Outdoor Propagation Analysis of Ultra Wide Band Signals

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Abstract

An ultra wide band (UWB) signal is defined as any radiation in which the 3-dB bandwidth is greater than 25% of the center frequency. UWB signals are characterized by extreme low powers and large bandwidths, which can be used for data, voice and video communication. Since UWB waveforms have very short time duration, they possess unique properties. For example in radar applications, these same pulses can provide very fine range resolution and precision distance and/or positioning measurement capabilities. These short duration waveforms are relatively immune to multi-path cancellation effects. In this paper we test the performance of a simulation to model the propagation of an UWB signal in outdoor forested environment. The simulation uses a combination of Finite Difference Time Domain and ray tracing methods to simulate the UWB wave propagation. The model takes into consideration the dielectric constants of the materials of the trees and measures the signal strength for vertical and horizontal polarizations of the UWB antennas placed at various heights and distances from each other. The results of the simulation are compared to measurements obtained from tests conducted at a wooded area in Seneca Creek State Park, Gaithersburg, Maryland. It was observed that up to 150 ft distance between the transmitter and receiver, the horizontally polarized antenna system gave better signal-to-noise ratio, but at greater distances the vertically polarized antenna system gave a better signal-to-noise ration performance. Three dimensional plots of the signal strengths and the signal-to-noise ratio for various transmitter and receiver distances are plotted for the system. These are compared with experimental results and observed that the simulation closely matched the experimental data. The results of the simulation and measurements will be used for further developing an UWB location and tracking system in outdoor environments.

Introduction

Ultra wide band technology has generated widespread scientific and commercial interest. Studies indicate that UWB technology is a viable candidate for short range communication and location/tracking systems in dense multi-path environments [1]. In this report UWB signal propagation in dense forest environment is measured and studied. Data collected from the measurements are compared with simulation results that combine ray tracing and finite difference time domain methods.

UWB Simulation System

The simulation technique involved a combination of ray tracing and Finite Difference Time Domain methods [2]. The ray tracing technique used ray shooting technique to disperse rays. When the rays intersect an object, a transmitted and a reflected ray are started. These rays are then traced to obtain further intersections. For complex structures like trees and shrubs we would not expect the ray tracing technique alone to provide accurate results. For example, it would be quite difficult and time-consuming to try to account for every signal path between the transmitter and the receiver, since due to the complexity of the environment it would require that we launch a very

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large number of rays. To overcome this ray tracing method was combined with Finite Difference Time Domain method (FDTD). There were many advantages of using FDTD method in combination with ray tracing. The effects reflection, diffraction and radiation can be fully addressed in FDTD method. Also it can simultaneously provide the field values at all points on the computational domain. However FDTD computation requires a large amount of memory and is computationally intensive. Thus a combination of ray tracing and FDTD was more suitable for this application. The ray tracing was applied to wide free space areas and when the ray intersects an object, reflected and transmitted rays are generated based on the material properties of the trees. The total field at a given point is determined taking into account the path loss for the entire distance the ray has traveled.

Ray Tracing and FDTD

In the development of the environmental model, the dimensions of the trees are read from a generated three-dimensional matrix file which stores the coordinates of the edges of the trees and their exact location on the computational domain. The tree is then enclosed in an irregular virtual FDTD box. When a ray intersects the virtual FDTD domain, the electric fields at the intersection point are stored in an array which is subsequently used by the FDTD method to compute the field intensities inside the FDTD domain. When the wave reaches the other end of the domain, the field values are stored again and the ray tracing is resumed [3].

Tree Modeling

The tree modeling algorithm used in the simulation was a modified Lindenmayer system (L – system) for generating trees [4] [5] [6]. The L – system was chosen because they provide a compact representation and can also be tailored to accurately provide species dependant parameters for trees. In our simulation the Lindenmayer system was used to more accurately represent the general shape of pine trees that were present in the forest. The system generated a simulated model of a tree and the program stored the values of the coordinates of the end of the trees in a three dimensional matrix The FDTD simulation used this matrix for the boundary conditions. The dielectric constant values of the soil material were also included in the simulation.[7] [8]

Results

Figure 1 shows the normalized field values as a function of distance for a horizontally polarized wave. It can be seen that the electric field values are high for a distance of up to 200 ft and then the field values starts to drop. This implies that the radio will lose lock at distances greater than 200 ft, which was verified through the actual test measurements.

Figure 2 shows the normalized field values as a function of distance when the antennas are vertically polarized. It is observed that as the distance between the transmitter and the receiver increases the electric field values increases. This was the same observation when the actual measurements are also made. The radios remained in lock up to 300 ft when the antennas were vertically polarized.

Figure 3 shows the field values in a 2-D plot as a function of distance between the transmitter and the receiver. It is observed that the field values initially are less and then increase at greater distances and remain constant.

Figure 4 shows the electric field values as a function of time as it varies in the presence of an intruder midway between the transmitter and the receiver. This plot could be compared to the actual measurement results obtained for the same conditions.

