

# Design of SPUDT / RSPUDT Low-Loss SAW Filters

## Abstract

The lecture reviews modeling and design of low-loss surface acoustic wave (SAW) filters using Single Phase Unidirectional Transducers (SPUDT) and reflective SPUDTs (RSPUDT). In particular, the lecture considers SPUDT/RSPUDT models based on cascading elemental cells represented by mixed scattering matrices. Furthermore, SPUDT/RSPUDT properties and corresponding SAW filter design techniques are discussed.

## *SAW Transducer Unidirectivity*

First, the lecture introduces the mixed scattering matrix (P-matrix) of a lossless reciprocal SAW transducer. Then, it shows that the acoustoelectric conversion function depends on the short-circuit reflection coefficient of the transducer. In particular, maximum directivity at one acoustic port occurs when the reflection coefficient at the opposite acoustic port becomes zero. In the general case, the overall reflection coefficient includes both mechanical reflections caused by the mass-electrical load effect and electrically induced reflections. Furthermore, the lecture demonstrates that maximization of the global SAW transducer directivity requires a 45° phase shift between the transduction and reflection centers.

## *Basic SPUDT Types*

The lecture considers three basic SPUDT cell types:

- 1) DART (Distributed Acoustic Reflector Transducer),
- 2) EWC (Electrode Width Controlled) structure, and
- 3) DWSF (Different-Width Split-Finger, or Hanma–Hunsinger) structure.

Next, the lecture analyzes their properties and compares relative locations of the transduction and reflection centers for different SPUDT elemental cells.

## *RSPUDT Properties and Advantages*

Next, the lecture generalizes the SPUDT concept to reflective SPUDT (RSPUDT) transducers. In contrast to conventional SPUDTs with uniform elemental cells, RSPUDTs may comprise cells with non-zero or zero transduction (excitation) as well as positive (forward), negative (reverse), or zero reflectivity. Consequently, the additional degrees of freedom significantly improve flexibility of SAW filter design. Furthermore, the lecture demonstrates advantages of RSPUDT designs over conventional SPUDT filters with respect to electrical performance and die size.

### ***SPUDT/RSPUDT Modeling***

The lecture considers SPUDT/RSPUDT models for low-loss SAW filter design based on recurrent cascading of elemental cells. First, elemental cells of different types are subdivided into subcells containing one active (hot, or live) or passive (grounded) electrode with a specified reflection coefficient. Next, the lecture cascades the elemental subcells using conversion of mixed scattering matrices into transmission matrices. Finally, cascading of all elemental cells yields the overall mixed scattering matrix of the SPUDT/RSPUDT transducer.

### ***SPUDT/RSPUDT Synthesis Techniques***

Practical aspects of SPUDT/RSPUDT design based on bidirectional SAW transducer prototypes are discussed. In contrast to conventional bidirectional SAW filters, RSPUDT filters require simultaneous synthesis of both SAW excitation (transduction) and reflection functions. Consequently, SPUDT/RSPUDT synthesis becomes considerably more complicated than synthesis of classical bidirectional SAW filters comprising non-reflective transducers. For design simplification, the lecture considers a simplified SPUDT synthesis algorithm in which a weighted reflection function is defined through the transduction autocorrelation function.

### ***RSPUDT SAW Filter Optimization***

The lecture discusses optimal synthesis of RSPUDT filters using Chebyshev approximation. Due to the complex nature of the transduction and reflection functions, the optimization problem is inherently highly nonlinear. Consequently, solving it requires advanced nonlinear programming techniques, which are both time- and memory-consuming. To reduce the number of optimization variables and, hence, the overall computation time, sampling and interpolation schemes are applied to the transduction and reflection functions.

### ***Examples of SPUDT/RSPUDT SAW Filter Designs***

The lecture illustrates SPUDT/RSPUDT design using a CDMA SAW filter with a center frequency of  $f_0=85.38$  MHz. Both a classical SPUDT design based on the autocorrelation technique and an optimized RSPUDT design are presented and compared. When properly matched, both filters provide effective triple-transit echo suppression and low insertion loss. However, the CDMA SPUDT filter requires a relatively long SMD package ( $19 \times 5$  mm), whereas the RSPUDT design provides improved electrical performance and a significantly smaller die size ( $13.3 \times 6$  mm).

Finally, good agreement between simulated and measured filter characteristics is observed.

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