Nature of Reflections

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This Lesson Presents

- Electric signal time travel in free space
- Travel time limitations in media OTHER than free space
- Making those differences simple
- Power transfer with
  - a shorted load
  - an open load
  - a matched load
- Under DC the reasons are very, very basic
- But a DC-transient view reveals something astonishing.

Time Travel

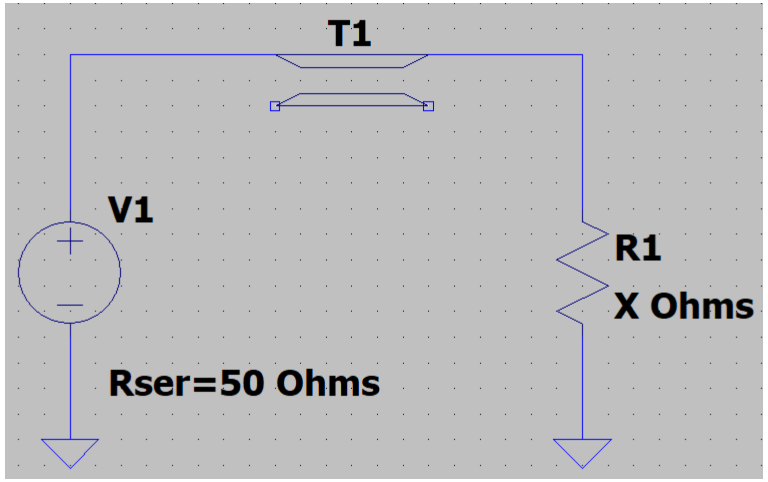
- An electric signal travels (as well as light)
    - In free space
        - at the speed of light 300e6 meters per second
    - In anything else
        - at slightly LESS THAN speed of light in free space
- Examples of anything else
    - Copper
    - Water
    - glass

An Easy Way to Specify How Much Less

- Velocity Factor
- For example, if an electric signal travels
  - In free space at 299,792,458 meters per second
  - And travels at 284,802,835 meters per second in a copper wire
  - The velocity factor (vf) OF THAT WIRE is the ratio of the two—0.95.
- Thus, vf is a parameter found on data sheets for coax and other cables typically used as antenna feedlines.

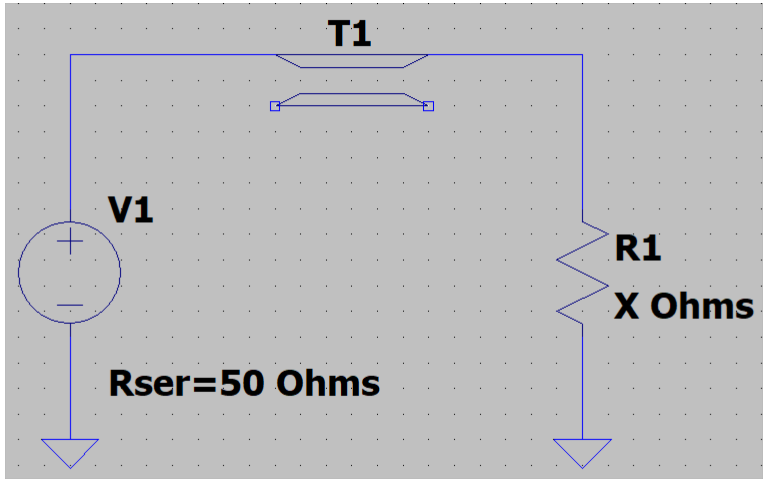
Maximum Power Transfer

- Maximum power is consumed by a load when the impedance of a system is matched.
- A “system” is the
  - Power source
  - Travel media
  - And load



