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This Week's Citation Classic

Smith W R, Gerard H M, Collins J H, Reader T M & Shaw H J. Analysis of inter- digital surface wave transducers by use of an equivalent circuit model. *IEEE Trans. Microwave Theory* **MTT-17:** 856-864, 1969.

A three-port circuit model which rigorously describes transducers for ultrasonic volume wave was found to be useful for describing surface acoustic wave (SAW) interdigital transducers. Although not derived from exact equations of SAW transduction, the model yields simplified yet accurate analysis and design procedures. [The *SCI*® indicates that this paper was cited 151 times in the period 1960-1977.]

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"This paper was a portion of my Ph.D. dissertation at Stanford University. It was closely tied to the work of H. M. Gerard, who was concurrently preparing a Ph.D. dissertation on the fabrication and experimental characterization of surface acoustic wave (SAW) interdigital transducers. In contrast to much of the theoretical work for SAW transducers, the model given in this paper is *not* based on the exact equations for surface waves in piezoelectric crystals. Instead, it appeals to some analogous properties of bulk-wave transducers in order to use equivalent circuits that existed in the literature. The resultant lack of rigor appears to have been more than compensated by the simplicity and completeness with which the model characterizes SAW transducers. The authors and others citing the paper have subsequently generalized the method to analyze and design interdigital transducers which are essential elements in all of today's SAW devices

"The high citation frequency of the paper is undoubtedly due to the subsequent wide use of SAW devices in military and commercial electronic systems and to the foresight of co-authors J. H. Collins and H. J. Shaw who anticipated this and stimulated the paper's early emergence. Their awareness of the relevance of our work to contemporary military and commercial needs was enhanced in large measure by J. H. Collins's concurrent roles as Research Associate at Stanford and consultant to Autonetics (now Rockwell International) The timeliness and direct applicability of the work were also enhanced by our interaction with W. R. Jones of Hughes Aircraft Company. It was his data on piezoelectric materials for SAW generation that enabled us to be first in adapting the bulk-wave circuits for quantitative description of SAW transducers without the need for fitting free parameters.

"For three years prior to my interest in SAW transducers, I had been analyzing bulk-wave transducers built by other graduate students. Having a college course background in physics rather than electrical engineering, I was using a wave-equation approach and failed to appreciate the three-port equivalent circuits in the literature. Meanwhile, H. M. Gerard was developing facilities for fabricating and testing SAW transducers, and our research adviser, H. J Shaw, approached me with the need for a theoretical model for Gerard's transducers. His promise of its use in a dissertation and my first look at an interdigital transducer were all that was needed to dispel my skepticism about three-port networks and to elicit most of the essential results in about four months.

"Enthused over agreement between theory and experiment, we hastily submitted for publication a manuscript which I had originally intended as an internal memorandum. However, I subsequently found a clearer way to organize the results and with help with the writing style from co-author T. M. Reeder, found this first of my papers published shortly thereafter."