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An Electronic Tracking System for Acoustic Telemetry

by

R. Nesbitt and H.O. Berktay

INTRODUCTION

In a companion paper, Goddard discusses the problems in high data telemetry from the headline of a trawl to the trawler. He then considers the possible use of a time-division system to combat the effects of multipath propagation in such a situation. In this paper, we propose to discuss the separation of the signal arriving via the direct path from that scattered from the sea surface.

Fig. 1 shows the geometry used for some experiments at Lake Bala the results of which are discussed later on. Referring to this geometry, it is clear that by using a directional receiving transducer, the direct arrivals can be selected and the signal energy arriving via surface scattering can be discriminated against. However, changes in the attitude of the receiving transducer can result in complete loss of signal, unless the receiver is somehow made to track the direct path.

The tracking operation can be implemented either by rotating the receiving transducer mechanically, or by using a receiving array and deflecting its beam electronically. Although mechanically tracking can provide more flexibility in terms of full two-dimensional coverage, the hardware involved may become much more costly than for an electronic deflection system covering a sector in one dimension only.

In any tracking system, information about the relative position of the source to be tracked must be available at the receiver. Then this information can be used to command the reciving transducer to "look" in the correct direction.

A simplified approach to obtaining tracking in one angular dimension only is to use a receiving transducer with a "fan" beam which can be deflected in the vertical plane, over a given sector. If the wider beamwidth in the other direction does not result in the reception of surface-reflected signals as a result of the roll of the ship, then a one-dimensional deflection system would be sufficient to isolate the direct path from the surface-reflected paths. The beamwidth in the vertical plane can be determined to obtain satisfactory directional filtering of the incoming waves.

If the multipath effects are due to reflection and scattering from the sea bottom, angular filtering may be more difficult. Accordingly, we feel that (particularly for bottom trawling) the transmitting transducer must be so constructed that very little energy is normally transmitted below the horizontal plane. This can be done mechnically by the use of a suitable hood, if knife-edge diffraction effects at the edges of the hood are minimized. The effect of such a constraint on the overall beam pattern in the vertical plane is not of much significance - within limits.

The electronic deflection of the beam can be either continuous or in discrete steps. For example, a form of scanning sonar system can be used for fixed observation along a given direction. Hence, the tracking operation can be effected by feeding the directional information about the position of the transmitter into such a system. Similarly, a beam-forming type of processing can be used to track the transmitter by selecting the appropriate beam. In the work to be described, the latter method was used mainly because of the simplicity and the cheapness of the required signal processing unit. The beam-forming equipment used it not described in detail.

The basic problem thus devolves on the obtaining of information about the relative direction of the transmitter.

Propagation tests at Lake Bala

To obtain more information about the behaviour of the signals arriving via the direct path and those due to the surface-reflected paths, some propagation tests were made in Lake Bala (in North Wales) over a range of about 220 m. using the beam-forming equipment. The geometry used is shown in Fig.1. The transmitting transducer had a beamwidth of about 30° in azimuth and about 60° in elevation. In a series of tests during March 1970, a continuous wave of 89 kHz was transmitted. With the receiver "scanning" in elevation, the signals received in a beam monitoring the direct path and one receiving surface reflections were recorded simultaneously on an instrument type tape recorder. The envelope statistics obtained are shown in Figs. 2 and 3.

The signal received via the direct path showed slow variations which could be attributed to the slow movement of the receiving transducer which was suspended from a pontoon, anchored to the bottom at four points.

The signals coming via the surface path showed noise-like characteristics, confirming some earlier results obtained by Goddard, who was using an acoustic frequency of 104 kHz but a much wider receiving beam. The histogram of the envelope is shown in Fig.2. A Rayleigh distribution is fitted on the same figure, showing that (except for the 'tail') a good fit exists. The cumulative distributions of the amplitudes of the signals arriving via the direct and the surface reflected paths are shown in Fig.3. These curves show that the amplitude of the signal received viathe direct path may be lower than that due to the surface reflections for a considerable portion of the time. This is an important consideration in deciding how to identify the beam monitoring the direct path.

The power spectrum of the envelope of the signal received via the surface was obtained by using a filter with a bandwidth of 1/4 Hz, and a variable centre frequency. The results indicate that the Doppler spreading in the surface reflections is very small, causing fluctuation rates of the order of a few Hz.

Further tests were made in June 1970, using the same geometry but with pulsed-carried transmissions. The pulse duration used was about 150 μs, and the pulse repetition rate about 10 per second. The signals monitored on the beam output corresponding to the direct path showed no multipath effects at all. The envelope histograms were obtained at various instants of time, the time being measured from the instant at which the peak of the pulse is received via the direct path. Some probability density contours obtained in this manner are shown in Fig.4. These results confirm that no signal arrives via surface reflections for a period of time following the arrival of the signal via the direct path.

It was also observed during these tests that the apparent angle of arrival of the direct path varied from March to June, becoming more nearly horizontal by about 4^{0}. This could be attributed to a change in the velocity profile of the lake (it is known that a thermocline exists in Lake Bala during summer months only. However, as detailed measurements were not made, a quantitative comparison of results could not be effected). This effect shows the value of using an acoustic system for determining the angle of arrival of the signals via the direct path - rather than relying on a knowledge of the geometry of the system and compensating for the ship's movements by using information obtained from say, gyroscopes.

