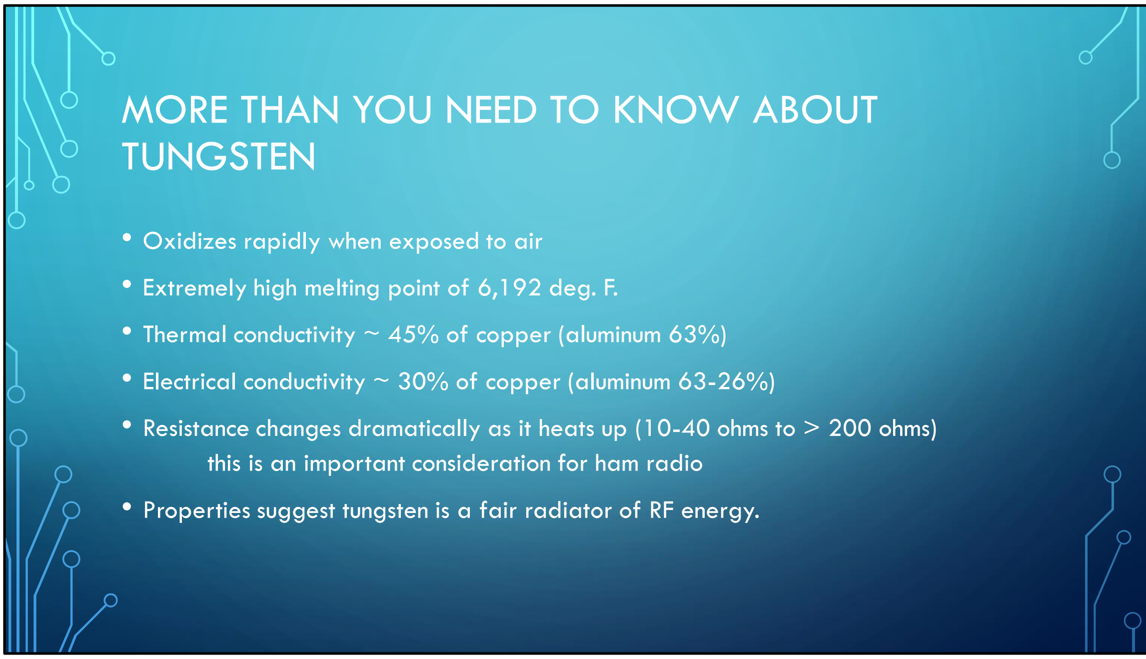
SEPTEMBER, 2018

Tungsten filaments do a fairly efficient job of turning RF energy into heat and light but this process is not complete. Some RF energy will be emitted as electromagnetic radiation into space.

Traditionally the lightbulb was used as a dummy load. The process was simple… turn u the power and tune the radio until the bulb lit brightly. Then hook up the antenna and start transmitting. This worked OK when tube radios were in use, but with the sensitive transistor and computer chip raduos common today, this is probably not such a good idea because of resistance variability in cold vs hot lightbulbs and high impedance bumps at several common frequencies of operation.



Various properties of Tungsten. Note that it is fairly high on the list of metals that conduct electricity. It is important to note that the resistance of tungsten changes dramatically as it heats up and this has implications for antenna tuning when lightbulbs are used.

RELATIVE ELECTRICAL CONDUCTIVITY

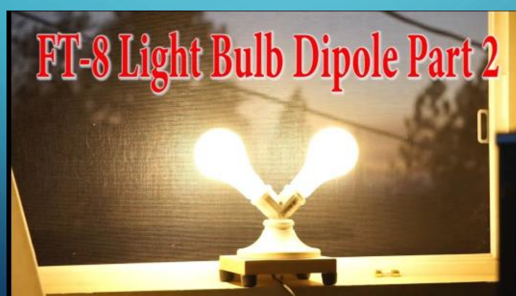
Material	Conductivity (s/m)	Relative to copper
Silver	68 x 10^6	113%
Copper	60 x 10^6	**100%**
Gold	43 x 10^6	72%
Aluminum (pure)	38 x 10^6	63%*
Tungsten	17.9 x 10^6	**30%**
Carbon steel	6.0 X 10^6	10%
Stainless Steel	1.4 x 10^6	**2%**

* 26% - 63% depending on impurities

Here is a list of common metals and their relative electrical conductivity compared to copper when used in electronic circuits, including radios and antennas. It is important to note that tungsten has significantly greater conductivity than stainless steel which is the metal used in the whips of mobile HF antennas.

CAN THE INCANDESCENT LIGHTBULB FUNCTION AS AN ANTENNA?

- We’ve all heard the stories



W’ve all heard the stories…..someone knows someone who was tuning an a lightbulb and ended up having a QSO. Does it really happen. From first hand experience – yes, and it is not difficult to do, especially with the new efficient digital modes of communication.

EVERYTHING WORKS – TOM SHILLER N6BT
QST – JULY 2000 P 47

- ‘The Illuminator’ – 150W bulb, 4:1 balun on a fence post for 10/10 contest
  - 14 countries in one day
  - Iowa to South Africa
  - ARRL DX CW contest - 28 countries, 41 total contacts
  - Briefly mentions the ‘tri-bander array’

The first detailed reported use of the lightbulb as an intentional radiator was published in QST in July, 2000. The lightbulb was used in two contests and experimentally in a quasi-phased array.

