# Simulation, Beam-forming, and Visualization of Bistatic Synthetic Aperture Sonar

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## LONG-TERM GOALS

The goal of this project is to develop a tool which can be used to simulate and assess the performance of multiple UUV's (Unmanned Underwater Vehicle) equipped with acoustic sensors, as well as develop beam-forming techniques that can be used to create images from such swarms of interacting acoustic sensors.

## OBJECTIVES

The objective of this task is to develop a multi-static imaging simulation whereby multiple transmitters and receivers are used to create an image. A second objective of this task is to develop a multi-static imaging simulation whereby the performance of multi-static source and receiver configurations can be predicted.

## APPROACH

PC SWAT (Personal Computer Shallow Water Acoustic Toolset) version 10.0 and earlier models the sonar of a system as a projector and receiver collocated within the same vehicle. The user is free to choose an arbitrary trajectory and 6-degrees of freedom of this vehicle.

This project will introduce multiple vehicles into PC SWAT where the projector and receiver may exist upon different vehicles, both of which may move along an arbitrary trajectory. This will entail using bistatic models for the reverberation and ship noise of the different vehicles. ARL/PSU (Applied Research Laboratory Pennsylvania State University) bistatic surface model and APL/UW's (Applied Physics Laboratory at the University of Washington) bistatic bottom scattering model will be used to assign a scattering strength to a point on the air-water interface or the water-sediment interface, respectively. An integral over the surface and bottom surrounding the receiver will be formed to predict reverberation (noise) at the receiver. The target strength model uses the bistatic Kirchhoff and Geometric Theory of Diffraction to predict the scattering from a 3-dimensional target. The only modification needed to this section of code is to place the projector and receiver on different vehicles. In addition to reverberation and typical ambient noise levels in the ocean there will be ship noise generated by the swarm of vehicles operating in a confined region. A time delay beam-former for the bistatic sonar will be developed. In addition, a method for displaying the bistatic image will developed by projecting the image onto the horizontal plane given the position of the projector.

NSWC PCD (Naval Surface Warfare Center Panama City Division) currently has a project to perform tank measurements of scattering from a bistatic arrangement, where the source and the receiver are mounted on separate rail systems. These tank measurements will be used to validate the bistatic model being developed by this task. Model predictions will also be compared with data collected by NSWC PCD and APL/UW in the NSWC-PCD Facility 383 test pond. This set of data was collected using realistic sized targets, and consists of proud, partially buried, and fully buried targets.

## WORK COMPLETED

The ability to compute the raw stave data for a bistatic sonar consisting of a source on one vehicle and a receiver on a second vehicle has been added to PC SWAT. The user can specify an arbitrary trajectory both the source and the receiver. The user can also specify all 6 degrees of freedom of the source/receiver about the center of the respective vehicle. The bistatic Kirchhoff approximation is used to describe the bistatic scattering from any of the predefined targets defined in PC SWAT. The bistatic scattering models described in Technical Report 9407 from the APL/UW was used to develop a bistatic reverberation model for the bistatic imaging simulation. Current work is focused on developing a bistatic time-delay beam-former for an arbitrary trajectory for both the source and the receiver.

Dr. Jon La Follet collected data from the 50:1 small scale test bed project that will be used to validate the bistatic imaging portion of PC SWAT 10.

## RESULTS

PC SWAT 10 alows the user to model the performance of a bistatic sonar, where the projector and receiver are located on separate vehicles. Input for the bistatic sonar simulation is accessed through the menu item "/Global/Imaging Bistatic". This menu item brings up a Property sheet similar to the "Global/Imaging" for monostatic sonars.

One difference between the mono-static and bistatic sheets is that the bistatic contains a separate property page for the receiver and transmit vehicles. On these two pages the user can specify a straight line trajectory for the projector and the receiver or the user can disable the USE DEFAULT TRAJECORY check box and input an arbitrary trajectory and motion for the projector and the receiver by modifying the spread sheets accessed through the menu item "Global/Vehicle Bistatic". The trajectory and motion in these spread sheets are similar to the one for the mono-static sonar.

Figure 1 depicts a screen shot of the Vehicle property page for the receiver. An identical property page is used for the projector. The user may choose to enter either a constant time or distance between successive pings. If the Default Trajectory check box is selected, PC SWAT will use a straight line trajectory for the vehicle determined by the input values on this page. The user can specify the vehicle speed, the vehicle depth, the x and y coordinates of the center of the trajectory, and the bearing of the trajectory. These input parameters will be used to define the default trajectory of the vehicle. The user can also choose to have the vehicle follow an arbitrary user supplied trajectory. This feat is accomplished by selecting the ENABLE VEHICLE MOTION checkbox and selecting the appropriate Motion/Trajectory type from the list box below the check box. The user will need to specify the trajectory/motion of the vehicle using the Vehicle Bistatic menu item. Finally the user can specify whether the sonar is an ahead-look, starboard, or port side-scan sonar by selecting the appropriate item from the SONAR TYPE list box.