Comparison between the Simulated and Measurements

Figure 5 shows the comparison between the field values for the actual measurements and the simulated results. The plot shows the difference between the field values as a function of distance between the transmitter and the receiver. It can be observed that the difference is approximately 0.001 from which it can be concluded that the simulation results match the measured results to a great extent. Thus it can be stated that the simulation results are validated by the actual test measurements performed.

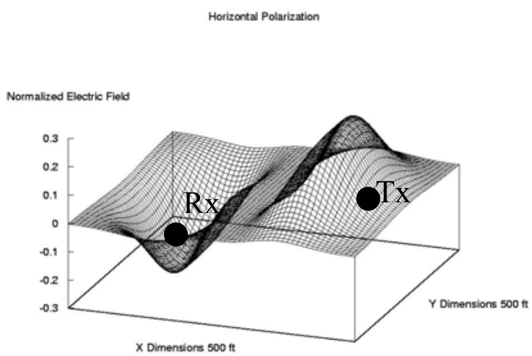

Figure 1

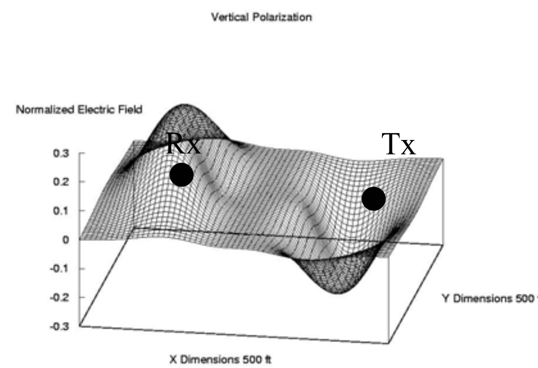

Figure 2

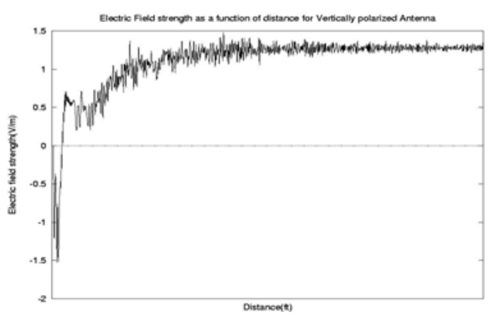

Figure 3

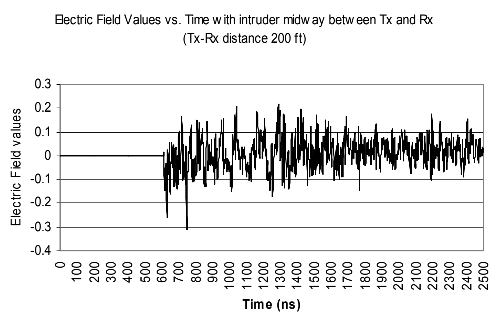

Figure 4

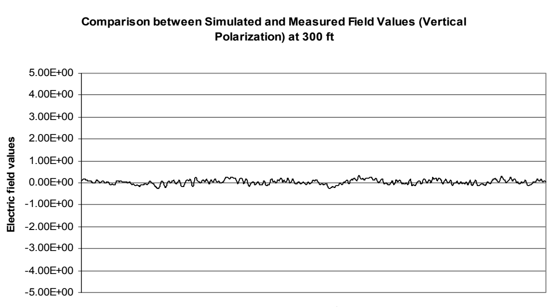

Figure 5

Parameters used for the Simulation

The pine trees were modeled as being 60’ tall with a diameter of 12” and a spacing of 8” between them. The tree boundaries were modeled using the Lindenmayer tree system described previously. The computational domain was set to 500’ X 100’. The distance between the transmitter and the receiver were increased in increments of 30 ft in the simulation model. The height of the receiver and the transmitter from the ground was set at 70”. The same data was used for the actual measurements also. The dielectric constants used in the simulation were soil (clayey)-wet -15, (clayey) dry – 6 and the pine tree (wood) -10. An intruder was modeled as a cylinder with a metal plate 6 ft height and radius 1 ft.

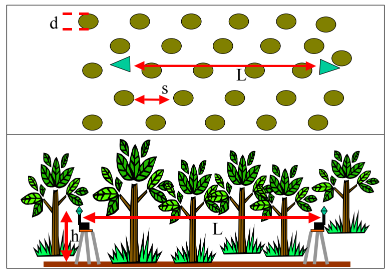

Figure 6

Conclusion

The results of the investigation on outdoor propagation of Ultra wide band signals are presented. The system was simulated for different polarizations of the transmitting and receiving antennas at various distances from each other. The modified Lindenmayer trees system was used to simulate the outdoor forest conditions and a hybrid method of ray tracing and FDTD was used to simulate the propagation characteristics. The simulated results were found to accurately model the actual test measurements. In the future, the simulation will be modified to include the full L-tree by including the effects of the needle and branch boundaries in the system and more accurately represent the dielectric constants of the components of the trees. One of our goals for the development of the simulation system is for use as a tool to aid the design of large UWB sensor web systems in outdoor environments, while minimizing the requirement for a large number of experimental test measurements, which more expensive and time consuming to set up. Thus we expect the simulation to greatly expedite the development and advancement of the UWB sensor web system.

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