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RECENT DEVELOPMENTS IN SAW DEVICE APPLICATIONS

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SUMMARY

This paper discusses recent developments in SAW applications by first reviewing the range of parameters achievable using current state-of-the-art devices. Examples of device applications in filtering, frequency sources and signal processing are then presented to provide an overview of how SAW devices are being utilized in various commercial and military electronic systems.

INTRODUCTION

Surface Acoustic Wave (SAW) devices are gaining popularity among system engineers as more and more realize their inherent advantages. To fully utilize the SAW technology, one needs to understand the capabilities as well as the limitations of current state-of-the-art devices. Examples of how SAW devices are being used in systems will serve as a guide to future applications by pointing out the various possibilities.

CURRENT CAPABILITIES

SAW devices have been configured into transversal filters, filter banks, delay lines, resonators, convolvers and dispersive filters. When combined with hybrid and integrated circuit technologies, they have been configured into oscillators, programmable tapped delay lines and filters, memory correlators and frequency synthesizers. Developments in recent years have greatly improved the performance of SAW devices. Some of these developments will be discussed in this section.

The SAW device discussed is not limited to the type utilizing the Rayleigh surface wave. Shallow Bulk Acoustic Wave (SBAW) devices which make use of horizontally polarized shear waves are considered part of theSAW device family. The addition of SBAW devices increases the range of achievable parameters of the SAW device by providing a wider choice of material properties, such as wave velocity and temperature coefficient of delay.

Bandpass Filters

The range of parameters achievable by SAW/SBAW filters is summarized in Table 1. In this table, the upper frequency range is listed at 5.2 GHz. The high operating frequency is a result of utilizing the SBAW which has a velocity 1.6 to 2 times higher than that of the Rayleigh surface wave.[1] Figure 1 shows a device response at this frequency.

Table 1. SAW/SBAW Bandpass Filter Capabilities

Frequency	10 MHz to 5.2 GHz
Bandwidth	0.05 to 67%
Insertion Loss	1.5 to 20 dB
Rejection	≥ 60 dB
Shape Factor	≥ 1.15 (40/3 dB)
Amplitude Ripple	< ± 0.05 dB
Phase Accuracy	± 0.5 deg rms

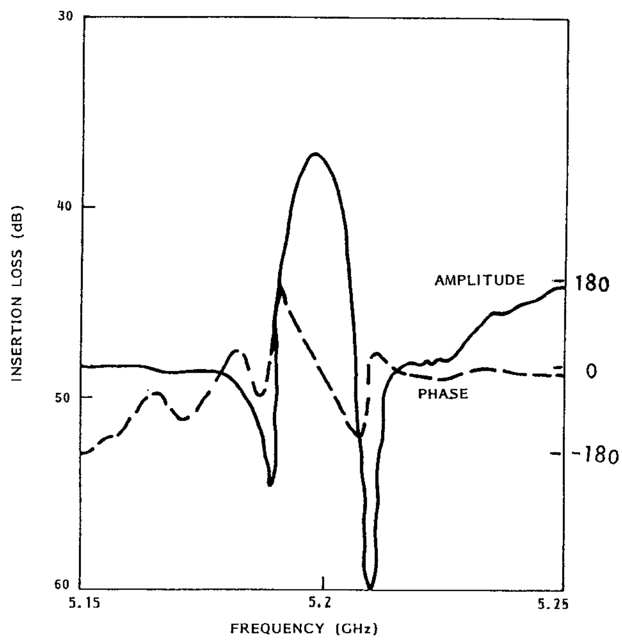

Figure 1. Frequency Response of a 5.2 GHz SBAW Delay Line

The insertion loss of SAW devices has also been significantly reduced in recent years. The various unidirectional transducer approaches have eliminated the need to increase the insertion loss of the device for better triple transit suppression. Filters with up to 19% fractional bandwidth and less than 2 dB loss have been demonstrated.[2]

Oscillators

SAW oscillators can be constructed using either SAW resonators or delay lines. The resonator approach achieves higher Q, while the delay line approach provides a wider tuning range. The current performance of SAW oscillators is summarized in Table 2. Significant recent improvements are in higher frequency of operation, better long-term aging and improved temperature stability.

Table 2. SAW/SBAW Oscillator Capabilities

Fundamental Frequency	20 MHz to 5.2 GHz
Oscillator Q	Up to 2500 for Delay Line. Oscillator, 30,000 for Resonator Oscillator
Mode Capability	Single Mode, Multiple Mode
Tunability	Up to 5%
FM Capability	Up to 1%
Output Power	10 dBm
Noise Floor	160 dBc
Frequency Stability	10^{-10} over 1 second
Aging Characteristics	1 ppm/year
Temperature Stability Over -40 to +70°C (Without Oven)	± 20 ppm

The aging characteristics are improved by carefully identifying the aging mechanisms and systematically eliminating them. Aging rates of < 1 ppm/year have been demonstrated.[3] Superior temperature stable cuts of quartz such as the SST cut and several doubly rotated cuts have also been identified. Recent experiments using a digital compensation technique have achieved < ± 3 ppm stability over a -10° to 100°C temperature range.[4]

Dispersive Filters

The current capabilities of SAW dispersive filters is summarized in Table 3. Wideband slanted transducers are now capable of 1 GHz bandwidth with moderate dispersive delay. For long dispersive delay, the reflective array compressor (RAC) device shown in Figure 2 is still the only practical approach. High quality fabrication yields RACs with phase errors less than ± 3°, and amplitude errors under ± 0.5 dB. Mounting and packaging techniques suitable for space are now being developed for RACs.

