A COMBINATION OF FD-TD AND PRONY'S METHODS FOR ANALYZING MICROWAVE INTEGRATED CIRCUITS

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ABSTRACT

It is demonstrated in this paper that in applying the FD-TD technique to analyze microwave integrated circuits, the long FD-TD time record required for generating accurate frequency domain scattering parameters can be extrapolated from a relatively short FD-TD time record by using Prony's method. As shown by comparison with the direct FD-TD generated results, the new approach using the combination of FD-TD and Prony's methods achieves the same type of accuracy with a time record computed over a much shorter time.

SUMMARY

1. Introduction

In applying the FD-TD technique [1,2] to analyze microwave integrated circuits, the transient time record may be required over tens of thousands of time steps in order to obtain accurate frequency domain scattering parameters via Fourier transformation. Depending on the complexity of the microwave integrated circuit being analyzed, which dictates the size of the spatial sampling grid to be used in modeling the physical structure, the computational time can run up to several hours. As shown in this paper, the accuracy of the scattering parameters is compromised if the transient time record is terminated too prematurely. However, it is also demonstrated in this paper that the required FD-TD time response can be efficiently obtained from a relatively short time record by using an extrapolation scheme based upon the Prony's method [3,4].

2. Method of Approach

As a first step in the extraploation scheme, a curve fitting procedure is employed to approximate the time record, computed over a relatively short period using the conventional FD-TD scheme, in terms of complex exponential functions whose frequencies of oscillation and damping factors are determined by Prony's method. The results for the future time steps, i.e., the late time FD-TD record, can now be generated very efficiently using the representation in terms of complex exponential while bypassing the time-consuming FD-TD computation altogether. The time saving resulting from the use of this extrapolation scheme can be very substantial indeed and it is not unusual to realize a reduction in computation time from hours to seconds.

This usefulness of the scheme outlined above is illustrated in this paper by considering a microstrip band-pass filter shown in Fig. 1, which is known to require a very long FD-TD time record of over 30,000 iterations (See Fig. 2), in order to obtain accurate S-parameters depicted in Fig. 3, that compare well with the experimental data in [5].

Using the new approach, a relatively short FD-TD time record of 5,000 iterations is generated as shown in Fig. 4. A window of 2,000 iterations is sampled at every 20 iterations to obtain 100 data points from which complex conjugate pairs of resonance frequencies and coupling coefficients are found by applying Prony's method. After experimenting a few times by shifting the window up and down the FD-TD time record, it is found that an 18-term series of complex exponential functions fits the FD-TD data satisfactorily as shown in Fig. 5. Using this 18-term series, a good approximation of the long FD-TD record of 30,000 iterations can be computed in seconds, saving hours of iteration time in the process.

Figure 6 shows the comparison between the waveform extrapolated by the new approach and the direct FD-TD waveform at late time, e.g., between the 7,000 and 10,000 iterations. If the truncated time record in Fig. 4 is used to compute the S-parameter, the result is shown in Fig. 7. Comparing Figs. 7 and 3, as illustrated in Fig. 8, one sees that the peaks in the S-parameter have been sharpened by including the late time transient waveform in the Fourier transform computation.

3. Significance and Potential Applications

As shown by comparison with the direct FD-TD generated results, the new approach using the combination of FD-TD and Prony's methods achieves the same degree of accuracy in a much shorter time. This method can be used for other potential applications that require the computation of response waveforms over a long period of time in order to obtain an accurate frequency domain result derived by Fourier transformation.

REFERENCES

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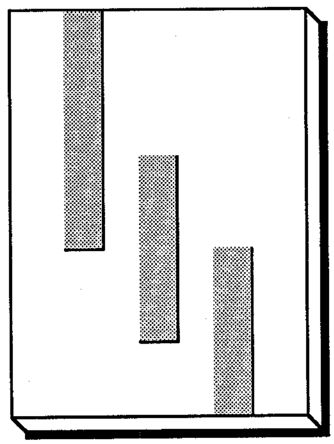

Fig. 1. Band-pass filter.