CAN THE LIGHTBULB BE OPTIMIZED IN AN ANTENNA DESIGN?

- What would happen if an induction coil were added to a lightbulb to allow multi-band tuning?
- Can a lightbulb even be tuned on multiple bands?
- Can radials improve return currents?
- How can the cold bulb – hot bulb resistance issue be managed?
- What makes a good lightbulb for an antenna?

These are the questions I am trying to answer with my research.

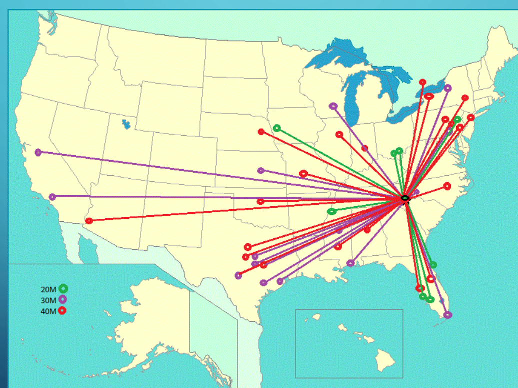
IN PERSPECTIVE

- The lightbulb antenna will never be an alternative to tried and true antenna designs for serious radio operation.
- The lightbulb antenna was developed just to see if it could be done.
- The goal was never to load a lightbulb as a stand-alone antenna. That is foolish.
- The lightbulb antenna is doing nothing mysterious. It appears to obey the laws of physics (but has nasty impedance bumps that make tuning challenging).

It is important to keep this research in perspective. The lightbulb antenna is pretty inefficient compared to more traditional wire and vertical antennas etc. It is not being proposed that the lightbulb antenna replace anything. This research was performed just to see if it could reasonably work. Also, the research did not just focus on the lightbulb. It was focused on how a lightbulb could be incorporated into an antenna system where the ability of the lightbulb to radiate would be maximized. No claims are made that the lightbulb is doing anything mysterious that cannot be explained by application of known physical or NEC modeling principals. In fact, the lightbulb antenna follows generally accepted physical principals of antenna operation very well.

To date, five different versions of the lightbulb antenna have been built and tested. The original version had a single loading coil to tune an Edison 60W ‘squirrel cage’ lightbulb on 40M. The second version used two regular lightbulbs with shorter filaments. The third version, again used the Edison bulb with a multi-tap coil for multiband operation. Versions 4 and 5 utilized two loading coils. A thin one for tuning from 20-30M, and a longer/fatter coil for tuning 40-80 meters. The last two versions also employ the big 84” filament lightbulb – Satco S2431.

FIRST 2 DAYS OF OPERATION WITH 1ST PROTOTYPE WERE ENCOURAGING



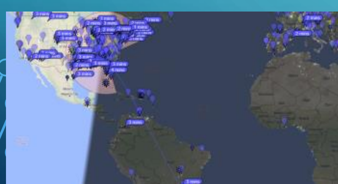
In the first two days of testing with the original lightbulb antenna, a number of QSOs, some out to 2000 miles, were completed on 40M, 30M and 20M. This was encouraging, so a decision was made to continue development.

In the beginning a number of lightbulbs were tested as radiators. Some worked well and others hardly worked at all.

IT LOOKS LIKE INCANDESCENT BULBS WITH LONG FILAMENTS WORK BEST

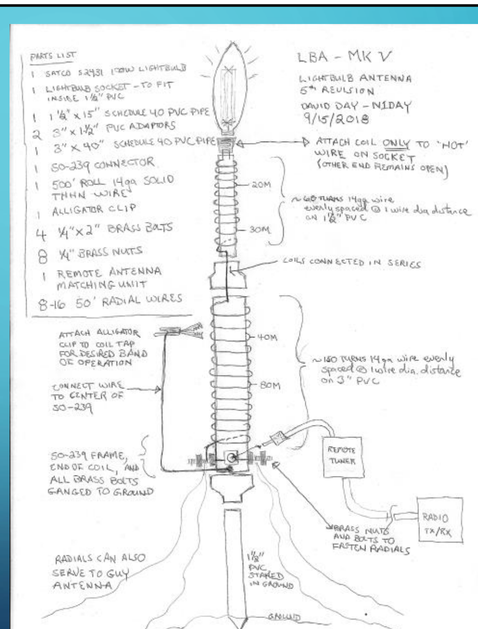
Satco S2431 (left) – 84” filament

Edison Classic ‘squirrel cage’ (right) – 42” filament



The key factor that makes a good lightbulb radiator is length of the tungsten filament. Version 3 utilized the Edison ‘squirrel cage’ lightbulb that contains about 42 inches of tungsten filament. It worked quite well, but when the oversized SATCO 84” filament bulb was used, all of the sudden the FT8 signal at 50 watts began to show up in Europe and South America. Receive performance improved as well. I doubt that you will find the S2431 bulb locally. There are 4-5 on-line retailers who sell this lightbulb.

