NARROW-BEAM TRANSDUCER SOUNDING SYSTEM

YIELDS EXCELLENT RESULTS IN OPERATION ABOARD USC & GS SHIP " SURVEYOR "

IHB Note. — In an article entitled *Some Recent Systems Development by U.S. Coast and Geodetic Survey* which appeared in the January 1965 number of the International Hydrographic Review Thomas J. HICKLEY gave a description of a system of a stabilized narrow-beam sounding system. The Bureau is glad to publish the present article which shows how very promising the performances of this system have been. This article is a Science Information Release of the U.S. Coast and Geodetic Survey and is Article No. 66-VII of the USC&GS Scientific and Technical Publication Group.

In February 1964, the U.S. Coast and Geodetic Survey ship *Surveyor* began field trials of a new electronically stabilized narrow-beam transducer (NBT) depth-sounding system. Since then, the NBT has been applied operationally to deep-sea soundings in the North Pacific Ocean survey program. At the time of its installation aboard *Surveyor,* the NBT system promised significant improvements in the accuracy and repeatability of deep-sea sounding data; now (*), as the operational results of NBT surveys arrive from the ship, it is becoming increasingly clear that the theoretical promise has been realized and even exceeded.

During the 1964 and early 1965 field seasons, the NBT system provided consistently better results than the older depth-sounding equipment. The narrow beam — 4.5 degrees (at the 10 db. down points of the acoustic fan) in the NBT system *versus* approximately 60 degrees in older echo-sounding systems — makes it possible for the first time to detect topographic detail directly below the ship in areas of extreme bathymetric irregularity. In older systems, echo returns tend to average the bottom over the full sweep of the beam, filling in valleys, narrow canyons, and the like; also, the breadth of coverage does not necessarily show bathymetric features directly below the ship.

In field trials aboard *Surveyor* during February and March 1964, comparative sounding runs were made with existing echo-sounders and the NBT system. Because both systems work on 12 kc, simultaneous recording was not possible along the same line; however, attempts were made to repeat lines with the NBT system. Both systems recorded on two recorders. A combined plot (fig. 1) of a line run first with an existing echo-sounder, then closely approximated in a repeat NBT run points up the new system's