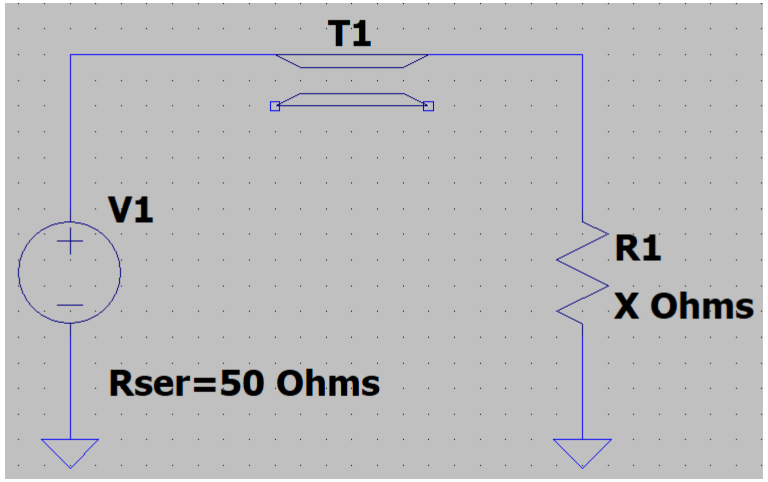
How do you get max power transferred?

- Consider the variables. With:
  - X much larger than R_{ser} you get
    - a much larger voltage delivered to the load.
    - But LESS current
  - X much LESS than R_{ser} you get
    - a much LESS voltage delivered to the load.
    - But much MORE current



Easy to Understand Example of Max P Xfer

- Ignoring the transmission line, Let V1=1 Volt and X = 50 Ohms
  - $V_{load} = 1Volt \frac{50\ Ohms}{50\ Ohms+50\ Ohms} = 0.5\ Volt$
  - $i_{load} = \frac{0.5\ Volt}{50\ Ohms} = 0.01\ Ampere$
  - $Power_{load} = ie = 0.01A * 0.5V = 0.005\ VA$ (Watts)
- Let X = 100 Ohms
  - $V_{load} = 1Volt \frac{100\ Ohms}{50\ Ohms+100\ Ohms} = 0.666666\ Volt$
  - $i_{load} = \frac{0.66666\ Volt}{100\ Ohms} = 0.0066666\ Ampere$
  - $Power_{load} = 0.00666 \ldots A * 0.666 \ldots V = 0.004444 \ldots\ VA$
- Let X = 1 Ohms
  - $Power_{load} = ie = 0.000386A * 0.0196V = 0.00038\ VA$
- Quiz: Which of the three values of X results in a max pwr xfer?

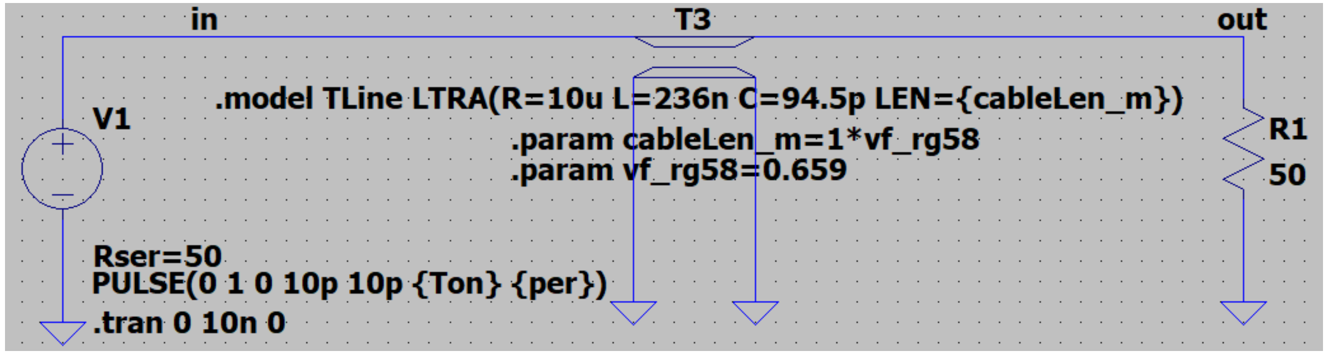


Enter the Transmission Line-RG-58

- Source is Tech-FAQ
  - Vf=65.9%
  - C=28.8 pF/ft, 94.5 pF/m
  - Z_0=53.5 Ohms
  - T_d=1.54 nsec/ft, 5.-52 nsec/m
- Calculated
  - $L = Z_o^2 * C = 50^2 * 94.5pF = 236$ nH/m
- Expected Latency via vf alone
  - T_d=Len/c*vf=1m/299.79e6 m/sec*0.659=2.20 nSec/meter

