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TECHNICAL NOTE

RECONFIGURATION OF THE HORIZONTAL BEAMFORMER (U)

Submitted to

U. S. Naval Undersea Warfare Center
San Diego, California 92152

Attention: Code D551

8 March 1968

SCIENCES AND SYSTEMS DIVISION • SAN DIEGO LABORATORY

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RECONFIGURATION OF THE HORIZONTAL BEAMFORMER

(C) The baseline implementation for the horizontal beamformer involves a change in the sampling rate. The new sampling rate and the mean propagation delay vary with beam steering. The resampling involved has been shown[1] to produce spurious responses which may fall anywhere in the band. The change in delay with steering produces a discontinuity in the signal which must be corrected prior to the correlator. It may be possible to sufficiently reduce the spurious responses by providing adequate interpolation in the resampling process. It may also be possible to satisfactorily compensate for the delay discontinuity.

(C) However, if it is technically and economically feasible, it would be preferable to eliminate the problems at the source. This means that the horizontal beamformer should be redesigned in such a way as to have a constant sampling rate (equal to the sampling rate in the vertical and sub-array beamformers) and a fixed mean delay. The constant output sampling rate would also make consideration of an all-digital interface to the digital signal processor more feasible.

(C) One such technique has been studied by GD/E.[2] The basic concept is shown in Fig. 1. Each sub-array output is delayed in a delay channel similar to those used in the vertical and sub-array beamformers. The delayed sub-array outputs are selected and summed to produce the desired horizontal beams.

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1 Memo to Grant Yee, Naval Undersea Warfare Center, Code D551, dated 15 September 1967, "Resampling in the Horizontal Beamformer (U), "TRACOR Document No. 354-C, CONFIDENTIAL.

2 "GD/E Monthly Progress Report A026-20233 covering 1 November 1967-30 November 1967 (U)," CONFIDENTIAL.