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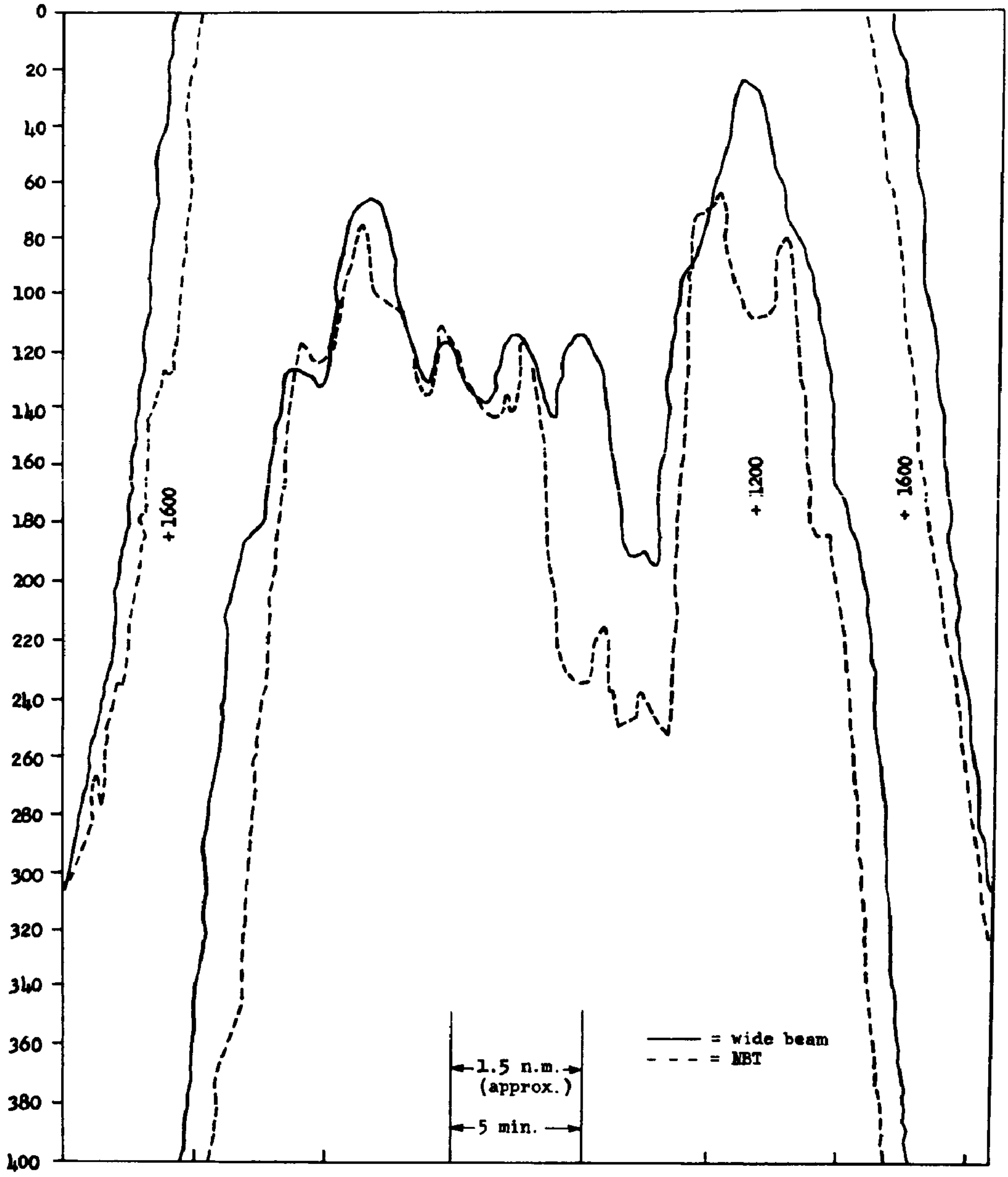

FIG. 1. — Comparative results of existing wide-beam and narrow-beam transducer echo-sounding systems along approximately the same track during field trials aboard *Surveyor*, 1964.

advantage. The wide beam shows shoaler depths on steep slopes than the narrow beam, and fills in the deep valleys and records higher peaks that are apparently not directly below the ship. The results of these field tests were considered to be satisfactory, and the NBT system was accepted for operational applications.

During the period February-June 1965, the NBT system was used as *Surveyor*'s primary deep-sea sounding instrument on the North Pacific ocean survey program. Results of these operations indicated that uniformly excellent results are available with the NBT system when all components function properly. Some difficulty was experienced with gyro failure after a service life of the order of 600 hours; this appears to have been corrected with the installation of a new gyro in April. As a result of gyro malfunction, however, it was found that the NBT system could be used successfully in two modes of operation : first, the normal mode, with the vertical gyro providing system reference; and second, with the system locked to the ship's vertical.

In the first mode, the analog record was clear and almost entirely noise-free, and the clarity and apparent accuracy of the bottom return were virtually unaffected by rolling of the ship. Depth comparisons at crossings averaged 0.1 percent over all types of bottom covered in the North Pacific Ocean Survey area.

In the second mode, without gyro reference, the NBT system continued to provide a sharper record than the older equipment, although legibility and accuracy decreased with increased roll of the ship. Depth comparisons at crossings run in this mode are theoretically less accurate than similar crossings made with older equipment; however, there was little actual difference except when the ship was rolling over uneven bottom topography. Operations in the second mode can be entirely successful and should not be precluded when the occasion demands.

All in all, the NBT system was considered to be far superior to any other deep-sea sounding equipment previously used by the Coast and Geodetic Survey.