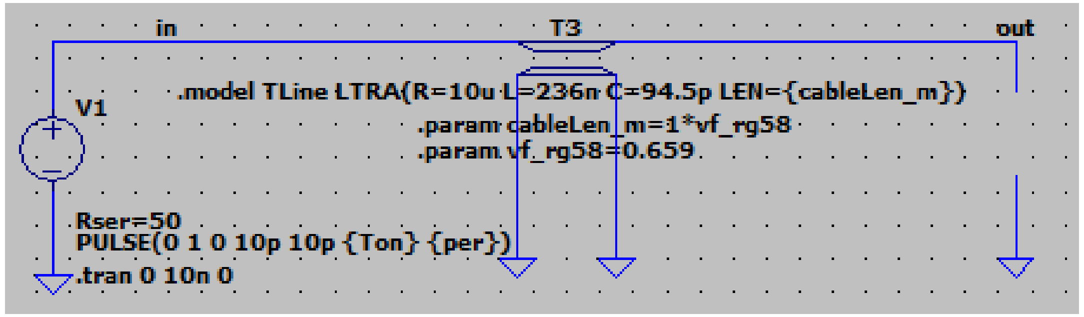
Critical Missing Observation!!!!

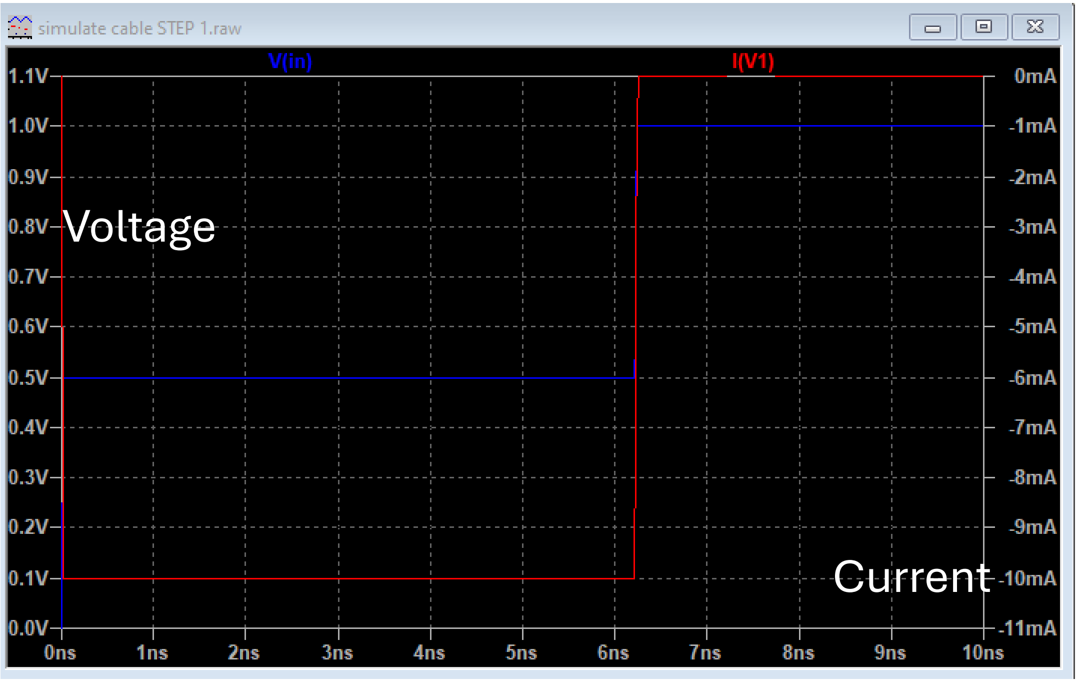
- Even in DC there are transient voltages owing to parasitics.
- EVERYTHING has parasitics, even lamp cord.
- Consider the earlier example but looking at what was there but we did not notice (or care about).
- Use a voltage pulse starting at zero and a pulse value of 1 Volt.
- A transmission line of 50 Ohms but options for open and shorted.



