RADAR PULSE EXPANSION/COMPRESSION FILTERS UTILIZING SURFACE ACOUSTIC WAVES

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Abstract

Surface acoustic wave pulse expansion/compression filters have been developed at Hughes which have applications to modern radar systems. A review will be presented of two pertinent applications and the advantages of these devices will be emphasized.

Introduction

A variety of surface acoustic wave (SAW) dispersive delay line filters have been developed at Hughes which have significant signal processing applications to modern radar systems.[1] The delay lines are designed to provide a linear FM (chirp) coded dispersed pulse waveform suitable for up-conversion and transmission and, following down-conversion in the radar receiver, decode the received radar signal and provide a correlated compressed pulse. The areas of primary emphasis associated with the development of these devices have included obtaining a variety of pulse compression ratios and dispersed pulse widths, minimized time-sidelobes on the compressed pulse, small size and weight and high reliability. These devices have potential applications to modern radars for airborne interceptors, high resolution ground mapping and long range surveillance. The significant advantages of the surface wave delay lines include low cost, small size and weight, ease of fabrication resulting in high yield and simplicity which provides high reliability.

This paper describes two specific radar applications and emphasizes the design and performance parameters. The first application is a pulse expansion/compression subsystem developed for a typical long-range radar wherein the transmitter peak power limitations required an unusually long dispersed pulse. Other areas of major design emphasis associated with this application included obtaining a large time-bandwidth product, minimized time-sidelobes on the compressed pulse, high receiver dynamic range, small size and weight and high reliability.

The second example to be described is a pulse compression filter designed for use in a doppler beam sharpening (DBS) mode in an airborne interceptor radar. In this second application the coherent dispersed pulse for the transmitter is generated actively in the radar exciter and the SAW delay line is used to compress the pulse in the receiver.

Pulse Expansion/Compression Subsystem

The design of the long-range radar subsystem features linear FM (chirp) waveform coding implemented using SAW dispersive delay lines fabricated on quartz substrates. The important performance parameters of this subsystem include:

- a maximum dispersed pulsewidth of 130 μsec with a 13 MHz bandwidth centered at 40 MHz.
- a compressed pulsewidth of 0.1 μsec at the -3 dB points with near-in sidelobe suppression > 25 dB and far-out suppression >45 dB.
- enhancement of the signal-to-noise ratio in the receiver in excess of 30 dB.
- receiver dynamic range > 70 dB.
- no thermal environmental control required. (Unit cycled from -30°C to +70°C with no significant changes in operational characteristics).
- a highly reliable design featuring a predicted MTBF > 600,000 hours.

The functional operation of the subsystem is shown in the block diagram of Figure 1. The inputs to the pulse expansion channel are a 40 MHz CW signal (+10 dBm) and a PRF trigger. The output from the expansion channel is a gated, limited, linear FM coded dispersed pulse (120 μsec) with a nominal S/N ratio of 60 dB suitable for up-conversion and transmission. The compression channel accepts the coded dispersed pulses, after down-conversion in the radar receiver, and compresses them in the time domain thereby providing the processing gain.

The linear FM coding/decoding function is accomplished using SAW filters. The requirement to provide a 120 μsec coded dispersed pulse using a quartz substrate of practical dimensions represented a significant design challenge. The approach taken is the slotted, circulative dispersive delay line configuration illustrated in Figure 2, where the -21° Y-rotated, X-propagating quartz substrate is rounded on one end and also slotted to accept the metal septum. The chirp-coded interdigital transducers are placed on the polished top and bottom surfaces such that the sound wave can circulate around the rounded end of the substrate. Insertion of the grounded metal septum in the slot between the two transducers provides effective electrical isolation and reduces the direct electrical leakage to > 40 dB below the compressed pulse.

The completed subsystem is illustrated in Figure 3 where, in addition to the overall enclosed unit, the pulse expansion and compression sections are shown with the separate dispersive delay lines in each section. The expansion channel contains a negative slope (down chirp) delay line and the receive channel a positive slope (up chirp) line. The receive channel delay line is segmented into 8 parallel outputs to permit integral time-frequency weighting for the purpose of time sidelobe reduction on the compressed pulse.