The NBT system uses a pitch-stabilized transmitting fan-beam across a roll-stabilized receiving fan-beam to acquire sounding data along a narrow track directly beneath the survey vessel. The intersection of the two fan beams is referenced to an aircraft-type vertical gyro unit, which provides two 400-cps synchronous signals through gyro pickoffs to pitch and roll compensator servos. These servos can dynamically maintain the vertical beams to give a composite accuracy of ± 1 degree under most operating conditions. The system is thus stabilized electronically, rather than mechanically, accommodating pitch to ± 10 degrees, and roll to ± 20 degrees (fig. 2). Soundings are displayed in analog form on a recorder; data in digital form are collected and recorded by the system's integral encoder.

The transmitting, or projector, array consists of a rectangular arrangement of watertight sections, with an active length of 117 inches, mounted with its long dimension parallel to the centerline of the ship. The receiver array is mounted forward of the projector array and athwartship, its 40 hydrophone elements positioned to define a rectangular acoustic face 12 ½ by 112 inches. An acoustically soft reflector is spaced behind the receiver array to maximize reception from the desired direction and minimize reception of ship noise. The *Surveyor* installation houses both arrays in sealed, low-drag blisters attached to mounting flanges of the ship's bottom. The convex housings are constructed of acoustically transparent material, stressed to withstand loads imposed by ship motion at high speeds, and hydrodynamically streamlined to reduce turbulence. Fresh, rather than

