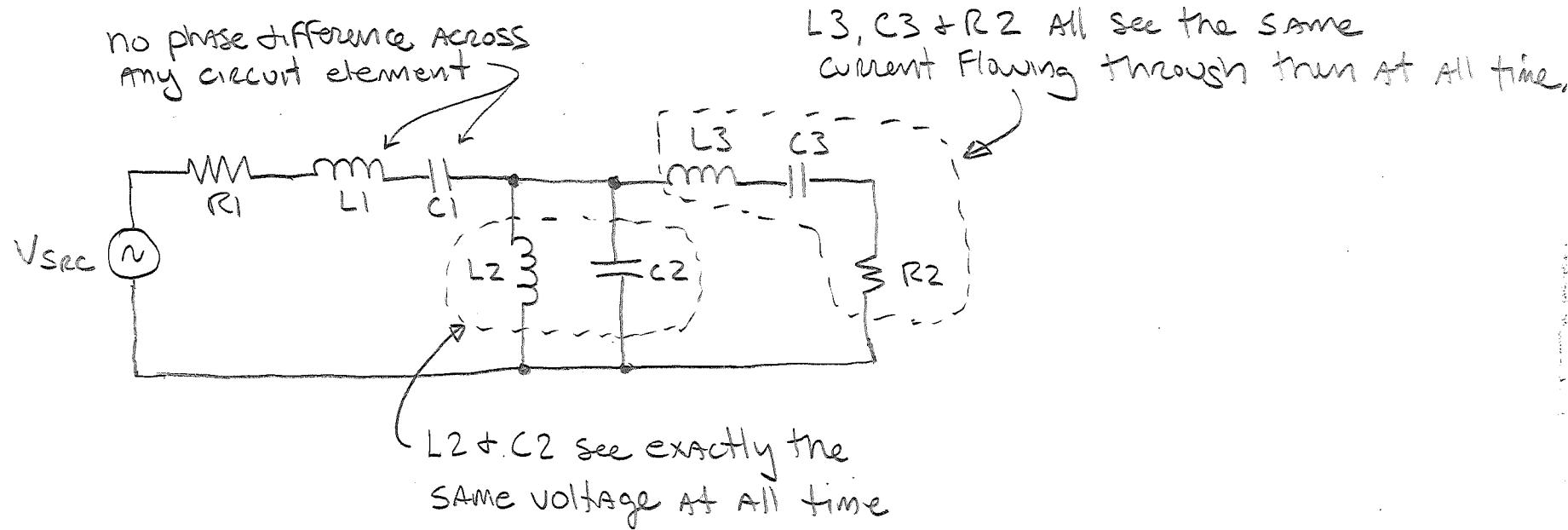


Lumped vs Distributed Ckts

As a designer, you need to understand if you are dealing with a transmission line environment or not. This translates to understanding if you have a lumped or distributed ckt.

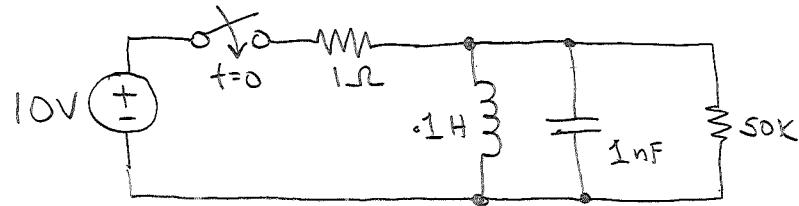
Classical circuit theory (KVL, KCL, etc.) deal with lumped circuits.

In a lumped circuit, the physical dimensions of the circuit are such that the voltage across or current through conductors or elements does not vary.



Lumped vs Distributed Circuits

Another lumped circuit:



When the switch closes at $t=0$, we assume the inductor and capacitor experience the applied voltage simultaneously.

We do not consider how the current begins to flow in the first few turns of the inductor. We assume the current at all points within the inductor change at the same time.