MOST RECENT DESIGN LBA – MK V

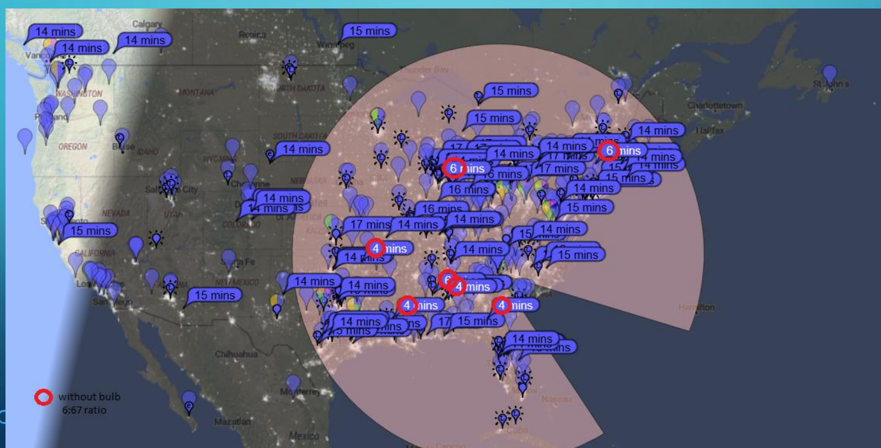


This is the current design and parts list for the lightbulb antenna – LBA MK V. With the exception of the S2431 lightbulb, everything to build the antenna is available at local hardware stores. In this version, two wires were used to wind the coils. A solid 14ga copper wire was used for the coil, and a stranded 14ga wire was used to keep spacing between coil turns and turn pitch uniform. As the coil was wound, light application of hot glue held everything in place. When the coil was fully wound, the stranded spacing wire was removed, and with each coil turn removed, the solid wire was glued permanently in place. This resulted in a much better overall coil than simply hand winding and trying to eyeball coil to coil spacing.

In verions 3 and 4 of the antenna, it was realized that creation of taps on the coil was causing coil deformations and structural weaknesses that can be expected to lower the Q factor and long-term survivability of the overall antenna. To address this problem, vertical slits about ¾" wide were created along the length of the PVC coil form and supporting ribs glued inside the form. By doing this, it is now possible to tap the coil anywhere along it's length in a manner that keeps the alligator clip securely in place without the need for soldered taps that were necessary on the versions 3,4 forms. Note that a slit was made on opposite sides of the form. This allows tapping of each coil without the possibility of accidently shorting the alligator clip to adjacent coil turns.

The coil built into the antenna turned out not to have enough induction to allow tuning on 160M. So an old coil from 630M experiments was placed in series with the antenna’s coil and then tapped to allow tuning on 160M.

DOES IT WORK? OR ARE THE OTHER PARTS OF THE ANTENNA RESPONSIBLE FOR RF RADIATION?



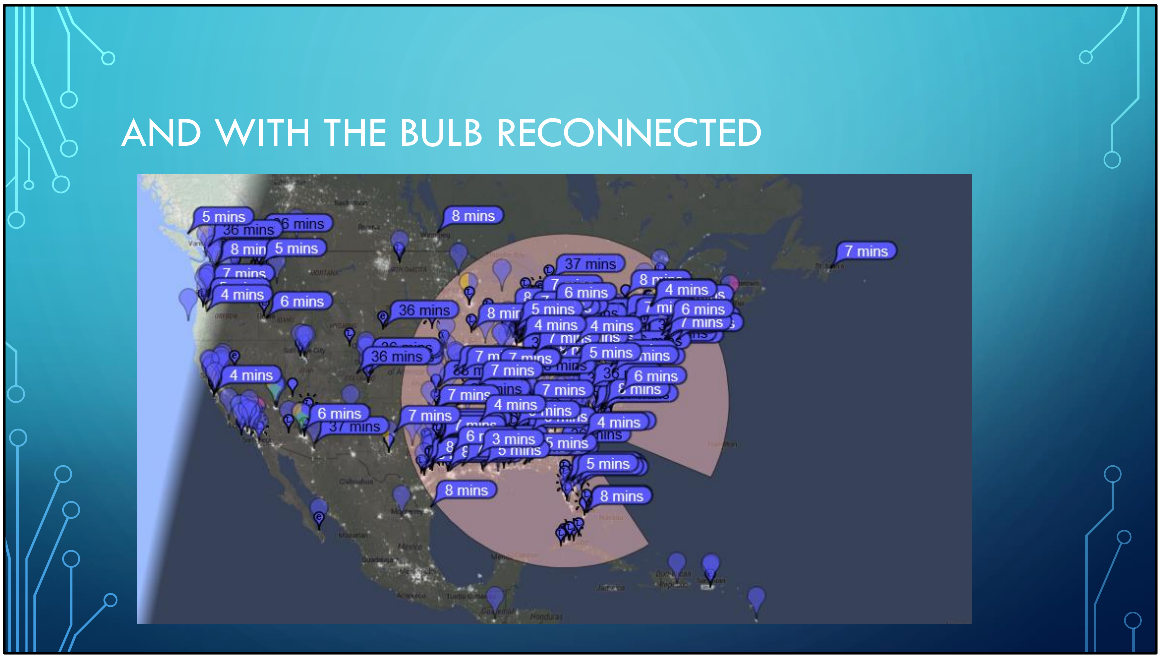
The big question is does the lightbulb actually make the antenna work, or is the radiation coming from the coil, feedline, and radials responsible for performance? Several tests were done to find out.

