D-1

A REVIEW OF ELECTRONIC WARFARE (EW) RECEIVERS WITH ACOUSTIC DEVICES

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ABSTRACT

This paper discusses the state of the art of channelized receivers with surface acoustic wave (SAW) filters, the impact of SAW dispersive delay lines on microscan receivers, and the general characteristics of Bragg cell receivers.

I. Introduction

The general requirements on EW receivers are: 1) wide instantaneous RF input bandwidth with fine frequency resolution, 2) wide dynamic range to process simultaneous pulsed (or CW) signals, 3) high throughput rate to encode the input signals on a pulse by pulse basis. Three generic receivers can potentially fulfill these requirements. They are channelized, microscan (also referred to as compressive), and Bragg cell receivers. In addition to the performance requirements, the EW receivers must be small in size and light weight especially for airborne applications. SAW filters and SAW dispersive delay lines (DDL) can be used to reduce the size of channelized and microscan receivers respectively. Each of the three receivers will be discussed briefly in the following.

II. Channelized Receiver

A channelized receiver uses a large number of contiguous filters to sort the input signals. The number of filters can reach several hundred, and the input signals are processed in parallel. The bandwidth of the filters is around 10 MHz which determines the frequency resolution. This kind of receiver should fulfill most of the requirements, but it is bulky. To reduce the size, SAW filters can be used. The input signals are usually down converted below 500 MHz, where SAW filters can be fabricated relatively easily. The adverse effects produced by the adaption of SAW filters are: 1) additional amplification must be provided to compensate the excess insertion loss of the SAW filters, 2) the outband rejection of the SAW filter is limited in comparison with that of a conventional filter as shown in Fig. 1. This characteristic degrades the instantaneous dynamic range of the channelized receivers, 3) the spurious response in the time domain of the SAW filter output (i.e., triple transit effect) as shown in Fig. 2., can slow down the throughput rate of the receiver. The processing circuits following the SAW filters must wait until all the spurious responses in the time domain are below a certain level, in order to process a new signal in the same filter channel. Therefore, the processing speed of the receiver will be slowed down. Two banks of filters each containing eight filter channels are shown in Fig. 3. The large one is made of conventional filters while the small one is made of SAW filters. The advantage of the size reduction is clear.

III. Microscan Receiver

A microscan receiver uses one dispersive delay line (DDL) and a sweeping local oscillator (LO) to convert the input signals into many narrow sequential pulses according to the input signal frequencies. By measuring the positions of the output pulses in time domain, the frequency of the input signal can be obtained. A microscan receiver block diagram is shown in Fig. 4. The input signal is mixed with a FM signal generated by a LO. The DDL following the mixer is used to compress the FM signal into a narrow pulse. The weighting filter will reduce the sidelobes of the output pulses to simplify following detection schemes. The key components in a microwave receiver are the DDL and sweeping LO. Traditionally, the DDL is a meander line which is a special kind of electromagnetic line. The sweeping LO is a voltage controlled oscillator (VCO). The meander line is usually very bulky, because it takes a relative long (EM) line to generate some useful delay time. The design of the VCO with linearizing circuit to match the frequency vs. time slope of the DDL is also very complicated. Both these components can be acoustic devices which will reduce the size of the receiver and may even simplify the design. A SAW DDL cannot only be used to compress the input signal but also be used to build an LO. If a pulsed signal is applied to the input of a DDL, the output will be an FM signal. Using this principle, one can build a sweeping LO via a DDL. The bandwidth of the DDL is closely related to the input bandwidth of the receiver. The wider the DDL bandwidth, the wider the receiver bandwidth. However, the compressed pulse width from the DDL is inversely proportional to the DDL bandwidth. Today the major difficulty in microscan receiver design, is development of practical digitizing circuits to handle these narrow pulses for wide bandwidths. Therefore, the bandwidth of the DDL is usually limited under 1 GHz. The dispersive delay time is inversely proportional to the frequency resolution of the receiver. The delay time usually under 1 μs which will provide a frequency resolution greater than 1 MHz.