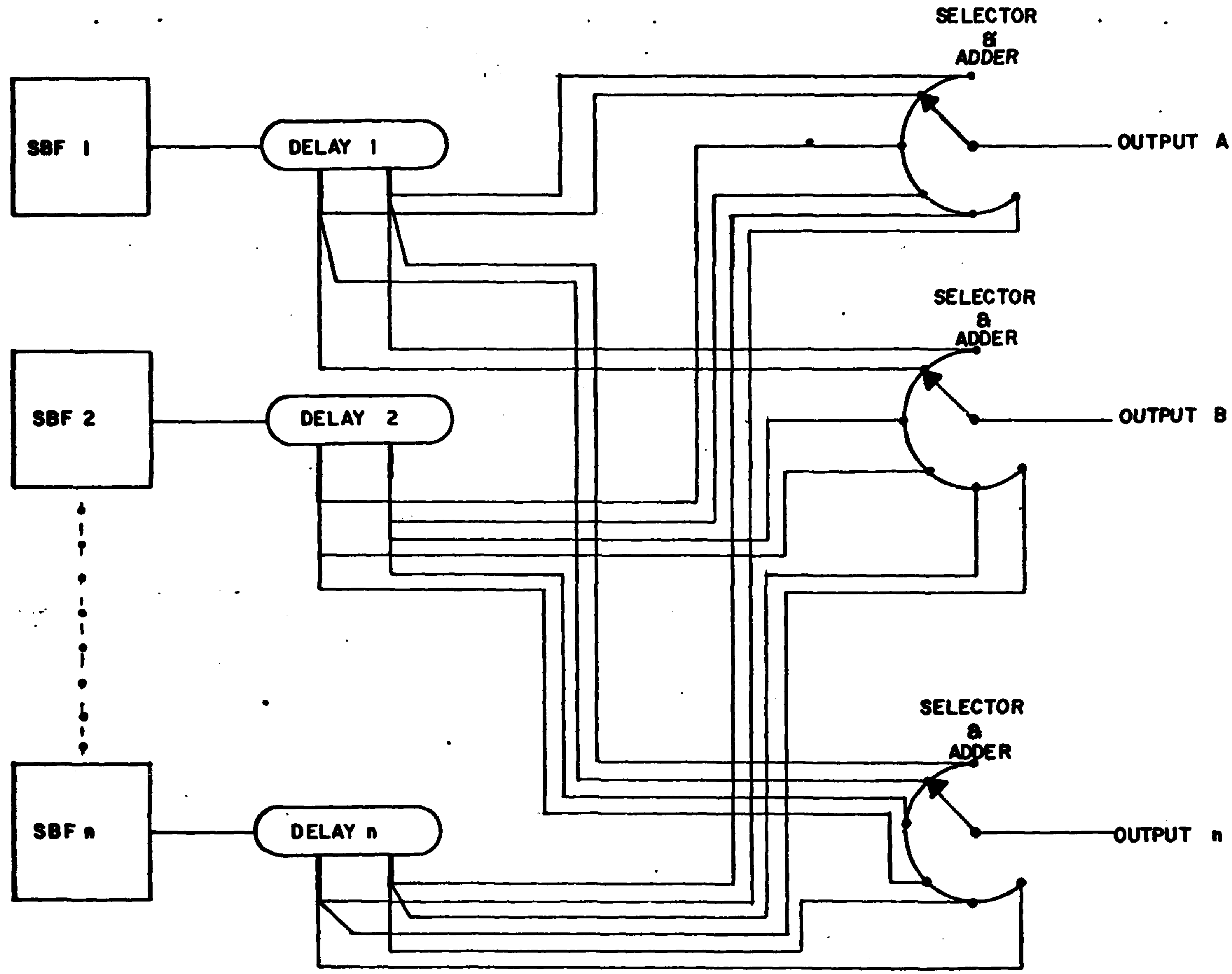

Fig. 1
Delay-and-Sum Horizontal Beamformer

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The horizontal beamformer thus follows the same design philosophy as the vertical and sub-array beamformers--the individual inputs are delayed and then summed. This is considerably more expensive than the sum and delay baseline approach.

(C) The alternate method shown in Fig. 2 should be considered for feasibility and cost. The sum and then delay method is an economical method of forming horizontal beams. The principal problem in the present application of this technique is the use of a variable sampling rate. Any given horizontal beam can be readily formed using a sum and delay technique at a fixed sampling rate. If a family of horizontal beams is formed covering 180^{o} at a given depression angle and spaced in such a way that the peak of one beam coincides with the first null of the beam on either side, then any intermediate beam can be formed by interpolation. This would require about 180 beams at 3000 Hz with the baseline array.

(C) The storage required to form 180 fixed beams is not greatly different from that required to form the present 150 beams. The present design requires that any beam be steerable in any direction. Thus, the delay storage is a total of about 30 ms for each beam. In the proposed configuration, the full 30 ms delay would be required only for those fixed beams near endfire. Beams near broadside would need only about 15 ms total delay. (A broadside beam can, of course, be formed with no delay at all. However, the mean delay for all beams must be the same for the interpolation process to work properly.). Thus, the increased storage for the 30 additional beams is offset by the reduced storage requirement for beams away from endfire.

