By Kent Britain,* WA5VJB

Connecting the Radio to the Sky

Ultra Wide Band (UWB)

We certainly are seeing a lot of articles these days on Ultra Wide Band, or UWB. The FCC has set aside 3.1 GHz to 10.7 GHz for UWB use. There is a lot of bandwidth and there are a lot of challenges for both transmitters and the antennas (photo A).

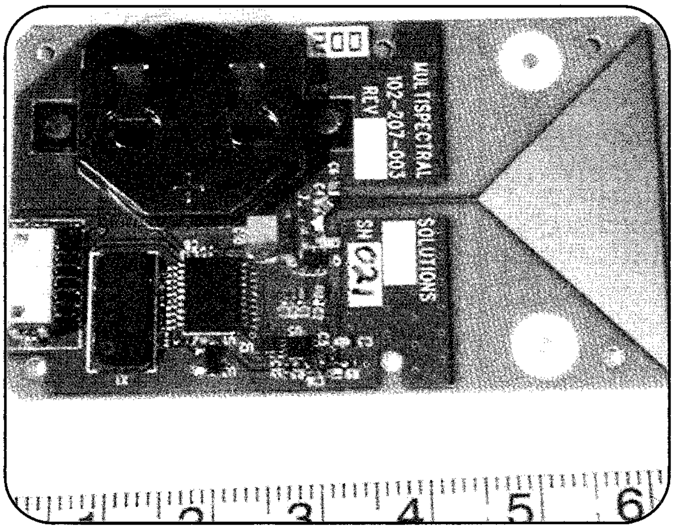

Photo A. Ultra-wide-band transmitter and antenna.

There are three main types of UWB signals being used at this time. The first type is simple FM. If I take my 5-GHz walkie-talkie and crank the FM deviation up to 500 MHz, this meets the FCC definition of UWB. No, that is not a typo. I didn't mean 5 kHz, but 500 MHz. Even the old C-band TVRO only used 30 MHz wide FM video. However, the idea is the signal is spread so thin that there isn't enough signal in any one part of the band to cause much interference. This is legal according to the FCC, but not commonly used.

The next UWB modulation is Orthogonal Frequency Division Multiplexing (OFDM). OFDM can be thought of as hundreds or even thousands of carriers each being separately modulated. It is kind of like one-thousand 9600-kb modems running in parallel. Thousands of these signals can result in data rates of over 250 Megabits/second. Demodulation of all these carriers is somewhat math intensive. However, with such little power in each carrier, again the interference potential is low. Also, to keep the FCC happy, the signals must be spread out over at least 500 MHz, and there are some complex formulas on how evenly the energy is spread out.

Impulse or Pulse Position Modulation was the original UWB modulation. The transmitter in photo A puts out a 1-watt pulse for 1-billionth of a second. This fast pulse isn't done with super-fast digital circuits, but rather with clever oscillator design. As the oscillator is turned on, the oscillator puts out five or six sine waves centered at 6 GHz and then shuts down as all the DC energy is used from the capacitors in the circuit. In many ways this is very similar to the self-squelching oscillators used in super-regenerative circuits for the last 90 years.

We had to use a Tektronix 11801 scope with a 26-GHz bandwidth to look at these fast pulses. The timing between pulses is used to send data. While the transmitter is putting out 1 watt, it has to transmit one-billion pulses to use up just one watt-second from the battery. That lithium coil cell will run the transmitter for over a year.

UWB Antennas

There are two big engineering problems with UWB antennas. The first is bandwidth; the antenna has to work over several GHz of bandwidth. The next problem is the Q of the antenna.

The typical resonant antenna is a high-Q structure. One way of looking at a high Q is to think of it as being similar to a flywheel that is spinning and spinning, thereby storing energy.

