



## **Overcoming UWB Antenna Design Challenges With FDTD Software**

*By Remcom, Inc.*

Aether Wire & Location, Inc. has pioneered the development of ultra-wideband (UWB) technology capable of identifying the position of many devices to centimeter accuracy over kilometer distances. This technology is applicable to many military and commercial applications ranging from tracking the position of soldiers on the battlefield to inventory control in a factory. As a pioneer in UWB technology, Aether Wire faced the challenge of developing antennas that preserve the original waveform over a wide frequency range while avoiding coverage gaps. The company's engineers discovered that finite difference time domain (FDTD) electromagnetic simulation software provides the ability to simulate antenna performance to a high degree of accuracy while providing reasonable computational times. "FDTD simulation helps us evaluate a wide range of antenna designs, making it possible to optimize antenna performance which in turn was crucial to the success of our UWB technology," said Bob Fleming, Chairman and Co-Founder of Aether Wire, Sunnyvale, California. "Over time we have gained a solid understanding of the factors that affect UWB antenna performance while saving a huge amount of time and money that would have otherwise had to be spent building and testing prototypes." Aether Wire use the XFDTD software package to carry out these calculations.

Over a decade ago, well before the name UWB had even been coined, Aether Wire set out to develop small, low-power transceivers that can be used for position location and low data-rate communications. Global positioning system (GPS) technology was in its infancy then but it was already clear that GPS was not the solution to this problem because it isn't accurate enough and because it cannot operate within buildings, urban areas, forests, etc. For most applications, what is desired is location relative to other people or objects. Aether's technology uses small, low-power transceivers that determine position by cooperatively exchanging an electromagnetic signal. The accuracy of this range determination is proportional to the relative bandwidth, the ratio of the signal frequency to the carrier frequency. With conventional sinewave technology, relative bandwidth is very small, at most a few percent using spread spectrum. The zero-carrier, spread spectrum technology pioneered by Aether Wire, on the other hand, provides a relative bandwidth approaching 100%.

### **Advantages Of Spread-Spectrum Technology**

Spread-spectrum technology makes it possible to achieve centimeter-level accuracy without using expensive microwave technology, because GHz bandwidth is obtained without a carrier. Aether Wire developed very small, low power, low weight, and low cost transceivers by integrating the electronics in CMOS without any inductive components. MEMS can be used to integrate the resonator for the timebase on chip as well. The antennas can be equally small, and can be driven directly by CMOS, because they are non-resonant, current-mode, and low voltage. UWB signals form a shadow spectrum which do not interfere with the sinewave spectrum. The transmitted power is spread over such a large bandwidth that the amount of power in any narrow frequency band is very small. The good features of spread spectrum are shared, including multipath immunity, tolerance of interference from other radio sources, and inherent privacy from eavesdropping. UWB signals have very good penetrating capabilities so transceivers can operate within buildings, urban areas, and forests.

Aether Wire engineers designed integrated circuits and found they could easily determine position by measuring time of flight between two localizers. They used impulse doublets consisting of positive Gaussian impulses that directly generate a very wide instantaneous bandwidth signal according to the time-scaling properties of the Fourier transform relationship between time and frequency. It soon became clear that the engineers faced significant antenna design challenges. They used a current mode antenna design that builds up resonance in a dipole until current rises to a level of approximately 8 amps. One of the major problems seen in early designs was a tendency of the electromagnetic field produced by the antenna to oscillate, crossing the zero axis after the point at which the impulse should end.