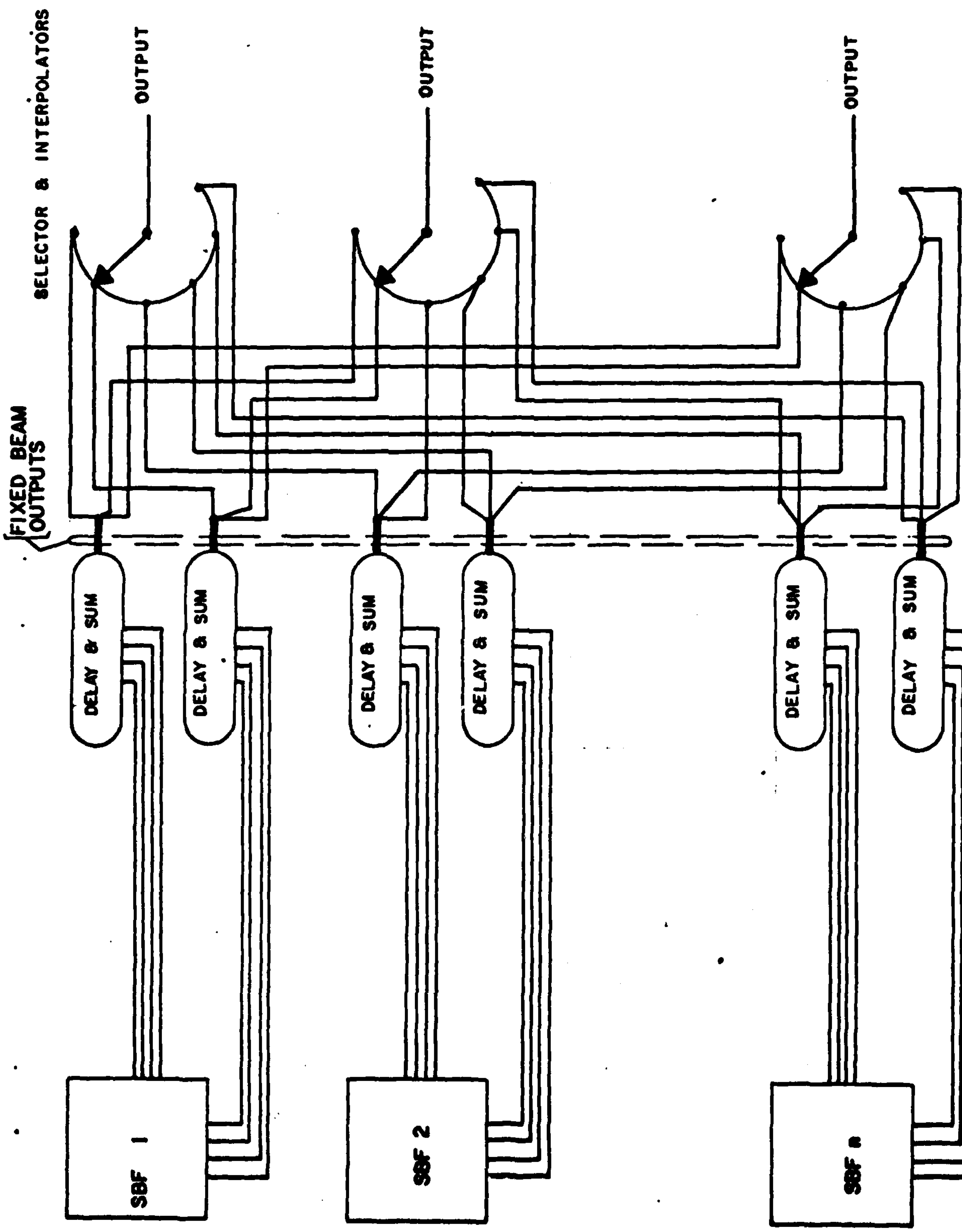

Fig.2
Sum-and-Delay Fixed-Beam Beamformers with Output Interpolation

(C) Note also, that the switching in the interface between the fixed beam HBF's and the SBF's is eliminated as is the equipment for programming changes in τ_α. All horizontal steering and stabilization is now done by switching and interpolating at the output of the fixed beam HBF's.

(C) It is the design of this switch that poses the greatest problem of feasibility. Assuming that the switch is feasible, the incremental cost of adding additional output beams is just the cost of the switch.

(C) One possible method for implementing the switch and associated interpolator is shown in Fig. 3. The composite horizontal steering control is a twelve-bit digital signal. Eight bits control a two-pole switch to provide outputs consisting of the beams on either side of the desired direction. The remaining four bits control the interpolator. This is shown as a pair of hardware multipliers. If the binary value of the interpolation code is a, then one beam is multiplied by a and the other by 16-a. The two weighted beams are then added. All of the bits generated by the multipliers should be carried into the adder. The adder output can be truncated to the number of bits which are present at the beamformer output. Note that 360° coverage can be obtained by adding an additional bit to the switch control and the 180 beam inputs from the other array. This requires that the two beamformers have a common clock.