IV. Bragg Cell Receiver

In a Bragg cell receiver, the input electric signal is converted into an acoustic wave propagating in a transparent medium (Bragg cell). The acoustic wave will modulate the index of refraction of the Bragg cell through elasto-optic effect. A laser beam interacts with the acoustic signal at a critical angle (bragg angle). These light sensitive signals are Fourier transformed via a proper optical lens system onto optical detectors where the optical signals are changed back into electric signals for further processing. The schematic of a Bragg cell receiver is shown in Fig. 5., while an actual Bragg cell receiver is shown in Fig. 6. The size of the receiver is very small. The size of the Bragg cell receiver can even be further reduced through integrated optical circuit (IOC) technology. The entire receiver including the laser, Bragg cell, lens system and photo detectors can be fabricated on a small chip with the laser and detectors butt on the ends.

The input frequency bandwidth of a Bragg cell receiver can be as wide as 1 GHz. The frequency resolution can reach 1 MHz. Today the primary deficiency of a Bragg cell receiver is the lack of dynamic range. The limitation is in the photo-detectors; however, improving the diffraction efficiency (η) of the Bragg cell will improve the dynamic range. In general, the narrower the Bragg cell bandwidth, the higher the η value. A 500 MHz bandwidth Bragg cell can have an η of over 30% per watt while a 1000 MHz one will have a η of less than 10% per watt. More research and development is needed on the IOC Bragg cell receiver to make it suitable for EW applications than that of the bulk wave Bragg cell receiver.

V. Summary

All the three kinds of receivers mentioned above are in the development stage. The lack of properly designed digitizing circuits following the video outputs of the receivers makes the evaluation of the receivers very difficult. Usually the digitizing circuits are considered part of an EW receiver. These digitizing circuits problems must be solved first in order to make a decent comparison of the three kinds of receivers. However, from the already known performance, the following conclusions are predicted: The SAW channelized receiver will have superior performances in comparison with microscan and Bragg cell receivers, but it will be relatively bulky and expensive. The Bragg cell will be the most compact one with relatively low dynamic range. The microscan receiver will be in the middle of these two kinds of receivers, both in performance and size.

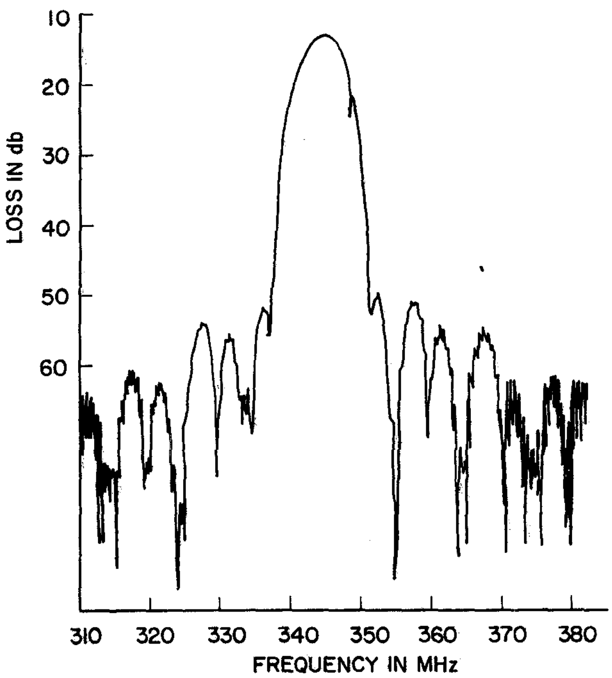
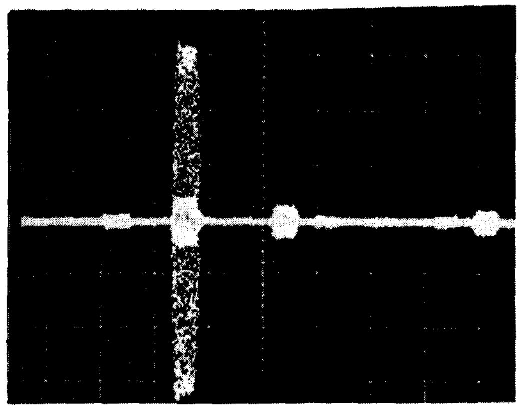


Figure 1. Loss vs. Frequency of SAW Filter Measured by Receiver Method



(10 mv/div., 2 µs/div.)

