ABSTRACT

The objective of this thesis is to develop new, pipelined architectures for realizing a class of adaptive equalizers with high throughput capability. Several approaches are considered to meet this goal, the first one being that of systolization. In particular this thesis takes up the issue of deriving an appropriate systolic array architecture for the adaptive decision feedback equalizer (ADFE). For this a symbol manipulation technique proposed earlier under the name "Systolic array design algebra" is considered. This involves developing first a "symbolic state space model" for the given architecture using its node variables and then applying certain transformation to this model enforcing systolic constraints. The ADFE architecture that is obtained by this process meets all systolic requirements and can be realized using processing cells that are simple and easy to realize. To avoid fanout the system needs to use a clock of speed twice that of input but this can in turn be used to reduce hardware complexity by about fifty percent.

The proposed systolic ADFE, like most of the available pipelined adaptive equalizers is, however, constrained to adopt the delayed LMS (DLMS) algorithm for coefficient adaptation that has slower convergence characteristics as compared to the LMS algorithm. The need for the DLMS algorithm comes from the presence of a latency at the output that causes the current output error to correspond to a past input. In order to overcome this shortcoming we next consider the problem of pipelining an ADFE with zero latency. An architecture is proposed in this respect that consists of a pipelined array of certain modules with the final output available at the first module itself. This makes the architecture free from latency and consequent requirement of DLMS based adaptation.

In our next treatment we concentrate on CORDIC based realization of the transversal adaptive equalizer. For this an alternative formulation of the LMS algorithm is proposed using a set of trigonometric and also hyperbolic angle variables which are monotonically related to the equalizer coefficients. The algorithm updates the angles directly instead of the equalizer coefficients and readily maps to a CORDIC array, with each CORDIC unit performing certain trigonometric/hyperbolic rotations to realize both the filtering and weight updating operation for each coefficient. The proposed architecture is more efficient in terms of hardware and thus power as compared to conventional one, as it replaces about fifty percent of the multipliers by CORDIC units. Further optimization is also possible by considering the sign versions of the proposed algorithm which eliminates the multipliers completely. Several high speed variants of these architectures are then developed using microlevel pipelining technique.

Since in many practical modulation techniques such as QPSK, QAM etc., the data set effectively becomes complex valued in nature, attempt is made here to map the complex LMS algorithm into suitable CORDIC based architectures. A reformulation of the complex LMS algorithm is carried out by expressing the complex tap weights in terms of their respective modulus and argument instead of the conventional real and imaginary components. Based on that, several pipelined architectures for complex domain equalizer optimized for different objective functions are developed by efficient utilization of pipelined CORDIC units for both the filtering and the updating operations.

Though the LMS algorithm is quite popular due to its simplicity, its convergence property worsens for data set with large eigenvalue spread. However, the same can be reduced by performing prefiltering in some orthogonal transform domain. Amongst various transforms, Karhunen-Loeve transform (KLT) is the optimal one because it decorrelates the data completely and it is also very much useful to be used for equalization since its basis vectors are data dependent and thus adaptable to quasi stationary input which is typically present in a mobile communication environment particularly with handoffs. An attempt is made here to develop a KLT based pipelined adaptive equalizer suitable for real time applications, which has traditionally been considered to be unmanageable computationally, by exploiting the enormous resource offered by present day VLSI technology. The parallel *Jacobi* method is employed for solving the eigensystem which is the computation intensive part in KLT and it is implemented with the help of CORDIC like structures by properly exploiting the parallelism inherent in the algorithm. The resultant architecture has got a very short critical path of only a single adder and thus can provide the high throughput that is demanded in real time applications.

Keywords : *Adaptive equalizer, Systolic array, Adaptive decision feedback equalizer, Pipelined architecture, zero latency, CORDIC, Trigonometric LMS, Hyperbolic LMS, Complex LMS, Parallel Jacobi method, Karhunen Loeve transform.*