MICROWAVE ANALYSIS USING TIME-DOMAIN PLOTS
CREATED FROM FREQUENCY-DOMAIN REFLECTIONS

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ABSTRACT

Using reflection data, an oscillographic display is created to separate parasitic inductive parameters at junctions from impedance changes. The reactance and resistive changes occurring at the same point in time are separated using subtraction techniques.

Introduction

The question is often asked, "What is the resolution with the time-domain technique?' Since resolution is qualitative, it would seem easy enough to define it in terms of time or space. However, the ability to identify, qualify, and separate elements which occur at the exact same point in time requires an exercise in identification, not just resolution by separation into discrete elements of time. The higher the frequency spectrum used, the better the time resolution; while the lowest frequency harmonic determines the total distance that can be scanned before the next pulse representation interferes with the first pulse position. This causes a false echo representation.

The resolving of microwave reflections produced by the change in reactance and resistance can be achieved using the moving-impulse-function-time-technique.[1] The microwave characteristic reflections produce a different impulse-function shape when resistive and reactive reflections are encountered. The positive resistance change does not disturb the general impulse function shape and a negative impedance simply reverses the pulse downward. The inductive change produces an entirely different effect causing the impulse-function to have both positive and negative values.

Theoretical models have been created to represent the electrical junctions where impedance changes and inductive effects occur. Although the data is a theoretical model, experimental measurements would produce a similar, though not perfect, response.

Circuit Modeling

This first model shown in Figure #1 represents a 10 centimeter long 50 ohm line terminated in a resistance of 10 ohms and .15 nanohenries in series with a terminating 50 ohm load. This model was analyzed at harmonically related frequencies from 180 MHz to 18 GHz in steps of 180 MHz. The electrical reflections were then converted into the time-domain using an impulse-function time-domain display. Figure #1 shows this impulse-function scan from 7.5 centimeters to 12.5 centimeters of time. If only the 10 Ω series resistance was encountered, the impulse-function would be located at exactly the 10 cm point in time. However, the small series inductance of .15 nanohenries causes a dip to occur at the end of the impulse-function in a negative direction. Figure #1 has been marked with a peak value point "A" and the reflection level of 60 Ω resistance occurring at the 10 cm time point where the reflection is +.091. The .15 NHy inductance causes the change of the impulse-function to occur "Δ" above and "Δ" below the normal resistive impulse level.

Figure #2 is the impulse-function time-domain for circuit #2. The coil has a .3 NHys inductance and the same 10 Ω series resistance. The peak impulse-function point is marked "A" and precedes the 10 cm time location and the "Δ" change is increased because of

