

IF SAW Filter Design: Theory, Modeling, Optimization

Abstract

The lecture presents an overview of IF SAW filter design and explains how to achieve accurate and optimal synthesis of state-of-the-art IF filters. It focuses on the basic properties of linear- and nonlinear-phase bidirectional periodic SAW transducers with a constant period (pitch) and constant metallization ratio (duty factor). For simplification, the quasi-static approximation is applied, assuming negligible interelectrode reflections.

Element and Array Factors

The SAW transducer frequency response is represented as the product of the array factor and the element factor. The array factor shapes the bandpass response, whereas the element factor is a wideband frequency-dependent function that distorts the ideal response. The element factor inherently accounts for the dependence on the metallization ratio and describes SAW transducer harmonic behavior. SAW transducers are classified according to symmetry type, sampling rate in time and frequency domains, and the even or odd number of electrodes. Their magnitude and phase symmetry properties are also analyzed.

Overlap- and Finger-Weighting

The lecture explains in details the difference between overlap- and finger-length weighted (apodized) SAW transducers and compares their advantages and limitations. It also provides practical recommendations for their correct application in SAW filter design. For each weighting method, the element factor and array factor functions are analyzed and compared. The element factor introduces passband distortion (slant), especially for wideband SAW filters. However, in most practical cases, this distortion is negligible. Therefore, the quasi-static model can be approximated with good accuracy by the impulse model, where the frequency response and transducer tap weights are directly related via the Fourier transform. As a result, the response can often be approximated by the array factor alone, which behaves as a trigonometric polynomial.

Ideal Frequency Response (Impulse Model)

The lecture further considers the properties and limitations of the impulse model for both linear- and nonlinear-phase SAW transducers. It shows that the array factor can be represented equivalently in the frequency, time, or Z-transform domains. The interrelation between these representations is discussed. The analysis in time and frequency domains is based on trigonometric basis functions. Contrary to this, the Z-transform analysis requires

searching Z-transform roots of the high-order polynomial. Z-transform roots (zeros) are classified according to their magnitude and phase characteristics. Their partial contributions to the overall SAW filter response are disclosed and explained.

Reduction of the Optimized Parameters

Finally, the lecture analyzes passband and stopband properties of the Z-transform roots and proposes methods to reduce the number of parameters required to describe the frequency response without sacrificing accuracy. Consequently, the optimization time for synthesizing the esired response can be significantly reduced.

The lecture material is illustrated with SAW filter design and modelling examples, as well as a live demonstration using the the author's proprietary SAW design [MATLAB®](#) software.

Contents

1. Introduction
2. Frequency response of a periodic SAW transducer
3. Basic properties and classification of SAW transducers
 - 3.1 Synchronous and asynchronous SAW transducers
 - 3.2 Overlap- and finger-length weighted transducers
 - 3.3 Array and element factors and their properties
4. Impulse model and discrete Fourier transform
 - 4.1 Frequency sampling interpolation and properties of the basis functions
 - 4.2 Time domain interpolation
5. SAW filter frequency response optimization
 - 5.1 Reduction of the optimized parameters in the time domain: baseband and bandpass responses
 - 5.2 Reduction of the optimized parameters in the frequency domain: over- and under-sampling and their applications
6. Frequency transformations of the SAW filter response (frequency scaling and shifting)
7. Z-transform of the SAW filter frequency response and its properties
 - 7.1 Interrelation between Z-transform and SAW filter response
 - 7.2 Classification of the Z-transform roots
 - 7.3 SAW filter synthesis using Z-transform root separation technique
8. Conclusions

Web version: [IF SAW Filter Design](#)