SURFACE ACOUSTIC WAVE DEVICES IN ELECTRONIC WARFARE

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In this paper the applications of acoustic surface wave device technology to electronic warfare systems have been reviewed. A variety of signal processing tasks such as simple time delay, frequency dependent time delay, programmable and discretely variable time delay, band pass filtering and generation and recognition of various coded waveforms can be performed by surface wave devices to improve the performance of EW system.

An effective electronic warfare system should have the capability to identify the hostile radars and to frustrate the attempts of these radars to track target. In the two key areas of this problem, SAW devices will play an important role by virtue of their unique signal processing capabilities combined with their small size and potentially low cost.

The devices will find use as frequency discriminators in set-on-receivers, as pulse compression filters in compressive or fast scanning receivers, as band pass filters in electronic support measure (ESM) receivers, as frequency memories in range deception systems and as waveform generator in target simulator. In this paper, first of all a understanding of the operation of a class of surface wave devices e.g. tapped delay lines, will be given. Then the role it can play in specific applications will be described. Finally experimental results and their implementation will be compared to other approaches for the realisation of the desired function.

TAPPED DELAY LINE APPLICATIONS

A simple surface wave delay line consists of a single piezo-electric crystal with metal interdigital electrode patterns photoetched on surface or a nonpiezoelectric substrate having a piezoelectric film deposited under or over the metal structure. The acoustic surface wave is generated by the application of a time varying electric field to input transducer and this acoustic signal is back converted into electromagnetic domain by a similar output transducer. The central frequency of operation is determined by the one half acoustic wave length separation between adjacent fingers of transducer and the time delay is simply the propagation time between input and output transducers. Tapped delay line can be constructed by utilising the property that acoustic signals are localised at free surface and may be 'tapped' anywhere along the propagation pattern by placing a transducer at the desired location. Tapped delay lines with fixed taps, connected directly to a summing bus, and programmable taps, connected through switches which permit control of the amplitude and phase of the tap output will both be useful in EW applications.

A tapped delay line may be used as a pulse stretcher which has its application in a range deception system[1]. In a pulse stretcher (Fig. 1), a burst of RF applied at input transducer will propagate along the array

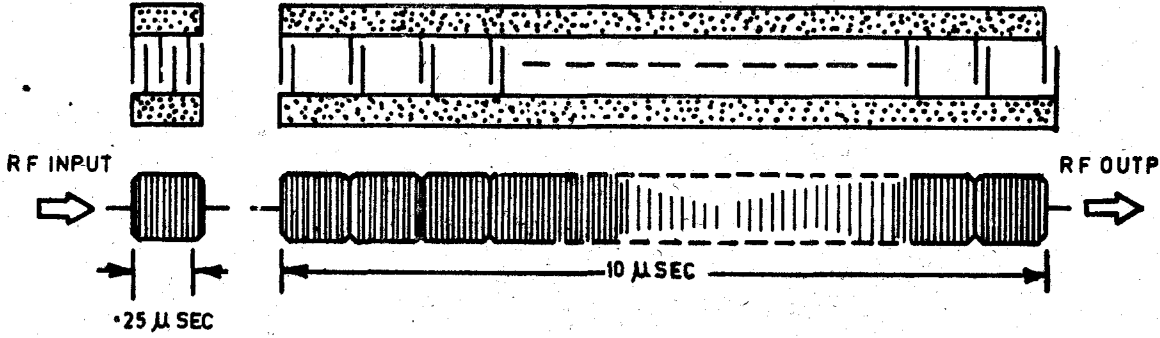

Fig. 1—Tapped delay line with fixed taps operating as a pulse stretcher.