In the first test, FT8 CQ was called for 5 minutes on 40M at 50 watts with the lightbulb in place. The number of stations reporting my signal on PSK reporter were then counted. This resulted in 67 stations across the US and Canada reporting my signal.

The lightbulb was then removed, antenna retuned, and transmission resumed. Over the next 5 minutes of transmission, only 7 stations reported my signal.

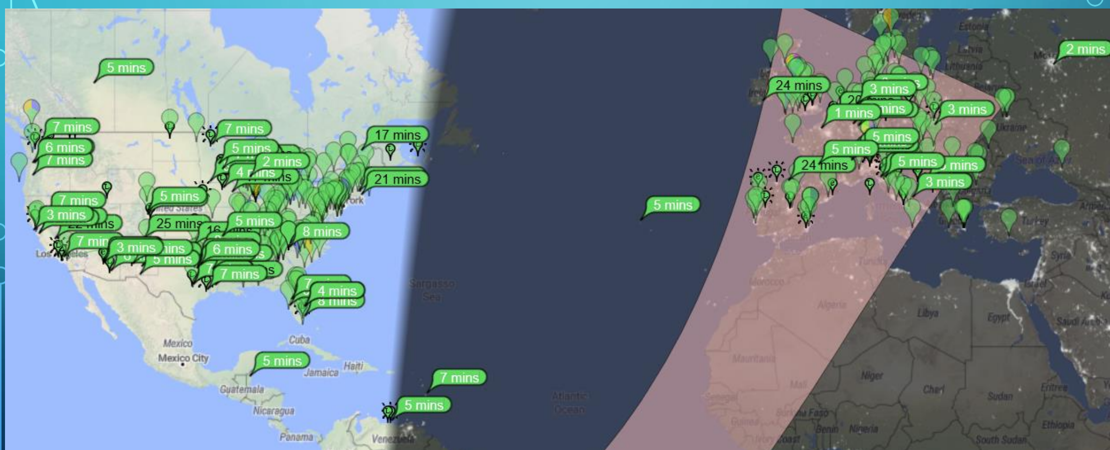
So, it appears that the lightbulb is resulting in a performance improvement ratio of about 10:1. Also, note that the stations reporting without the lightbulb in place were not nearly as distant from my QTH (NC) as stations reporting when the lightbulb was in place. This result was the same on 30M and 20M as well.

With the lightbulb in place, multiple stations tried to answer my CQ. Without the lightbulb, only one local station tried to answer me. This was consistent on all bands as well.

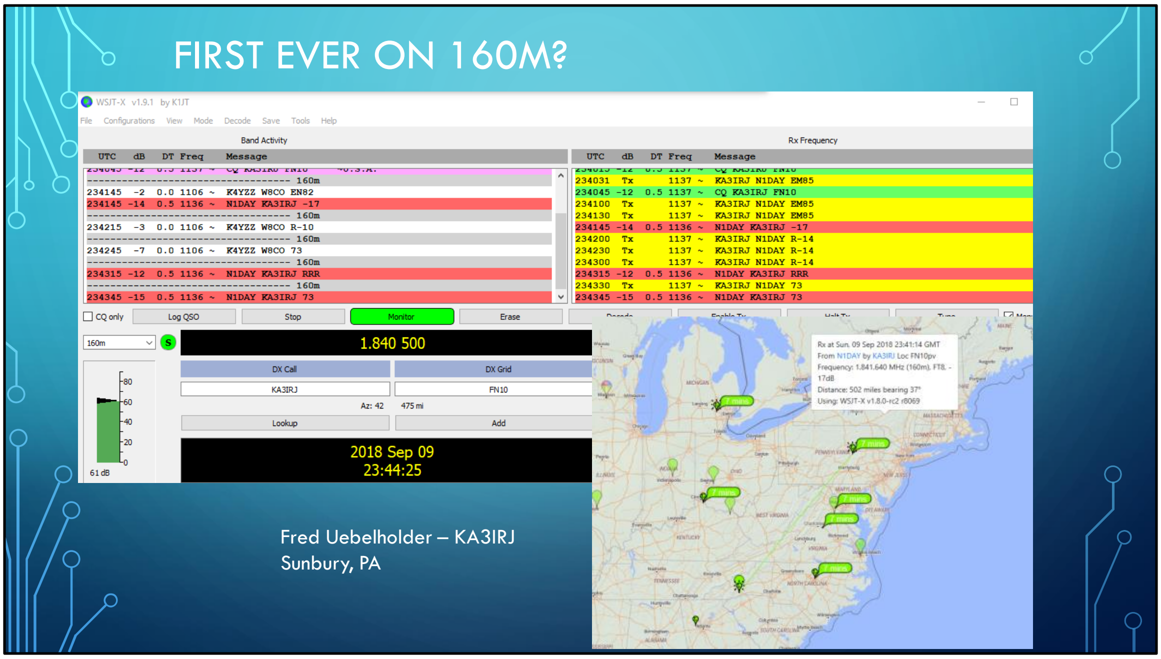


For the next test, I then put the lightbulb back into the antenna, retuned, and transmitted for another 5 minutes. Once again, the original distant stations were reporting my signal. It appears that success of the antenna is due to the big lightbulb.