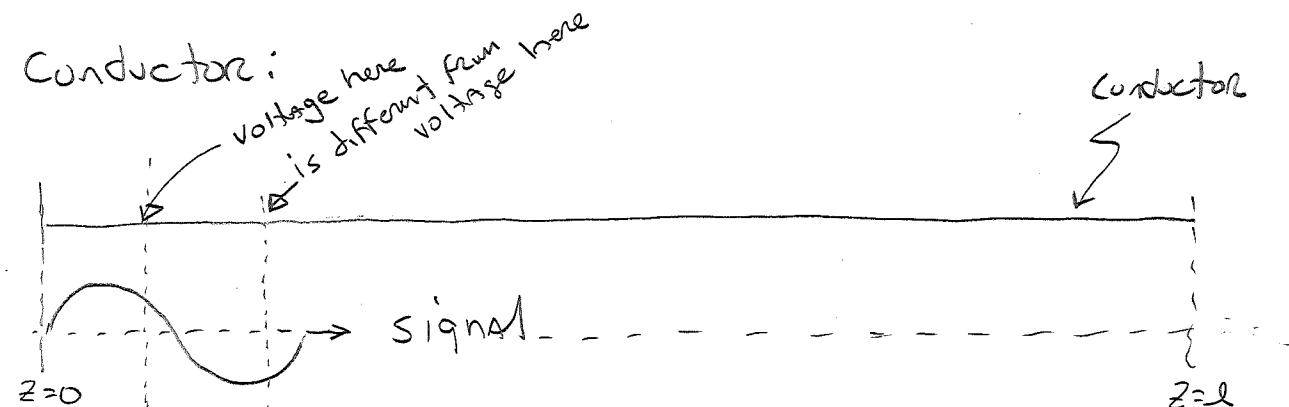
Across both conductors and circuit elements, we assume no phase differences or signal transit times for a lumped circuit.

Lumped vs Distributed

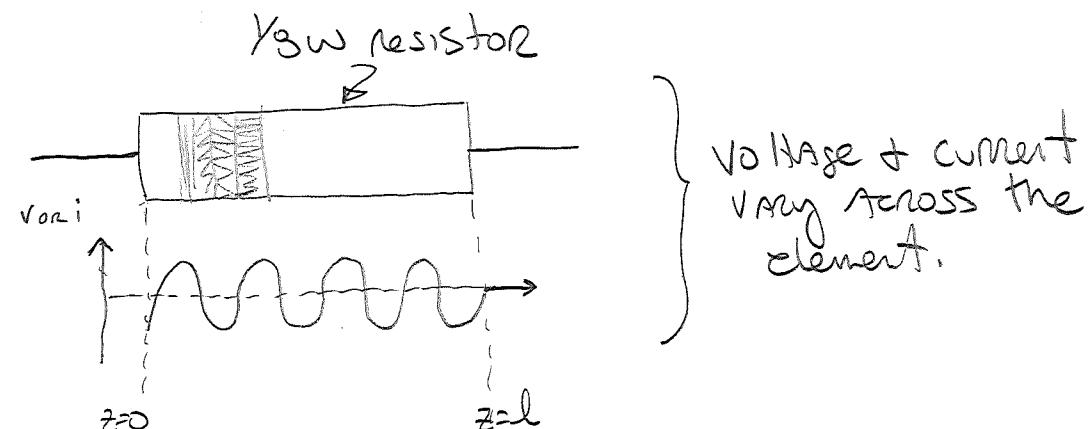
In distributed circuits, the length of conductor and circuit elements is of great importance.

Distributed conductors and circuit elements exhibit signal transit time and/or phase differences. It takes time for a signal to arrive at a point. At a fixed time, the voltage differs between points.

Distributed Conductor:

