Complex 3D Modeling of Sea to Land Scenario

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Abstract: This paper presents results from sea to land propagation using Wireless InSite®. The effort explores the effects of various elements in the scene and how they impact the results. The various elements in the scene include the ships out at sea, the ships docked, the docks themselves, the buildings around the dock area, and the material properties of each.

Keywords: RF propagation, Shooting and Bouncing Rays, Diffraction, Sea to Land Communication

1. Introduction

Sea to land communication is a vital communication link that is difficult to accurately model due to the complexity the scene. Some specific scenarios are ships communicating with docks while they are out to sea, ships communicating with other ships docked, and even ships communicating with other ships out at sea. All of these communication scenarios must be carefully and accurately modeled to ensure the safety of everyone involved.

Different elements in the scene can impact the propagation due to the nature of the object. For example, ships are common place in a sea to land scenarios. Additionally, ships are usually made out of metal which is highly reflective and they have odd angles which produce unusual interactions. Finally, docks can impact the propagation because the docks break up the scene and can introduce more diffractions and multipath.

This paper explores the various elements within a complex sea to land scenario of a ship coming into a dock and communicating not only with the dock master on land but the ships around the area both docked and out to sea. The first step is to show propagation over only sea water then add the land in the scenario then add the docks then the buildings then finally add the ships. Each step will show the complexity of this type of scenario. All scenarios are modeled using Wireless InSite.

2. Shooting and Bouncing Ray Tracing Theory

A full explanation of shooting and bouncing ray (SBR) tracing theory is beyond the scope of this paper, but a brief introduction will put this study in to context. More detail of the SBR ray theory and GTD theory can be found in [1]-[5]. The geometry is constructed as faces. Each of these faces has a material assigned to it in the GUI. Rays are cast from the transmitter points and when they are intercepted by a facet of the geometry, Wireless InSite calculates the angle for the reflected path using the material properties of the face. The rays are traced up to a user defined maximum number of reflections or when the rays leave the calculation area.

If transmissions are used, Wireless InSite will pass the ray through the geometry and apply attenuation and a phase change based upon the material properties of the face. The user controls the number and type of interactions that InSite will use. Ray tracing will continue along this path until the path either encounters the receiver, or it reaches the maximum allowable interactions.

Once rays have been shot and bounced from all active transmitters within the scene, rays are shot from all diffraction edges found and traced from there. Diffraction locations are determined from the shooting and bouncing rays. Diffractions occur at locations of field discontinuities. This will occur at locations such as building corners. Wireless InSite will use the shooting and bouncing rays to find adjacent rays where one ray strikes a face, and the next ray misses the face. Wireless InSite knows that for the second ray to miss that face there must be a discontinuity. It then finds that discontinuity location so that it can launch diffraction paths. Diffractions are similar to transmitting antennas in terms of the number of rays produced. A diffracting edge launches a large number of lower energy rays. This is why requesting a large number of diffractions in each path can increase the run time. By comparison a simple bounce produces one new path.

One issue with SBR is that the rays are launched at discrete angles. This means that if the receive antenna is modeled as a point in space the ray would have to strike the exact receiver point in order to capture that energy. To overcome this issue, Wireless InSite employs the concept of a collection radius for each receiver. If a ray passes through this collection radius around a receive antenna point it is considered to have hit that particular receiver. Some experimentation is needed when determining collection radius, but the calculation engine makes some intelligent choices regarding the size based upon the size of the scenario. It is scene, frequency, and size dependent.

The final step is to evaluate the electric field based on the path interactions between the transmitter and receiver. Currently, Wireless InSite does not consider any near zone fields in its evaluation. In free space, the electric field in the far field can be written as:

3. Scenarios

A typical scenario was developed to show the effects of material properties within a sea to land communication scenario. The transmitter is a half wave dipole transmitting within the sea at 900 MHz with a Sinusoid waveform. Fig. 1 shows a depiction of the transmitter on the ship in the lower right corner of the figure. This mimics a ship out to sea communicating with receivers all around.

The receivers are an isotropic antenna. There are multiple receiver sets within the scene. One is a grid covering the whole scene. This is to show how the interference patterns from the direct and reflected waves change in the different mediums. The second set is a route from the transmitter to the dock. Fig. 2 shows the receiver locations within the scenario in relation to the transmitter. There is also a point receiver on top of the building that the vertical grid passes through. This is the shore based receiver location that will be examined in detail.

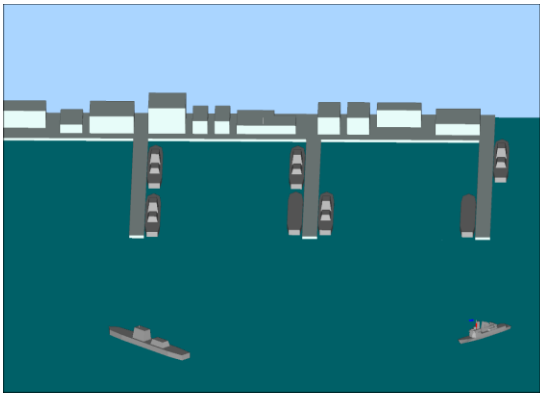

Fig. 1. Ship yard scene without receiver grids.