Open Option

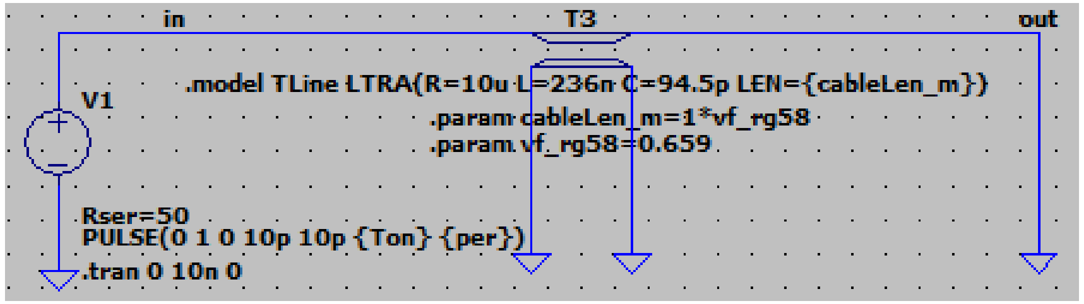
- Load is open
- But 10 mA flows for 6.2 nSec.
- Voltage at source is only half for those 6.2 nSec
- Then goes to full voltage.
- Why?
  - Because of characteristic impedance—Z_0.
  - $Z_0 = \sqrt{\frac{L}{C}}$
  - EVERYTHING has parasitic elements.

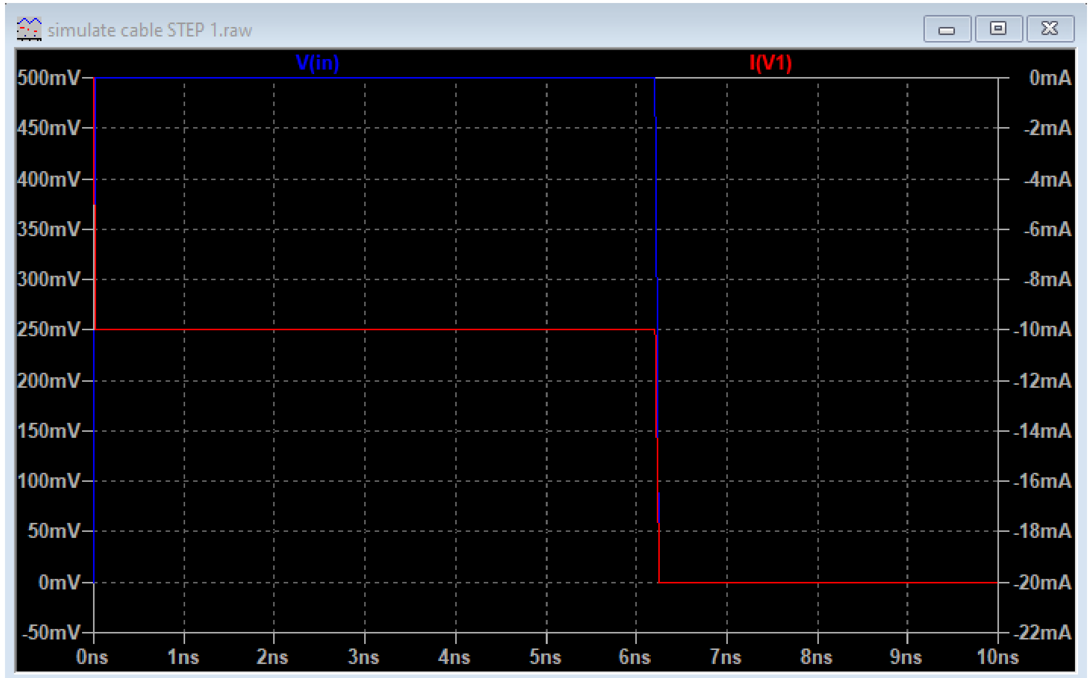




What about a short?