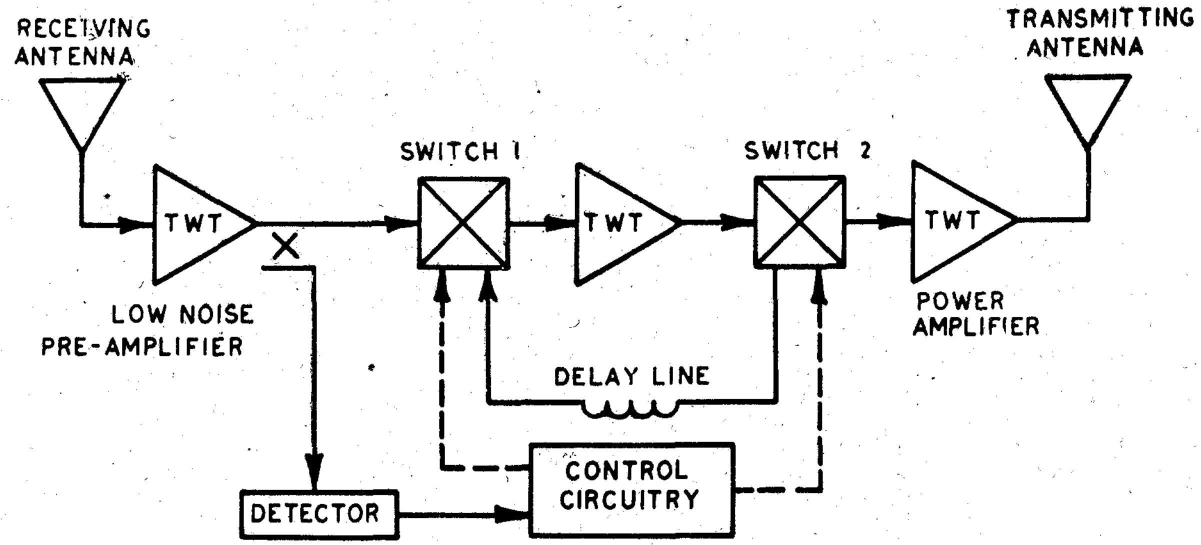

Fig. 2—Range deception system.

of taps exciting each tap in succession. The output of the line will be a pulse which is *n* times longer than the input signal where *n* is the number of taps. A range deception system (Fig. 2) involves a recirculating delay line capable of storing a signal for many microseconds. The time delay for pass around the delay line is less than or equal to width of signal pulse. A switch permits the circulating signal to be switched to a transmitter, whenever desired. The result is equivalent to stretching the input pulse by a factor equal to the number of recirculations. The control determines when a response will be made by opening switch 2 at appropriate time, in effect creating a variable delay. The time delay between the arrival of original signal and the transmission of the return signal is progressively increased. This return signal is at a much higher power level than the skin return from the target so that range gate of the radar is captured and progressively moved farther away from the real target. The surface wave pulse stretcher can effectively accomplish the signal storage task in an acoustic frequency memory system. A system[2] with the instantaneous band width upto 200 MHz and switching speed 15 ns have been developed using both fixed and switchable tapped delay to achieve discretely variable timing of the output in steps of 40 ns upto 40 μs.

At present, a typical recirculating frequency memory consists of a specially designed TWT and a considerable length of coaxial cable or waveguide. The large size, weight and matching problems of TWT are the drawback of this system. The acoustic system offers substantial improvement in size, weight and the matching problems of TWT are eliminated. The principal drawback of acoustic system is its small band width compared to coaxial or waveguide system. A partial solution to this problem is the development of materials as aluminium nitride which will facilitate operation at large band width or to consider the use of several channels each covering a piece of the desired band.

In a programmable tapped delay line (Fig. 3) it is possible to activate only one tap at a time and the time delay depends on which tap is operating. This discretely variable delay device is able to deal with FM or phase coded threat signals. A spread spectrum transreceiver[3] operating at 435 MHz with a 20 MHz chip rate have been demonstrated using a programmable tapped delay line with 128 times spaced inputs. The spread spectrum technique can play an important role in an effective antijamming system. The programmable tapped delay line may also have use in an augmentation or signature simulation scheme. The purpose of which is to reproduce the radar signature of an extended reflecting body such as a large aircraft. When used in this application, all of the delay line taps would be operating, but the output of each tap would be amplitude weighted, resulting in a pulse amplitude modulated waveform (Fig. 4). A target simulation can be used either as a disruptive measure discussed above or as an aid in system development and automatic testing.