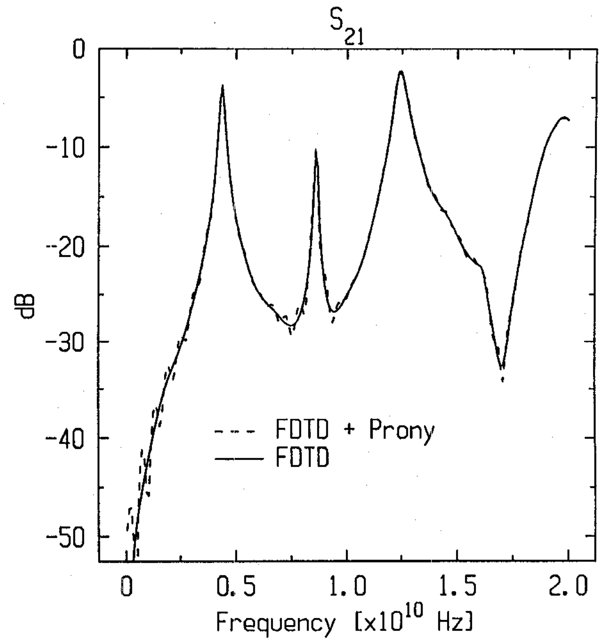

Fig. 3. S-parameter obtained by Fourier transformation of Fig. 2.

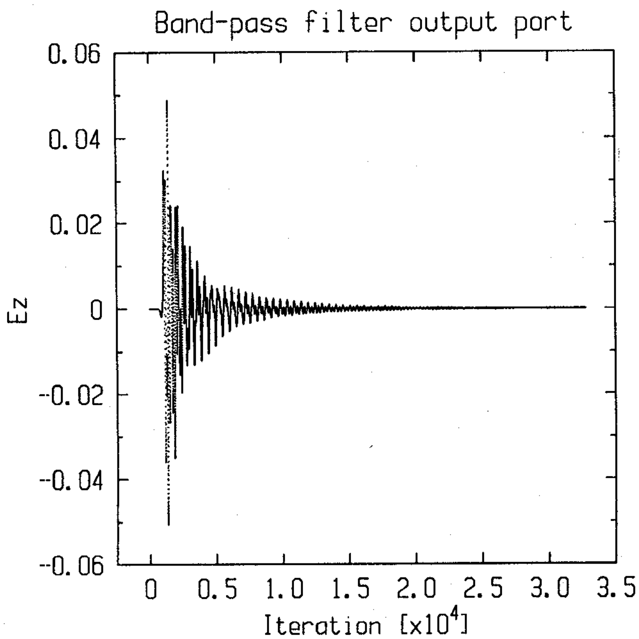

Fig. 2. FD-TD time record of 33,000 iterations.

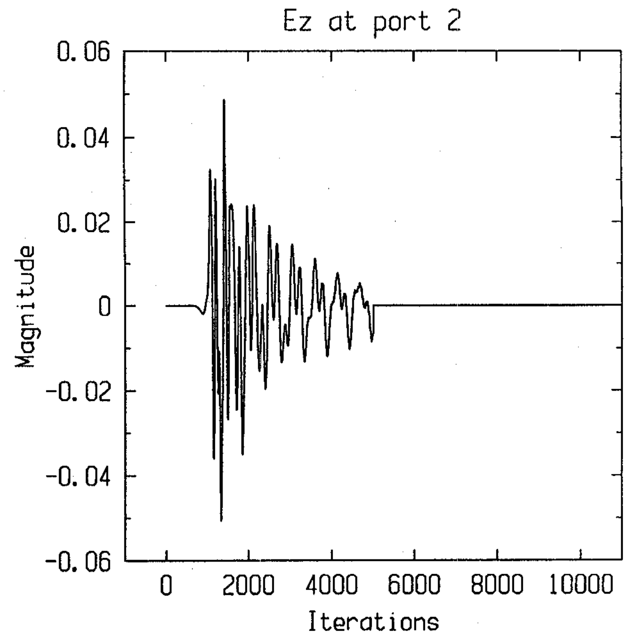

Fig. 4. FD-TD time record of 5,000 iterations.

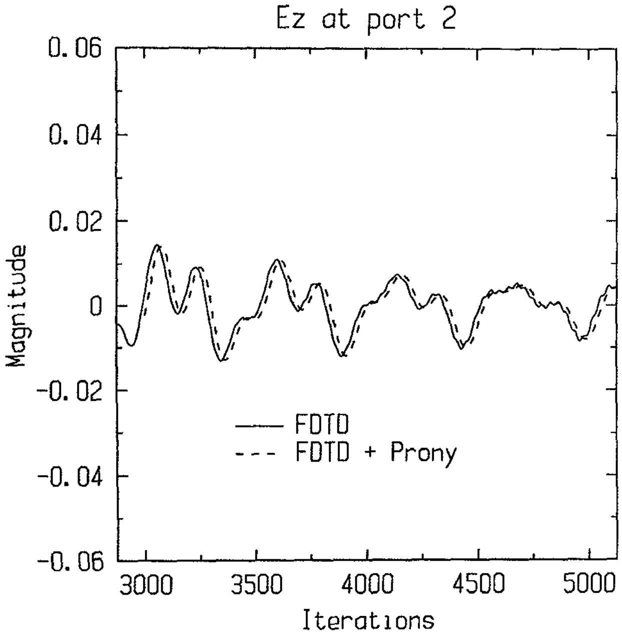

Fig. 5. Curve-fitting by Prony's method in a window of 2,000 iterations.

