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A Method of Separating Approach and Recede Pulse Doppler Radar Echoes

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CONTENTS

ABSTRACT

A doppler-sense separation technique, applicable to the Madre radar system, separates radar targets into approaching and receding targets. The presentation of unambiguous doppler frequencies of up to one-half the radar sampling rate is made possible. In addition, three desirable collateral features can be obtained: (a) some suppression of earth backscatter returns, (b) simple i-f bandwidth control, and (c) the availability of range-gated and essentially continuous-wave signals. The separation technique has a theoretical signal-to-noise ratio improvement of 3 db.

PROBLEM STATUS

This is an interim report on one phase of an Air Force (RADC) sponsored problem; work on this and other phases is continuing.

AUTHORIZATION

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A METHOD OF SEPARATING APPROACH AND RECEDE PULSE DOPPLER RADAR ECHOES

INTRODUCTION

Statement of the Problem

The work described in this report has been an effort at extracting all of the doppler frequency information possible from the Madre radar (1,2). In brief, this radar is an hf coherent pulse doppler system requiring suppression of the earth backscatter returns and employing a signal processor with storage times of from 20 seconds to 7 minutes, a time compression of about 83,000 to 1, and a variety of signal analysis methods.

In coherent pulse doppler radar systems it is common to convert received signals to a zero intermediate frequency (bipolar video). With such a system, unambiguous doppler can be indicated for frequencies up to one-half of the pulse repetition frequency (sampling rate); however, approach or recede information is lost. If an i-f placed at one-quarter of the pulse repetition rate (PRR) is used, approach or recede targets can be identified by displacement above or below the i-f frequency, but the available unambiguous doppler extract is one-eighth of the pulse repetition rate.

In this report the application of a doppler-sense separation technique that effectively separates Madre radar system targets into approaching and receding targets will be discussed.

Proposed Solution

After considering several possible solutions to the problem of separating approach and recede targets, it was decided to choose a pair of filters, each having a bandpass of one-half the pulse repetition frequency (Prf) of 180 pps for Madre, with the crossover point at the i-f carrier selected (100 kc/s). Although approach and recede doppler can be separated, all range resolution will be lost. To preserve range information, the sideband filters can be gated "on" for a short part of the interpulse period. A workable system that would retain essentially the range resolution of the Madre primary system would require a bank of 22 pairs of filters sequentially gated on for 240 μsec. The outputs of low and high sideband (LSB and HSB) filters would require separate data processing and display channels.

Sideband filters having the characteristics shown in Fig. 2, with a 12-db notch at the carrier frequency, will give some rejection to the lower doppler frequencies. Since earth backscatter returns appear within a few cycles of the carrier frequency, an improvement in earth backscatter suppression can be realized. In theory all near-zero doppler return rejection could be accomplished by sideband filters with appropriate skirt design. It will be noted that the gate width determines the frequency bandpass since the doppler separation filters are relatively narrow. The 240-μsec gate example is compatible with the normal 4-kc/s system bandwidth. When a more restricted bandwidth is desirable (due to co-channel interference, for example), it may be secured by using a wider gate with, of course, a sacrifice in range resolution. By providing an adjustable gate-width facility, the radar i-f bandwidth is easily controlled.

Another collateral result of nominal 80-cps bandwidth filtering of a range-gated segment of the i-f is that this achieves the correct format for doppler-time-history analysis and display, that is, an essentially cw signal is available for processing. Without such a capability it is necessary to range-gate and "boxcar" prior to processing.

Some preliminary work on mechanical filters at NRL demonstrated that a ten-element torsion-mode filter could produce the desired bandpass characteristics.

DESCRIPTION OF DEVELOPED EQUIPMENT

The block diagram of Fig. 1 indicates the equipment that was developed for this problem. One pair of magnetostriction filters, with the bandpass characteristics shown in Fig. 2, was developed on contract with RCA, Camden, N.J.

