MICROWAVE ACOUSTIC DEVICES IN SYSTEMS

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SUMMARY

Advances in microwave acoustic technology and the attendant progress in device development have been steady for about the past two decades. Progress has been evident not only in the surface acoustic wave (SAW) area but in bulk acoustic wave (BAW) technology as well. This progress has resulted in higher frequencies of operation, more efficient and compact devices for more demanding systems applications. Examples of such devices and applications are described in this paper.

OVERVIEW

As indicated in Figure 1, the development of SAW filters and related devices such as delay lines and resonators began in the late 1960s.[1] Approximate milestone dates are shown for other important devices such as correlators,[2] dispersive delay lines,[3] and SAW integrated acousto-optics. The development of BAW technology is displayed over a comparable time period in Figure 2. Although quartz resonator technology has seen its first half century the development of VHF-UHF, microwave bulk mode plate resonators is relatively recent.[4] The application of the stress compensated (SC) cut quartz in the 5th and 7th overtones and the use of shallow bulk acoustic resonators[5] has extended the frequency of piezoelectric bulk mode devices to 1 GHz and above. The mid-1960s saw a thrust in R&D toward the realization of wideband microwave delay lines. A large part of this effort was devoted to thin film piezoelectric transducers and with this development cam high overtone bulk acoustic resonators, bulk mode acousto-optic devices, and monolithic (integrated) resonators. Figure 3 portrays in part why interest in BAW and SAW has been sustained.

Figure 3 compares the wavelength ranges of electromagnetic waves with BAW/SAW and MSW (magnetostatic waves). Acoustic waves are about fives orders of magnitude smaller than electromagnetic waves and this translates into device sizes and weights that are very attractive from the systems standpoint. Figure 4 shows an example of the size comparison for 100 nanosecond delay lines. Positioned diagonally across the figure is a coiled coaxial delay line encased in plastic. Between it and the scale at the bottom

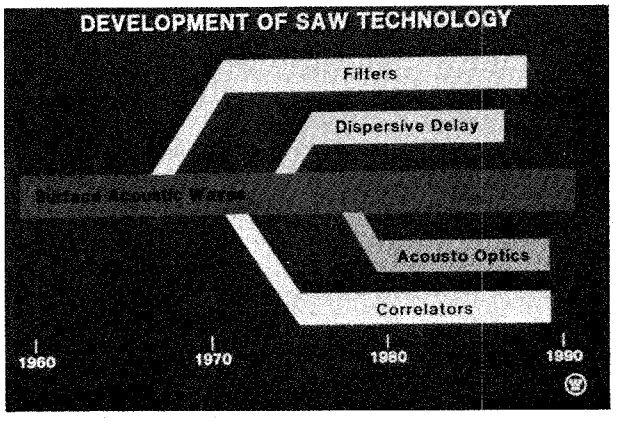

Figure 1. Surface Acoustic Wave technology development.

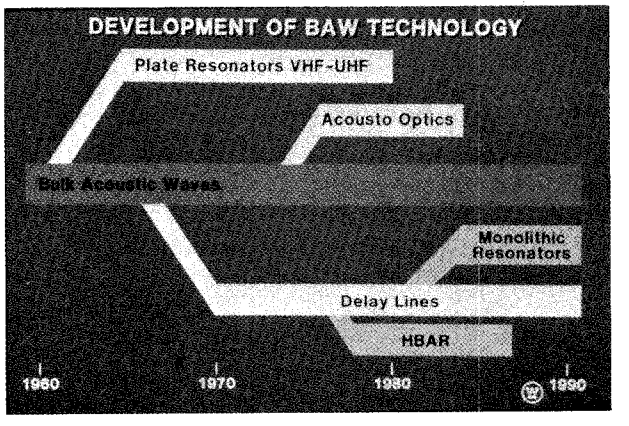

Figure 2. Bulk Acoustic Wave technology development.

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of the bottom of the photo is a packaged bulk mode acoustic delay line. The length of the body of the package is about one half of an inch. In addition to the obvious advantages of size and weight, the systems designer is given considerable flexibility in that more delay liens can be used with more freedom of placement in systems circuits.

SOME SYSTEMS APPLICATIONS

In the foregoing, the advantages of acoustic delay lines over coaxial lines was pointed out. In this section specific applications of such devices are emphasized together with other highlighted devices. These devices are arrayed in Figure 5 in associated with various systems functions. Beginning at the top left in the figure, a beveled substrate is used with precise transducer location to provide real time stepped delay for antenna beam steering.[6] In the systems montage these devices are found in the combiner which feeds the T/R modules. Real time microwave memory is provided by BAW delay for ECM applications while both BAW and SAW devices find application in electronic support measures (ESM).[7] Table 1 compares the properties available from each technology for these applications. As is shown, BAW technology offers the widest bandwidth at the present time.[8]

In addition to the higher frequency thrust in quartz crystal resonators other approaches are under investigation. Two such approaches are the film resonator (FBAR) with integration potential in both silicon and Gaas and the higher overtone bulk acoustic resonator (HBAR). The former show potential for fully integrated filter and frequency control functions.[9] The HBAR has been shown to provide direct microwave stabilization of oscillators without multiplication or other, more complex, means.[10] These devices provide loaded Q values in excess of 50,000 at 2 GHz.

