ABSTRACT

Key Words : *SAW, IDT, transducer, surface acoustic wave filters, apodization, overlap, window functions FIR algorithms, eigen functions, DFT, FFT, Fourier transform non-iterative design, Hermitian conjugate, non-symmetric transfer functions, aliasing, sampling, non-dispersive, impulse duration, shape factor, sidelobe, mainlobe, even and odd series, orthogonal functions, cosine series, velocity errors, diffraction, harmonic response, metallization, crystal cutting angle, propagation angle, etching ratio.*

Surface acoustic wave (SAW) devices are a unique class of microelectronic components operating in VHF/UHF bands and have remained unchallenged, since their inception in 1965 [1], by CMOS or any other aggressive technology. However, the advancement of lithographic techniques in VLSI technology has broadened the frequency range of SAW devices from RF to microwave frequencies [2]. Out of the large variety of SAW devices, bandpass filters are the most popular for signal processing applications in a wide range of electronic systems [3,4]. The key attraction of SAW filters is the technique of apodization [5] of interdigital transducers (IDTs) for shaping frequency response curves. It is possible to synthesize any arbitrary bandpass response shape, symmetric or non-symmetric/dispersive or non-dispersive, by iterative computer-aided design methods based

on FIR techniques. Such designs are expensive and usually consume lots of computer space and time. Non-iterative design methods, on the other hand, are computationally fast and inexpensive and can be modified analytically to suit particular applications. The latter is still quite popular among SAW designers. The present author has investigated some non-iterative design methods based on "eigen" functions [4,5] and studied the effects of frequency aliasing and velocity errors on SAW filters. Experimental verifications have also been performed in most of the cases.

Narrowband SAW filters which find extensive applications in IF stages of various communication sets like TDMA, CDMA, VSAT, microwave radio, etc., need optimized chip size in order to reduce filter cost. A new design approach is described in the thesis using the eigen functions proposed by Vasile [24] which gives optimized impulse duration. The earlier method [24] required a minimum of three eigen functions to obtain a flat passband. However, the new approach described in the thesis uses only two eigen functions, resulting in shorter impulse durations compared to the method proposed by Vasile. A figure of merit has been proposed to compare the various design approaches. The new approach has a better figure of merit. Experimental verifications of this new approach was done by fabricating a 45MHz SAW filter with 700KHz bandwidth using two eigen functions. The measured and theoretical responses matched quite well.

With the boom in the wireless industry all over the world, the components going into the wireless sets are also experiencing the exponential growth in the market. SAW filters are one of such components experiencing the high growth. The trend in the wireless sets is towards miniaturization. Thus the SAW filters used in the wireless sets need to be miniaturized in order to be competitive. The thesis has dealt with various non-iterative design methods using several eigen functions [30] tailored to the specific requirements. The main emphasis has been made on avoiding "over-design". A new approach to design using eigen functions in which the positive and negative sidelobes of the two eigen functions overlap resulting in the minimized sidelobe levels, has been presented. Further reduction in sidelobes is achieved by placing the nulls of output transfer function on the maxima of the sidelobes.

Extending the design approach followed earlier based on two eigen functions, several design options with various eigen functions as described by Malocha and Bishop [30] have been proposed. The design options are given in a table and frequency response plots are generated. The parameters chosen are impulse duration, sidelobe level and shape factor. A prototype SAW filter based on this approach is fabricated. The measured frequency response agrees well with the theoretical plot.

The need for more efficient eigen functions for SAW filter design is much more relevant than earlier, as SAW filters have established themselves as the key components in RF signal processing. This has led the author to investigate the SAW filter design, using the cosine even or odd series functions proposed by Malocha and Bishop [30] with modified value of coefficients to reduce the sidelobe levels. A general orthogonal set of eigen functions has been proposed for even and odd series. The coefficients of these functions have been determined by minimizing the first (N-1) sidelobes (N=Number of terms in the eigen function). A new condition, for determination of coefficients uniquely, is presented. Plots of these new eigen functions are given along with a simulated plot of a sample SAW filter.

Some investigations on non-symmetric SAW filters were also done using eigen functions. In the first case, the non-symmetric transfer function is sampled at $2f_o$ (f_o is the centre frequency), like a conventional SAW filter sampling. However, the reconstructed frequency response became symmetric. This phenomenon, which is called frequency aliasing, results when a signal is sampled at less than $2f_s$, where f_s is the maximum frequency of the signal. In the second case, the sampling rate was increased to $4f_o$ which is higher than $2f_s$. The reconstructed response retained the non-symmetric shape. Two prototype SAW filters representing the two cases were fabricated on 128° rotated Y-cut, X propagating lithium niobate substrate. The experiments confirm the universal applicability of Shannon's sampling theorem.

While designing SAW filters on a certain substrate material, the surface wave velocity of the material is a critical parameter which has to be accurately estimated. However, several parameters [118-126] affect SAW velocity. Thus, accurate estimation is not always possible which results in velocity errors [118]. The effect of velocity errors on the frequency response of SAW filters has been investigated in the thesis. A detailed analysis shows that the velocity errors cause centre frequency shift and bandwidth variation for the apodized and the unapodized transducers. An experiment was conducted by fabricating a prototype SAW filter at 36MHz to confirm the validity of the above analysis. The simulated response and the measured response were found to be in good agreement.