As shown in figure 1, on average, an electron must go back and forth on a dipole about 30 times before it leaves as an electromagnetic wave. Furthermore, it is only after the energy has built up on the antenna that it starts to look like 50 ohms. Back on 40 meters, this means that for the

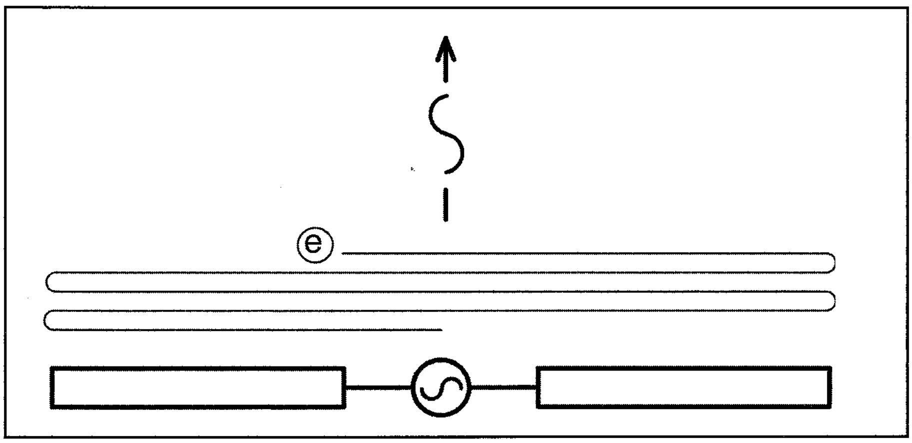

Figure 1. A typical electron takes 30 passes to radiate as a wave.

*1626 Vineyard, Grand Prairie, TX 75052
e-mail: <wa5vjb@cq-vhf.com>

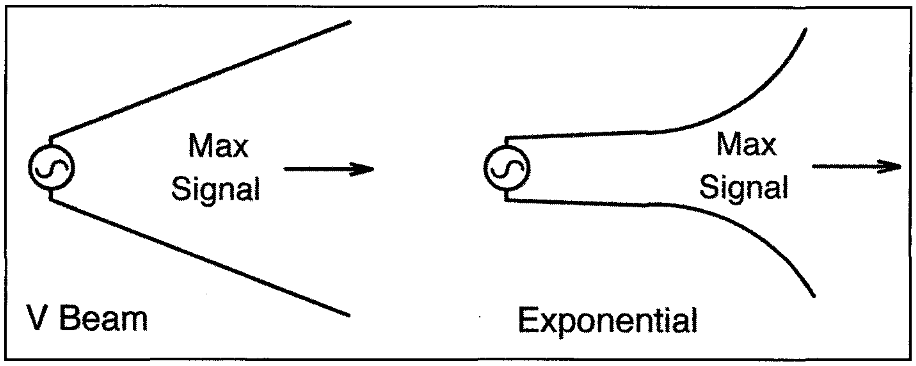

Figure 2. Dipole to V to Vivaldi antenna.

first 1/7,000,000 second your inverted-V looks like a dead short to your transmitter. Then, 1/7,000,000 second later the antenna has an impedance of a few ohms. Also, only after a few dozen waves have gone into the antenna does the voltage start to build up and it begins to approach the typical 50-ohm load. Of course, the average ham isn't all that worried that it takes few millionths of a second for the impedance of the antenna to stabilize.

However, for the designers of high-speed data networks and high-resolution RADAR systems, the transmitter impedance and the antenna impedance may be a lot different for these short pulses than it is for a CW signal. Also, the time it takes for the voltage to build up delays the pulse. Now my nice short pulse has been delayed by the ringing currents in the antenna, lengthening and delaying the data.

Exponential Antennas

If we start out with the simplest beam, we just take a dipole and point the elements forward, as in figure 2. Make the elements longer and longer, and the gain goes up. We now have the V beam, and when several wavelengths long, we start to build a rhombic antenna. On HF the ends of the wires are usually terminated with load resistors. However, if we make the wires thicker and thicker, we get a good SWR without the load resistors and build what is known as the Ram's Horn antenna. The Vivaldi antenna in photo B is from this same family of transmission-line antennas—a very wide bandwidth and modest gain, but unlike the dipole we don't have all that much circulating current.

