Ultrasound Pressure of a Weak Spark

By Phil Anderson, WØXI

Radio amateurs and shortwave listeners have been following the lead of power company technicians in using hand-held broadcast band AM radios, AM capable VHF radios with small yagi antennas, and ultrasound receivers to locate sparking sources causing radio frequency interference. Perhaps the best summary on search techniques is a book titled AC Power Interference Handbook, written by Marv Loftness, an EMC power engineer (ref 1). The book summarizes well the nature of sparking on AC Power distribution systems, dispels a number of myths, outlines search methods, and focuses on AM and VHF radio equipment to get the job done. Only recently has ultrasound become a larger part of the search formula.

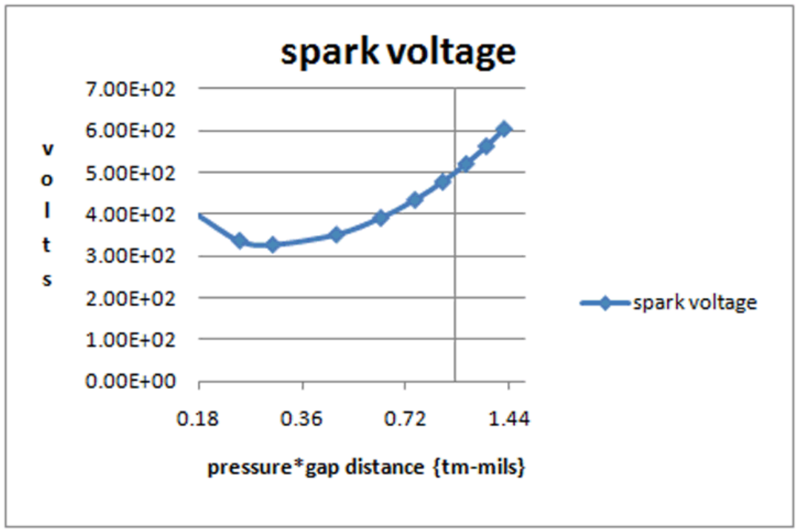
My interest in ultrasound was initially focused on listening to biological sources, such as bats communicating during flight or while echo-locating insects to eat. As a radio amateur, that interest grew, of course, into exploring the details of and designing bat detectors. The best architecture of simple detectors turns out to be the ubiquitous direction conversion receiver with an ultrasonic piezo detector replacing the usual RF antenna. Most bat activity can be heard from about 25 to 50 kHz within the ultrasound spectrum, which ranges from 20 kHz to about 2 MHz. The higher frequencies are used in medical and mechanical fault location applications.

While in the process of exploring and designing several bat detectors, I ran across articles outlining the use of ultrasound to assist in locating sparking sources causing RF interference. I became frustrated, however, when I couldn’t find any articles that spelled out the pressure levels generated by the sparks. I wanted to compare those with transmission levels of bats. I figured that their transmission levels would have to be similar, at least for weak sparks, or the ultrasound receivers being used to find noisy power line sources just wouldn’t work! This led me to devise and carry out an experiment to measure the pressure produced by a weak spark that would be similar to that found on an AC distribution line running to homes. A brief description of this experiment follows.

