

# This Week's Citation Classic

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**White R M.** Surface elastic waves. *Proc. IEEE* 58:1238-76, 1970. [Dept. Electrical Engineering and Computer Sciences, Univ. California, Berkeley, CA]

Surface wave characteristics of particular importance for electronic devices are discussed. These include propagation of different types of surface waves, transduction, amplification, and wave guiding, focusing, and reflection. Applications described include filters and coding devices, optical modulators, and the measurement of surface properties of solids. [The *SCI*<sup>®</sup> indicates that this paper has been cited in over 150 publications since 1970.]

Richard M. White  
Department of Electrical Engineering  
and Computer Sciences  
University of California  
Berkeley, CA 94720

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"The invitation was to write a ten-page tutorial review paper on the theory and application of surface acoustic waves (SAWs), for both the expert and the general highly trained reader. Written in an eight-month period, the paper turned out to be quite comprehensive, with 33 pages of text and 245 references. Its comprehensiveness probably contributed to its frequent citation.

"Writing it provided a satisfying opportunity to review the international literature in the field, and to describe some topics I'd studied since 1964. After concentrating on ultrasonics in graduate school and working in industry on microwave devices, I was then seeking tenure at Berkeley, and was attempting to observe SAW amplification in semiconducting cadmium sulfide. We tried photoetched glass transducer combs which only sometimes worked.

"Having just come from developing spatially periodic slow-wave circuits for traveling-wave tubes, it was clear to me that we could employ the piezoelectric effect of the CdS itself by using deposited spatially periodic electrodes. The interdigitated electrodes, connected to either an alternating voltage source or to a detector, should couple to surface waves provided the periodic distance was chosen to produce a cumulative interaction, that is, it should equal the wavelength of the surface wave.

"A first test with quartz was successful, and transducers of evaporated aluminum were then put on a polished CdS crystal, permitting us to observe SAW amplification. The interdigital transducer (IDT) was thus invented independently out of necessity here, but not, as it developed, for the first time. It had been described by Mortley<sup>1</sup> in an October 1965 paper in *Marconi Review* that I saw much later, and I believe that similar work was being carried out at Bell Telephone Laboratories.

"Exploration and application of SAW phenomena occurred rapidly. A plot of publications cited in the paper showed near exponential growth through 1969. It is possible to find SAW analogies for most distributed wave phenomena. For example, Huygens' principle, mode coupling, periodic transmission-line phenomena, and the Cherenkov effect, to mention just a few, all find use in inventing, understanding, explaining, and designing SAW devices. There is a one-to-one correspondence between structure and function in this subject that is appealing and that permits one to work with very simple ideas.

"During the period 1965-1970, we explored many SAW phenomena and devices, including resonant reflectors, focusing IDTs, wrap-around and regenerative delay lines, and thermoelastic SAW generation. Not everything worked. Coupling between adjacent quartz piezoelectrics failed because we needed lithium niobate, but it was too expensive. Viewing SAWs directly in the stroboscopic scanning-electron microscope failed because our sensitivity was too low. Through all this work, the graduate students did most of their own device fabrication—as they still do here—but with able assistance, particularly from Dot McDaniel.

"Fortunately, surface waves turned out to be useful, but we would have studied them anyway because they are inherently interesting.

"Reports of more recent work in the field can be found in a special issue of *IEEE Transactions* on microwave acoustic signal processing."<sup>2</sup>

1. **Mortley W S.** Pulse compression by dispersive gratings on crystal quartz. *Marconi Rev.* 28:273-90, 1965.
2. **Reeder T M,** ed. Special issue on microwave acoustic signal processing. Sponsored jointly by the Microwave Theory and Techniques Group and the Sonics and Ultrasonics Group of the IEEE. (Whole issue.) *IEEE Trans. Microwave Theory MTT-21*(4), 1973; *IEEE Trans. Sonics Ultrasonics SU-20*(2), 1973. 151 p.