INTRODUCING
AN OPERATIONAL MULTI-BEAM ARRAY SONAR

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PRECIS

The Multi-Beam Array Sonar Survey System is a revolutionary new bathymetric charting system in use by the U.S. Naval Oceanographic Office. This equipment represents a major advance over conventional echo-sounders as well as contemporary multi-beam sonars. The system collects and processes thirty to sixty depths (dependent upon survey accuracy requirements) from a ninety degree wide fan-of-sound. These multiple depths delineate a wide strip of the ocean bottom perpendicular to the ship's track and provide for the rapid acquisition of bathymetric data. Thus, use of this new sonar system greatly increases U.S. Navy deep-ocean survey capabilities and collection of bathymetric data for contour chart production.

The complete survey system is divided into two subsystems — navigation and sonar. The navigation subsystem provides ship's attitude and geographic position data. The sonar subsystem *transmits* the 90° fan-of-sound, *receives* separate echoes for each of the individual returning beams, *correlates* sonar returns with navigational data, *computes* and *processes* sonar data for display and recording.

SONAR DATA PROCESSING DESCRIPTION

A general understanding of signal processing is necessary to appreciate data generated by this complex system. Succeeding passages will provide a functional description of sonar signal processing. Also, the reader should refer to illustration figure 3 which offers a flowchart of this text.

Signal flow begins at the sonar oscillator, which is keyed approximately every 10 seconds to provide a short output pulse of CW energy. This pulse is applied to the pitch compensator circuits for electronic adjustment of

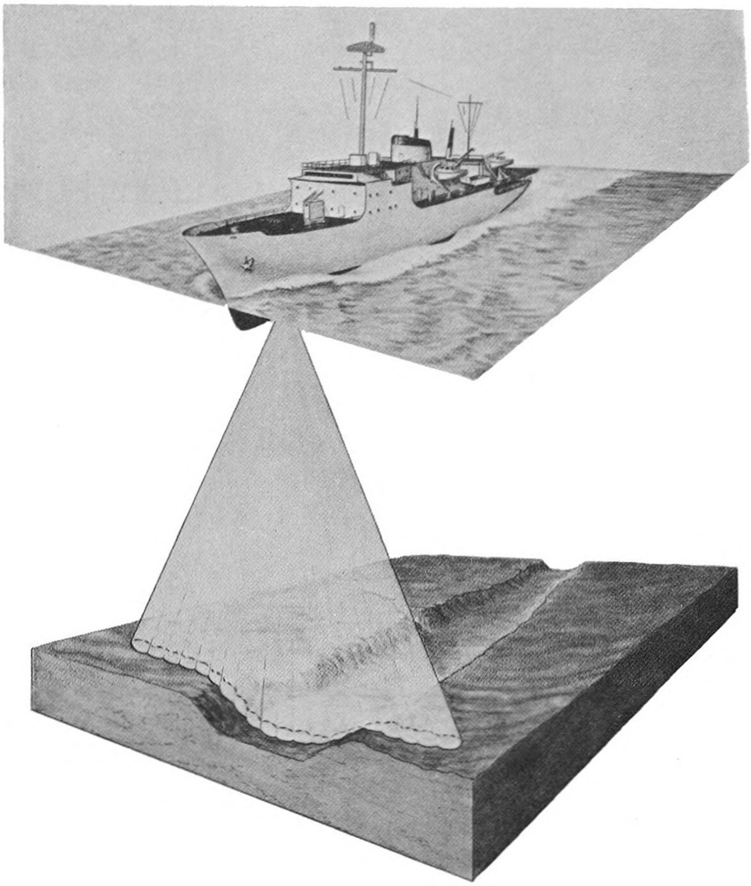

Fig. 1. — Illustration of multi-beam sonar.

the signal, proportional to ship's pitch, as measured by an external gyro-compass. The pitch compensator uses the pitch input order to set up a network of pitch resolvers, varying in accordance with ship's pitch, and to individually phase shift the output signal for each projector element in the array. Electronic stabilization is necessary to assure transmission of the fan-of-sound to true vertical. The phase shifted signals are amplified by the transmitters to drive the array of projector elements. The signals now form the 90° fan-of-sound in a vertical plane, perpendicular to the ship's track, and projected toward the ocean bottom.