Figure 2 illustrates the raw sonar data from a stationary projector and a moving receiver on a dB scale. The projector and receiver are 30 meters apart at the point of closest approach and there is a volume point target between them.

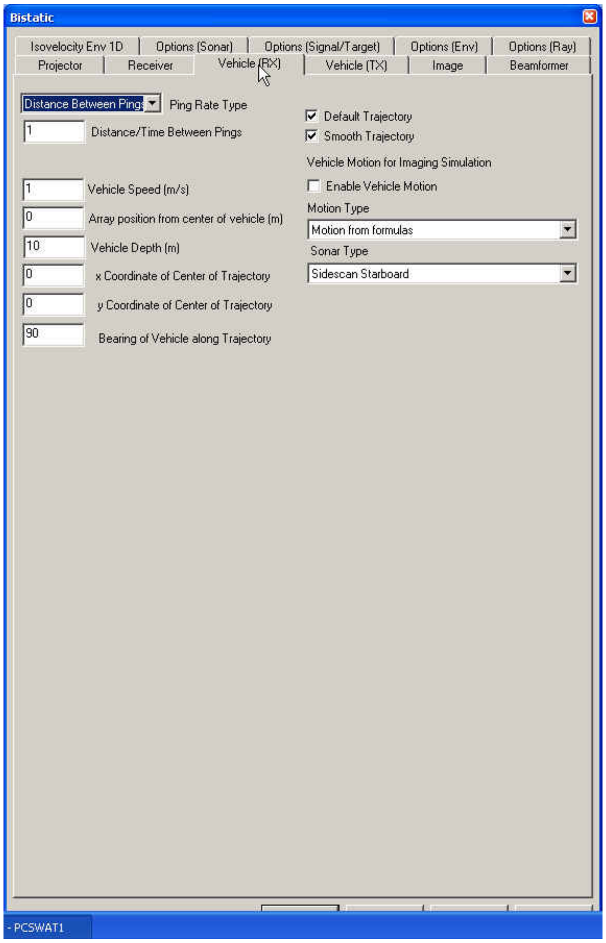


***Figure 1. Bistatic Vehicle Property Page for Receiver***

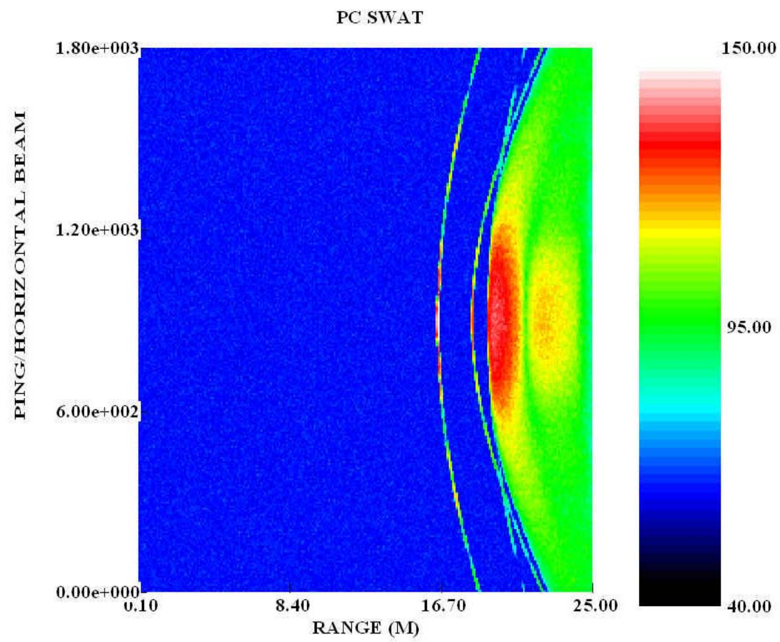


***Figure 2. Raw stave data for a stationery source and moving receiver for a point target***

## IMPACT/APPLICATIONS

This tool can be used to predict the performance of multi-static configurations of UUV's operating in littoral environments.

## TRANSITIONS

PC SWAT is currently being used throughout DOD (Department of Defense) and DOD contractors to model sensor performance.

## RELATED PROJECTS

Dr. Sammelmann is also working on a related SERDP (Strategic Environmental Research and Development Program) project to study scattering from partially buried and buried targets.