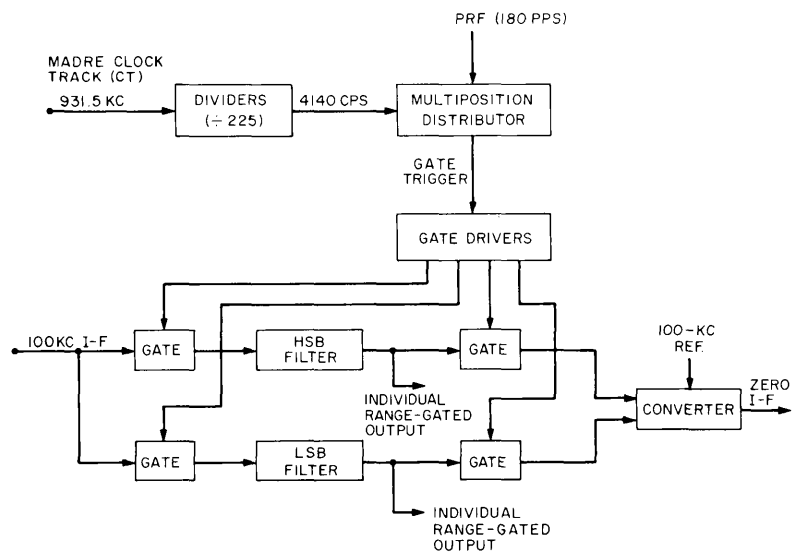


Fig. 1 - Experimental equipment and circuits used to separate approach and recede radar targets by the use of doppler information in the Madre radar system

The counting and commutating circuits necessary to make the filter gating compatible with the Madre system were developed at NRL.

The gate-switching rate required for a 23-range segment system at a 180-cps prf is 4140 cps. This was obtained by dividing the Madre clock track (931.5 kc/s) by 225.

A multiposition distributor using three Burroughs BX-1000 beam switching tubes is shown in Fig. 3. The initial position was set by the system sync and driven by the divided clock track. This distribution provided appropriate trigger pulses for the filter gates.

Gating was accomplished with a dual transistor chopping unit. The Solid State Electronics Model 50P. In the "on" condition this unit has a maximum signal level of 10v peak to peak and near unity gain. In the "off" condition the gain is down approximately 40 db.

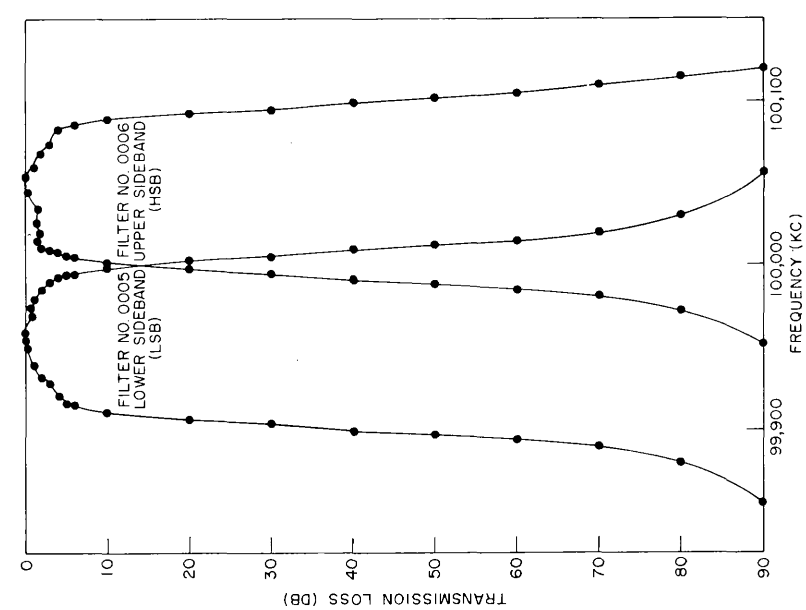


Fig. 2 - Bandpass characteristics of the lower sideband (LSB) and the upper sideband (HSB) filters developed for the circuit shown in Fig. 1