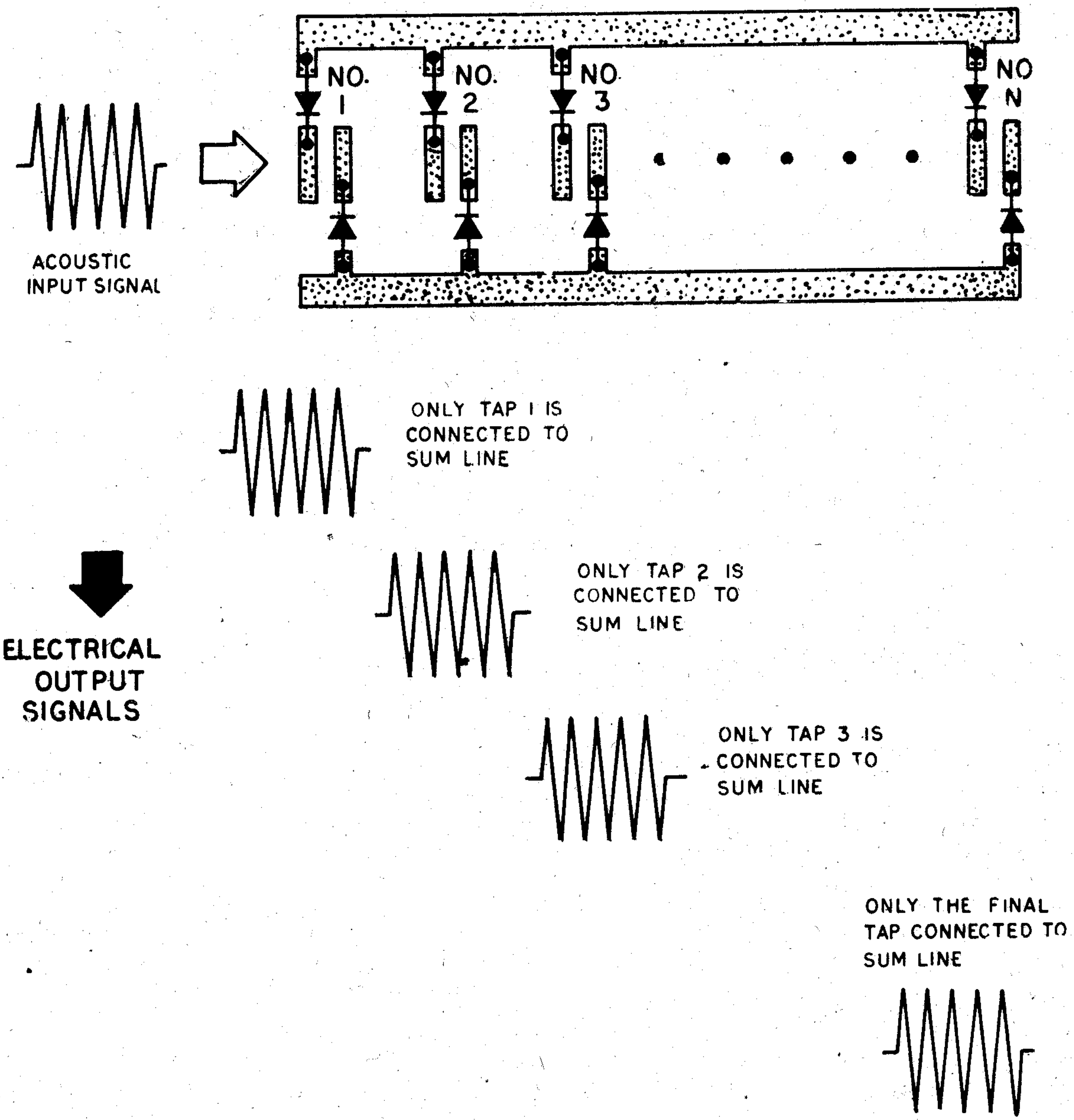

Fig. 3—Programmable tapped delay line.

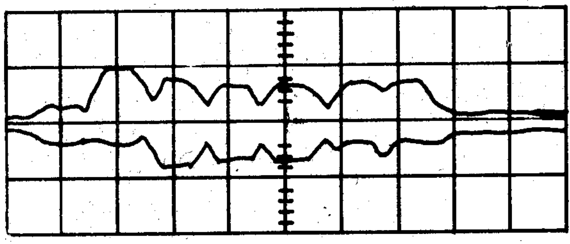

Fig. 4—Amplitude modulated waveform demonstrating target signature simulation.