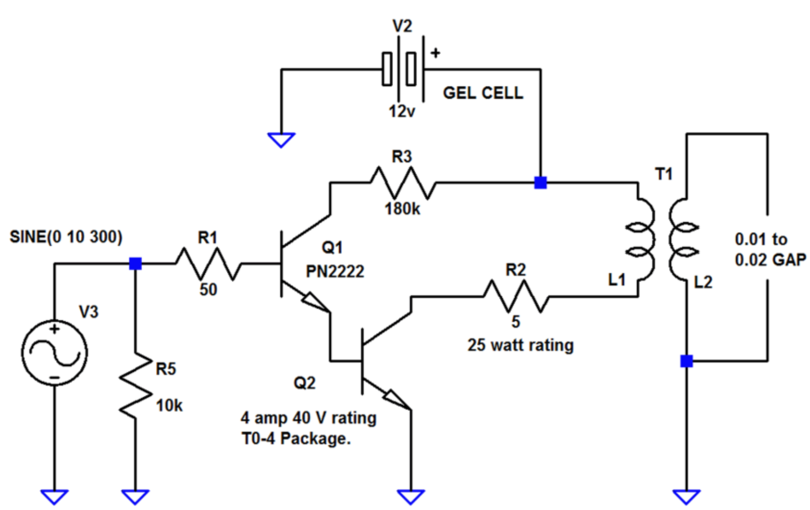
Sparking Theory and Apparatus Design

The first tasks were to research the nature of sparking and to design an apparatus to generate sparks on the lab bench. The web is amazing as we all know. I quickly accumulated a number of articles on the physics of sparking and there was no end of turn of the century (1900) spark transmitter examples. It took a bit longer to come up with a low-voltage sparking mechanism.

A Swiss physicist, Friedrich Paschen, carried out the initial work on the nature of sparking in 1889 (ref 2). He arranged two parallel plates in a gas and varied the voltage across the plates for various distances between the plates. Data were recorded whenever the gas broke down due to arcing. These data fit to a curve produced his law. In general terms, the breakdown voltage is proportional to the product of the pressure and the distance between the plates. For air at standard pressure and temperature the minimum breakdown voltage achievable is 327 volts for small gaps between the plates. See the plot.

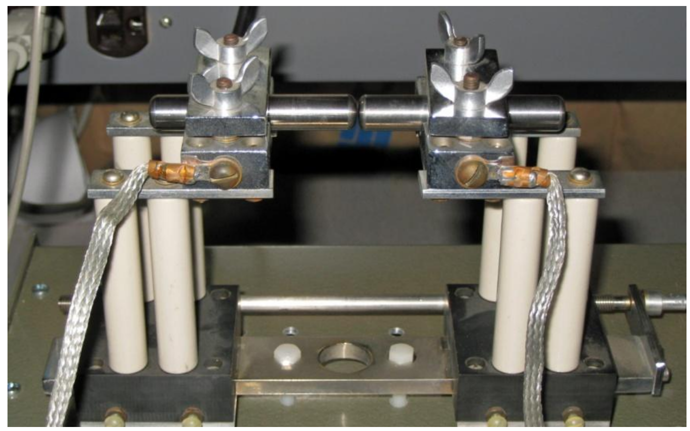


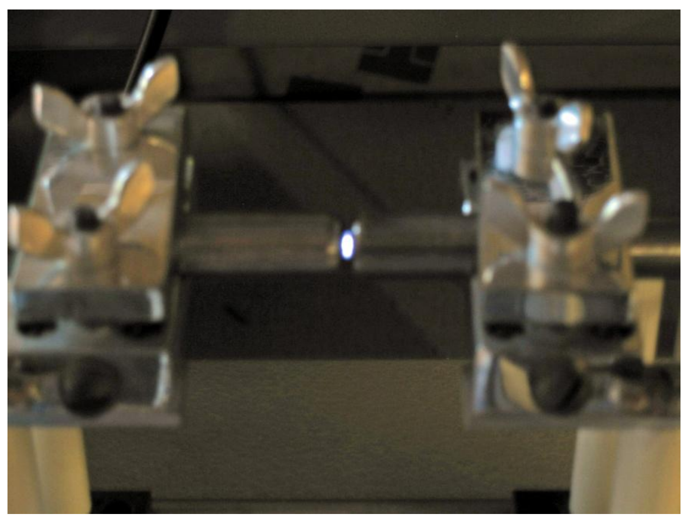
I set out to replicate this result, using what I call a “weak” spark. I didn’t use a typical spark transmitter circuit, circa 1910, since those circuits employed the use of 20 KV or higher. I settled for the circuit of Figure 2, a modification of the Hammond Museum of Radio’s demo spark transmitter (ref 3). They attached a simulated antenna load to theirs, which tuned the frequency of transmission. I didn’t want a tuned load but simply a metal gap – like on power distribution equipment – so removed all tuned circuits. I also didn’t want to take the time to build the



signal source so instead drove the circuit with my bench signal generator. Q1 and Q2 were used to isolate the generator from the transformer primary and Gel Cell and a 25W limiting resistor was placed in the collector circuit of the power transistor. A T725 Bogen audio frequency inter-stage transformer was used to step the primary up to the required 400 volts – or thereabouts. Two tungsten electrodes were used to establish the gap.