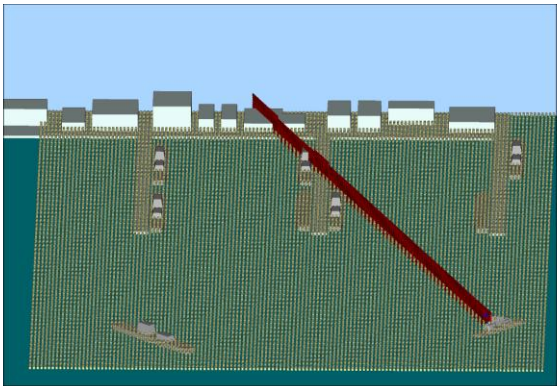

Fig. 2. Ship yard scene with vertical surface (Red) and horizontal grid of receivers (Yellow).

The motivation for this effort was to determine the effects of different materials and geometry on the propagation within the scene. It is widely accepted that it is important to accurately model all aspects of the scene, including the geometry and the material properties in order to accurately model land to sea propagation. However, it is unclear which aspects affect the propagation the most. As part of the setup, different materials were used and the material properties are listed in Table 1. Sea was used as the control material to serve as a baseline to compare against all other materials.

Table 1: Material properties for land materials

Material Name	Conductivity(S/m)	Permittivity
Concrete	0.015	7.0
Dry Earth	1.0e-003	4.0
Wet Earth	2.0e-002	25.0
Wood	0.0	5.0
Sea Water	0.2	81

Once the scene was setup, pieces were removed from the scene to examine the effects on the propagation at the shore based receiver, as well as the path from the ship to shore and the horizontal receiver grid. The four scenarios appear in table 2.

Table 2: Scenario details

Scenario Number	Setup
1	All Elements in Scene
2	Ships Removed from Scene
3	Buildings and Ships Removed from Scene
4	Ocean Only

4. Results

At the heart of this scenario is one transmitter on the ship communicating to one receiver on the shore. Table 3 summarized the results at this single receiver point on the dock. Comparing scenario 1 to scenario 2 it is apparent that reflections off of the ships at the dock are contributing energy to communication channel between the ship and the shore. Removing the ships increases the path loss 6 dB. Removing the buildings opens up some additional blocked paths but this only decreases the pathloss by 0.37 dB. Even with the scene opened up around the receiver it is interesting to note that the path loss with all elements in the scene produced less loss then the scenario with no building present. The final run with continuous ocean produced the lowest amount of loss.

Table 3: Results at single receiver for each scenario

Scenario number	Setup	Path Loss at Shore Receiver
1	All Elements in Scene	88.75 dB
2	Ships removed from Scene	94.37 dB
3	Buildings and Ships Removed from Scene	94.0 dB
4	Ocean Only	87.89 dB

The most interesting result was that the least amount of loss was recorded with all objects present in the scene. This must be due to the multipath diffractions and reflections off of the metal ships. Fig. 3 shows the path loss in the vertical plane of receivers from the transmitter on the ship to the receiver on the shore. The location of the Shore Receiver is labeled in the figure. The path loss colormap shows that there are areas of lower loss (green) present in the scenario with the ships that is absent from the scenario without the ships. The scenario without ships shows higher loss (red) towards the top of the receiver grid. The scenario without the ship does show a green band of high energy close to the ground that is absent from the scenario with the ship, but this energy is too low to the ground to affect the results on the shore based receiver located 18 meters above the dock. The picture is showing that something is happening in terms of energy being directed onto the receiver, but it does not providing a clear picture of what is actually happening and where the increased energy is coming from. At first glance this appears to be an error with the calculation.