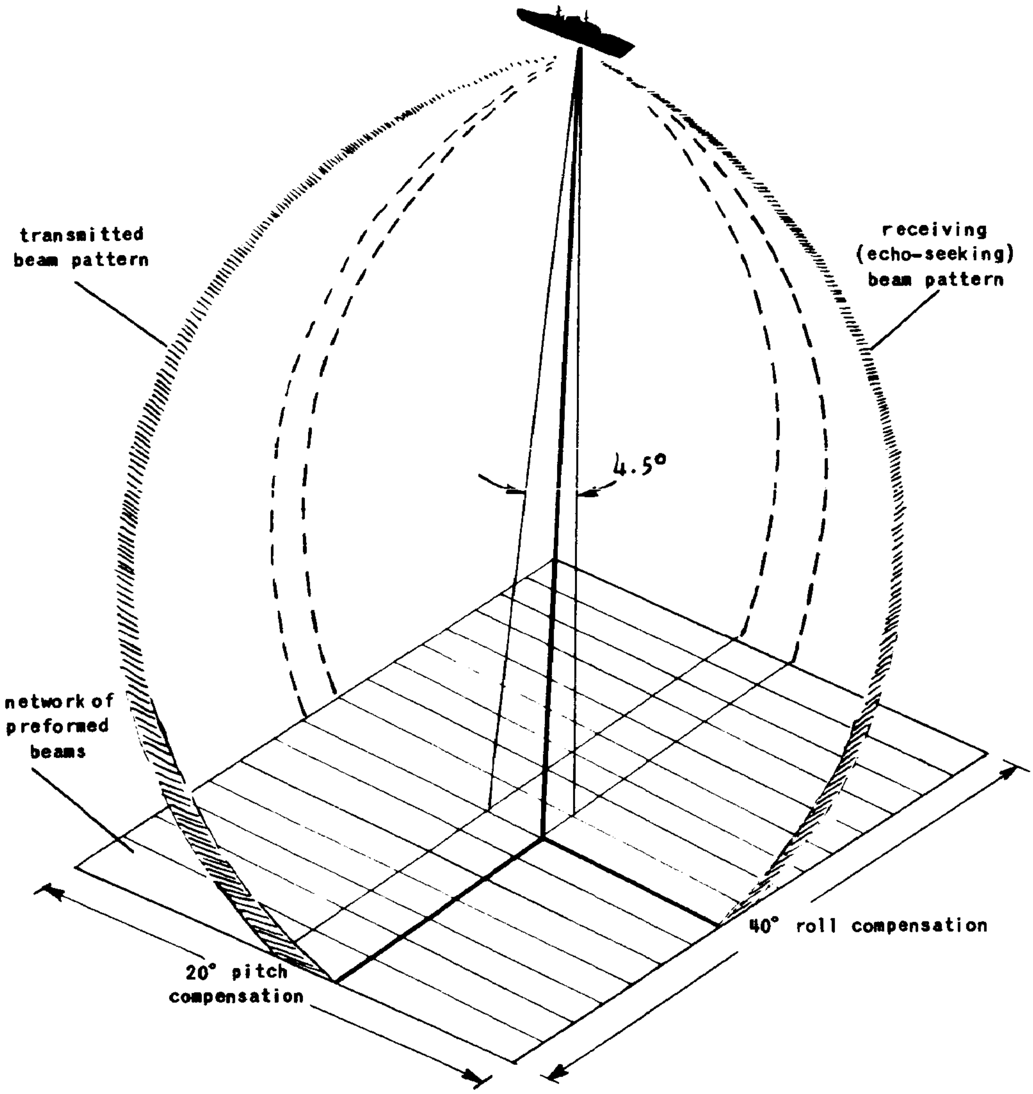

FIG. 2. — Pitch and roll compensation in the narrow-beam transducer echo-sounding system.

salt, water is the flooding agent, to minimize corrosion; in the event of seal failure, the arrays may be free-flooded with salt water.

In operation (fig. 3), a 12-kc carrier current from a stable oscillator is applied to a keyer-controlled modulator, which accepts closures from the analog recorder, and passed through a driver amplifier to a phasing network controlled by the pitch servo system. A phase-controlled signal from each phase resolver is applied to power amplifiers, which use a saturated base drive to generate a square wave with a peak power slightly greater than 400 watts. Each element of the projector array is driven by an individual driver module, which in turn receives input from individual pitch resolvers in the pitch compensator unit. The output wave from the