### **Move From Build And Test To Simulation**

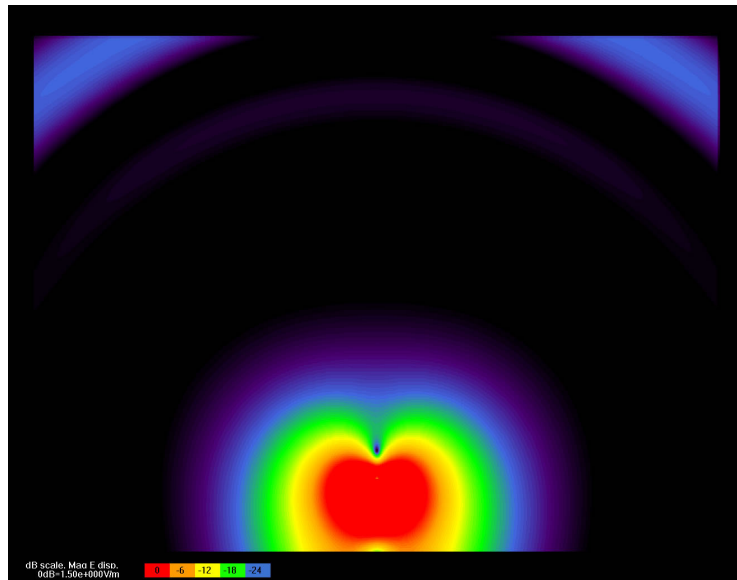
“In the early phases of our work, we built and tested a considerable number of antennas and saw this problem reappear over and over again,” Fleming said. “It was taking us about a week to build and test each antenna design. It became clear that we might need to go through hundreds of designs to find one that worked the way we wanted. It was far too slow and expensive to reach our goals using this method. We tried several open source packages that had been developed at universities as well as a commercial package that at that time was the standard tool for antenna design. None of them worked they way we wanted them to. The best that we tried was an open source version of the FDTD method but it wasn’t stable enough for industrial use. Then we heard about a commercial implementation of the FDTD method, XFDTD from Remcom Inc. We tried it and discovered that it provided both the accuracy and the robustness that we needed. We have used it every since as our primary antenna design tool.”

A key advantage of XFDTD is that it not only predicts antenna performance but also provides a wide range of diagnostic information not available from physical testing.

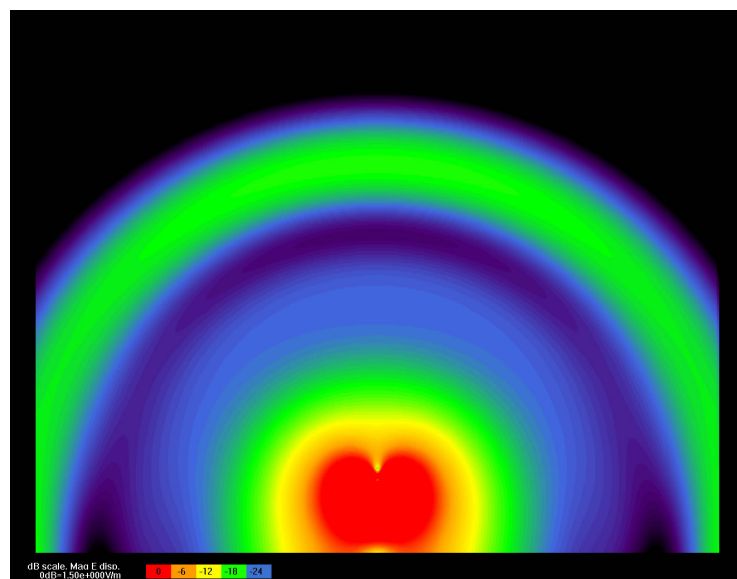
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Aether Wire engineers have used the software to formulate guidelines, some of which that have since become basic to UWB antenna design. For example, the software helped engineers determine that current mode antennas generate an electric field in the near zone that is the opposite polarity of the current generated in the far zone. XFDTD also helped understand how the transition in the polarity works. Aether Wire engineers produced approximately 100 simulations one time step apart to demonstrate how the field is generated and converted them to an animation to help customers understand the phenomena.