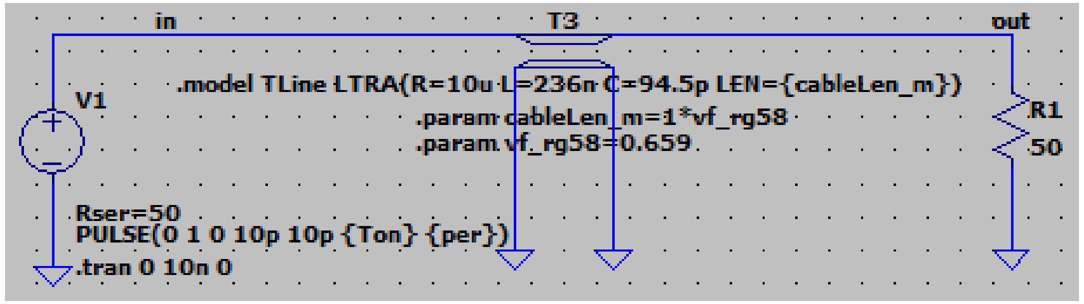
- Load is shorted
- But 10 mA flows but then switches to 20 mA at 6.2 nSec.
- Voltage source is HALF for those 6.2 nSec and THEN zero.
- Why?
  - Because of characteristic Z—Z_0.
  - $Z_0 = \sqrt{\frac{L}{C}}$
  - EVERYTHING has parasitic elements.

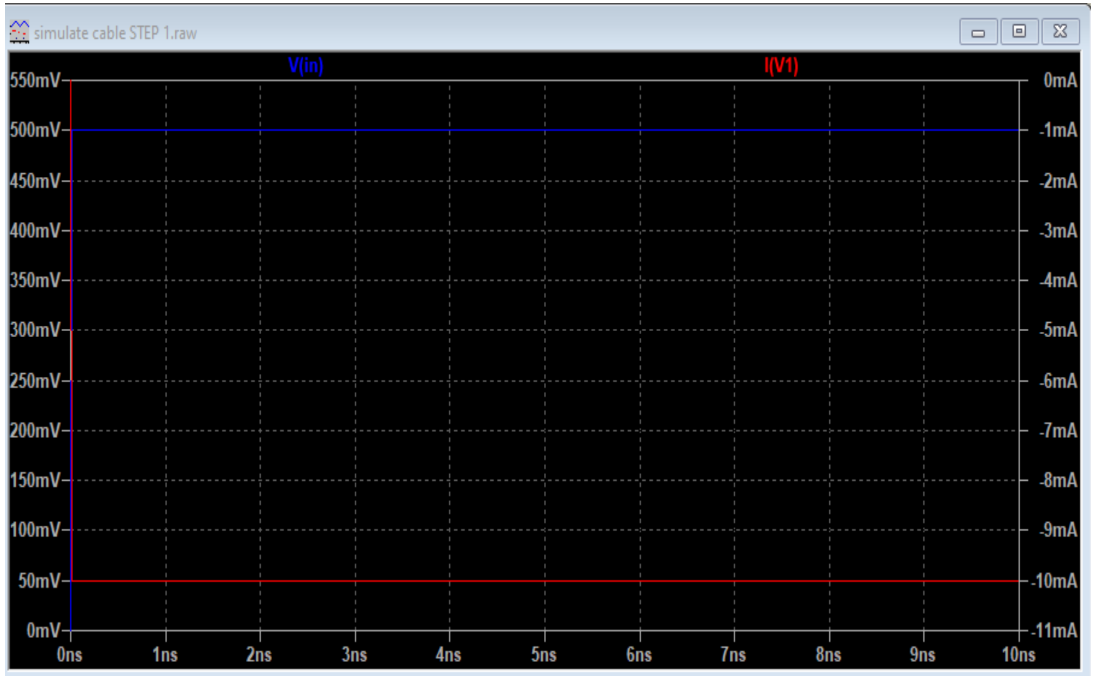




With Matched Impedances

- Load is matched—50 Ohms
- From time zero no changes.
- Voltage source is HALF at the get-go.
- Why?
  - Hold on to your hats, folks.
  - Because THERE ARE NO REFLECTIONS.





An Antenna for a Load

- Let us now suppose that our "load" is our antenna.
- An optimized antenna will have Z = 50 ± j0 Ohms
- Our transmission line will also have Z = 50 ± j0 Ohms
- And lastly, our transmitter Z = 50 ± j0 Ohms
- But suppose the antenna were
  - Z = 67.0 – j30.0 Ohms at 146 MHz
  - That defines an SWR = 1.68
  - A little excessive but tolerable
  - What does it do?

Continued Next Month…

- See you next month—April 2025.