The sonar projectors are hull-mounted in watertight sections parallel to the keel of the ship forming a rectangular source for the line of acoustic signals. The receiving hydrophones are also hull-mounted, but are forward of and transverse to the projector array. They are positioned athwartships to define a rectangular acoustic face in planes parallel to the bottom returns. This arrangement is called a crossed-fan system (See illustration figure 2). An acoustically soft reflector is placed behind the hydrophones to maximize reception from the desired direction and minimize reception of ship noise. Both arrays are sealed in low-drag blisters made of acoustically transparent material and hydrodynamically streamlined to reduce water turbulence.

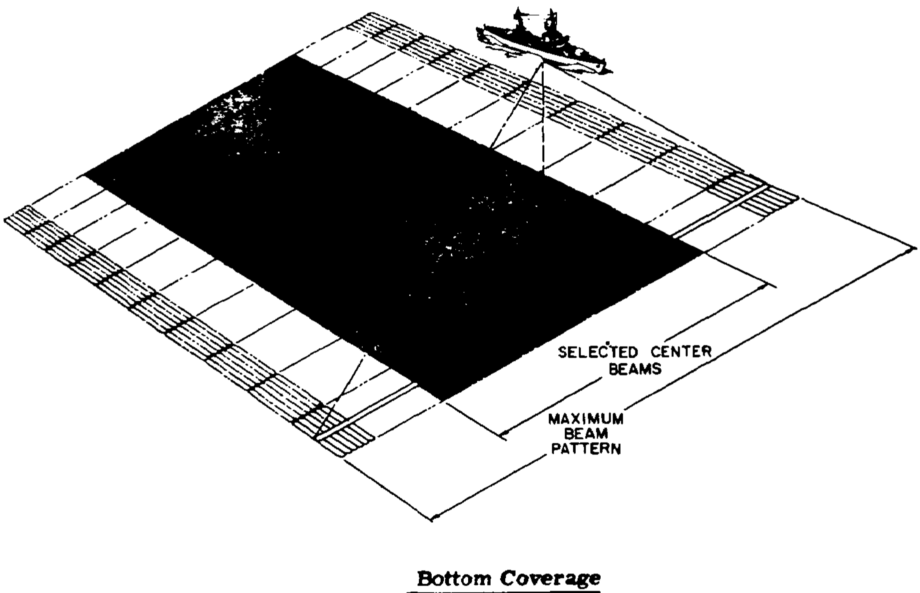

FIG. 2. — Relationship of receiver beams, several of which are shown above drawn in the fore-and-aft direction, to the transmitted fan-of-sound shown in the athwartships direction.

Bottom coverage is directly proportional to the depth of water. As indicated by illustration figure 4, at a depth of 1 850 fathoms the fan-of-sound covers about two nautical miles of ocean bottom. Obviously, this system is most effective in deep ocean areas. In shallower areas, the multi-beam sonar adds little additional sounding information in comparison with conventional echo-sounders.

Acoustic signals received by the hydrophones are converted to electrical signals, and each hydrophone output signal is input to a separate pre-amplifier. The amplified signals are applied to a beam-forming matrix, the output of which comprises preformed beams fixed in directions relative to the ship. The preformed beams are input to the roll compensator, which stabilizes them with respect to the earth's vertical. A servo, driven by the vertical reference gyrocompass, positions the rotor of the roll compensator so that the rotor position varies proportionally to ship's roll angle. Each of the output beams (30 to 60) represents a side looking angle, now fixed, independent of ship's roll.

These signals are now processed by separate receivers whose function is to amplify, band limit for noise rejection, adjust gain to reduce dynamic range, perform envelope detection to extract the signal from the carrier, gate outside lobes and noise, and perform envelope filtering for optimum response to the signal waveform. After extensive processing by the receiver circuits, the signals are put into a digital format; combined with incremental data for ship's pitch, roll, and heading; and are input to the system computer.