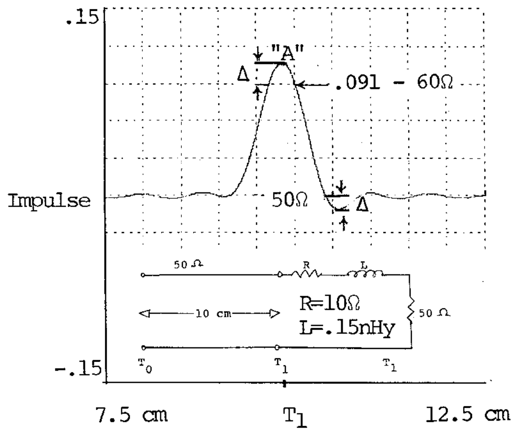

FIGURE 1 Impulse-function Time-Domain for Circuit #1

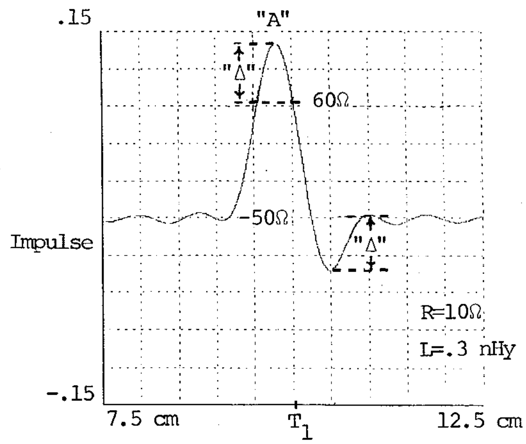

FIGURE 2 Impulse-function Time-Domain for circuit #2

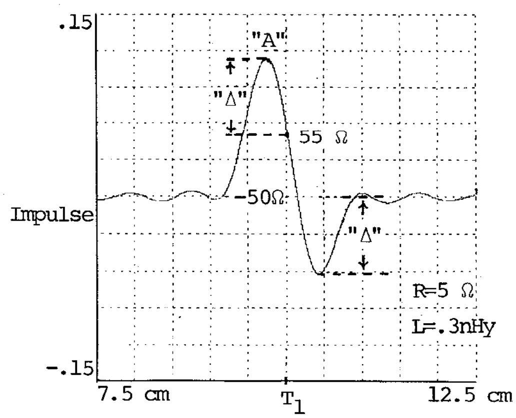

FIGURE 3 Impulse-function Time-Domain for circuit #3

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the increased inductance.

Figure #3 is the impulse-function time-domain for the third circuit where the same inductance is used as in circuit #2 and the series resistance changed from 10Ω to 5Ω. Figure #3 now has a nearly sine-function shape.

The +5 Ω impedance level point (55Ω) is marked and is near the 10 cm time point. The "Δ" value produced by the inductance appears even larger than it does in Figure 2 although the inductance value is the same.

The fourth circuit, shown in Figure #4 has a 10 cm, 50Ω line with a series inductance of .3 NHys which is terminated in a 2.5 cm long, 40Ω line which is terminated in 50Ω at the 12.5 cm reference point. The impulse-function from circuit #4 now indicates the lower impedance effect at the 10 cm time point and the inductance still produces an increase "Δ" before the 10 cm point and a "Δ" dip beyond the 10 cm point.

Figure #5 is an overlay of the circuit #2 and circuit #4 showing the time-domain difference when a 10Ω series resistance is changed to a 40Ω line with a junction inductance value remaining at .3 NHys.

Figure #6 was the overlay of the impulse-function from circuits #2 and #3. This overlay was the change of 5Ω resistance with identical inductances at the 10 cm point. Subtracting the time plots of Figure #3 from #2 shows the 5Ω resistance in Figure #7. The peak value in resistance in Figure #7 indicates approximately 54.5Ω. Subtracting the 5Ω resistance of Figure #7 from #3 gives the remaining inductance only, having a peak value of .09123 which computes to be .3 NHys shown in Figure #8.

Figure #9 is now an overlay of Figures #2, #3, and #8. These three impulse-function curves shown in Figure #9 reveal how inductance and resistance values, although at the same point in time, are separated. Figure #10 is a Smith Chart impedance plot of the two circuits and the extracted inductance plotted at the same reference point of 9.99 cm and clearly indicates the inductance and resistance components.

When the inductance extracted from circuit #3 is subtracted from circuit #4, the result is the time plot Figure #11 indicating a 40Ω line without the junction inductance effect.

Conclusions

This exercise using ideal theoretical circuit elements to represent junction inductance and impedance changes has demonstrated the power of using the time-domain representation to separate parasitics from normal junction impedance changes. When time separation is not possible then the ideal impulse-function of the known impedance changes can be subtracted leaving behind the parasitics which can be then deconvoluted into the frequency-domain for further identification. The location of reference-time-points can easily be marked and ideal circuit representations can be used as changes which can be subtracted in the time-domain to de-embed the parasitic parameters.

[1]"Time-Domain Oscillographic Microwave Network Analysis Using Frequency-Domain Data", M. E. Hines, H. E. Stinehelfer, Sr., MTT 22 #3 March 1974.