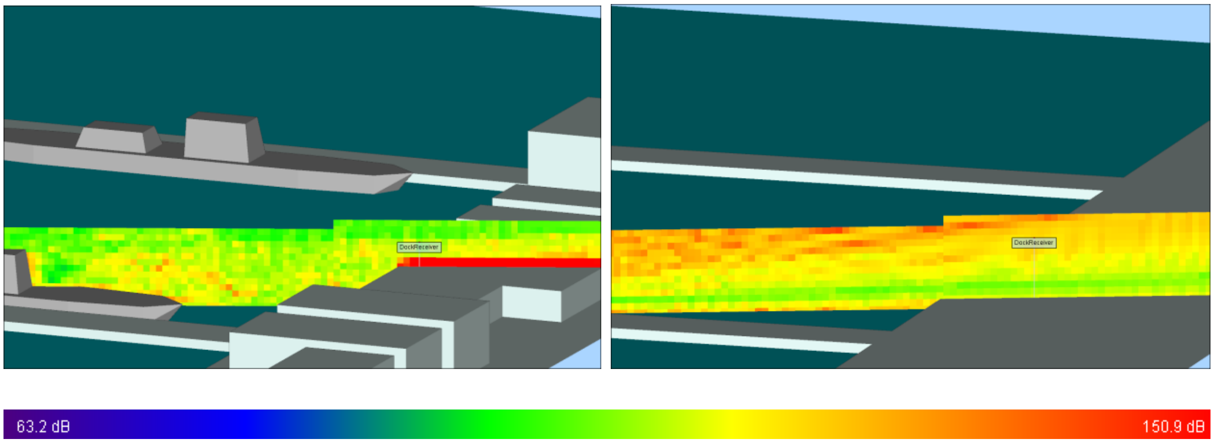

Fig. 3. Path loss in vertical plane of receivers;
with ships (Left) and without ships and buildings (Right).

In order to understand where the energy is coming from, Fig. 4 shows the actual paths from the 3D ray tracer for the full scenario and the scenario without ships or buildings. The figure shows visually why the scenario with the ships produces more energy at the dock receiver location. The ships in the harbor are strongly reflecting the energy onto the receive antenna. There are several strong reflection points on the ship on the upper left side of the figure, along with strong reflections off of the ships closer to the receiver. These ships were randomly placed in the harbor to mimic a realistic scenario. The fact that they dominate the scene in terms of reflected power was unintentional. It does relate back to the original point of this study, which was to determine what affects the results from a complex scenario such as a ship communicating to shore in a crowded harbor. In this case the flat metallic sides of the boxy ships are greatly affecting the results from this scenario. They created the perfect reflecting surface to increase the amount of energy incident on the receive antenna.

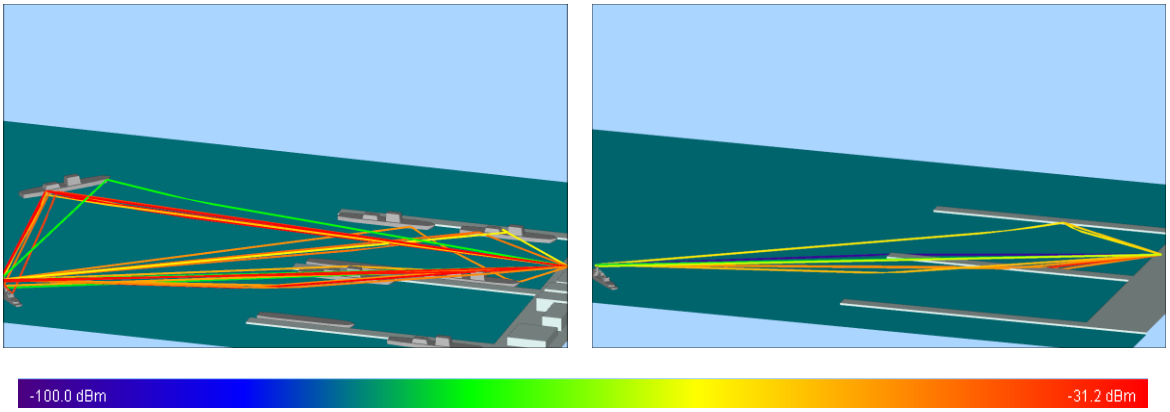

Fig. 4. Propagation paths to shore based receiver; with ships (Left) and without ships and buildings (Right).

Looking at the results from the rest of the scenarios the next object that is affecting the propagation results is the building. Looking at the results with and without the buildings (no ships in either case), there is a 6 dB difference between the results. In this case the building is blocking some of the energy that would otherwise strike the receive antenna. This result makes sense in the fact that some of the reflections off of the water and off of the dock would come off at low angles. The presence of the building blocks this energy from hitting the receiver.

5. Conclusions

The geometry and materials within the scene impact the propagation of waves when modeling sea to land communication links. The SBR method used within Wireless InSite properly models the behavior when the rays interact with the geometry and the material. The initial results did not appear to make sense in that the more objects in scene actually increased the amount of energy on the receive antenna. When looking for affects along the plane between transmitter and receiver the result was confirmed, but there was no cause for the increase in energy. Resorting to an analysis of the actual paths produced by the 3 D ray tracer revealed that the ships were points if high energy reflection, which was not obvious by the setup of the problem. What this shows is that in a complex scenario, it is not always obvious what will have the biggest impact on propagation results. This means that any simulation is only as good as what is put into the model and that objects that don't seem important at the time may actually dominate the result.

Some future work that can be done within the scene to more accurately model real world situations would be to replace the antennas with antenna patterns from the antenna manufactures. The crude models of the ships could be replaced by more realistic geometry which may reduce the amount of energy reflected off of the ships and onto the shore. There are models available from ship manufactures that can be obtain and imported into Wireless InSite. The material properties of the ship can be varied as well. In addition, roughness values could be varied to determine the impact on the results roughness has on the energy. Another potential area to explore is to manually make a rough sea by creating a sinusoid wave pattern in the sea water terrain.

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