Log Periodics

Because the log periodic is an array of dipoles, it also has the tendency to resonate and stretch out a sharp pulse. The log periodic in photo C covers 2 to 11 GHz and the entire UWB band. Two years ago we used that same log periodic as the feed for a 12-inch dish and were able to collect data from that 6-GHz trans-

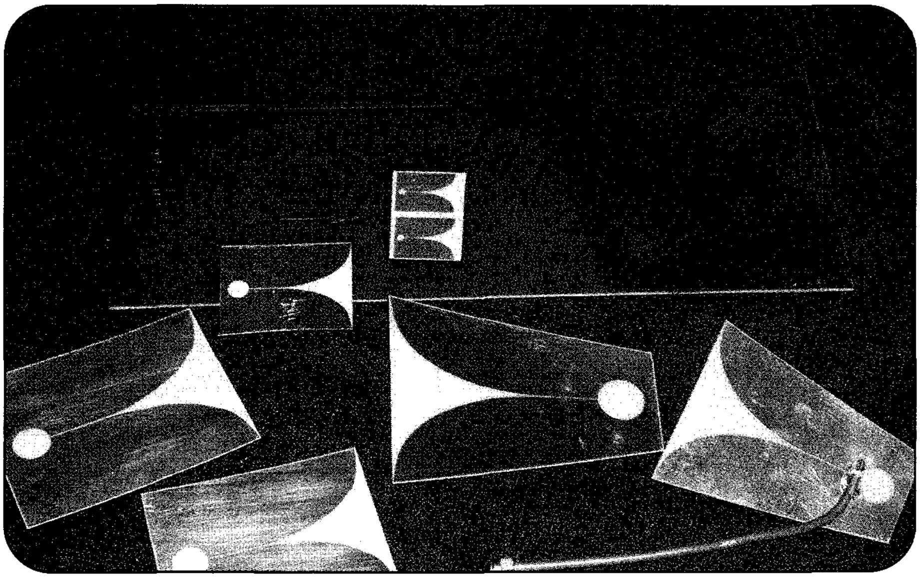

Photo B. Exponential or Vivaldi antennas.

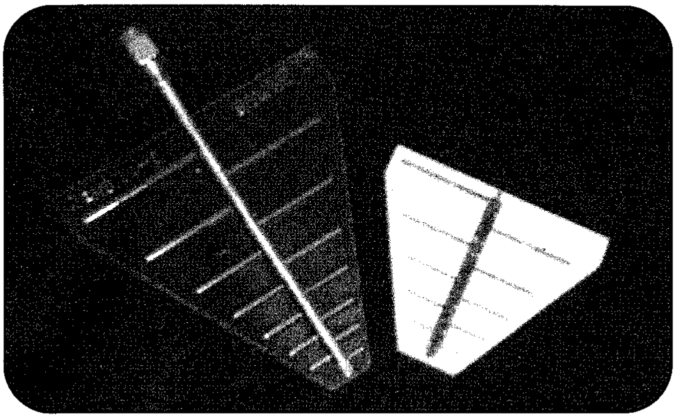

Photo C. Log periodics and UWB.

mitter in photo A at over two miles. UWB is not necessarily a short-range mode.

Scimitar Antennas

The Scimitar antenna has a long history in both electronic warfare and as a telemetry antenna in the Apollo space program. The inner radius sets the high frequency, and the outer radius sets the low-frequency range of the antenna. The Scimitar in photo D has an excellent 400–1500 MHz bandwidth. From a practical side, the antenna has a natural input impedance of about 20 ohms, so some kind of 20–50 ohm matching network is necessary.

Furthermore, it is usually the bandwidth of this matching network that sets the bandwidth of the antenna. A simple Scimitar covering the entire UWB band is small, simple, and becoming popular on many UWB products. When I come up with a simple matching system a multiband Scimitar should make a good ham project.