30M - @ 6PM 9/8/18

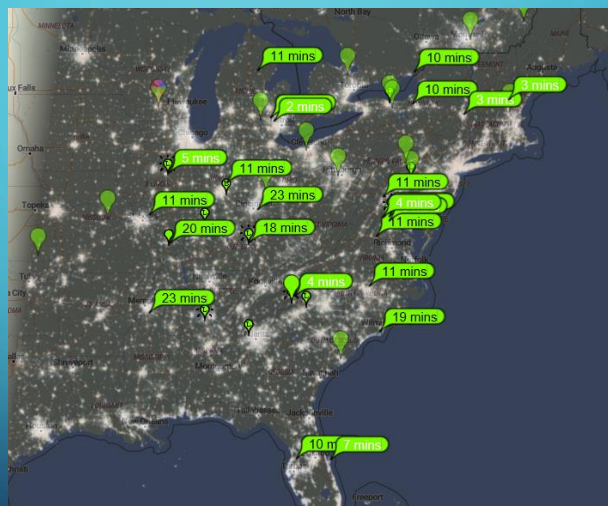


That evening, things really started to pop – especially on 30M and my 50W lightbulb signal was being reported in many countries. I have since had many similar results on 40M, and 20M. I have also been reported several times in Europe on 80M.

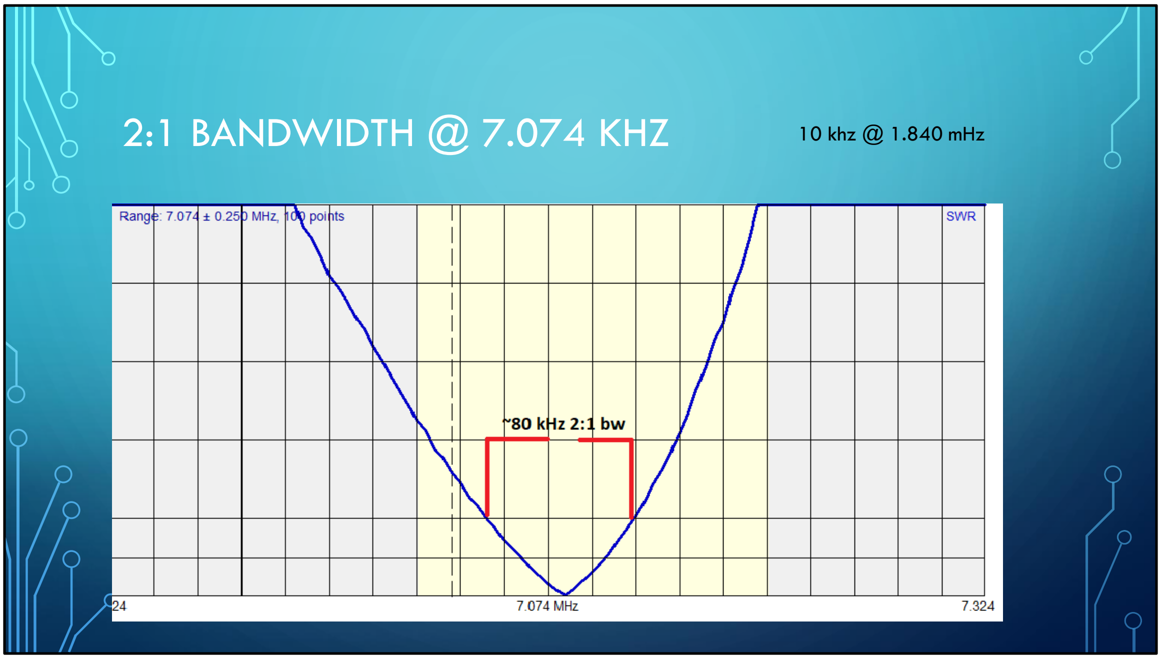


On September 9th, I installed the 160M conversion coil on the antenna. The first station contacted was KA3IRJ in central Pennsylvania. This was at a distance of over 400 miles. As all previous experiments by others with lightbulbs focused on 40M and up, this is likely the first ever 160M QSO completed using a lightbulb as an antenna. Fred and I exchanged emails and I am happy to report that he was as excited about the event as I was.

