

# Factorizational Synthesis of SAW Bandpass Filters

## Abstract

In the lecture, factorizational synthesis of surface acoustic wave (SAW) filters is considered. This is a non-standard design technique for SAW filters with prescribed magnitude and linear-phase (LP), nonlinear-phase (NLP), or minimum-phase (MP) characteristics. It is based on factorizing (splitting) the overall SAW filter frequency response into two partial responses attributed to the input and output apodized interdigital transducers (IDT), respectively. The core of the design procedure is searching roots (zeros) of the Z-transform using the roots solving program (root solver) for high-order polynomials.

Properties of Z-transform roots are discussed. Furthermore, the roots are classified with regard to their symmetry, invertibility and phase. They can be grouped according to their location with respect to the unit circle. These groups contain a single zero (monozero) on the real axis, two mirror zeros (bizero) on or off the unit circle and four inverse and mirror zeros (quadroplet, or quadrozero) off the unit circle. Passband and stopband magnitude and phase responses of each group and their contributions to the SAW filter response are analyzed.

## Linear- and Nonlinear-Phase SAW Filter Synthesis

Several roots separation schemes and algorithms are discussed. For LP design, both IDTs may have identical NLP responses, which cancel each other due to complex conjugation in the overall SAW filter response. This phase cancellation ensures the LP SAW filter response within the entire frequency range.

For narrowband SAW filters, apodized LP or NLP IDTs can be approximated by withdrawal-weighting (or polarity-weighting). This allows to convert dual-track SAW filter topology with multistrip coupler (MSC) into conventional single track (in-line) one. Given the design specifications, the algorithm results in the minimum length SAW filters which are typically 20- 30 % shorter if compared to the conventional designs techniques (for example, with two identical apodized IDTs).

## Minimum-Phase and Quasi-Minimum-Phase SAW Filters

The algorithm can be adopted to design optimum (or suboptimum) MP SAW filters from the LP prototype. The only additional step is inversion of the outside Z-transform roots inside the unit circle. Such a MP design minimizes SAW filter time delay if compared to the LP SAW filter that could be useful in some applications.

The length of MP SAW filters may be further reduced by applying more sophisticated optimum design procedures providing “minimum-minimum” length SAW filters for prescribed magnitude shape specifications. Two different MP synthesis algorithms based on the LP prototype are considered which are similar to the MP design of non-recursive finite impulse response (FIR)

digital filters. A general principle is moving LP prototype stopband roots off the unit circle. The first method is known in digital filtering as [Hermann-Shuessler](#) procedure, where the optimum equiripple LP response is offset in such a way that stopband zero pairs merge into the double zeros. Alternatively, a direct optimal synthesis of the positive real-valued LP prototype can be applied. In both methods, the desired MP response is a square root of this LP prototype response.

MP SAW filters may be useful in applications where non-dispersion requirements are not too severe and, hence, a slightly non-linear phase response is still acceptable. A reasonable compromise between LP and MP SAW filter designs may be attained in quasi-MP filters which contain a small portion of zeros outside the unit circle, whereas the most zeros are located inside the unit circle. The proportion between internal and external Z-transform roots takes control on deviation from the LP towards the MP property.

The lecture presents design examples of the LP, MP and quasi-MP SAW filters.

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