Fig. 2. Signals of Output #3 of SAW Multiplexer

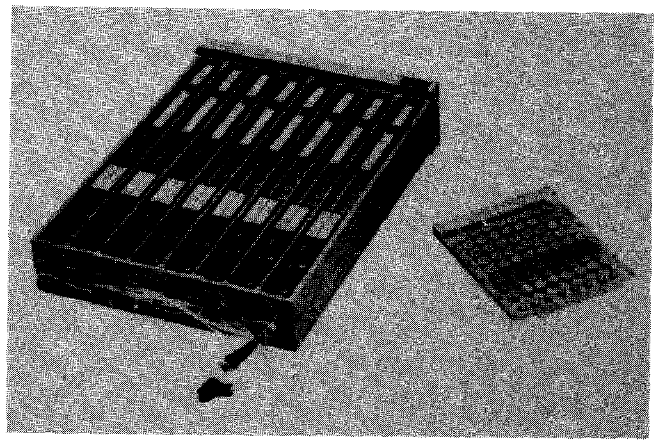


Figure 3. SAW Feasibility Model of Channelized IF Processor Compared with Brassboard Model

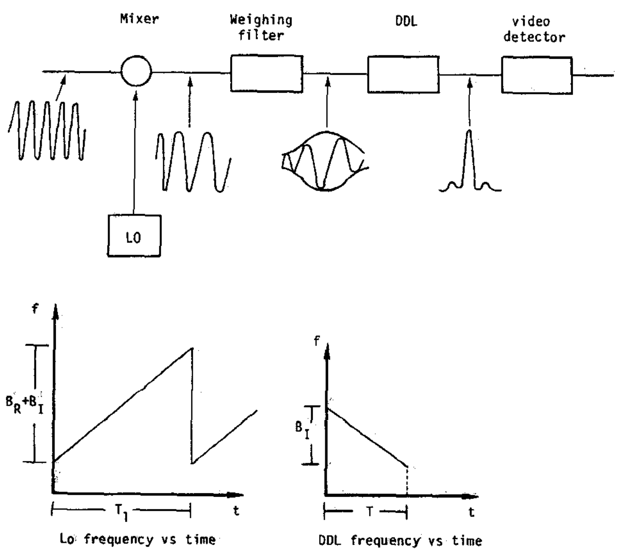


Figure 4. Schematic of a Microwave Receiver

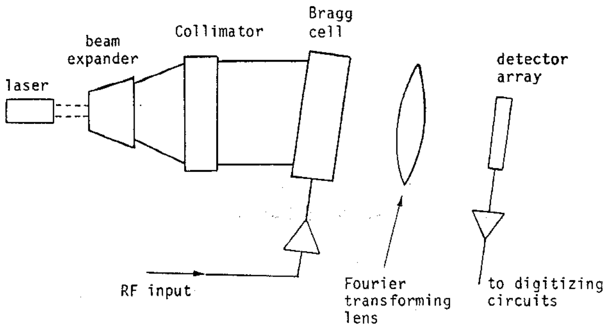


Figure 5. Schematic of a Bragg Cell Receiver

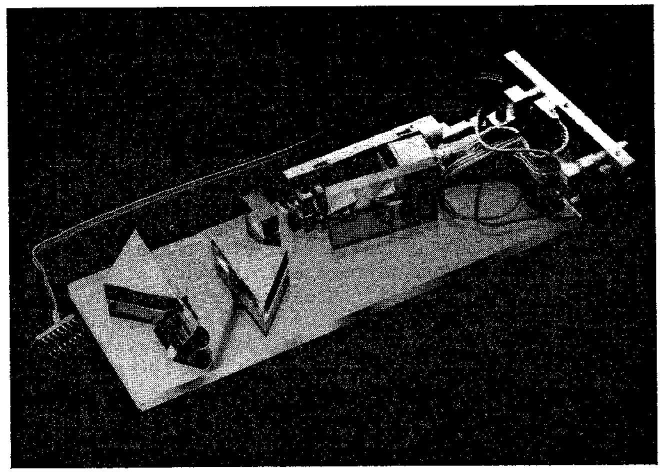


Figure 6. The Optical Bench of a Bragg Cell Receiver