CONCLUSIONS

As we have indicated, acoustic devices have enhanced system performance when used in first time designs. In addition, where the interface with existing systems remains cost-effective, acoustic devices have won acceptance by designers and users. More opportunities exist for these devices working at higher microwave frequencies and wider bandwidths.

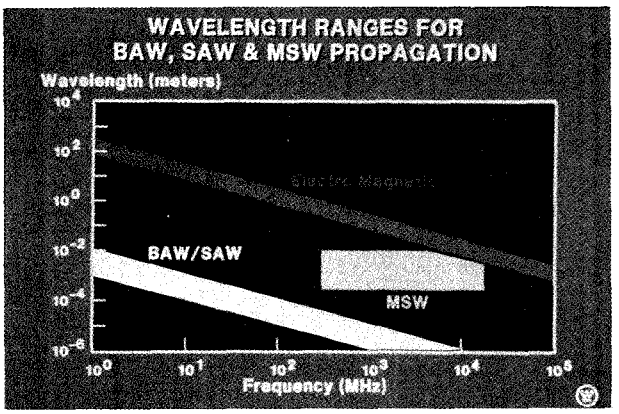

Figure 3. The wavelength of BAW and SAW is 10^{-5} that of electromagnetic waves. Magnetostatic waves (MSW) are shown for comparison.

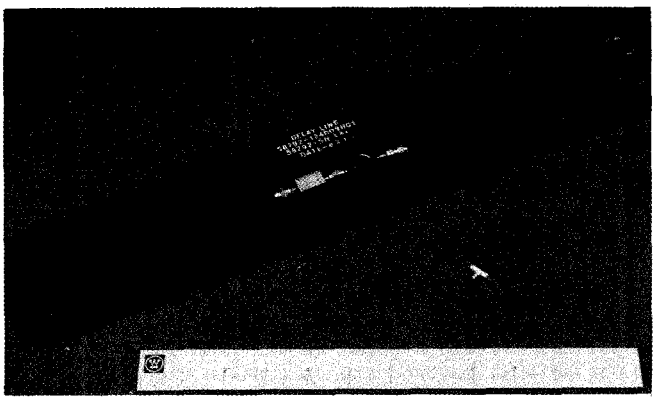

Figure 4. Electromagnetic (coaxial) delay line encased in plastic is compared in size to a packaged bulk mode acoustic line. The acoustic delay line is between the scale and coaxial line to the right in the photograph. The scale is 12 inches long.

COMPARISON OF DELAY LINE PROPERTIES

Technology	Frequency Range	Dispersive Delay	Constant Delay	Tappable	Tunable
SAW	10 MHz - 2 GHz	Yes 60% BW	Yes 60% BW	Yes	No
BAW	1 MHz - 20 GHz	No	Yes 75% BW	No	No
MSW	500 MHz - 20 GHz	Yes 1 GHz BW	Yes 500 MHz BW	Yes	Yes

Table 1. Delay line properties using surface acoustic waves (SAW), bulk acoustic waves (BAW), and magnetostatic waves (MSW).

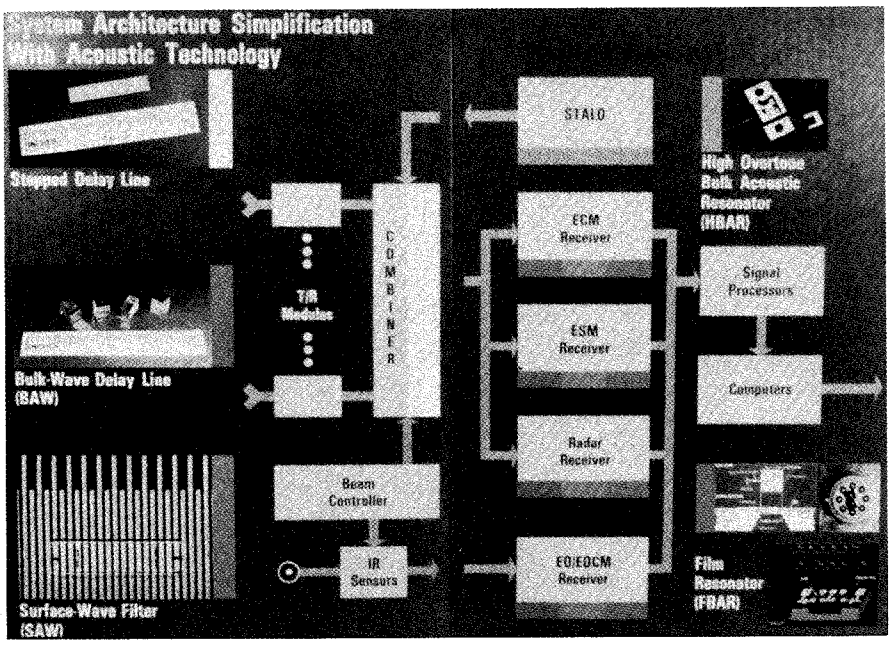

Figure 5. System applications of a number of microwave acoustic devices including delay lines, SAW filters, high overtone bulk acoustic resonator (HBAR), and the film (integrated) resonator.

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