What's the Actual Range?

Testing and Optimizing SONAR Navigation Systems.

This paper describes how to empirically determine the effective range you can expect with your Desert Star Systems gear. Please see the *"What's The Maximum Range?"* application note for a discussion on the **theoretical** maximum range you can expect with your system.

Theoretical calculations of the maximum range of SONAR systems are generally based on several simplifying assumptions; homogenous environments, simplification of spreading losses and adsorption, etc. There may be occasions where the actual range achieved is quite different from the expected range. The actual range can be less than expected, for example when there is some blockage of acoustic energy like in a thick kelp bed, or the range can greater, when there is significant ducting present. While theoretical calculation have their place it is sometime quite advantageous to just measure the quantity of interest, in our case the operational range of a SONAR navigation system.

The theoretical calculations that Desert Star Systems uses in determining standard operational ranges are conservative, in 90% of all environments you will achieve these or greater ranges.

Background

A brief oversimplified introduction to signal detection

Desert Star navigation products (LBL & SBL) determine positions from the measurements of ranges to known locations (baseline stations, or surface station transducers). These range measurements are made by measuring the time it takes an acoustic signal (a ping) to travel between the end-points of the range of interest. In order for the range measurement (and hence the position determination) to be successful, the acoustic signal must be detected.

A signal is said to be detected if a pressure wave of the proper frequency has an amplitude greater than a set threshold.
All signal detection really means is hearing the ping. The ping must be of the proper frequency and loud enough to hear.

We assume from now on that by signal it is meant a signal of the proper frequency. There are two reasons why a signal will not be detected, the signal is too weak (too quiet), or there is too much noise.

A useful analogy might be trying to listen to an interesting speaker, lets call her Sue, at a crowded party. Imagine your are standing across the room trying to listen to Sue, however you are having trouble hearing what she is saying, you cannot detect her signal. There are several things that can be done to remedy the situation. You could move closer. Sue could speak louder, i.e. generate a stronger signal. You could force everyone else to be quite, i.e. remove noise. In general it will be easiest to move closer too Sue.

Weak signals

There are many possible cause for a signal being too weak. The most common cause by far is signal blockage. The acoustic signal can not pass through certain objects, most notably those containing air. Blockage will make it appear that the signal is too quite and it may not be detected. Blockage can be cause by air bubbles, kelp, rock outcroppings, mud, etc. The best way to combat signal blockage is to avoid it.

Other causes of weak signal include damaged equipment (broken station or transducer), using the system at too great a range, thermoclines, surface effects, using a system in a liquid with a greater sound adsorption, etc. There are a large number of possible causes for a weaker than expected signal and often it will be difficult to determine the cause of a weakened signal.

Noise

Noise is essentially the detection of an unwanted signal. In order for a signal to be detected there must be a method of separating the signal from any noise present. Essentially, the signal must be louder than the noise. Desert Star hardware performs signal extraction through filtering and tresholding. Filtering is the operation of passing a signal at specific frequencies. Thresholding is the operation of classifying a signal based on amplitude. Basically the systems listens on a specific channel (frequency) for a signal above a certain level (threshold). If a signal of the appropriate frequency is received and it has an amplitude above the threshold it is a valid signal and not noise.

Operations

Operating Range Determination

In general the system will work as long as the range for communication is less than 1 Km. The standard rule of thumb for long baseline systems is to set up a survey area of 500mx500m. The standard rule of thumb for short baseline systems is to insure that range from the surface transducers to the mobile station be less than a kilometer.

The simplest method of determining your operating range is to just try it at various ranges. However, this is often too time consuming, costly, and frustrating.

The most complex way of determining your operating range would be to systematically model all spatial and temporal acoustic propagation characteristics of your operation area and theoretically calculate the maximum range. Again, you will probably not want to do this.

The rest of this note describes a fairly quick method of determining your actual operating range using standard Desert Star tools.

Noise Test

The first step is to conduct a noise test.

The goal of this test is to determine the general noise characteristics of your area of interest.

Run DT-TEST on the station that you will be using to perform the test. This will usually be a diver station or surface station. Figure 1. Shows a screen dump of DT-TEST running in the DiveTerm terminal window. The display on a diver station would look similar.

Press 6 to run RX Test.. Figure 2. Shows RX test being run.
There are two control keys in RX Test. F1 Sets the Gain. F2 Sets the frequency.

Gain

There are four gain settings starting at zero increasing in sensitivity, 0,1,2,3. Each increase in gain doubles the sensitivity. In general you can always use gain 2.