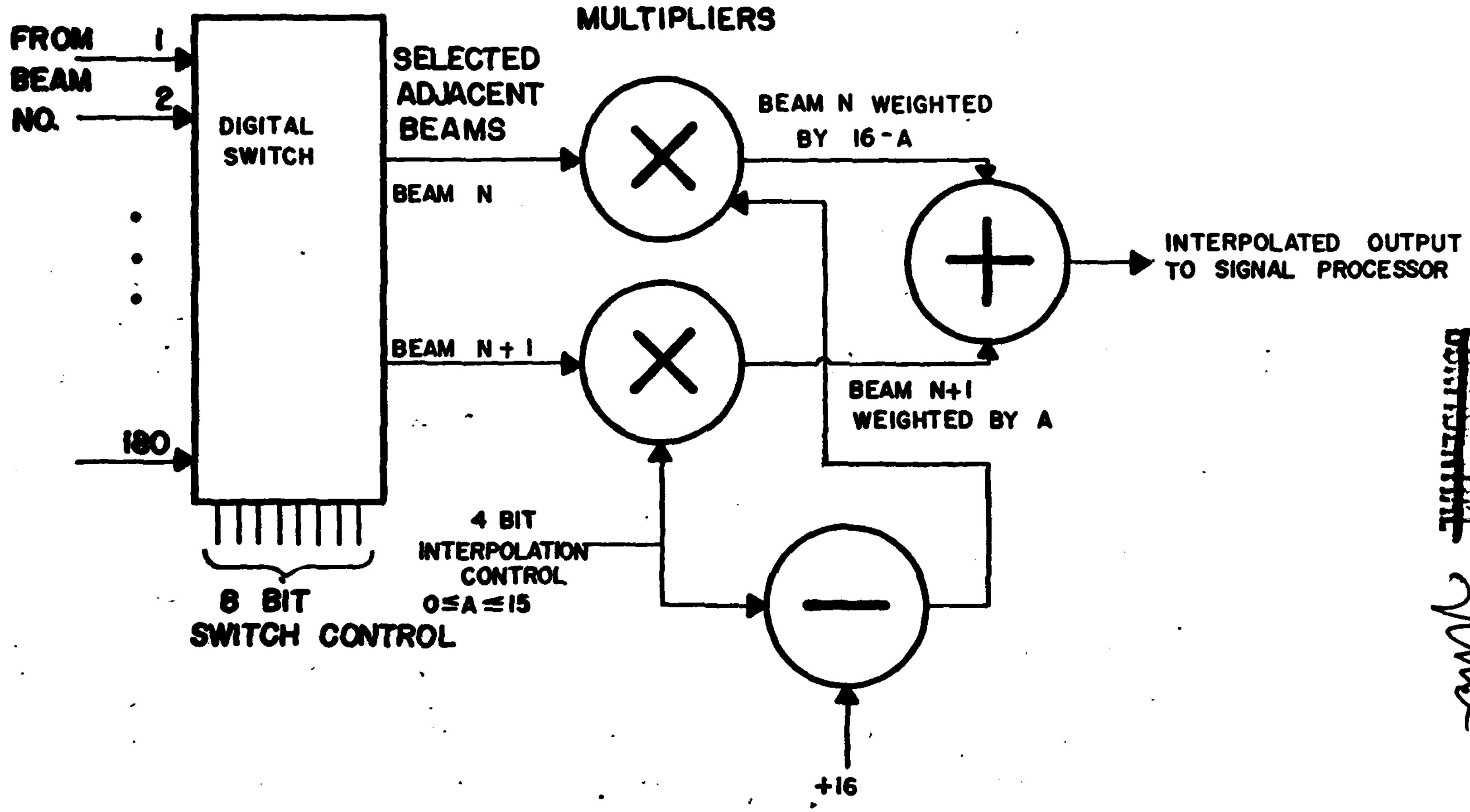
FROM BEAM NO.
1
2
180
DIGITAL SWITCH
8 BIT SWITCH CONTROL
SELECTED ADJACENT BEAMS
BEAM N
BEAM N + 1
MULTIPLIERS
BEAM N WEIGHTED BY 16 - A
BEAM N+1 WEIGHTED BY A
4 BIT INTERPOLATION CONTROL
0≤A≤15
+16
INTERPOLATED OUTPUT TO SIGNAL PROCESSOR

Fig. 3