TRANSIENT ANALYSIS OF LUMPED PARAMETER RLC CIRCUIT FOR DIFFERENT DAMPING CASE USING ONE DIMENSIONAL TRANSMISSION LINE MODELING (TLM) METHOD

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ABSTRACT

Here, the transient analysis of lumped parameter RLC circuit is analyzed for different damping case using one dimensional TLM method. The circuit is modeled to derive the required algebraic iterative equation using stub model of the above mentioned method. The model equations using TLM method are arranged systematically so that those can be implemented easily to the existing MATLAB software for the purpose of analytical result. We considered the analytical result of the classical method using differential equations as the reference method for comparison. Finally, the analytical results using TLM method are compared with classical method for appraisal.

***Keywords*: *Classical method, damping, lumped, stub model, Transient analysis*.**

INTRODUCTION

The TLM method is first introduced by [1] and then further developed by [2-7].They described that it is a space and time discretizing method for time domain modeling of electromagnetic structures. The TLM method is not only the powerful method for the analysis of the numerical and creative electromagnetic problems, but also provides a strong technique for analytical solution of lumped parameter electric circuit. Lumped means concentrated instead of being distributed.

The TLM method was applied to Microwave and millimeter wave circuit modeling [8], nonlinear electromagnetic structures [9-10], arbitrary frequency dispersive boundaries and materials [11-12]. To the best of authors knowledge, there is no published work concerning the solution of the problem for lumped parameter RLC circuit considering different damping case.

Motivated by above all the above, here, the TLM method is used to make the transient analysis of lumped parameter RLC circuit for different damping. For this reason, we considered two steps [13]. Firstly TLM equivalent network is drawn by replacing the concerned lumped network for the derivation of the simple algebraic equations. And secondly the network is solved by using one type of iterative methods.

The remainder of this paper is organized as follows. Section 2 describes the methodology and formulation. The Transient analysis is depicted in section 3. Numerical results are shown in Section 4 and section 5 provides the concluding remarks.

2. METHODOLOGY AND FORMULATION

For ‘Stub’ model of capacitor let us consider the following Fig.1 at time step k from [6]:

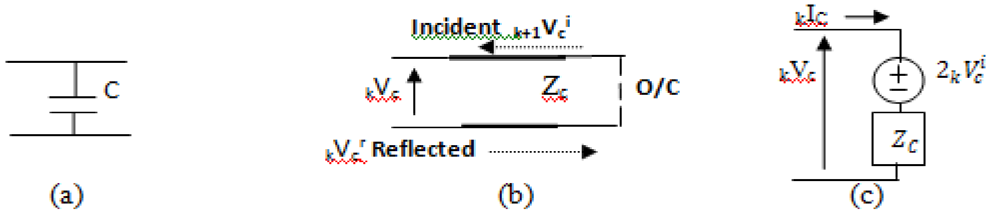

Fig. 1. (a) A capacitor, (b) its Stub model, (c) Thevnin’s equivalent of the stub model .

The stub model shown above has per unit length error inductance and pure capacitance of L_d and C_d respectively .The length of the line is Δl and round- trip time is Δt. From the Fig. 1.(b) => $C_d\Delta l=C$

Velocity of propagation, $u = \frac{\Delta l}{\Delta t/2} = \frac{1}{\sqrt{L_d C_d}}$

$$\Rightarrow L_d = \frac{(\Delta t)^2}{4C\Delta l} \quad (1)$$

So the characteristics impedance,

$$Z_c = \sqrt{\frac{L_d}{C_d}} = \frac{\Delta t}{2C} \quad (2)$$

From Fig. 1. (c) => we can write for k+1 step,

$$_{k+1}V_c^i = {}_kV_c^r \quad (3)$$

It is a reasonable choice because reflection coefficient of load for open circuit termination is 1.