DISPERSIVE DELAY LINE APPLICATIONS

The surface wave dispersive delay line (DDL) may be used in frequency discriminator and compressive receiver. In the dispersive transducer the separation between electrodes, which determines operating frequency varies continuously from one end of the transducer to the other. Two such dispersive transducer as shown in Fig. 5 can exhibit the frequency dependent time delay—the high frequency will be launched and received at near ends of the transducers and experience a short propagation path, while the low frequencies will travel the longer propagation path between the far ends of the transducers. This property can be utilised for the measurement of frequency. Identifying the frequency of a hostile radar and turning on an oscillator at that frequency constitute the fundamental mission of the set-on-receiver. This receiver is practically useful in the context of expendable jammers.

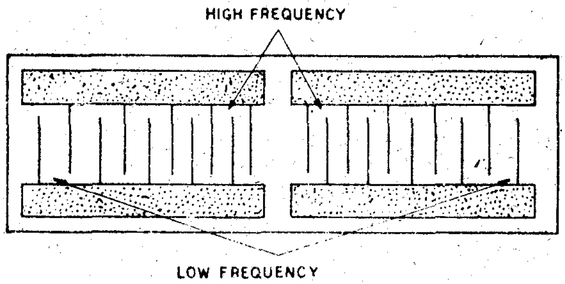

Fig. 5—Dispersive delay line.

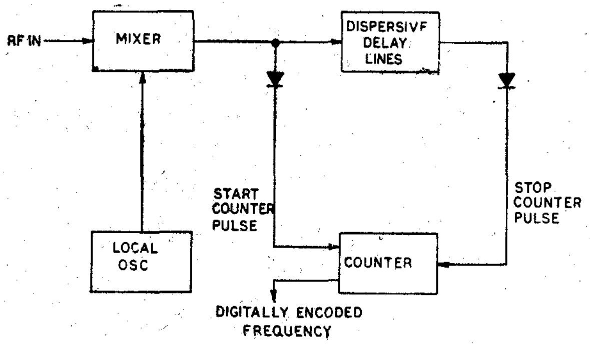

Fig. 6—Frequency discriminator operation.

In a surface wave frequency discriminator (Fig. 6) a RF signal is down converted to the frequency band in which the DDL operates, then applied simultaneously to the surface wave device and a threshold circuit. The threshold signal is detected and used to start a digital counter. The IF signal applied to DDL is delayed by an amount which is proportional to the received frequency. The signal is then detected and used to stop the counter. The count obtained during this interval is proportional to the received frequency. Dispersive delay line with 150 MHz bandwidth and 10 microsecond dispersive delay have been successfully operated in this application. The large bandwidth requirement for this application may lead to problems of spurious signal generation and broad band impedance matching.

Of the other approaches for frequency discrimination, the most attractive is the instantaneous frequency measurement (IFM) receiver. This approach is based upon a phase measurement between two signals which travel over propagation paths of slightly different lengths. The IFM operates at RF to yield frequency discrimination directly and does not require frequency conversion. The disadvantages of IFM receiver are a narrow dynamic range of phase detectors within which accurate frequency measurement can be made and large size. It has been shown[4] that trade offs are in favour of surface acoustic wave approach compared to other approaches.

The DDL may also be used to generate and compress a linear FM wave form. The compressive receiver (Fig. 7a) uses pulse compression alongwith the separation of different frequencies according to time delay. It is an intercept receiver which is capable of instantaneously analysing and sorting into fine frequency resolution cells all signals residing within a broad RF spectrum. The received signals are frequency modulated by fast scanning LO in order to match them to compression filter. When this is done signal detectability is determined only by the available signal energy and frequency resolution is limited only by duration of signal. The compressive receiver is able to separate time coincident input signals at different frequencies as shown in Fig. 7b. The two signals shown arrive at the input of receiver at the same time, but with different frequencies. Each is processed in the manner described above resulting in two linear FM signals with a slightly different centre frequency, when two signals are applied to the compression filters each will be compressed by part of the delay line that is sensitive to its particular frequencies. Because of the dispersive delay characteristics of the filter, the signals will appear at the output at different times.