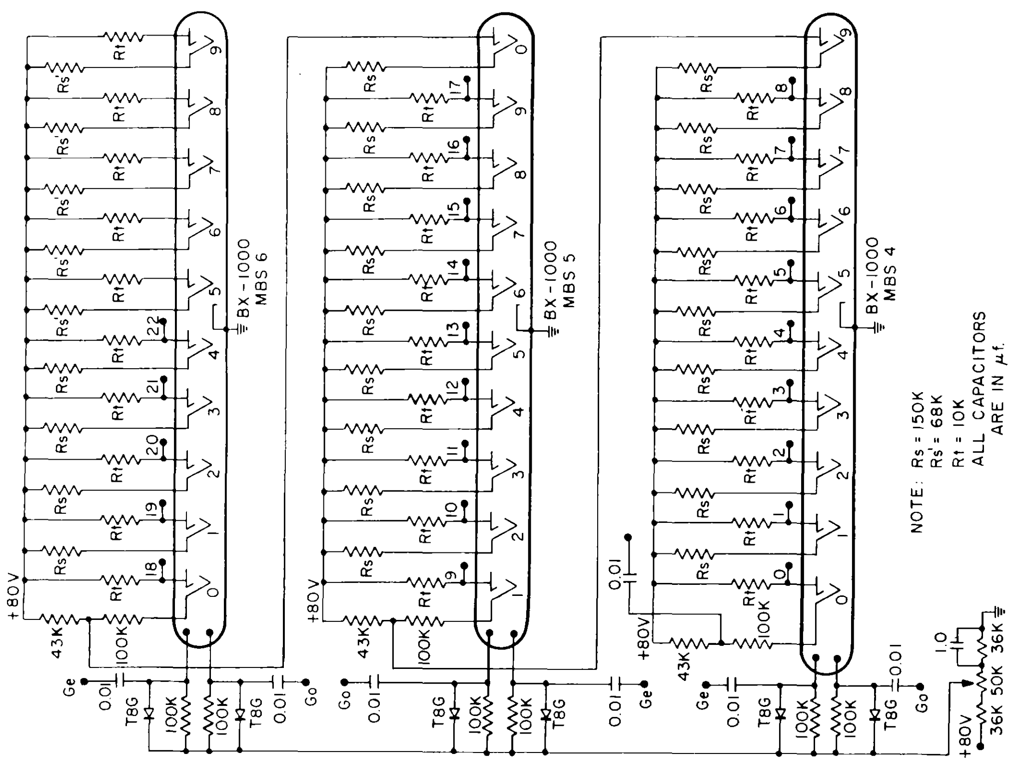
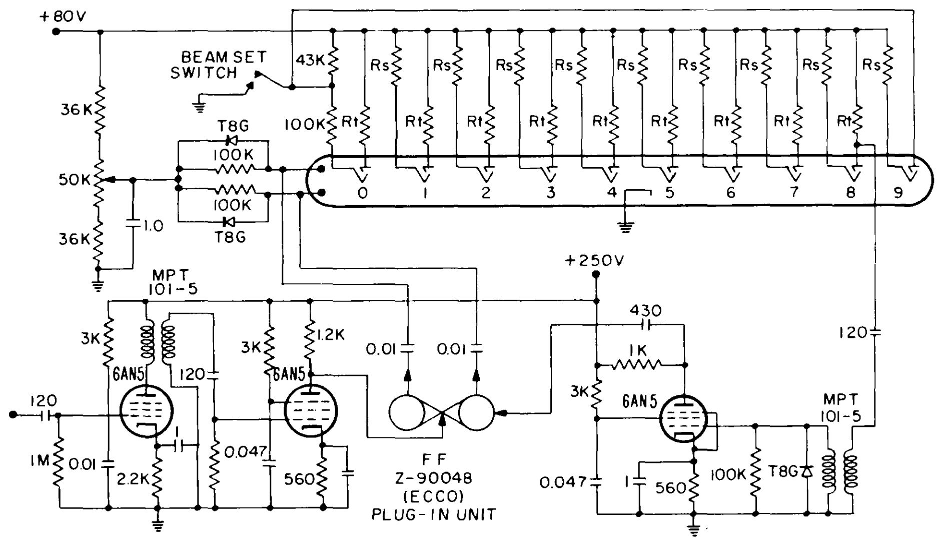
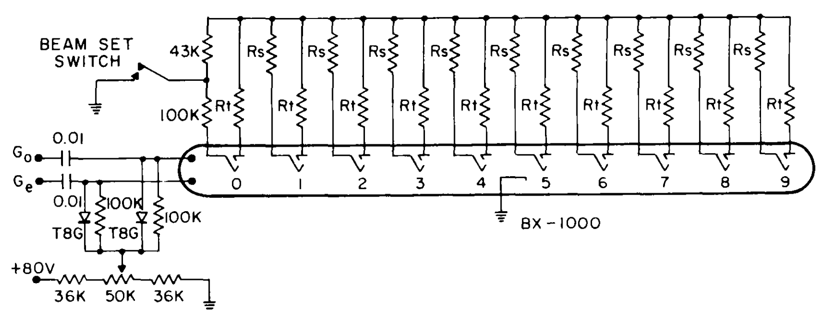