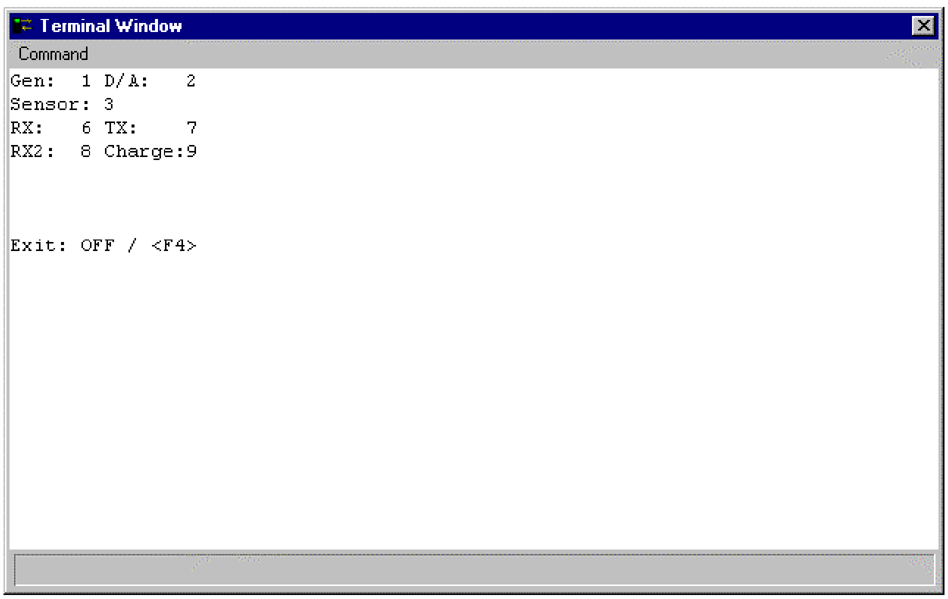

Figure 1. DT-TEST Run in DiveTerm

Frequency

This is the frequency in Hertz. This should be set to the frequency of interest minus 5. In figure 2, we are looking for a signal at 34000. When doing a noise test this should be set to the default 29000.

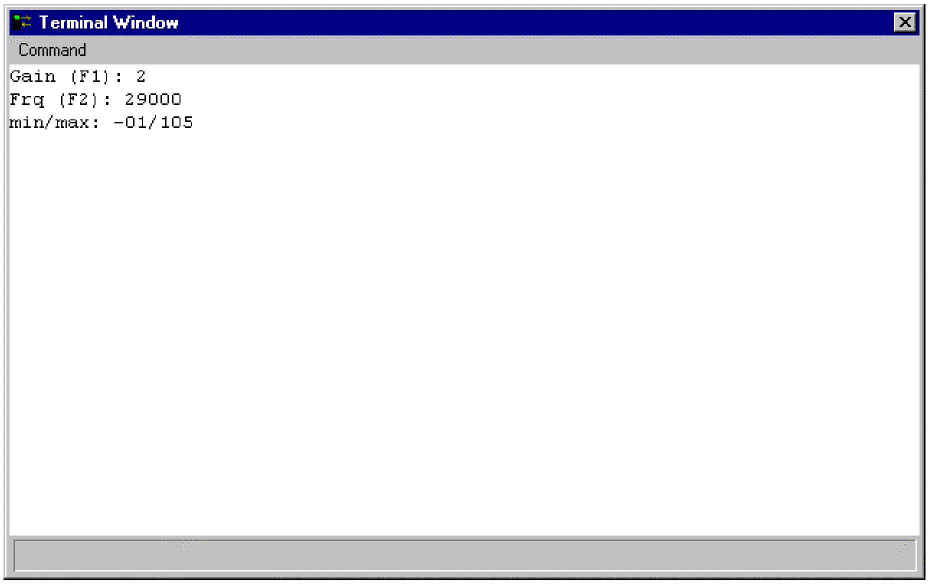

Figure 2. RX Test

The purpose of this test is to detect broad band noise, such as caused by biological sources such as snapping shrimp. Broad band noise is noise that has frequency components across a wide range. This is the most common type of noise that you will encounter. It is also possible that you will encounter noise on a specific frequency, such as from another piece of underwater acoustic equipment (like a depth sounder for example). If you suspect noise on a specific frequency you can press F2 to change to that frequency. If you want to perform a thorough test, you would run the noise test on all frequencies that you are using. These frequencies can be obtained in the Advanced Configuration Screens in **DiveBase** or DiveTerm.

RX tests listens on the selected frequency and measures the minimum and maximum signal detected in a 5 second period. A graphical display is used on the diver station, however it is not necessary for our purposes.

Performing the Test:

Place the transducer at various locations in your area. Remain in the same location for at least a minute. Record or remember the average max value that you have seen. Be aware that this will pick up noise from scuba regulators and impacts on the transducer so try to minimize these events. Make sure you also record the gain and frequency that you used during the test.

You will want to perform the test in as many locations around your site as time and patience permit.

You will now have a reasonable approximation of the noise characteristics in your operational area. In order for the system to work all signals must be above this noise level. The maximum readings that you have recorded represent the minimum threshold that the signal must be above in order to be detected.