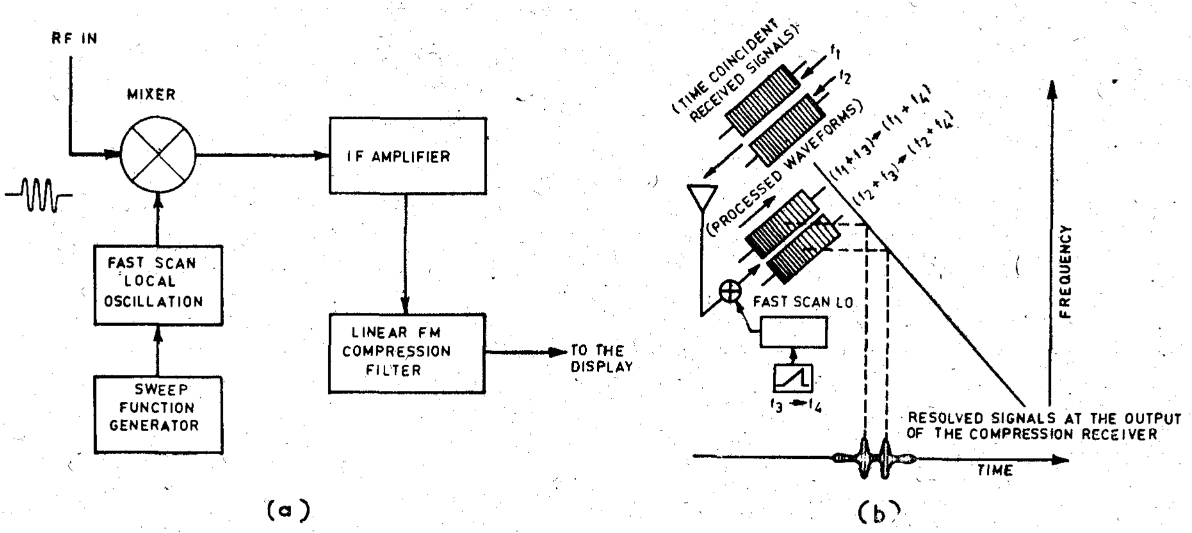

Fig.—7 (a) Compressive receiver, (b) Process for separating simultaneous signals.

A compressive receiver[5] has been designed to intercept signals rapidly and to maintain 100 KHz frequency resolution over a 100 MHz instantaneous RF frequency band. The complete frequency range is swept at the rate of 50,000 times per second (each 20 microseconds) and nearly 1000 frequency resolution cells can be examined per sweep and correlated with previously measured signals. It exhibits unique advantage as frequency signal sorter over superhetrodyne receiver or contiguous comb filter bank because of its large time band width product with solid state size.

BAND PASS FILTER APPLICATIONS

The impulse response and therefore the frequency response of a surface wave filter can be controlled by finger position and by the extent of overlap between adjacent fingers or finger width of the transducer. Surface wave filters may be combined into a contiguous filter bank which in turn becomes an integral part of an electronic support measure (ESM) receiver. The ESM receiver can classify a large number of signals according to frequency, direction of arrival, pulse width and pulse recurrence frequency. All the filters in the bank have a common input but separate, discrete outputs. An input signal is applied to the common input but emerges, ideally from only one output and is thus characterised in that particular frequency band.

Fig. 8 is an n channel filter array consisting of n acoustic filters and output matching amplifiers. Typically, an input matching amplifier is driving eight filters. An eight channel filter bank having a 3 dB bandwidth of 5 to 25 MHz in the frequency range 100—500 MHz has been demonstrated[6, 7]. Significant cost reduction would be possible by the fabrication of filters and amplifiers depositing *ZnO* films on silicon substrate. In an acoustic filter bank, by switching in a return line, each channel can be converted into an oscillator using a suitable feed back circuit. Thus it can have application as an 'fm noise jammer'. Attempts by other techniques to fabricate contiguous filter bank include YIG filters, lumped element filters, stripline filters, cavity filters, and active filters. Each of these approaches suffers from various combinations of complexity, large size, excessive power consumption, operational deficiencies over usable temperature range and cost ineffectiveness.

CONCLUSION

It has been shown that surface wave devices may offer attractive solution to some of the problem areas. of electronic warfare system. The device type of particular interest namely tapped delay line, dispersive delay line and band pass filter have been discussed in detail. Uses in applications such as range deception system, spread spectrum technique, target simulation, frequency discriminator, compressive receiver, contiguous filter bank and noise jammer have been discussed. The penalties associated with the use of surface wave devices are frequency limitations which force operation at intermediate frequency and small band width. Another limitation of these devices is insertion loss. Frequency conversion may be performed by conventional hetrodyning and at intermediate frequency it is easy to make up for insertion loss by solid state amplifiers. It may be necessary to operate devices in parallel to achieve the desired system band widths. However, these penalties are relatively light and in the cases cited in this paper the trade-offs are favourable to surface wave devices.

