Mixed Scattering Matrix for SAW Devices: Properties and Applications

Abstract

TThe lecture provides a comprehensive overview of mixed scattering matrix (or P-matrix) theory and its applications to SAW devices. First, the lecture discusses properties and interrelation of the admittance, wave scattering, and mixed scattering matrices of an arbitrary acoustoelectric multiport network. In a particular case, a surface acoustic wave (SAW) interdigital transducer (IDT) is analyzed as a three-port device with two acoustical ports and one electrical port.

Admittance, Scattering, and Mixed Scattering Matrices

By definition, mixed scattering matrix **M** is a hybrid matrix combining properties of the scattering matrix **S** and admittance matrix **Y**. Based on the relationship between acoustic and electric variables, the lecture derives conversion equations between admittance, scattering, and mixed scattering matrices. Furthermore, matrix constraints imposed by reciprocity and power conservation are discussed. For a reciprocal and lossless SAW transducer, matrix elements satisfy a self-consistent system of equations accounting for reciprocity and power conservation.

SAW Transducer Modeling Using Mixed Scattering Matrix

Next, the general equations are applied to SAW transducer modeling. An unapodized SAW transducer is treated as a reciprocal and lossless three-port acoustoelectric network. Mixed scattering matrix is generalized to the case of apodized (aperture-weighted) SAW transducers by the closed-form integration of the unapodized elemental channel over the acoustic aperture. The lecture explains physical meaning of the mixed scattering matrix blocks and their elements. In addition, the number of independent P-matrix elements is determined.

Mixed Scattering and Transmissison Matrices

The lecture also derives conversion equations between mixed scattering matrix **M**, mixed transmission matrix **T**, and wave scattering matrix **S**. Mixed transmission matrix **T** interrelates acoustic waves at the input and output acoustical ports together with terminal current and voltage at the electrical port. Therefore, transmission matrices are very useful for cascading SAW components in multicomponent SAW device analysis.

SAW Transducer Quasi-Static Approximation

In the quasi-static approximation, a short-circuit SAW transducer is assumed to be non-reflective. In practice, this approximation is valid if the central frequency f0 of a SAW transducer is sufficiently far from the synchronous frequency fs = v/2p, where v is the effective SAW velocity and p is the transducer period (pitch). Consequently, this assumption significantly simplifies SAW filter modeling. With negligible interelectrode reflections, the mixed scattering matrix reduces to its simplest form for SAW transducer modeling. Conversion between scattering and transmission matrices in the quasi-static approximation completes consideration.

The lecture material is illustrated by the design and modeling examples and with a live computer demonstration using the author's MATLAB SAW Filter Analysis Toolbox (SAWFAT).

Contents

Web version: *https://intrasaw.com/if-saw-filter-design*