Beam Selection

If a known binary sequence is transmitted in the form of on-off keying of the carrier, and it is identified in the receiver by the use of digital correlators, then the first arrival can be identified as belonging to the direct path. In this way, the beam receiving signals arriving via the direct path can be identified and connected to the commusications receiver. If the alignment sequence is repeated every 100 ms, say then any variations in the relative positions of the two terminals can be detected and compensated.

In the work to be described, the transmitter worked at a frequency of 89kHz and had a bandwidth of about 10kHz. Thus, the bit duration used for the alignment sequence (a 7-bit Barker sequence was made about 0.1ms. This meant that the information was interrupted for about 1ms every 100ms, giving a transmission time loss of about 1%.

Tests made at Lake Bala with the transmitter transmitting only the alignment sequence (with the carrier suppressed for the rest of the time) showed that the beam selection system was working correctly. However, a shortcoming of the simple system being tested was observed when transmitting a frequency-modulated carrier as well as the alignment sequences. The frequency-modulated carrier arriving with different time delays from various parts of the surface acquired amplitude-modulation in sympathy with the modulating signal. Therefore, the envelope of the output of the beam monitoring acoustic signals scattered from the sea surface showed amplitude modulation at the modulating signal frequencies, as well as slower fading characteristics. The combined variations of the envelope was sufficient at times to produce unwanted outputs from the digital correlator. Although a second stage of logic was available in the system, reducing the probability of false operation, the unwanted outputs from the correlator were so numerous at times that a number of false beam-selections could result. We foresee a number of possible ways of overcoming this problem. Firstly, the probability of unwanted correlations can be reduced considerably by using a ternary system for the transmission of the Barker sequences, instead of the binary system available at the moment. A second possibility is to interrupt the channel after the transmission of an alignment sequence for a period long enough for the multipath effects to die out, and to use this period only for beam slection. In a typical system, this may represent a reduction of time available for transmission of data to about 80-90%. Finally, an adjacent frequency band may be used to obtain alignment information, while data is transmitted continuously on the high-speed data channel.

In practice, it is likely that a combination of the three solutions mentioned above will prove the best solution. For example, the high data rate channel can be used for the un-interrupted transmission of the video signal from a high resolution sonar system mounted on a trawl or on a submersible, while the alignment channel can also be used to relay low data rate information (temperature, depth etc.) to the surface vessel.

The beam-selection logic will be discussed, and experimental results relating to the performance of the system will be shown during the presentation.

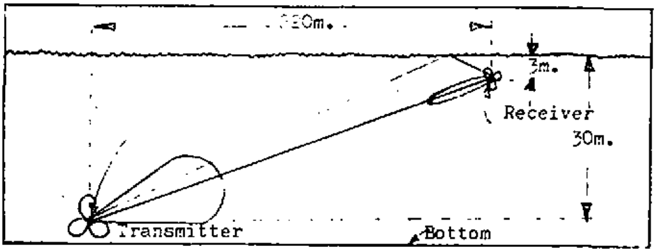

Fig. 1. Transmitter Receiver Geometry

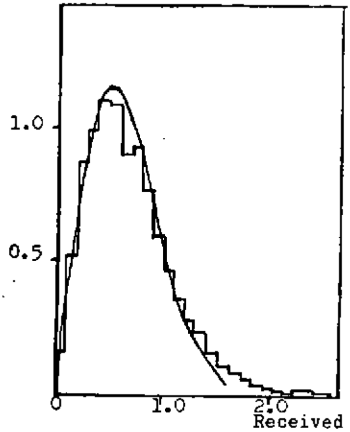

Fig.2. Histogram of the received envelope for the surface path.

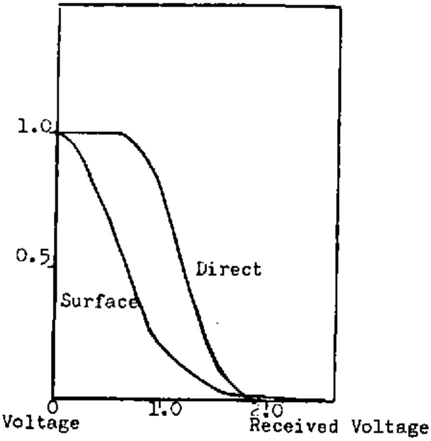

Fig.3. Cumulative probability distribution ofthe envelopes for the direct and surface paths.

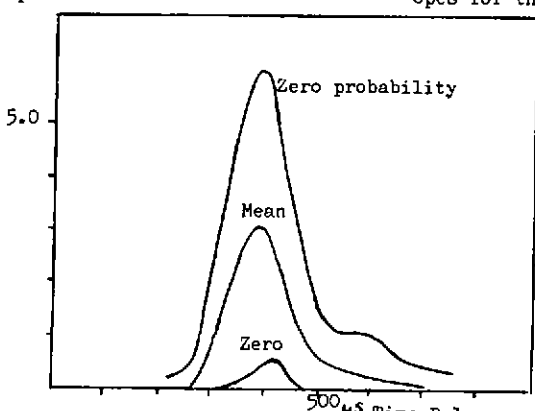

Fig.4. Probability contour diagram for the received envelope via the surface path.