The system computer calculates a depth for each sonar beam and the reference position for each bottom point in relation to the ship. These data

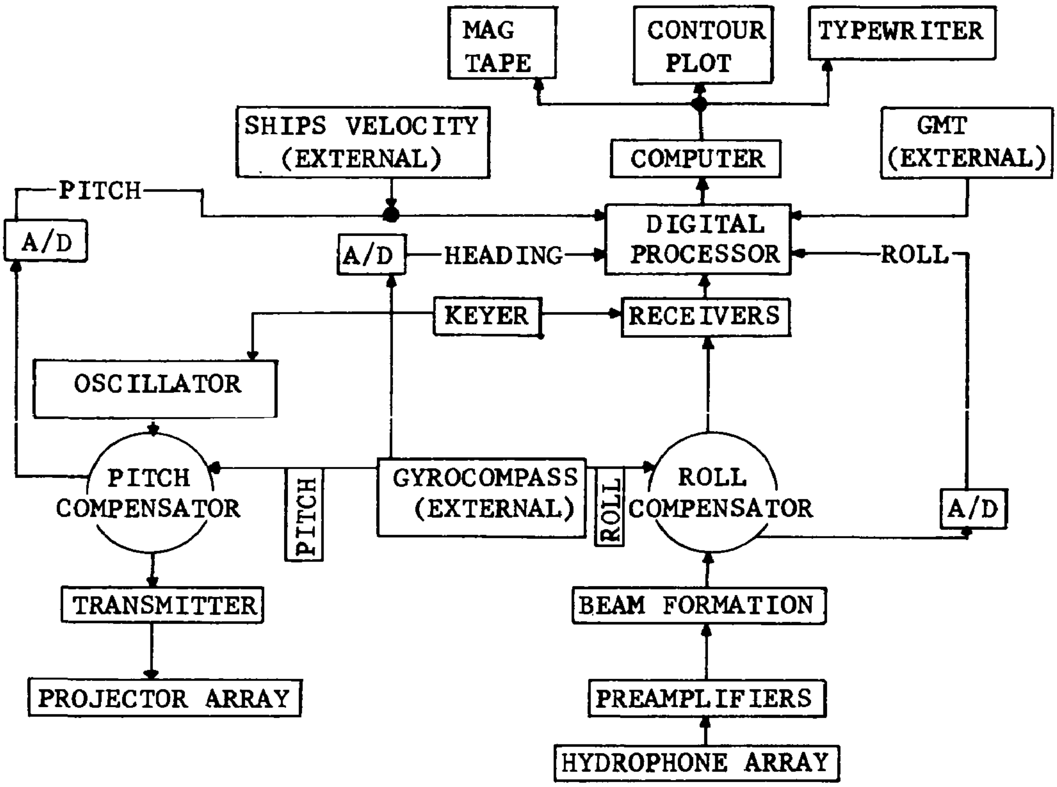

FIG. 3. — Multi-beam sonar survey system data flow diagram.

are ouput to an X-Y plotter system which computes contour locations and draws an on-line contour chart. These data are also written on magnetic tape for further processing or storage.

The contour chart output can be plotted in real-time at a variety of scales and contour-intervals. Illustration figure 4 displays a portion of an actual contour output. This example shows about four square miles of ocean bottom as surveyed near the Blake Plateau. These data were collected from a nine-minute portion of a single survey line, and succeeding adjacent lines would develop a contour chart with complete bottom coverage. Thus, for the first time the hydrographer is able to work with data offering coverage equivalent to that of an aerial photograph. Future development of multi-beam sonars, if similar advances are made in ship navigation, should provide bathymetric charting data of a quality similar to that used today for topographic mapping.

