

Simulation of Multiport/Multitransducer SAW Devices

Abstract

This lecture considers modeling and simulation of complex multiport/multitransducer surface acoustic wave (SAW) devices. In particular, a SAW system under analysis may have an arbitrary number of electrical and acoustic ports and may contain any number of interdigital transducers (IDTs) or other SAW components. Two systematic simulation approaches are considered:

- 1) global mixed scattering matrix
- 2) recurrent cascading of the mixed (hybrid) transmission matrices.

Modeling Assumptions and Simplifications

For simplicity, a SAW device is assumed to consist of an arbitrary number of IDTs and reflective gratings (reflectors). All SAW components may operate in acoustically and/or electrically coupled or isolated configurations. The method combines IDTs with adjacent reflectors into unidirectional reflector-transducer pairs (generalized IDTs). Each generalized IDT is described by its mixed scattering matrix. Gaps between SAW components are modeled by shifting phase reference planes. Reflectors are treated as a special case of a generalized IDT with short-circuit electrical termination. As a result, the analysis reduces to a system of N generalized IDTs.

Global Mixed Matrix Method

The lecture first discusses advantages and drawbacks of the global mixed matrix approach. It uses an interconnection matrix to eliminate coupled acoustical ports from the system of equations. In many practical cases, this enables closed-form matrix equations for multicomponent SAW systems. However, the method is computationally intensive, since it requires construction of a large global matrix and repeated matrix inversions at each frequency.

Cascading of Transmission Matrices

Alternatively, the lecture considers the component cascading approach. It is based on mixed (hybrid) wave transmission matrices, which relate incident and reflected acoustic waves as well as electrical currents and voltages. For cascading, an auxiliary electrical port is introduced. This approach is well suited for MATLAB® implementation and does not require matrix inversions. However, recurrent computations may lead to numerical instabilities when compared with the global matrix method.

Isolated SAW System

In the case of an isolated SAW system (without external incident waves), the overall mixed scattering matrix reduces to the electrical nodal admittance matrix. Standard nodal network analysis can then be applied.

Comparison of Both Methods

Both simulation approaches are general and accurate. In a SAW system, they fully account for multipath acoustic propagation and interactions. Furthermore, both methods separate device modeling and system-level simulation. In practice, generalized SAW components are first modeled and then combined either via an interconnection matrix or by cascading. This provides strong modularity, since only component models need to be updated.

Closed-Form Solution for Three Generalized SAW Transducers

For tutorial and practical purposes, the lecture derives closed-form matrix equations for three in-line generalized SAW transducers. The results are method-independent. These equations are general and include many practical SAW devices, such as classical SAW filters, one- and two-port resonators, and Double Mode SAW (DMS) filters.

Conclusion

In summary, either of these two approaches can be effectively applied to modeling low-loss SAW filters for mobile communications. The former approach is more suitable for closed-form analysis of the complex SAW devices. The latter approach is more computer-oriented. It is convenient for programming and computer simulation.

Finally, both approaches are illustrated by the design and modeling examples and with a live computer demonstration.

Contents

1. Introduction
2. Analysis problem for multicomponent SAW system
3. Global mixed scattering matrix method
 - 3.1 Electrical and acoustical variables on the ports
 - 3.2 Mixed (electro-acoustic) scattering matrices
 - 3.3 Coupled and uncoupled acoustical ports
 - 3.4 Interconnection matrix
 - 3.5 Closed-form block-matrix solution of the analysis problem
4. Hybrid transmission matrix approach
 - 4.1 Elemental cells and generalized SAW transducers
 - 4.2 Recurrent cascading algorithm
 - 4.3 Multiport SAW system loaded by acoustic two-port junctions
5. Design examples and analysis results
 - 5.1 One-port SAW resonator
 - 5.2 Two-port SAW resonator
 - 5.3 Double Mode SAW (DMS) filter
6. Conclusions