Fractal Antennas

In photo E you can see my Stage 5 Sierpinski fractal antenna. There has certainly been a lot of hype about fractals, and claims about their use with UWB. On the right you see a triangle of copper the same size as the Sierpinski. Whether the antenna is on network analyzer, or in the field, there is no significant difference in their performance. As to filters, this filter flattened out at 3.1 GHz. Thus, UWB starts at 3.1 GHz with very strin-

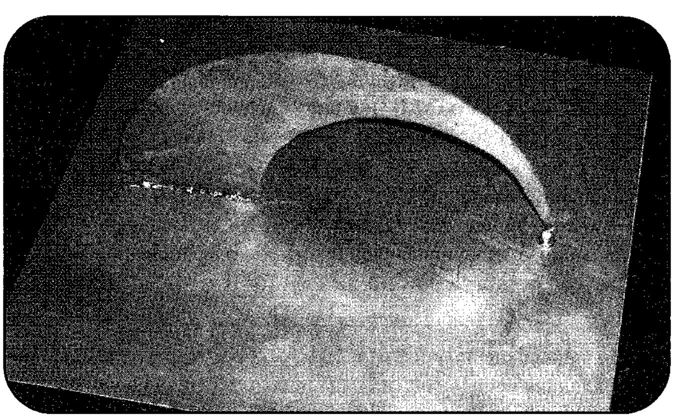

Photo D. Scimitar antenna.

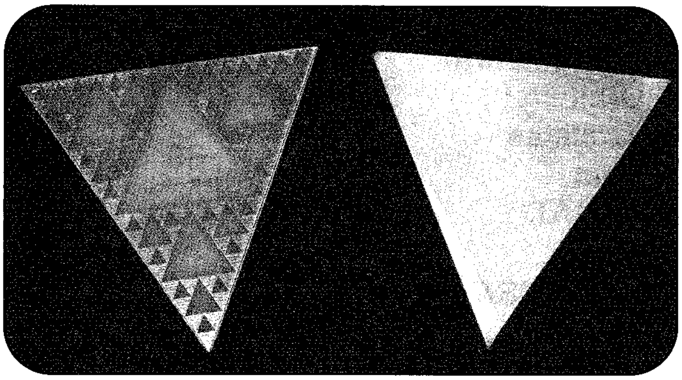

Photo E. Fractal antennas.

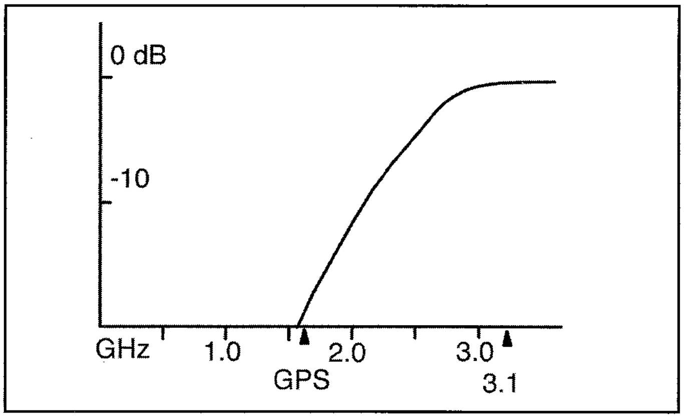

Figure 3. Gaussian response filter protecting GPS.

gent limits on how much signal/noise the UWB transmitter can put on the GPS band.

I always thought that the 3.1-GHz lower frequency limit for UWB was a kind of strange number. The early UWB systems were the impulse types. These short pulses on the order of one-billionth of a second long can make quite a racket. Some of the early UWB systems took out UHF TV, cell phones, and more importantly, GPS. Taking out GPS took out two major systems. First was navigation. For the FAA, this problem became a "safety of flight" issue.