For ‘Stub’ model of inductor let us consider the following Fig.2 at time step k from [6]:

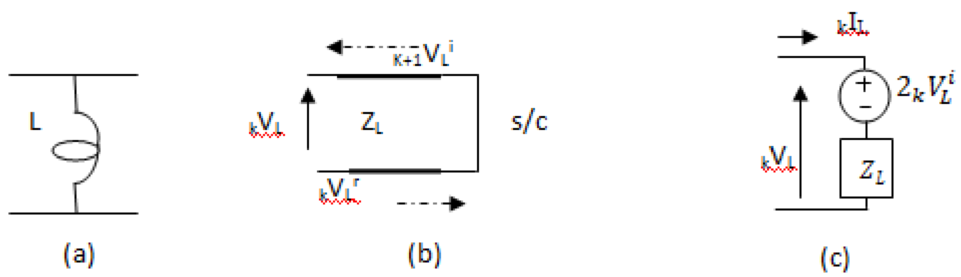

Fig. 2. (a) An inductor (b) its stub model (c) Thevnin’s equivalent of the stub model.

Similarly the characteristics impedance,

$$Z_L = \sqrt{\frac{L_d}{C_d}} = \frac{2L}{\Delta t} \quad (4)$$

From Fig. 2. (c) => we can write for k+1 step,

$$_{k+1}V_L^{i} = -\, _{k}V_L^{r} \quad (5)$$

It is reasonable choice because reflection coefficient of load for short circuit termination is -1.

Both the figures (Fig. 1 & Fig. 2.) above are shown for time step k. The required number of time step for simulating or solving the circuit is determined from the knowledge of total observing time. If the total observing time is t and the round- trip time is Δt ,then the total number of time step(let n) will be such that it satisfies the condition (n-1)Δt=t if the initial time is zero .

3. TRANSIENT ANALYSIS WITH DAMPING

The Transient analysis can be defined as the analysis of circuit behavior for a period of time immediately after independent source have been turned on or turned off. Damping factor is the amount by which the oscillations of a circuit gradually decrease over time.

Let us define, the damping ratio, $\zeta = \frac{R}{2L}$ (6)

When ζ>1 is called overdamping which causes no oscillations. The special case ζ=1 is called critical damping and it is the minimum damping that can be applied without causing oscillations. And, for ζ<1, represents underdamped condition which contains oscillations.

A series RLC circuit is shown in Fig. 3(a) and the equivalent TLM model is shown in Fig. 3(b). we found the current, I(t) for the following circuit for different cases (over damped, critically damped and under damped case).

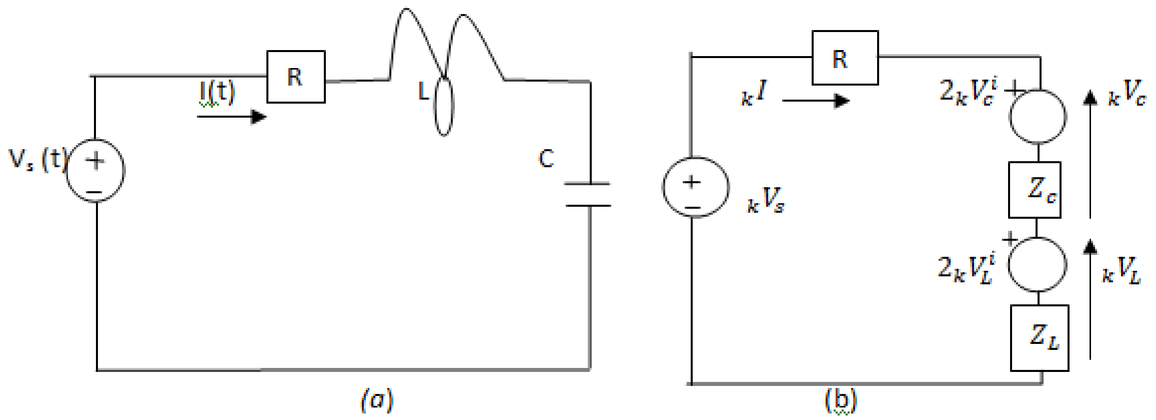

Fig. 3 . (a) A series R-L-C Circuit (b) its TLM equivalent using stub model.