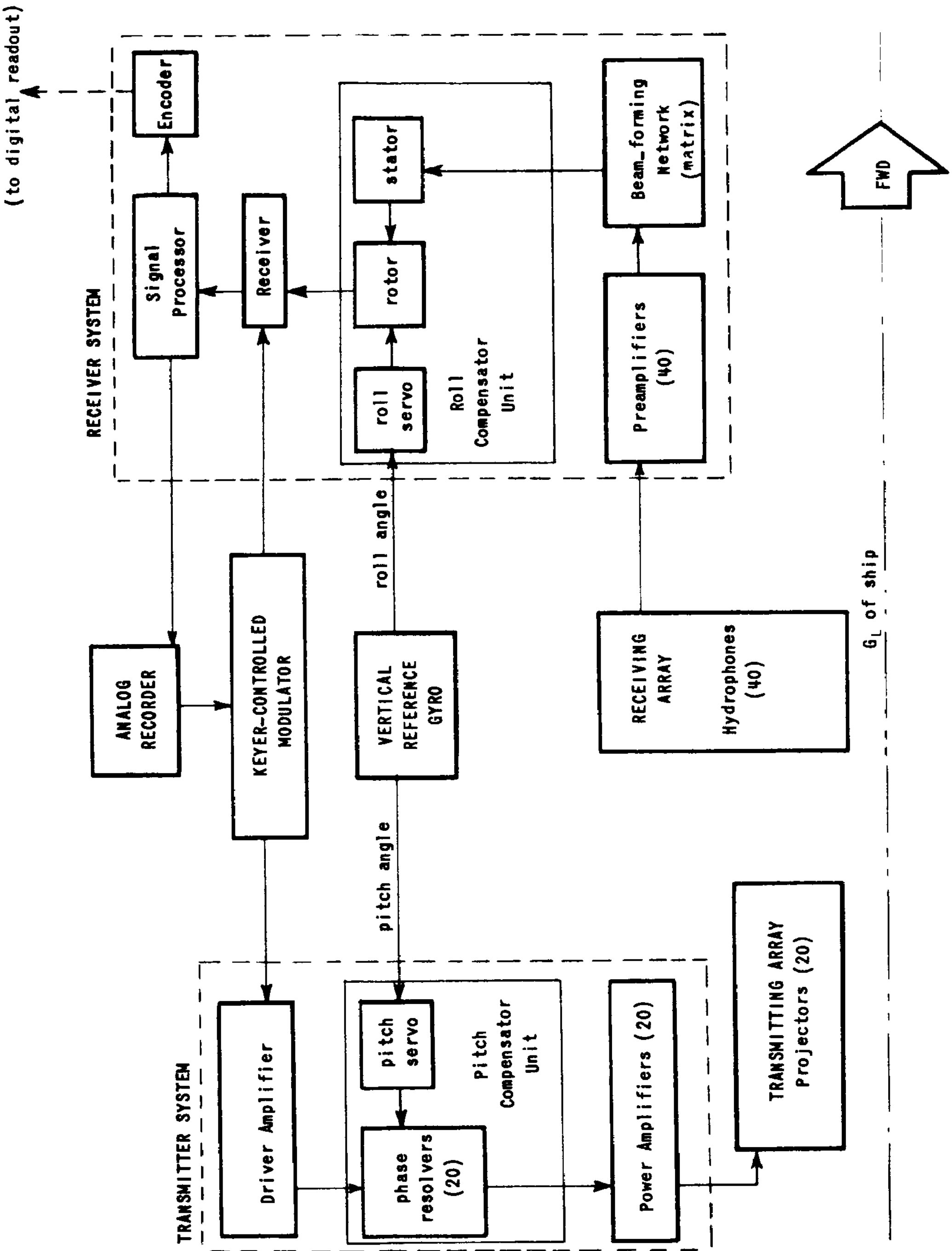

FIG. 3. — Schematic diagram, narrow-beam transducer deep-sea echo-sounding system.

driver module is filtered in the high-Q circuit of the resonant transducer, and projected toward the ocean floor as a 2.5-kw, 7-msec acoustic pulse.

The reflected acoustic signal is sensed by 40 line hydrophones in the receiver array, and passed through 40 corresponding preamplifiers to a beam-forming network, or matrix. Because of the difference in arrival time of the wave front at each hydrophone, a maximum response to a plane wave arriving from a given direction can be obtained by phase-compensating each preamplifier output signal, and then linearly summing the output signals. The beam-forming network, interpolating between the 0-, 90-, 180-, and 270-degree phase outputs of the preamplifiers, performs this operation for each angle of arrival, computing a set of 16 preformed beams covering 20 degrees on either side of the 4.5-degree vertical beam.

From the beam-forming network, the 16 preformed beams are fed into a roll compensator, which interpolates to form a beam which at any instant is centered on the true vertical. A servo driven by the vertical reference gyro positions the rotor of the roll compensator, which interpolates between the 16 input sections of the stator.

The vertical beam signal selected by the roll compensator is applied to the receiver, which amplifies the signal, detects the composite signal, and determines which part of the signal is the desired echo. A generator provides time-varied gain control voltage, a desirable feature when processing underwater reflected signals because the reverberation and expected signal vary as functions of time. The generator recycles to provide synchronization with the repetition rate of outgoing pulses.

The composite signal envelope prepared by the receiver is then filtered and compressed logarithmically by the signal processor, and passed to the digital encoder and the PDR.

The NBT system used aboard *Surveyor* was designed and built by the Harris ASW Division of General Instrument Corporation. The system has a rated depth of 6 000 fathoms, and depth resolution at 4 000 fathoms of ± 1 fathom, at an operating frequency of 12 kc. Although the flexibility of the system's sonar parameters permits operation to a minimum depth of 50 fathoms, it is doubtful that *Surveyor*'s NBT system will be used in such applications; shoal-water echo-sounders are already available with greater accuracies than the NBT system offers. Additional units on order by the Coast and Geodetic Survey will include an oblique scanning capability, which will permit lateral reconnaissance of bottom features on either side of the survey vessel. This will be accomplished using the same essential components described above, with additional receivers.

The implications of the good results obtained with the NBT system aboard *Surveyor* are far-reaching. In terms of the mission of the U.S. Coast and Geodetic Survey, the NBT system means higher orders of accuracy and greater efficiency for the deep-sea portions of the Nation's Ocean Survey Program. The operational successes of the NBT system are one more way in which the Coast and Geodetic Survey, and other private and governmental institutions, pioneer new methods to gather knowledge of the land beneath the seas.