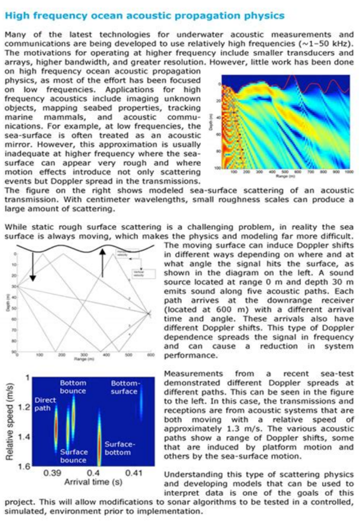

High frequency ocean acoustic propagation physics

Many of the latest technologies for underwater acoustic measurements and communications are being developed to use relatively high frequencies (~1–50 kHz). The motivations for operating at higher frequency include smaller transducers and arrays, higher bandwidth, and greater resolution. However, little work has been done on high frequency ocean acoustic propagation physics, as most of the effort has been focused on low frequencies. Applications for high frequency acoustics include imaging unknown objects, mapping seabed properties, tracking marine mammals, and acoustic communications. For example, at low frequencies, the sea-surface is often treated as an acoustic mirror. However, this approximation is usually inadequate at higher frequency where the sea-surface can appear very rough and where motion effects introduce not only scattering events but Doppler spread in the transmissions. The figure on the right shows modeled sea-surface scattering of an acoustic transmission. With centimeter wavelengths, small roughness scales can produce a large amount of scattering.

While static rough surface scattering is a challenging problem, in reality the sea surface is always moving, which makes the physics and modeling far more difficult. The moving surface can induce Doppler shifts in different ways depending on where and at what angle the signal hits the surface, as shown in the diagram on the left. A sound source located at range 0 m and depth 30 m emits sound along five acoustic paths. Each path arrives at the downrange receiver (located at 600 m) with a different arrival time and angle. These arrivals also have different Doppler shifts. This type of Doppler dependence spreads the signal in frequency and can cause a reduction in system performance.

Measurements from a recent sea-test demonstrated different Doppler spreads at different paths. This can be seen in the figure to the left. In this case, the transmissions and receptions are from acoustic systems that are both moving with a relative speed of approximately 1.3 m/s. The various acoustic paths show a range of Doppler shifts, some that are induced by platform motion and others by the sea-surface motion.

Understanding this type of scattering physics and developing models that can be used to interpret data is one of the goals of this project. This will allow modifications to sonar algorithms to be tested in a controlled, simulated, environment prior to implementation.