Fig. 3 - Multiposition distributor using three Burroughs BX-1000 beam switching tubes



NOTE: Rs = 150K
Rt = 10K
ALL CAPACITORS
ARE IN μf.

Fig. 4 - Schematic of the ÷ 9 tube used in the Madre clock track divider



NOTE: Rs = 150K
Rt = 10K
ALL CAPACITORS
ARE IN μf.

Fig. 5 - Schematic of the ÷ 5 tubes used in the Madre clock track divider

A gate with greater dynamic range may be desirable for the complete system. A solid-state monostable multivibrator with appropriate isolation and bias provided the balanced drive required for the chopping unit.

The clock track division was done in three steps (9×5×5), each step employing a BX-1000 tube. The divide-by-9 tube, Fig. 4, is driven by an ECCO FF plug-in unit which is triggered by a pulse formed from one-half cycle of the clock track, as shown on the figure. One section of the tube has been eliminated, thus allowing one complete cycle of the beam for every nine trigger pulses. The output of the target preceding the eliminated section is amplified and used to reset the ECCO FF.

The divide-by-5 steps, Fig. 5, utilize all ten sections of the tubes with the grids driven directly by separate targets of the preceding tube.

RESULTS

Target Separation

Figure 6 shows the results of a simulated receding doppler of approximately 40 cps. The signal levels were set just below the system saturation point.

In Fig. 7 the same test procedure was followed as in Fig. 6 but with a simulated approach doppler as the input signal.

The input and output circuits of the magnetostriction filters were gated on for a longer time than the actual width of the simulated target, thus accounting for the longer range spread from the filtered channels (Figs. 6(b) and 7(c)).

