COUPLYING FAST WALSH TRANSFORM WITH WAVEFORM RELAXATION TECHNIQUE TO ANALYZE LOSSY COUPLED TRANSMISSION LINES

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Abstract— A new approach, based on the waveform relaxation technique and fast Walsh transform, is first presented for the analysis of lossy coupled transmission lines (LCTL) with arbitrary terminal networks. The simulation accuracy of the new method can be greatly improved, the disadvantage which always exists in previous methods [1]-[8] can be avoided and a considerable saving in time and memory of CPU is obtained.

INTRODUCTION

The recent advance of GaAs MESFET and HEMT technology has reduced the single device switching time to tens of picoseconds or less. The interconnection lines which once considered as insignificant stray elements now have an important impact on overall system performance. Accurate simulate of lossy coupled transmission lines is becoming more and more important in the design of high speed digital IC's.

In the past few years, many methods, such as Djordjevic [1], Ghione et al [2], Passlack et al [3], Schutt-Aine et al [4] [5], H.Grabinski [6], Chang [7] and You [8], have been developed to analyze the time-domain response of LCTL. In all of these methods, FFT or numerical inversion of the Laplace transfcrm (ILT) must be used in order to obtain the time response from frequency domain to time domain. The accuracy of the methods depends critically on the transform accuracy of the reconstruction approximation of the complex response. Obviously, the FFT or ILT's capability of reconstruction of the response waveform has some limit, especially for the rectangular pluse imput, and some unavoidable errors always exist.

In this paper, a new method, based on the fast Walsh transform, is first presented for the analysis of LCTL with arbitrary terminations. The accuracy of the approach can be greatly improved and the disadvantage which always exists in previous methods [1]- [8] can be avoided.

THEORY

I. Fast Walsh Transform

IF2

Walsh functions form a complete orthogonal set of rectangular waveforms taking only two amplitude values +1 and -1. It is defined as WAL(n,t), where t is a time period and n is an ordering number. For a time series f(t), it can be expressed in terms of the sum of a series of Walsh function, viz.

$$f(t) = a_0 WAL(0,t) + \sum_{n=1}^{N-1} a_n WAL(n,t)$$

$$f(t) = a_0 WAL(0,t) + \sum_{n=1}^{N-1} a_n WAL(n,t)$$

$$\frac{a_0}{2} = \frac{1}{T}\int_0^T f(t)WAL(0,t)dt$$

$$a_n = \frac{1}{T}\int_0^T f(t)WAL(n,t)dt$$

The advantage of reconstructions of a complex waveform from Walsh rather than Fourier has been described by Siemens [9]. It may be noted that since the sine and cosine function of FFT can not be represented exactly by a finite of bits, then a source of truncation error is introduced. The fast Walsh transform, on the other hand, involves only addition and subtraction and precise respresentation is possible, so that the transform itself has not errors.

The typical example is shown in Fig.1, the diagram shows the effect of transformation, thresholding and reconstruction for a rectangular waveform. This matches the form of the Walsh function and results in efficient reconstruction for considerably less than Fourier terms.

It is also mentioned that a considerable saving in time and memory of CPU can be obtained by using fast Walsh transform (FWT) rather than FFT, because the multiplication or diviation operation in FFT is replaced by the add or subtraction operation in FWT and the complex number operation in FFT is replaced by the real number operation in FWT. Some comparative figures are given in table I, where the data series is 1024 samples.

II.The Time Response Calculated by Coupling Fast Walsh transform with Waveform Relaxation Technique

The waveform relaxation method is a technique for solving systems of ordinary differential equations by iteration and system decomposition. It is successfully applied to analyze LCTL by Chang [7].

In our work, we apply the congruence transform technique for n- conductor system to obtain decoupled lossy transmission lines interconnection with congruence transformers, and couple fast Walsh transform and waveform relaxation technique to form a new algorithm. The main procedure is similar to Chang's [7] except the replace of FFT by fast Walsh transform and the replace of congruence transformer by Tepolitz matrix [15].

RESULTS

To illustrated the efficient of the new method, consider the circuit of Fig.2, the example is from [1]. Fig.3 shows the comparison of our result with that of using Chang's method [7].

The test result shows that the new method can greatly improve the analysis accuracy for the rectangular pluse imput, because it matches the form of the Walsh function, meanwhile, the CPU time and memory has been saved by using fast Walsh transform.

CONCLUSION

In this paper, we first present a new approach to analyze lossy coupled transmission lines with arbitrary terminations. It can greatly improve the analysis accuracy and save the time and memory of CPU.

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Table I: Some Comparative Figures

Transform	Times (s)	Storage
Fourier	9.48	4 K
Laplace(M=11)	7.50	3 K
Walsh	2.20	2 K

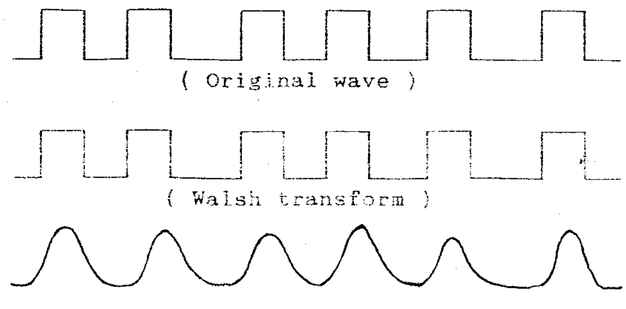

Fig.1 The Typical Example of the transformation effect

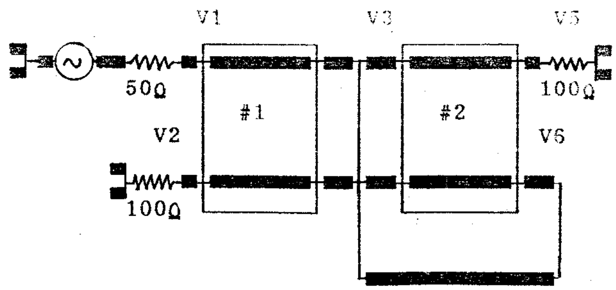

Fig.2 The Simulation Circuit (from [1])

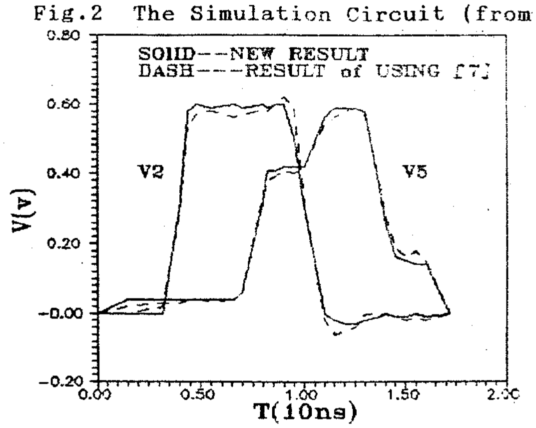

Fig.3 The Comparison of our Result With that using Chang'method [7]