CURRENTLY PRACTICAL ACOUSTIC SURFACE WAVE DEVICES

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This paper presents a survey of the presently available surface wave devices and the range of frequency, bandwidths, etc., which can be considered practical at this time. The discussion is limited to devices intended for various analog signal processing functions. A short term projection of the next generation of devices is also included.

Introduction

It can be said without contradiction that acoustic surface wave technology has lead to a class of very important signal processing devices during the last five years.[1] The development of these devices has been made possible by the recent developments in both microelectronics circuit fabrication techniques and sophisticated modeling techniques for the device performance. It is the purpose of this paper to list the important devices and to indicate which components can be considered to be sufficiently well developed to be included in current and anticipated systems hardware. Included also will be a discussion of the important operational parameter ranges and the limitations of the device performance. The emphasis here will be on devices which are considered to be currently available and which fill needs in radar, communications, and other signal processing systems.

The devices to be discussed in this paper are all based on the use of piezoelectric substrates and interdigital metal electrode transducer structures for the generation and detection of Rayleigh surface waves. There are many laboratory devices today which rely on more complex mode propagation, the interaction between the surface wave and electrons, and the use of active devices. It is considered that although these devices are interesting and have been proven in the laboratory, they have not yet met the test of practicality to which this talk is dedicated. The devices to be considered here will be limited to those devices which have been proven to have applicability and which have demonstrated acceptable performance in the systems environment.

There will be some discussion of the next generation devices; however, these devices are rather simple extensions of the existing device technology which has been proven practical. Discussion also will be limited to devices which are demonstrably achievable within the next one to two years. An outline of requirements for the future acceptance of surface wave devices in general will be included. In particular, the need for aging studies for all classes of surface wave devices will be emphasized.

Tapped Delay Line Transversal Filters

The basic acoustic surface wave device is a deceptively simple embodiment of the classical transversal filter.[2] The output is the convolution of the input with the impulse response of the device. The simplest configuration is that of a delay line which has two colinear interdigital transducers on a piezoelectric substrate. Two obvious characteristics of such a device are that (1) the output signal is delayed in time with respect to the input and (2) the interdigital transducer is inherently a bandpass filter. As is well known, the spatial periodicity of the interdigital array and the velocity of the substrate material determine the center frequency and the separation between phase centers determines the time delay. The capability for tapping the surface wave continuously along its propagation path made the realization of transversal filters a simple matter.[3]

The simple two part delay line is useful for many applications and will be discussed later in relation to bandpass filters and frequency control. The next type of surface wave device to be exploited has been the transversal matched filter as applied to radar pulse compression problems. Pulse compression filters for radar were the first such filters to be used in real systems.[4] This acceptance has been due in part to the fact that such filters could be retrofitted to replace large bulk wave devices and digital pulse compression systems. Since linear FM has been the most common encoding, most pulse compressors have been developed to compress a chirped waveform.

Surface wave pulse compressors are typically used at IF frequencies from approximately 60 MHz to 300 MHz. Laboratory devices operating at L-band have been demonstrated[5,6] but are not currently available. Time bandwidth products of 10^2 and sidelobe levels suppression of greater than 30 dB have been practical for several years. More recently, the reflective array correlator (RAC) has been demonstrated[7] to achieve time bandwidth products of 10^3 to 10^4. The RAC will be mentioned again as one of the important new devices which will receive additional development during the next two years.

The flexibility of electrode placement in an interdigital transducer array makes possible the realization of transversal matched filters for arbitrary complex waveforms. Phase coded waveforms are readily implemented. For example, biphase coded matched filters have been developed for maximal length sequences as well as for special codes such as the Barker[8] sequences. Filters for the generation and correlation of PN sequences have been developed for many chip rates and sequence lengths. A typical such filter would be for a 10 MHz chip rate and a 127 chip length. Such devices are expected to impact spread spectrum communications, ranging and IFF applications. As in the case of chirp pulse compressors, the frequency range is normally from ten to several hundred megahertz.

Most of the codes which have been described by Cook and Bernfield[2] can be implemented using surface wave techniques. An example is the set of Frank[9] polyphase codes. Other interesting codes include the orthogonal Golay sequences which can be used for multiplexing. Matched filters are now practical within the limits of center frequency and bandwidth associated with all surface wave devices. Chip lengths greater than 10^3 have been demonstrated.[10]

Bandpass Filters and Frequency Control

The use of surface wave devices for bandpass filtering and frequency control has the potential for

Table I

SURFACE WAVE DEVICES
SWD BANDPASS FILTER CAPABILITIES

Parameters	Practical	Developmental	Projected
Center Frequency	10 MHz-1.0 GHz	10 MHz-1.5 GHz	1 MHz-2 GHz
Bandwidth	50 kHz-0.4 f_o	50 kHz-0.4 f_o	20 kHz-0.8 f_o
Minimum Insertion Loss	6 dB	2-3 dB	1-2 dB
Minimum Shape Factor	1.2	1.2	1.2
Minimum Transition Bandwidth	50 kHz	50 kHz	20 kHz
Sidelobe Rejection	45 dB	65 dB	70 dB
Ultimate Rejection	60 dB	80 dB	80 dB
Deviation from Linear Phase	$\pm$ 1.5°	$\pm$ 1.5°	$\pm$ 1.0°
Amplitude Ripple	0.5 dB	0.05 dB	0.05 dB
Triple-Transit Suppression	-40 dB	-50 dB	-50 dB

being the most pervasive application of this technology. A device consisting of two uniformly spaced, uniformly overlapped interdigital transducers is a bandpass filter. The center frequency is controlled by the periodicity of the electrodes and the bandwidth by the number of periods. Introducing amplitude and phase weighting on the impulse response of the filter makes possible a wide range of shape factors and side lobe levels.[11] As a bandpass filter this device is important since there is no competing filter technology for moderate fractional bandwidths at UHF. As a delay element in the feedback path of an amplifier, the device yields an oscillator which provides good stability but which can be used for FM up to several percent of the center frequency.[12]

Table I lists some of the important parameters for surface wave bandpass filters and illustrates the trend from practical devices through performance obtained in developmental devices to projected performance. With the current practical devices it is not possible to obtain the low insertion loss and low in-band ripple. Both can be obtained simultaneously with a multiphase transducer described below. The specifications for sidelobe suppression and ultimate rejection are conservative, since 65 dB sidelobes and greater than 80 dB ultimate rejection are routinely achieved for developmental devices.

Important New Components

The RAC is perhaps the most significant new matched filter for pulse compression.[7] It affords large time bandwidth products and good phase linearity for the price of increased fabrication complexity and/or cost. Current fabrication utilizes ion milling to form grooves for surface wave reflection. This is a time consuming process but results in good device performance.

A relatively new surface wave component is the UHF resonator.[13] This device is based on the creation of a surface wave reflection cavity using distributed reflectors and an interdigital transducer for the tap. The electrical performance (e.g. equivalent circuit) of this resonator is identical to that for bulk crystal resonators at lower frequencies. The fabrication depends only on photolithography for geometry control and is much better suited for higher frequency operation. This type of resonator has been shown to be single moded and to have lower spurs than the conventional bulk resonator. Advances in fabrication techniques are required to make this component practical.

A third advance in surface wave devices is the development of a unidirectional transducer[14] for low loss filters with good triple transit suppression. Development of suitable amplitude weighting techniques for this transducer will make nearly ideal surface wave bandpass filters possible.

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