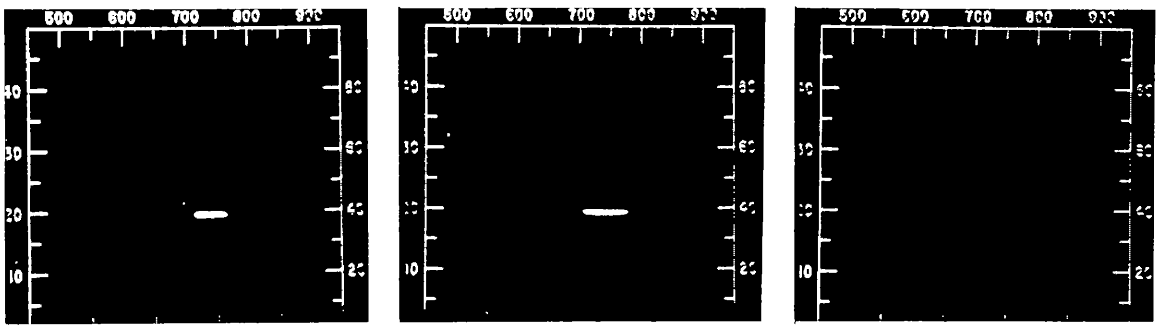


Fig. 6 - Simulated target receding with a doppler frequency of about 40 cps. (a) Conventional Madre radar system primary display; (b) the same receiver, converter, data processing, and display channel with the LSB magnetostriction filter inserted before the synchronous detector; (c) the HSB filter replaces the LSB filter. Horizontal scales represent the range (mi); right-hand scales represent the doppler frequency (cps), and the left-hand scales are not applicable.

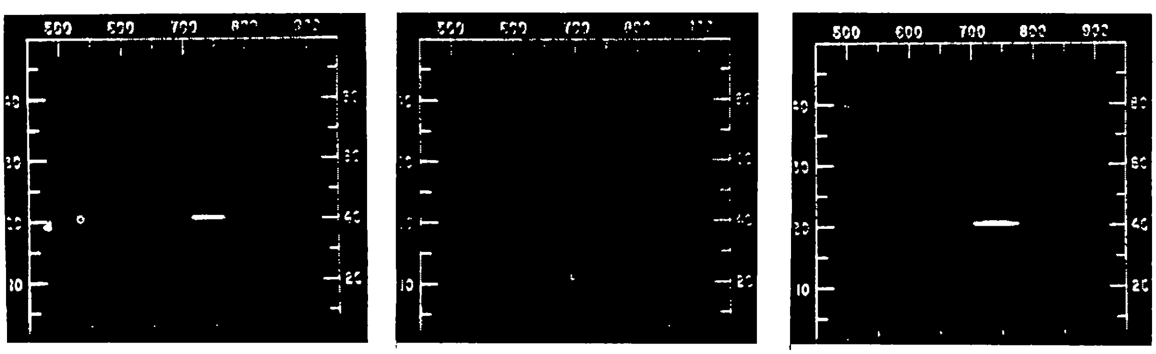


Fig. 7 - Simulated target approaching with a doppler frequency of about 40 cps. (a) Conventional Madre radar system primary display; (b) the same receiver, converter, data processing, and display channel with the LSB magnetostriction filter inserted before the synchronous detector; (c) the HSB filter replaces the LSB filter. Horizontal scales represent the range (mi); right-hand scales represent the doppler frequency (cps), and the left-hand scales are not applicable.

Signal Processing Gain

Using the doppler separation filters reduces each channel input bandwidth by one-half and could provide a 3-db improvement in the signal to white-noise ratio presented to the signal processor. A precise comparison of relative sensitivity of the doppler-separated and ambiguous doppler methods was not accomplished. However, observers experienced in the operation of the Madre radar believed that separated channels allowed detection of smaller signals.

Equipment Illustrations

Figure 8 shows the chassis mounting of the magnetostriction filters with the cover removed from one filter.

Figure 9 shows the magnetostriction filter element in some detail.

Figures 10(a) and 10(b) show, respectively, a top and bottom view of the chassis containing the dividing and multiposition distributor circuits.