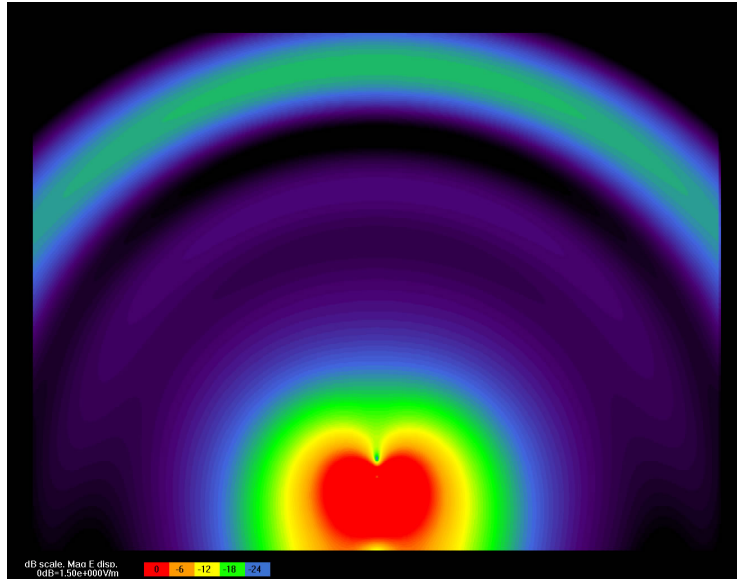
**Figures 1 , 2, and 3:** Near field electric field magnitude snap shots in time.



*Figure 1*



*Figure 2*



*Figure 3*

### **Iterating To An Optimized Design**

Aether Wire engineers can create and evaluate approximately six new designs per day, making it possible to iterate much more quickly to an optimized design. Furthermore, simulation helps engineers gain an understanding of the sensitivity of various performance characteristics to design parameters much faster than in the past. For example, this method made it possible to determine relatively quickly that the key to solving the undershooting problem described earlier is to use very low impedances.

“With a normal sine wave antenna you can use a driver to match the impedance to the antenna,” Fleming said. “On the other hand with UWB, every time you design a new antenna you have to design a new driver. Problems with drivers are very difficult to detect. XFDTD helps us go through enough parameter changes to quickly get a sense of what affects driver performance. That’s not to say that it provides exact results. But, it consistently is very close. For example, our simulations may tell us that the antenna optimizes at 0.1 ohm. That puts us in the ballpark and perhaps we will build a few iterations and discover that optimized value is actually is 0.12 ohm.”

### **Managing Tradeoffs**

The size of the antenna is often critical because when the antenna is less than a  $\frac{1}{4}$  wavelength long the delay needs to be increased which reduces efficiency. On the other hand, a larger antenna tends to distort the impulse because the impulse is not able to illuminate the entire loop. Aether Wire engineers find that simulation provides an essential tool for managing this tradeoff in order to keep efficiency high while also maintaining the

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desired waveform. Using these methods, the company has been able to maintain its position at the leading-edge of UWB technology despite the upsurge of interest in this field and many competitors that have followed in its footsteps.

The combination of communication and accurate position location capability within very inexpensive devices has opened up a host of applications. A sampling of military and commercial applications includes:

- Monitoring large numbers of sensors dispersed over an area for nuclear, biological, or chemical threats.
- Geospatial registration for warfighter visualization.
- Synthesis of large aperture antennas for tight beam communication, using scattered transceivers that know their precise relative location and synchronization.
- Survey and construction.
- Keeping track of mines, armaments, equipment, vehicles, etc.
- Keeping track of personal items, such as one's children, pets, car, purse, luggage, etc.
- Inventory control in stores, warehouses, shipyards, railroad yards, etc.
- Finding fire fighters in a burning building, police officers in distress, or injured skiers on a ski slope.
- Arbitrating rules in a sports event, playback of motions for coaching, or viewing the re-creation of an event.
- Keyless locks and rooms that adjust the light, temperature, and music sound level of an office or home.
- Automatically adjusting motion picture camera focus and motion-tracking for matching digital effects

Using XFDTD for electromagnetic simulation is helping Aether Wire quickly develop products that meet the specialized needs of these applications.