The pulses also took out most cell-phone systems. A little bit of noise on the cell-phone bands just means your range drops a bit, and the battery in your phone gets used up a little faster since the phone has to run more power. However, the cell-phone problem went right back to the navigation problem. All those cell towers are kept in sync with the time signals from a GPS antenna on that same tower.

Without GPS, the cell sites lost sync. Therefore, the "experts" who said those short pulses would never bother anyone did not agree with the field work that showed impulse UWB chew up and spit out a number of systems.

The FCC and FAA's first priority was to protect the GPS band around 1.575 GHz. You can't just put a Drake TVI filter on a UWB signal, because the filters mess up the pulse. Therefore, the engineers looked at a UWB-compatible filter with a notch centered at 1.575 GHz. A pulse gets rounded off and stretched out when it goes through a filter. Also, the "ringing" stretches out the pulse. Therefore, a simple high-pass filter is not going to fix these interference problems. However, there is a class of constant group delay, or Gaussian filters.

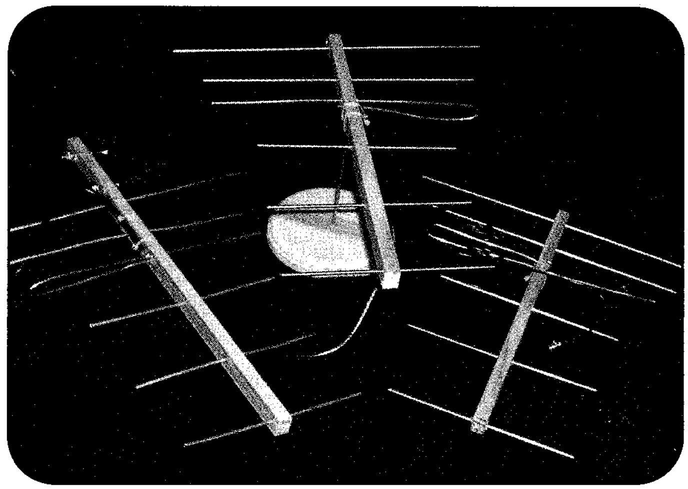

Photo F. UHF HDTV "Cheap Yagi."

These keep the pulse nice and square. Even so, Gaussian filters don't have a very sharp response.

In figure 3 we have a Gaussian filter with the notch right at 1.575 GHz to give maximum protection to GPS. The filter rolls off at 3.1 GHz. Now you know where that 3.1-GHz limit came from for the bottom of the UWB band. The upper limit is 10.7 GHz. Above that frequency are mainly military radars, and they don't like any competition.

Back to the experts who claimed that those high-power one-billionth of a second pulses would never bother anyone on the UHF bands: They missed several little things in the real world. First, most radios have some kind of filter in their front end. These filters again ring and lengthen out the pulses. The high-power UWB systems still have enough power through the filters to saturate the first transistor in the receiver. Now the power supply and bias supplies have to recover from this full-power whack, and this takes a few thousandths of a second. Of course, the pulse continues into IF, and IF filters lengthening out the pulse even longer. Now the pulses are long enough to blank out data, put bars on your TV set, or wipe out GPS systems and any cell towers on which they are located.

The HDTV Transition and Simple TV Antennas

If you subscribe to the other two magazines published by CQ Communications (*CQ* and *Popular Communications*), you know that I write for both of them as well as *CQ VHF*. It is because of the coming transition to digital television before my next *CQ VHF* column that I mention a construction article in *Popular Communications*. You will find a downloadable copy of the construction project for my HDTV version of the "Cheap Yagis" (photo F) at: <http://www.popular-communications.com/23-AntennasWeb92708.pdf>. Of course, a subscription to *Popular Communications* is the best way to go for this timely information, but CQ Communications has made a special exception to its embargo policy of current articles for this HDTV project.

As always, I enjoy your input and suggestions for future topics. You can e-mail me your antenna questions or suggestions at <wa5vjb@cq-vhf.com> and visit <http://visit www.wa5vjb.com> for additional antenna projects.

73, Kent, WA5VJB