<u>Solution</u>: From **Fig. 3 (b),**

The current at time step k, $_kI = \frac{_kV_s - 2_kV_c^i - 2_kV_L^i}{R + Z_c + Z_L}$ (7)

Voltage across the capacitor, $_kV_c = 2_kV_c^i + {_kI}Z_c$ (8)

Again voltage across the inductor, $_kV_L = 2_kV_L^i + {_kI}Z_L$ (9)

Now, $_kV_c^r = {_kV_c} - {_kV_c^i}$ (10)

Similarly, $_kV_L^r = {_kV_L} - {_kV_L^i}$; (11)

At time step (k+1), $_{k+1}V_c^i = {_kV_c^r}$ (12)

And $_{k+1}V_L^i = -{_kV_L^r}$ (13)

4. NUMERICAL RESULTS

For the **circuit of Fig. 3,** we take, time step, k=201; so total time t=(201-1)*0.1=20 s, Over damped case (R=3 Ω ,L=1 H, C=1 F), Critically damped case(R=2 Ω , L=1 H ,C=1 F), Under damped case (R=1 Ω , L=1 H , C=1 F) and $V_s(t)$ =10V. For different values of round trip time Δ***t*** **,** the analytical results are shown below:

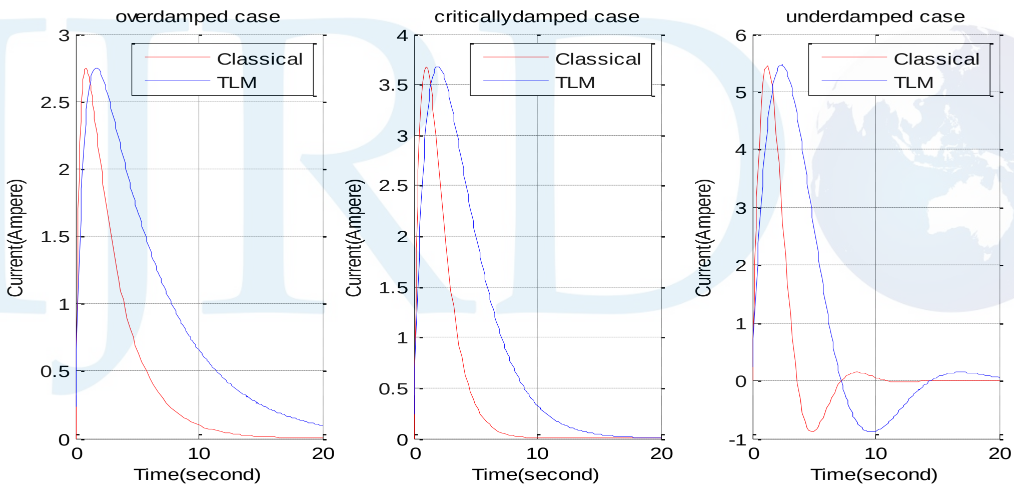

Fig. 4. Analytical results of Fig. 3 using the both classical and TLM method for round trip time, Δt=0.05 s.

