Factorizational Synthesis of SAW Bandpass Filters

Abstract

Design technique of surface acoustic wave (SAW) filters with prescribed magnitude and linear-, nonlinear-, or minimum-phase characteristics by factorizing (splitting) the overall SAW filter frequency response into two partial responses is considered. The key point of the design procedure is the roots search of the Z-transform using the roots solving program (root solver) for high-order polynomials. Separate responses of the input and output SAW interdigital transducers (IDT) are found by sharing the Z-transform roots in the systematic manner between input and output SAW transducers resulting in their apodized patterns, in general case.

Several roots separation algorithms are considered. For linear-phase design, both transducers may have identical non-linear phase responses which cancel each other in the overall SAW filter response due to complex-conjugation. The mutual phase cancellation results in the linear-phase overall SAW filter response within the entire frequency range. For narrowband SAW filters, apodized non-linear phase SAW transducers can be approximated by withdrawal-weighted (polarity-weighted) SAW transducers. Given the desired specifications, the algorithm results in the minimum length SAW filters which are usually 20-30 % shorter if compared to the commonly-used designs with two identical apodized IDTs. It is shown how the algorithm can be adopted to design suboptimum and optimum minimum-phase SAW filters from the linear-phase prototype. To design suboptimum minimum-phase SAW filters, the only additional step is inversion of the outside Z-transform roots inside the unit circle. Such a minimum-phase design minimizes the filter time delay that could be useful in some applications. However, the SAW filter doesn't have the minimum length.

The length of minimum-phase SAW filters may be further reduced by applying more sophisticated optimum design procedures which leads to the "minimum-minimorum" length SAW filters within prescribed magnitude shape specifications. Two different minimum-phase design algorithms based on the linear-phase prototype are considered which are similar to the minimum-phase design of the non-recursive digital filters with the finite length response. The general principle is to move prototype stopband Z-transform roots off the unit circle in the overall linear-phase SAW filter response. The first procedure is the known in the digital

filtering Hermann-Shuessler procedure, another is direct synthesis of the positive-valued prototype, with the desired minimum-phase response being a square root of this prototype response.

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

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