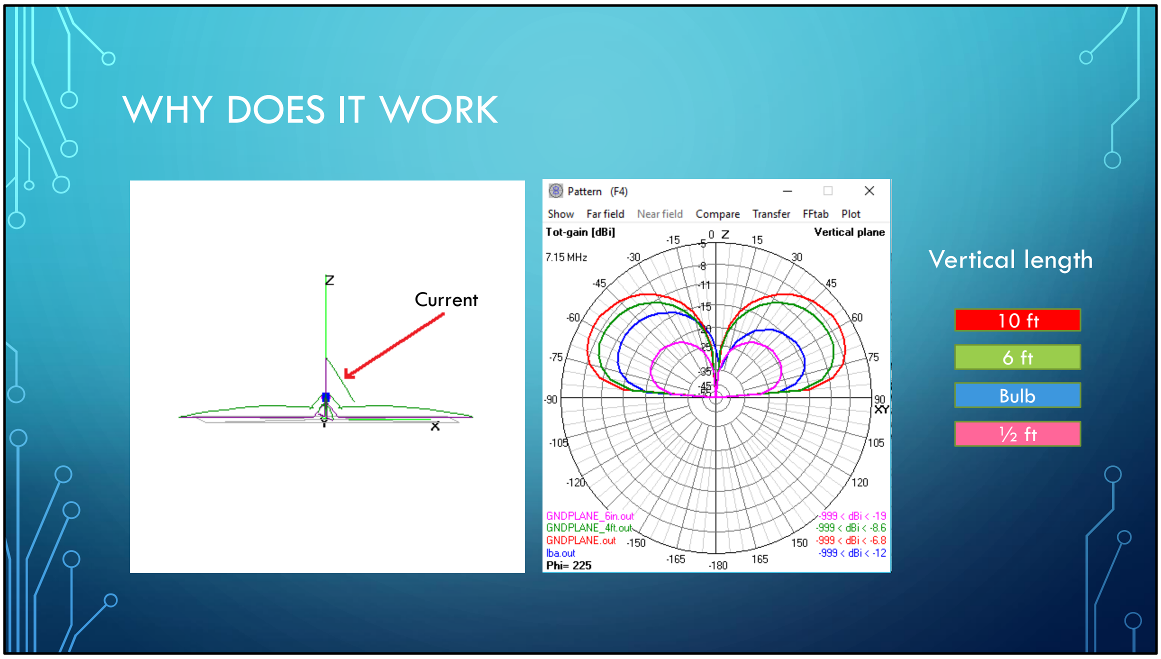
160M



On the first night of 160M transmission, I was pleasantly surprised to see stations at 600 miles distant reporting my signal. Since that first night, this has become common place and exceeded my expectations for performance on 160M.



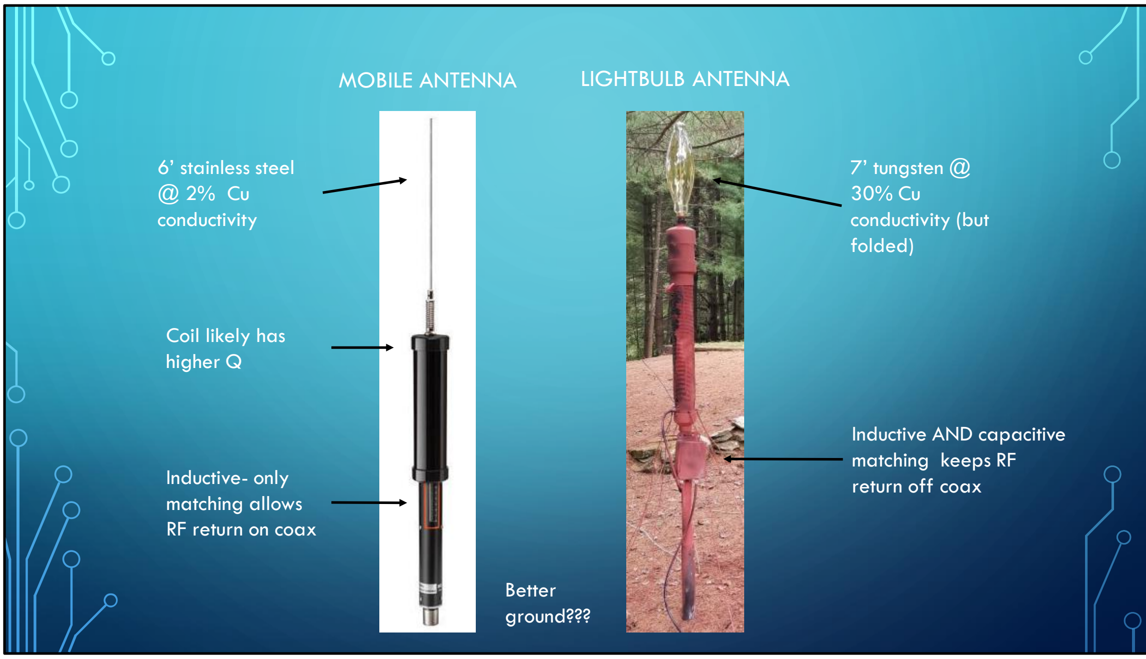
The 2:1 bandwidth looks pretty good on the antenna. It is not really wide which would suggest a poor quality antenna. On 40M the 2:1 bandwidth was about 80 kHz and this dropped to 10KHz on 160M. So attention to tuning of the antenna when doing large within-band shifts in frequency is important.



The big question is why does the antenna work?

To best explain, think in terms of a mobile antenna. A mobile antenna has a good ground (vehicle or radials if being used at a fixed location), a large induction coil, and a short stainless steel whip usually about 6-8’ long. The interaction between all three components is necessary to get the antenna to operate. The coil adds inductance to resonate the electrically short antenna, and the whip provides a conductive surface along which current can vertically travel and be radiated from the antenna. The radials provide a return path for current from ground to complete the circuit.

In the case of the lightbulb antenna, the filament in the lightbulb replaces the vertical element of an electrically short antenna of a mobile antenna-like design. It is this filament that allows the vertically polarized current to flow above the coil and be radiated. The modeling done on the antenna shows what happens in terms if dB performance as the whip element is shortened, replaced by a lightbulb, and finally eliminated.