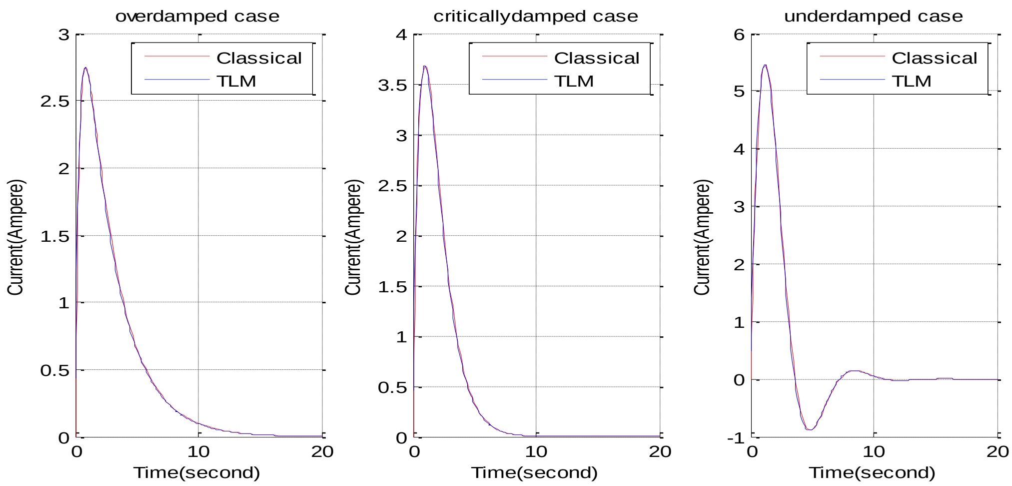

Fig. 5. Analytical results of Fig. 3 using the both classical and TLM method for round trip time, Δt=0.1 s.

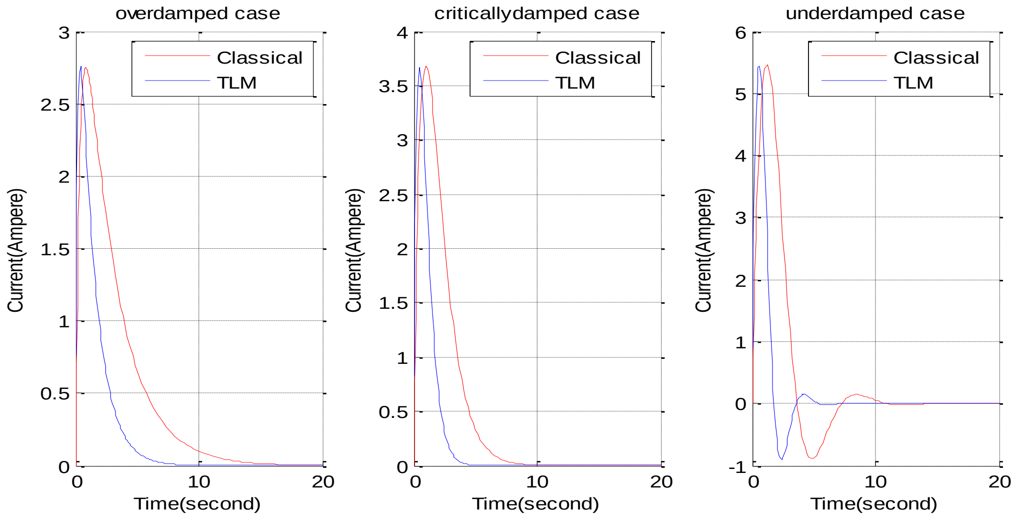

Fig. 6. Analytical results of Fig. 3 using the both classical and TLM method for round trip time, Δt=0.2 s.

5. CONCLUSION

The validity of TLM method was examined by comparing the analytical results of these lumped element circuits with classical analysis .The analytical results using the both classical and TLM methods were identical in shape. When the round trip time is increased, the analytical result using TLM method decreases significantly. We got an overlapping shape when assumed the value of the round trip time of 0.1 second. Really, TLM is a very simple, easily understanding method. In this method, there is no need to supply the initial value of the desired quantities. Only all the initial incident voltages should be assumed to be zero. Finally, we conclude that TLM method is the powerful tools for solving not only for the distributed parameter electric circuits but also for the lumped parameter electric circuits. The impact of the round trip time for TLM method on the analytical results for other types of lumped parameter electric circuits can be studied in the future.

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