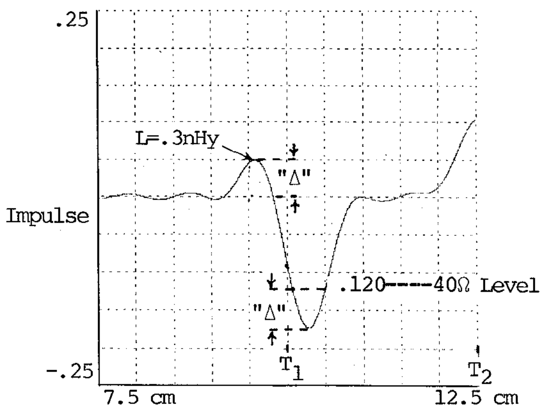
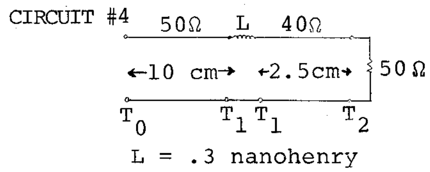


FIGURE 4 Impulse-function Time-Domain for circuit #4



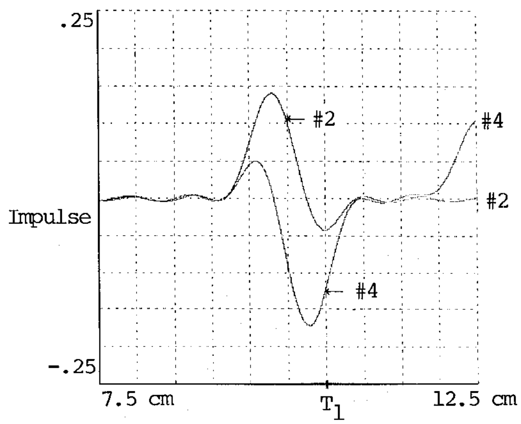


FIGURE 5 Overlay of Impulse-Function Time-Domain for circuits #2 & #4

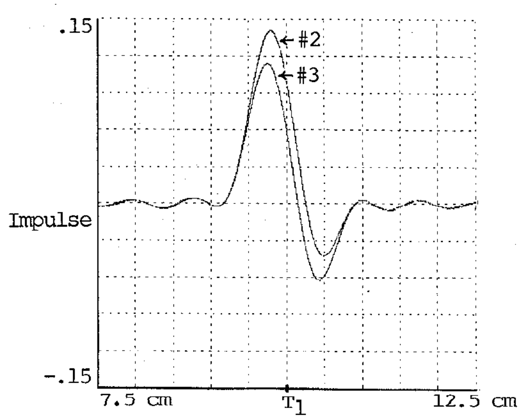


FIGURE 6 Overlay of Impulse-function Time-Domain for circuit #2 & #3
Circuit #2 has R=10 with L=.3 nHy
Circuit #3 has R=5 with L=.3 nHy

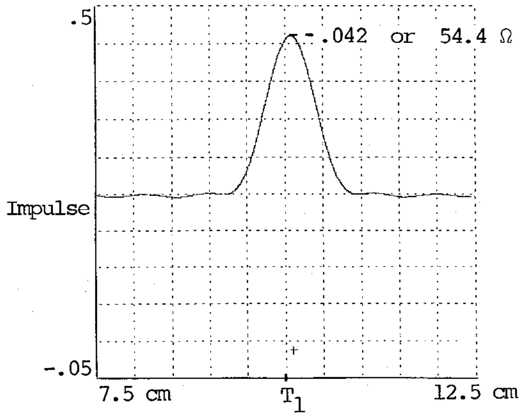


FIGURE 7 Impulse-function of resistance only, created by subtracting the .3nHy inductance of Figure 3 from that of Figure 2.

The subtraction of .3nHys & 5 ohms from circuit #2 leaves a 5 ohm resistance.