A good rule of thumb is to set the threshold to twice the average max value you recorded.

You can set the gain and threshold hold in the Advanced Configuration screens in DiveBase and DiveTerm. Figure 3. Shows this screen with a gain setting of 2 and a threshold setting of 12.

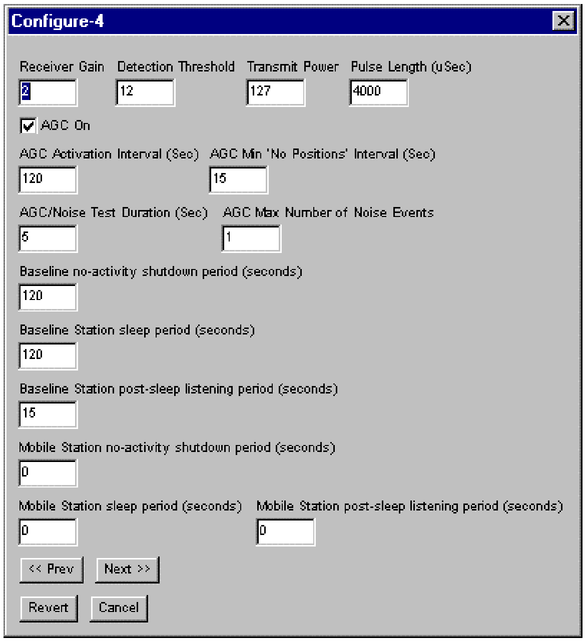

Figure 3. Advanced Config screen.

Transmission / Reception Test

Now that the noise threshold has been determined you can measure the actual operation range.

This test will require the use of two stations. One station will be set up to transmit continuously and the other station will be used to receive.

Run DT-TEST on the transmitting station, Press 7 to start TX (transmit) test. Figure 4 shows TX Test in a DiveTerm terminal window, the diver station display will look similar.

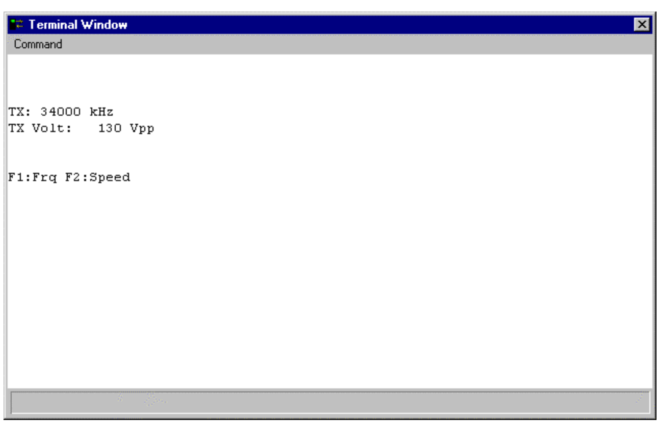

Figure 4. TX Test

Pressing F1 will change the frequency in 1 kHz increments. Pressing F2 will toggle the transmit speed between slow and fast. TX Test defaults to a transmit frequency of 34 kHz and a slow speed. The defaults are fine for this test.

Run RX test as described above on the second station. Leave the frequency set to the default 29 kHz (34 kHz - 5 kHz). This station will now be listing for the signal from the transmitting station.

Place the transmitting station in your operation area. If you are using a long baseline (AquaMap) setup it is a good idea to place the transmitting station in the location of your baseline stations.

Take the receiving station and move to various locations in your operation area. Leave the transducer in the same area for around a minute and note the maximum signal received.

When the maximum signal received is less than the average noise level measured in the prior test, you have reached the maximum operational range.

The signal propagation characteristics may be different depending on your placement and direction to the transmitting station. It is a good idea to run as many trials of this test to make as complete a 'map' as possible.

This method will provide you with a fairly accurate estimate of the range of your system in a given local. It is prudent to insure that the actual ranges between stations remain somewhat (75%) less than the average operational range measured.

Summary

Briefly here are the steps to take when attempting to measure the actual operational range of a system in a specific location.

1) Measure the average broadband noise level using RX-Test
   Run RX-Test at a variety of sites in your operational area, making note of the maximum noise signal seen.
   Set the gain and threshold in the Advanced configuration to twice the average maximum noise signal seen.
2) Measure the maximum detection range from a transmitting station to a receiving station
   Run TX-Test at a variety of sites and measure the signal level to a variety of sites, making note of the range at which the received signal falls below the average threshold that was determined in step 1.
3) Setup your operation to insure that the range between any two stations is less than the maximum range determined in step 2.

The more locations you can perform each test the better the model of signal propagation characteristics will be. The best method of performing these tests depends greatly on the site at which you are working, however this paper should guide you through the basic method of running these tests.