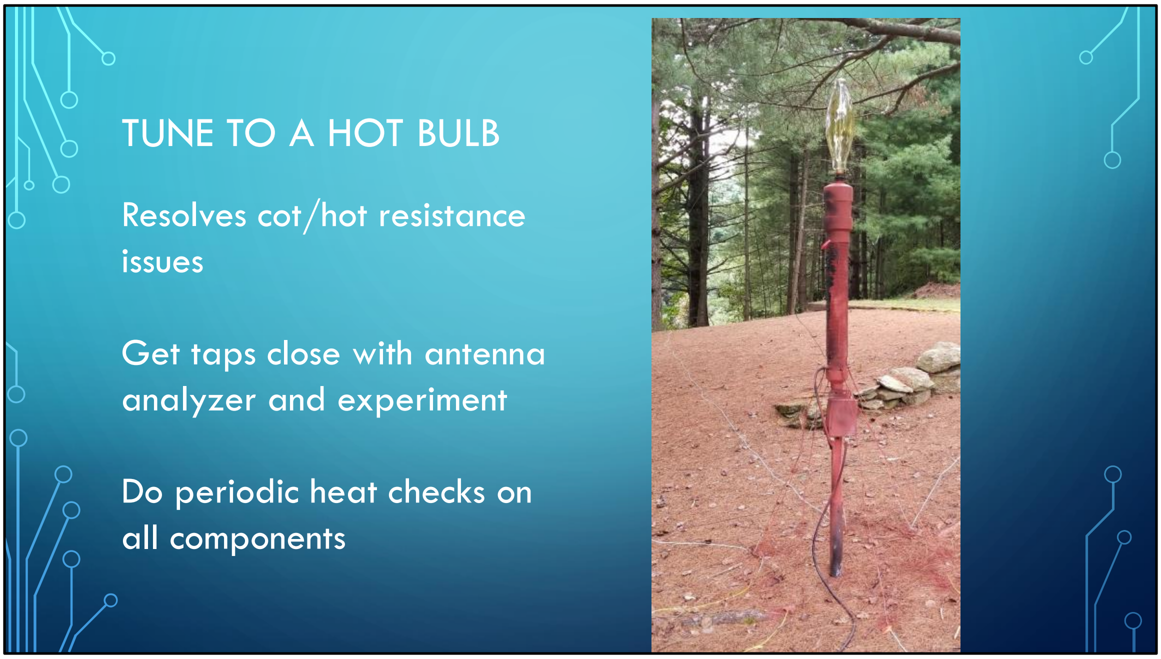
Here is a picture of a popular mobile antenna with a 6' stainless steel whip next to version 4 of the lightbulb antenna. The are very similar. But remember, the lightbulb contains a better radiator than stainless steel and this difference likely makes the lightbulb antenna perform better than one would think it should.

Also note that the lightbulb antenna uses a remote antenna tuner to keep return current off the coax and this minimizes signal losses that can commonly occur when doing antenna matching from in-shack tuners.

Quite a few field strength measurements were performed to see where the antenna was radiating energy. The meter used was a Heliognosis that measures field strength in microwatts and milliwatts per cm2. As can be seen from the pictures, the feedline is radiating minimal energy and energy return from the radials is distributed and minimal (I need more than the present 8 radials radials to further improve the antenna return path current). At the top of the induction coil, radiation is also minimal when the lightbulb is not in the circuit. When the lightbulb is added to the circuit, the current at the top of the coil jumps from 0.18 milliwatts to 35 milliwatts per cm2.

From the area of the lightbulb, very little current is detected when the lightbulb is removed from the circuit. When the lightbulb is in place, the radiated energy pegs the field strength meter at 40milliwatts/cm2.

Based on the experiences and test results covered in the last several slides, I think it is safe to say that the lightbulb is a critical component in performance of the antenna.



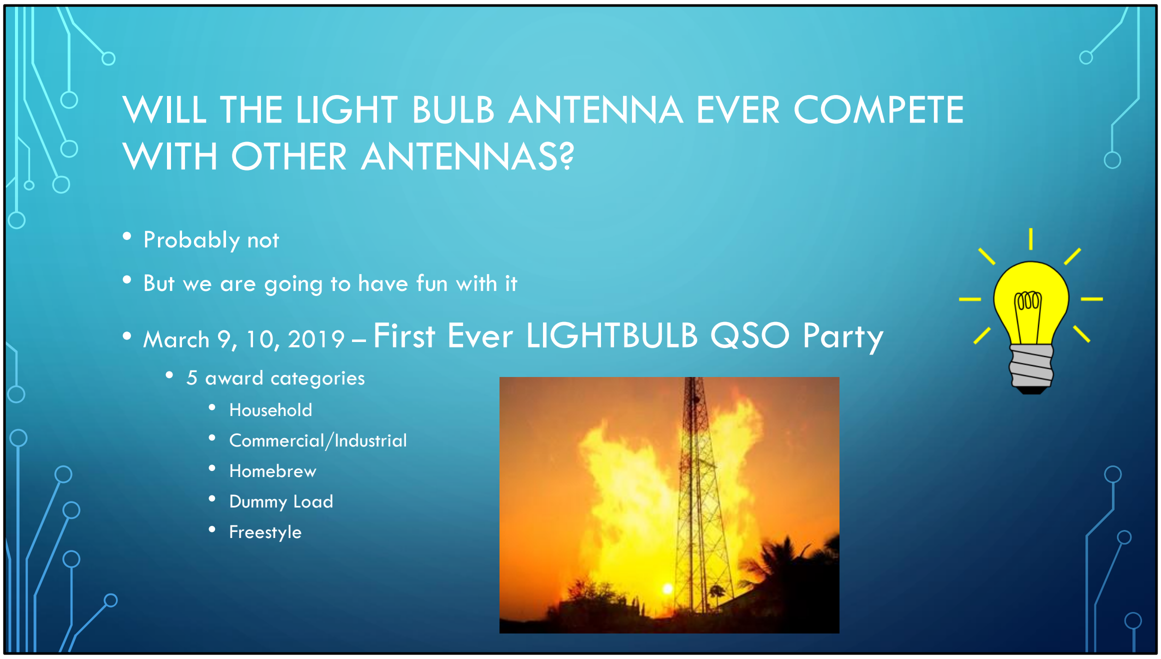
A few things were learned in the process of making FT8 contacts with the antenna. These relate to the changes that occur in the resistance of tungsten filament as it goes from cold to hot when RF energy is applied. To resolve the problem of creeping SWR after the antenna is tuned due to heating of the filament, always do antenna tuning on a hot lightbulb. By allowing the radio to transmit for a short period of time before tuning, the tungsten filament resistance is given a chance to stabilize. Then when tuned, a match appropriate to a hot bulb will be found by the tuner. As a result SWR drift while operating will be minimized or eliminated.