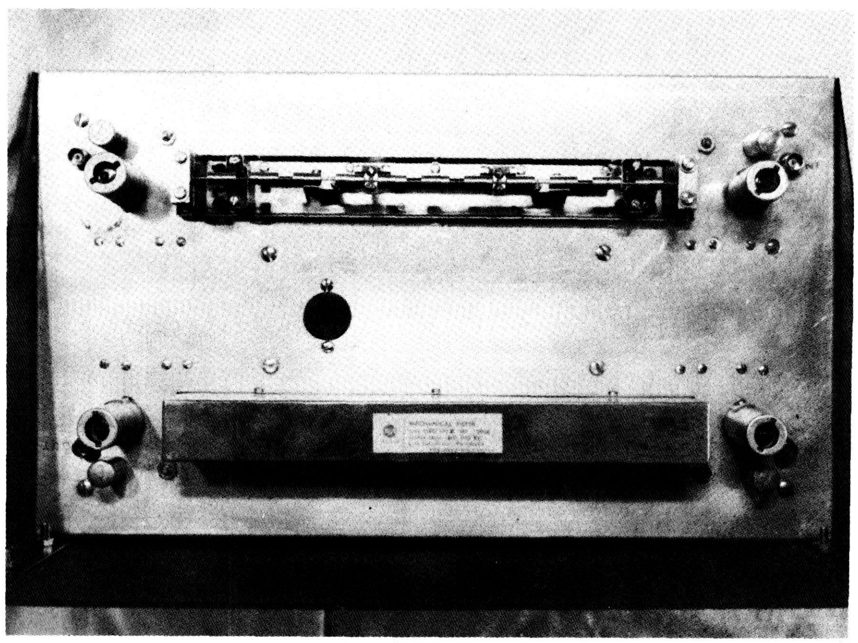


Fig. 8 - Chassis mounting of the magnetostriction filters with cover removed from one filter

CONCLUSION

The performance of the experimental magnetostriction filters showed the feasibility of a doppler-sense separation system based on their use. The single pair of filters developed has been useful in target cross-section echoing studies. The use of such a system for