Creating a Spark

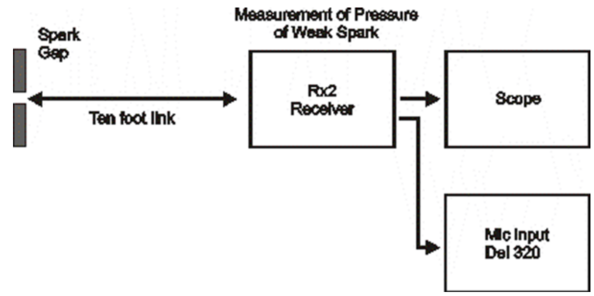




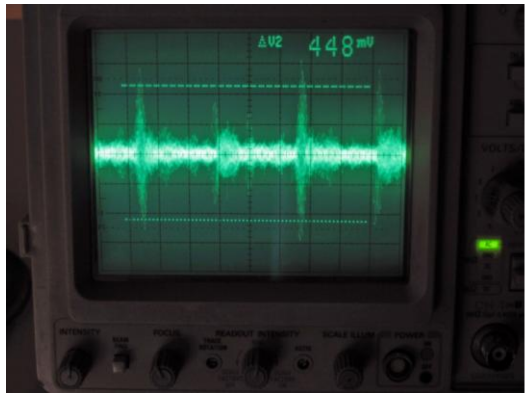
The picture at right is of NØAPJ's air gap fixture (on loan to me). The rod at the back bottom with shaft out to the right allows the user to adjust the gap while operating. The air gap is between the two rods at the top.

I set the initial gap at 50 mils (0.050 inches). At first I couldn't see a spark when keying the generator (with a code key in series). Following the clue of the spark voltage graph, I decreased the gap in small steps. Finally, to my delight, sparking commenced with the gap set at 20 mils (thickness of three sheets of paper). The picture at the right shows the spark generated at about 360 volts. Sounds neat; I could just hear it at one foot.

My final task was to determine the pressure generated by the weak spark. I arranged the link displayed in Figure 5. An Ultra-RX2 receiver covering 30 to 50 kHz was set ten feet from the spark gap and channel one of the scope was attached to the output of the first amplifier. The Line Out (audio) was run into the mic jack of my Dell 320.



The scope picture shows the spiking nature of the pressure wave generated by the sparks. Even though I drove the transformer with a 300 to 400 Hz signal, there is no evidence of audio. The sparks are so narrow that they generate RF and ultrasound pulses across a wide spectrum with each positive transition of the generator voltage driving the transformer. The voltage peaks measured were about 0.5 volt. Having calibrated the RX2 earlier, and taking into account the distance from the spark gap, the peak pressure emitted was about 0.5 Pa (75 micro-psi) at ten feet. The sound file recorded during the experiment, weak spark.wav, can be downloaded at www.midnightscience.com/ultra-articles.html . Keep in mind that the audio heard in down-converting the pressure signal to audio range will sound different with different spark voltages and spark gaps.



As expected, a weak spark generates a peak pressure of roughly the same level as a strong bat transmission. With my 8-inch diameter 6-inch parabolic dish added to the RX2, the same level of signal could be heard at greater than 50 feet. So, one should be able to hear moderate sparking on AC power distribution lines.

References:

1. Friedrich Paschen (1889). *Annalen der Physik* **273** (5): 69–75.
2. “AC Power Interference Handbook, 3rd Edition,” Marv Loftness, KB7BB. You can purchase a copy from midnightscience on the web.
3. “The Sounds of a Spark Transmitter: Telegraphy and Telephony,” John S Belrose, Radio Sciences, Comm Research Center, Ottawa, ON, K2H SH2, Canada; www.hammondmuseumofradio.org/spark.html.
4. “Acoustic Measurement of the Arc Voltage Applicable to Arc Welding and Arc Furnaces,” Michel G Drouet and Francois Nadeau,” J. Phys. E: Sci. Instrum., Vol 15, 1982. Printed in the UK.