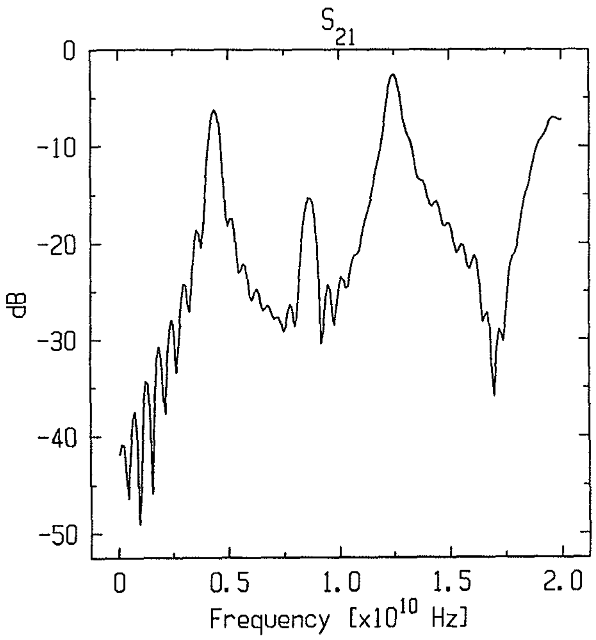

Fig. 7. S-parameter obtaind by a truncated FD-TD time record in Fig. 4.

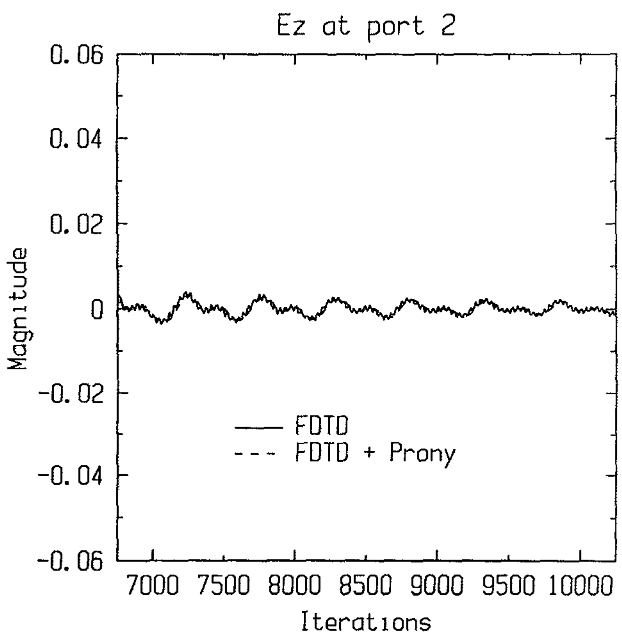

Fig. 6. Extrapolating the time transient waveform to late time.

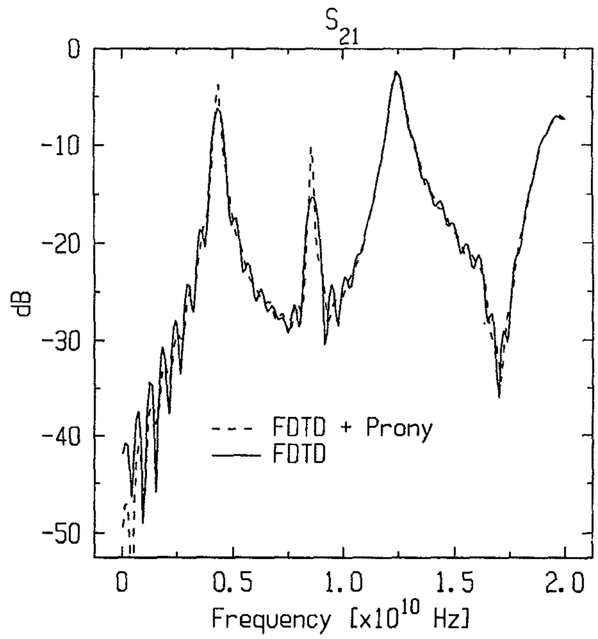

Fig. 8. Sharpening of the peaks in the S-parameter computation by including the late time transient waveform.