Also, when finding an appropriate tap on the antenna's coil using an antenna analyzer, it if a waste of time to strive for a perfect tune. Just get as close as is easily achieved and then experiment with tuning at power. Because the resistance (and impedance) will change as the tungsten filament heats up there is no way around doing some experimentation in finding the most appropriate tap point on the coil for any given band of operation.

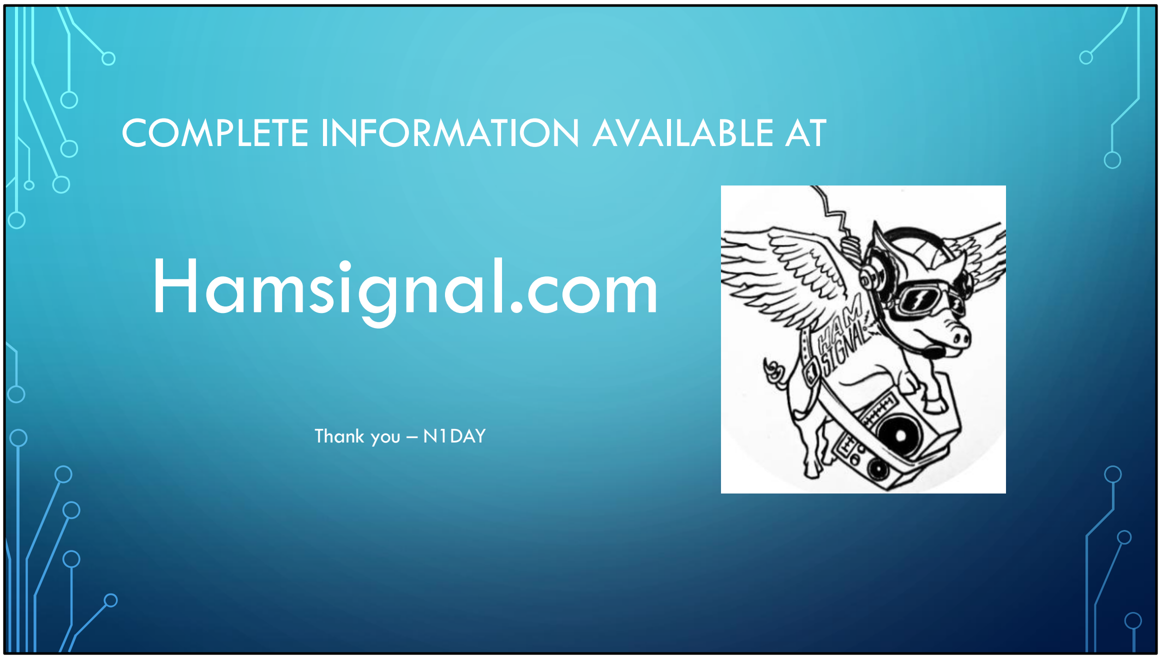
Finally, after several minutes of transmission at power, turn the radio off and go out to the antenna and put your hands on all of the components. You may feel a little warming right above the tap point on the coil, but if you are finding any 'too hot to touch' places anywhere on the antenna, go back and check your retuning process.

I have found that if the lightbulb gives a dull glow during transmission, this is a good sign that power is getting to the lightbulb and being radiated and not ending up overheating some other component of the antenna.

Performance of the lightbulb antenna to date has exceeded my expectations. As of mid-September 2018, I have completed over 400 QSOs, mostly on FT8 with some on Phone and PSK 31. I have also had a handful of completed QSOs to Europe with the furthest QSO being > 4,000 miles to DF2SD in Germany. My FT8 signal has also been reported on PSK Reporter in over 30 countries with the most distant being Australia on 40M.



In conclusion, will the lightbulb antenna ever compete with more traditional antenna designs? Probably not, but it certainly has been a lot of fun developing the concept. In March of 2019, I will be competing in the first-ever QSO party designed specifically for those HAMs using lightbulb antennas.



I keep a blog at hamsignal.com. You can go there to read about all of my experiments in development of the lightbulb antennas. I have also included schematics and parts lists for the antennas if you are interested in exploring your own designs.