The type of radar pulse expansion/compression waveforms and the performance obtained in the laboratory with this subsystem are shown in Figure 4. The points to be noted are: (1) the dispersion on transmit, with limiting and gating, to provide a linear FM coded pulse width of 120 μsec with a nominal 60 dB signal-to-noise ratio, (2) compression on receive with direct electrical leakage reduced to < -40 dB below the compressed pulse and (3) the compressed pulse with a 0.1 μsec pulsewidth with near-in sidelobes < -25 dB and far-out sidelobes < -45 dB.

DBS Mode Pulse Compressor

In this second application to be described, the SAW filter is used in the receiver of an airborne tactical radar, when operating in the DBS mode, to compress the dispersed pulse which is generated actively in the radar exciter.

System coherency is achieved with active linear chirp by referencing the phase of each dispersed pulse to a crystal controlled CW oscillator. The frequency sweep over the dispersed pulse length is linear to an error of < 0.5% over a 9 MHz bandwidth. This dispersed pulse is then up-converted for microwave transmission and following down conversion of the return signal to 60 MHz in the receiver, the pulse is compressed passively in a SAW filter.

The low noise performance of the transmitted pulse train in the doppler region is illustrated in Figure 5 where the spectral line to noise ratio is shown for the frequency region between the PRF lines near the carrier.

The compression filter is fabricated on ST-cut quartz and has 20 μsec of dispersion over a bandwidth of 6.5 MHz centered at 60 MHz. After Gaussian frequency weighting the compressed pulsewidth at the 4 dB point is 0.2 μsec. The compressed pulse is shown in Figure 6 where it is seen that the close-in sidelobes are on the order of 30 dB below the peak.

References

1. J. Burnsweig, S. H. Arneson and W. T. Gosser, "High Performance Large Time Bandwidth Surface Wave Filters", IEEE Ultrasonics Symposium Proc., 72 CHO 708-850, pp. 276-279.

Acknowledgements

The authors acknowledge the contributions of S. H. Arneson, W. T. Gosser, C. F. Bancroft and G. D. Fisher to the work described herein.

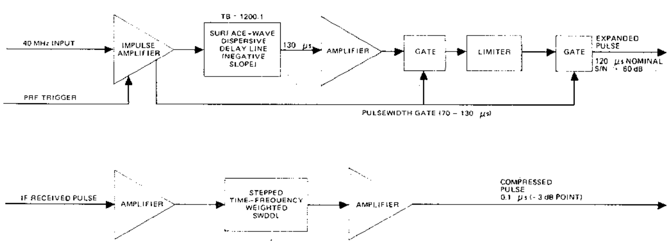


Fig. 1. Functional block diagram of the pulse expansion/compression subsystem.

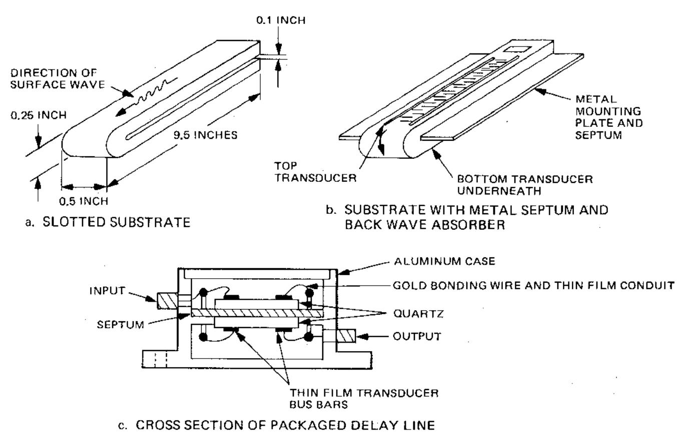
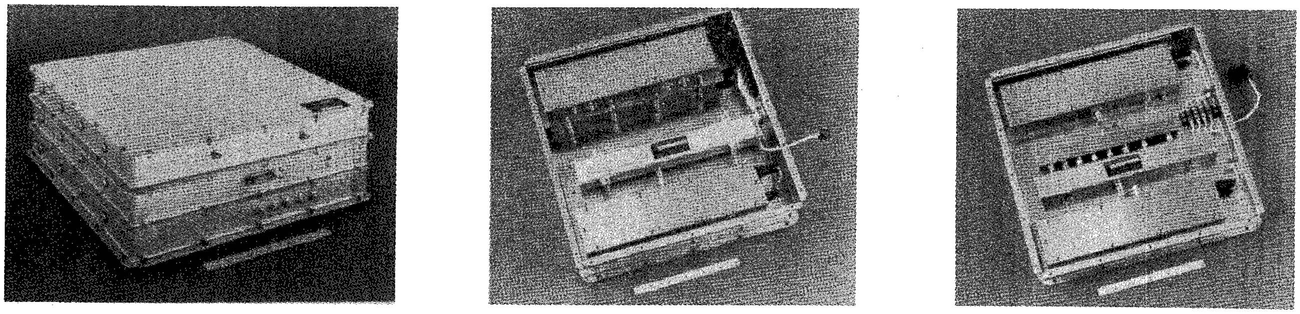