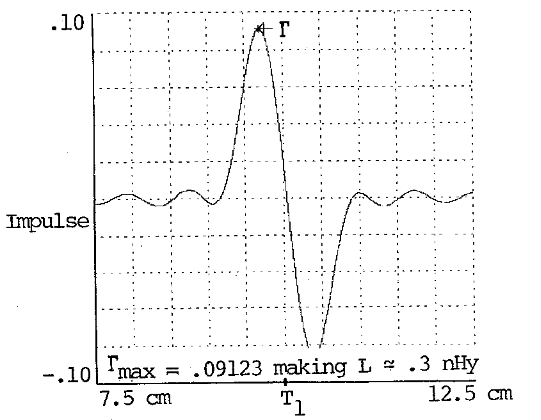


FIGURE 8 Impulse-function of inductance only, created by subtracting the 5 ohm resistance of Figure 7 from that of Figure 3.

The subtraction of 5 ohms from circuit #3 reveals a .3 nHy inductance.

The value of this inductance can be calculated from the peak impulse value, using the equation:

$$L\ (\text{nHy}) = \Gamma * 3.29$$

where Γ is the peak impulse-function value.

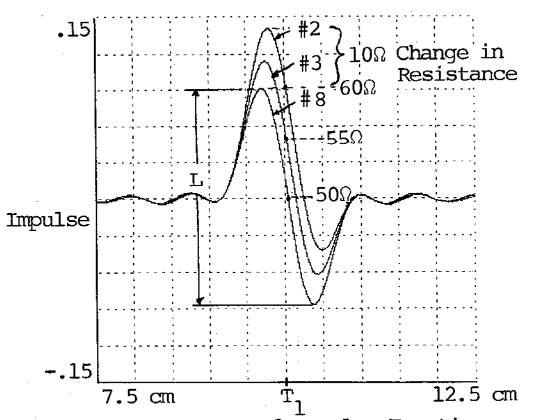
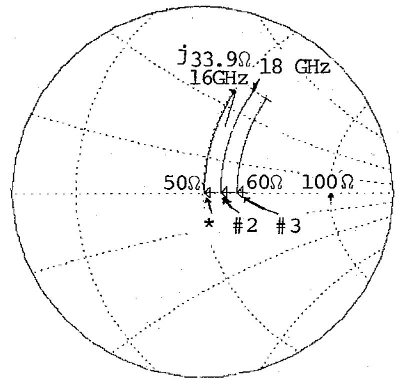


FIGURE 9 Overlay of Impulse Function Time-Domain of Figures 2,3, & 9



Γ_{max} = .50

FIGURE 10 Overlay of Impedance of Circuit #2 & #3 with Phase Shift set to 9.99 cm with the extracted Inductance of Figure #9 located also at 9.99 cm

* This is extracted inductance separated by subtracting the resistive difference between #2 and #3 from #3 to give inductance only without the resistive component.

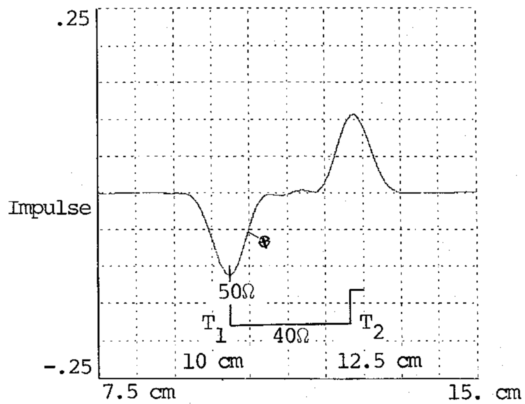
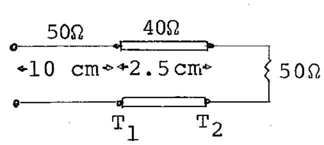


FIGURE 11 Impulse-function time-domain of 50 ohm to 40 ohm change of impedance after inductance at reference plane T_1 subtracted.



40Ω line without inductance