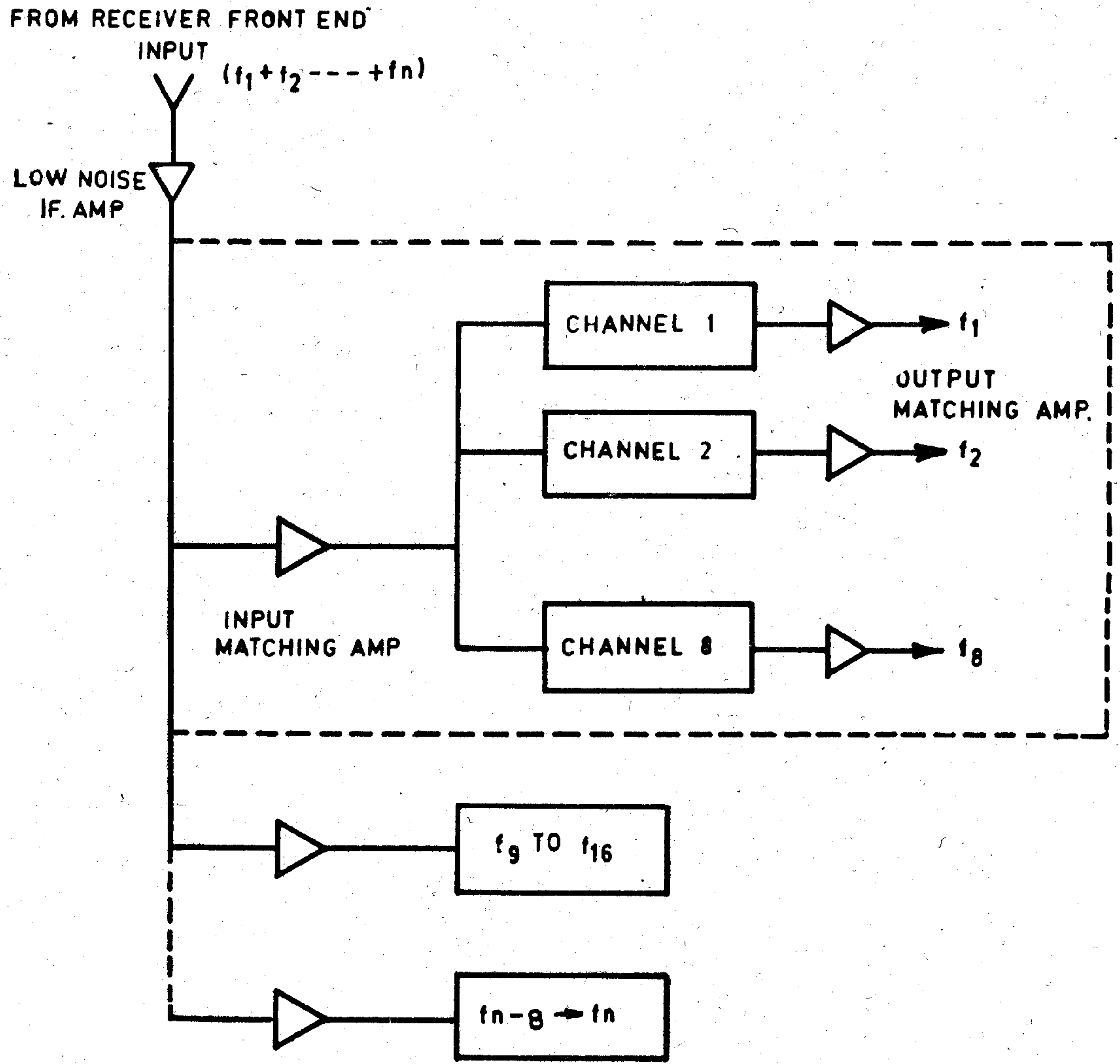

Fig. 8—*n* channel filter array transplexing makes use of input/output matching amplifiers to drive upto eight SAW filters.

With amplification, mixing and wave guidance observed in these devices and by monolithically integrating surface wave and semiconductor technology we may look forward for a day when frequency conversion, *i-f* amplification, frequency sorting and fixed and variable delay all function can be combined into a miniature EW package.

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