Table 3. SAW Dispersive Filters

Device Types	In-Line Chirp Transducers Slanted Chirp Transducers Reflective Dot Arrays Reflective Array Compressors
Bandwidth	5 to 1000 MHz
Dispersive Delays	0.1 to 90 μsec
Insertion Loss	20 to 40 dB
Time Bandwidth Product	Up to 16,000
Phase Accuracy	± 3 deg rms

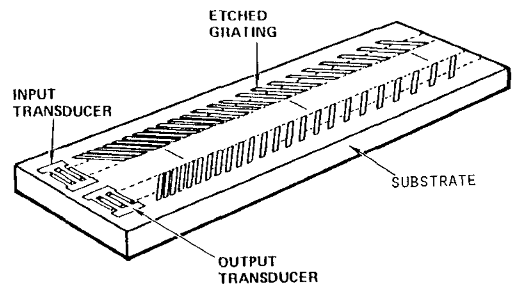

Figure 2. Configuration of RAC Device

SYSTEM APPLICATIONS

Judicious insertion of SAW technology into systems can greatly enhance performance, reduce size and complexity, lower cost, improve reproducibility, and increase reliability. This section discusses the advantages of SAW devices and gives examples of system applications.

Frequency Filtering

The advantages of SAW filters are compact size, light weight, high reliability, good reproducibility, and low cost in large volume. Currently they are used extensively in the IF Stage of telesystems.[5] Examples include TV, CATV, mobile telephones, satellite transponders and receivers. On the low cost and high volume end, TV filters are being produced at quantities of millions per year at a unit cost less of less than $2.00. These filters are capable of meeting complex phase and amplitude specifications. On the high reliability end, SAW filters have been manufactured to meet the most stringent military and space requirements. An example of this is the bandpass filter shown in Figure 3 which was developed for the Tracking and Data Relay Satellite (TDRS). Presently, even the most complex SAW devices such as the 6" RAC are being manufactured to meet space qualification standards.

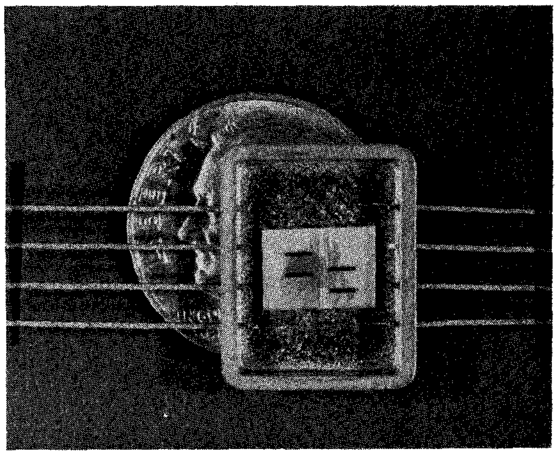

Figure 3. Space-Qualified SAW Bandpass Filter for TDRS

Frequency Source

The trend in modern telesystems is to operate at higher and higher frequencies. SAW oscillators with their high fundamental frequencies offer advantages of less multiplication and less spurious noise at a lower noise floor level. Recent advances in SAW oscillator aging have made them comparable to those of bulk crystals at much lower frequencies. Substitution of SAW oscillators for bulk crystal oscillators will greatly reduce size, complexity and power consumption of systems.

Examples of present and future application of SAW oscillators are local oscillators for TV receivers and mobile telephones,[6] microwave oscillators for the Army radiosonde which is part of the Army Field Artillery Meteorological Acquisition System (FAMAS), NAVSTAR Gps receivers,[7] and military radar[8] systems. Most of these have requirements which run up to tens of thousands of units.

Signal Processing

Compared to digital signal processors, SAW devices are somewhat limited in the range of functions available. However, in cases where SAW devices are applicable, they perform many analog signal processing functions efficiently. The dispersive ("chirp") filter, for example, has been used in radar systems for pulse expansion and compression. It is also one of the key components of the compressive receiver. When the phase information of incoming signals is retained and processed, this compressive receiver can be configured into a direction and frequency content of an incoming signal. The RAC (refelective array compressor) device is also now being used in multi-frequency shift keying (MFSK) demodulators and chirp Fourier transforms for spread spectrum communication systems.

CONCLUSIONS

As SAW technology matures, improved design and fabrication techniques will significantly reduce the design cycle and the cost associated with incorporating SAW devices into systems. The continued growth of SAW applications is therefore justified both technically and financially.

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