ADDITIONAL INFORMATION

The sonar subsystem was designed and built by the General Instrument Corporation of Westwood, Massachusetts. This company also built the

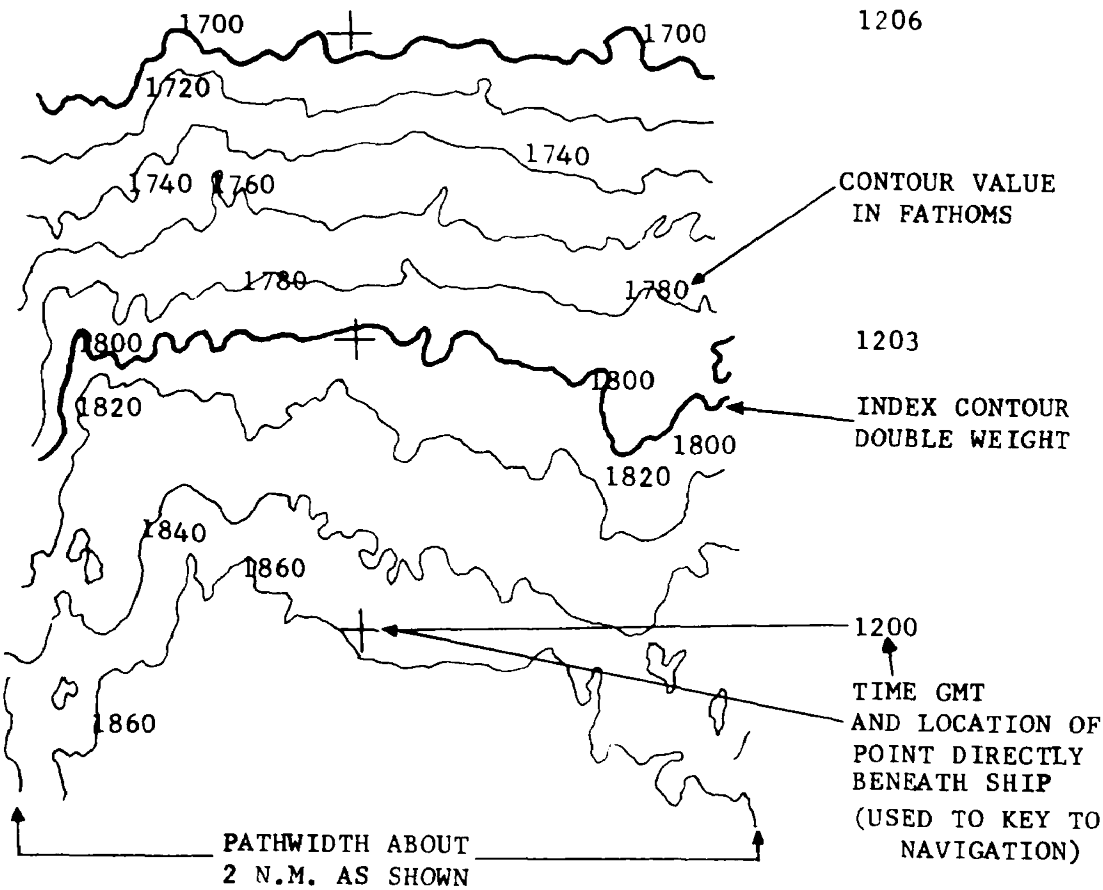

FIG. 4. — Contour strip drawn from about nine minutes of sonar data at a 20 fathom contour interval.

Narrow-Beam Transducer Sounding (NBT) System which is a similar sonar for use by the U.S. Coast and Geodetic Survey. Differences in the two systems lie in the more sophisticated signal processing circuits of the multiple-beam sonar and its capability to provide a real-time contour chart of the ocean bottom sounded by the fan-of-sound. Readers may refer to the January 1966 issue of the *International Hydrographic Review* for additional information on the NBT System.

The concept of a multi-beam sonar was presented by M.J. TUCKER in the July 1961 issue of the *International Hydrographic Review*. Also, M.J. TUCKER in the January 1960 and July 1960 issues discussed concepts of directional echo sounding and electronic stabilization. Examination of the aforementioned articles will provide general background information to better understand the theory upon which the multi-beam sonar equipment was designed.