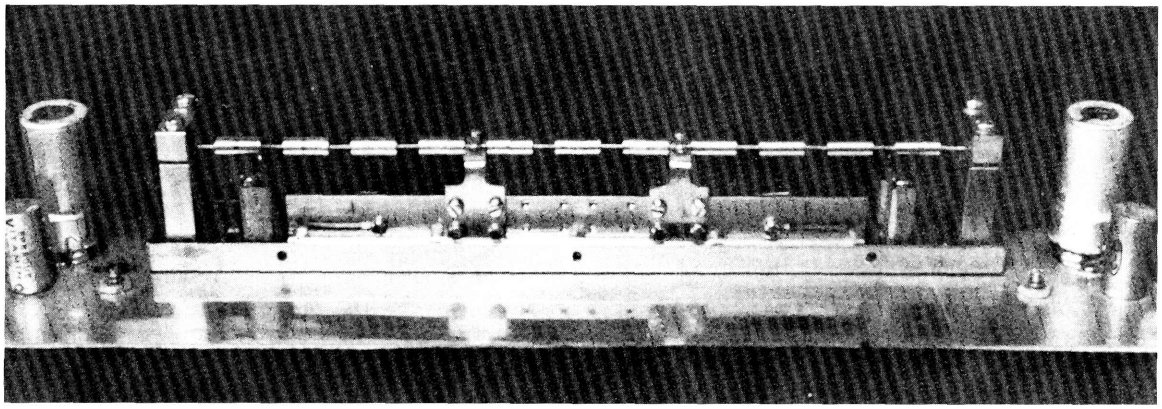
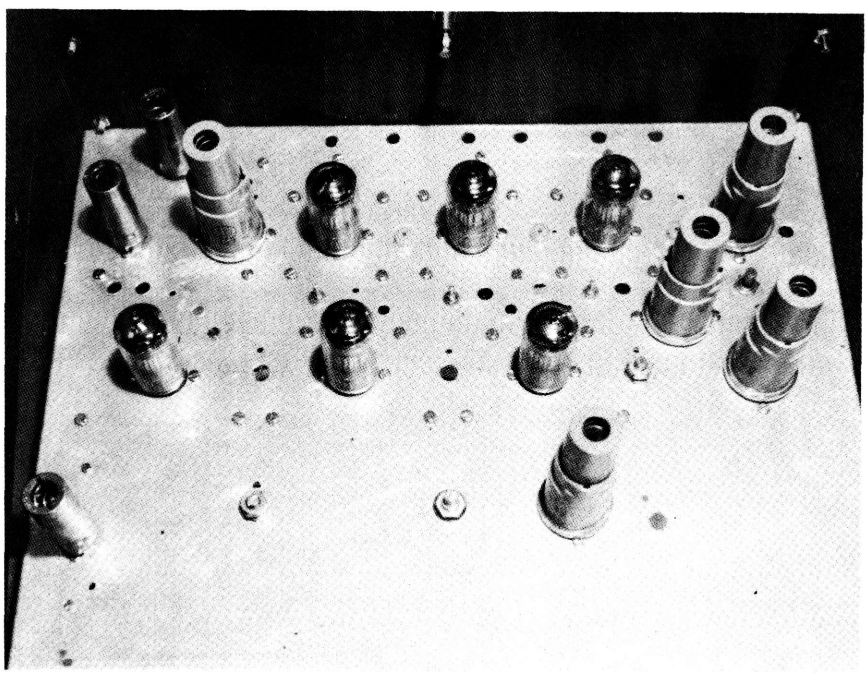
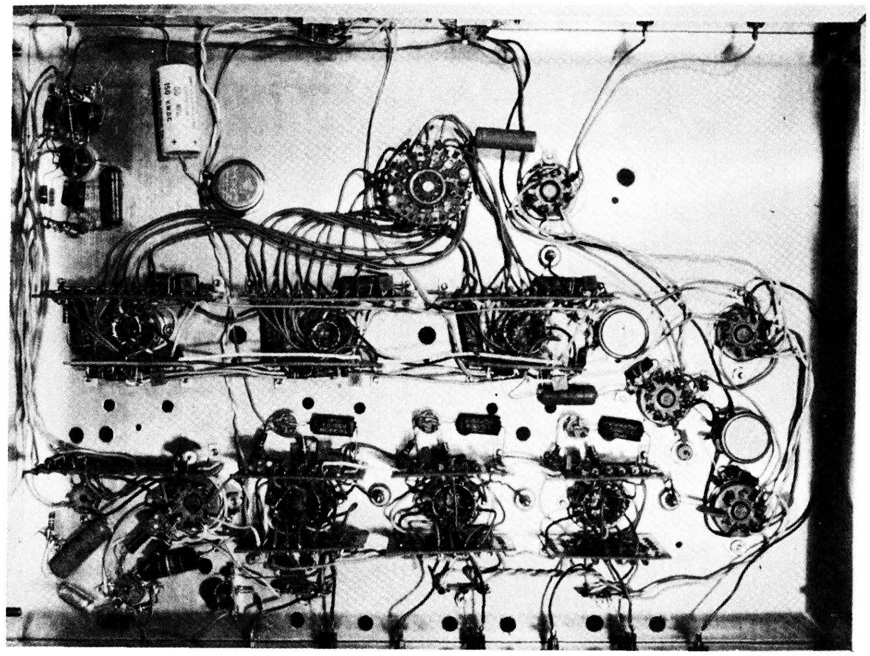


Fig. 9 - Close-up of magnetostriction filter element



(a) top view

Fig. 10 - Chassis mounting of the dividing and multiposition distributor circuits



(b) bottom view

Fig. 10 (continued) - Chassis mounting of the dividing and multiposition distributor circuits

target separation permits the presentation of unambiguous doppler frequencies up to one-half the target sampling rate. In addition, three desired collateral features can be obtained. These are (a) some suppression of earth backscatter returns, (b) simple i-f bandwidth control, and (c) the availability of range-gated and essentially continuous-wave signals.

The construction of magnetostriction filters with the characteristics necessary for this purpose proved to be a tedious procedure and efforts to acquire a sufficient number for a complete set were abandoned. A contract has been let for the construction of 25 pairs of crystal filters having the same characteristics as the experimental pair. Future plans are to install these as a part of the Madre research system at CBA.

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