Fig. 2. Slotted circulative dispersive delay line configuration.



a. Enclosed assembly. b. Expansion unit. c. Compression unit.

Fig. 3. Pulse expansion/compression subsystem hardware.

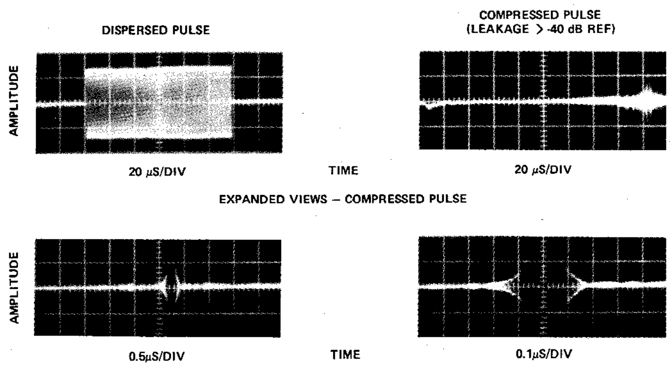


Fig. 4. Pulse expansion/compression waveforms and performance.

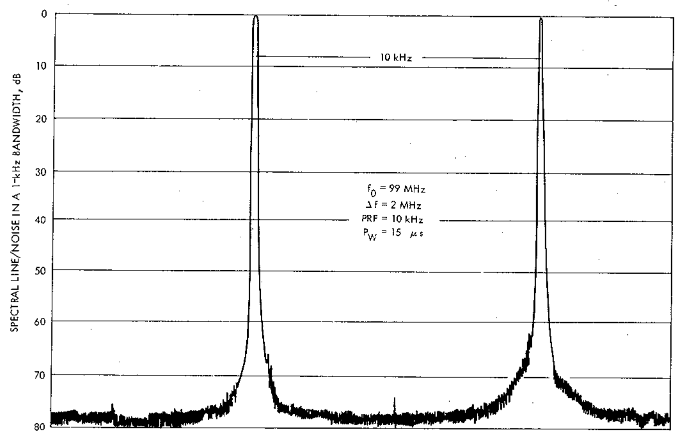
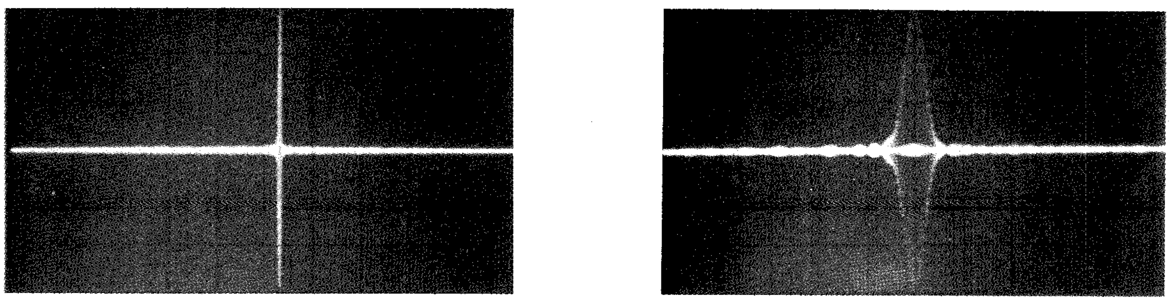


Fig. 5. Low noise performance of transmitted pulse train in the Doppler region.



5 μsec/CM 0.5 μsec/CM

Fig. 6. Compressed pulse performance of DBS filter with Gaussian frequency weighting.