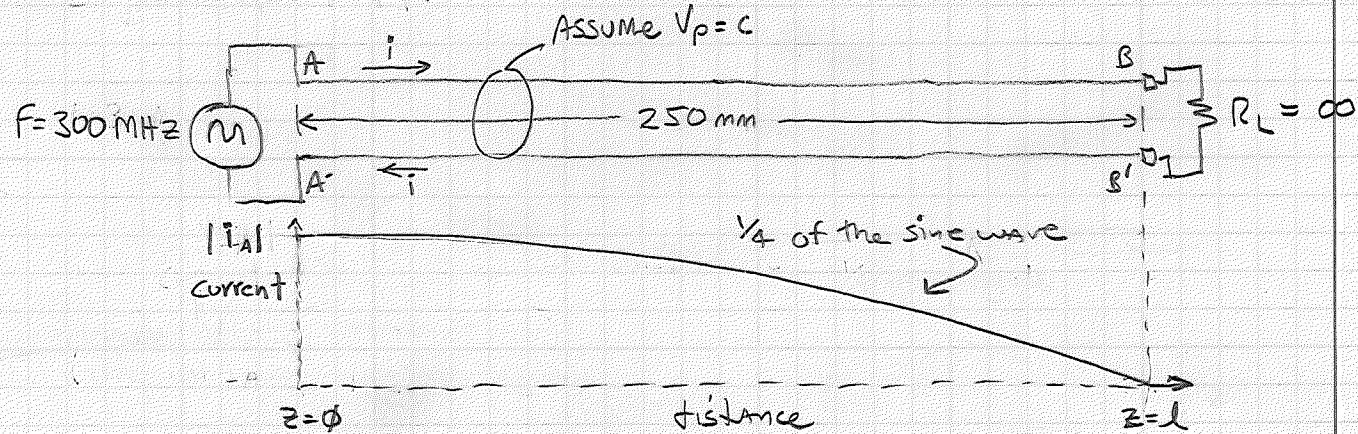


Distributed Element:

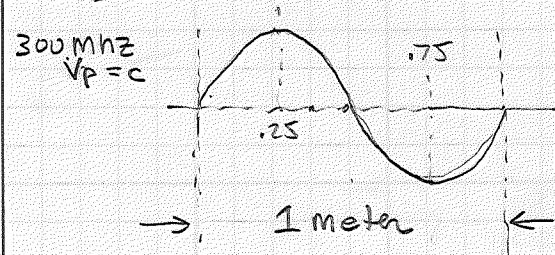


2.2 Distributed vs Lumped

Here is the case where the electrical length of the T-line is a significant portion of the wavelength. (electrically long)



$$\text{in free space } \lambda = \frac{c}{F} \text{ so } \lambda = \frac{300 \times 10^6 \text{ m/s}}{300 \times 10^6 \text{ Hz}} = 1 \text{ m or } 1000 \text{ mm}$$



The 300MHz wave is stretched over 1 m in free space.

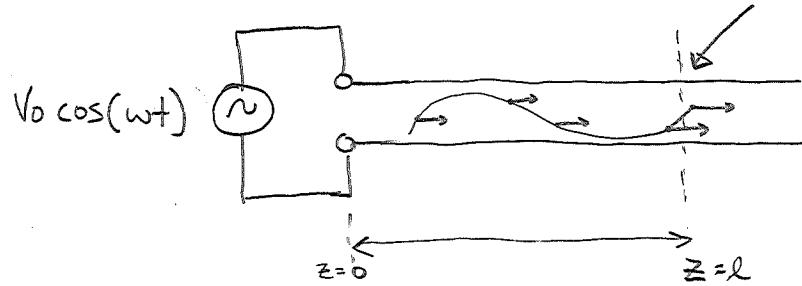
Current at A, A' is a maximum.
Current at B, B' is zero

} Obviously A distributed element!

What is electrical length?

4a

Sinusoidal Signals on Electrically Long Lines.



what is the voltage here? $(V(+, z))$

The voltage or current at some location on an electrically long line is a function of $\frac{time}{t} + \frac{distance}{z}$

$$V(z, t) = V_0 \cos(\omega(t - \frac{z}{v_p}))$$

indicates wave is traveling in
the positive z direction

the time it takes for the signal to get to the point $z=l$

$$= V_0 \cos(\omega t - \omega t_d)$$

$= V_0 \cos(\omega t - \omega \frac{z}{v_p})$; $\frac{z}{v_p}$ is the time it takes to get to our point of interest

$$= V_0 \cos(\omega t - \beta z)$$

$\beta = \frac{\omega}{v_p}$ } this has units of
RAD/sec ÷ meters/sec $\Rightarrow \frac{\text{radians}}{\text{meter}}$

This relationship tells us voltage at a point (distance) and at a particular time.

β is known as the phase constant. It tells us how fast the phase is changing with distance. It takes into account the frequency and the physical medium the wave is traveling through.

Electrical Length

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We have a relationship for voltage at a point with respect to time & distance.

$$V_0(z,t) = V_0 \cos(\omega t - \beta z); \text{ where } \beta = \frac{\omega}{v_p}$$

However, we know that $\lambda = \frac{v_p}{f}$ And thus $v_p = \lambda f$

So by substitution, $\beta = \frac{\omega}{\lambda f}$

$$= \frac{\omega}{\lambda f}; \text{ And since } \omega = 2\pi f$$

$$= \frac{2\pi f}{\lambda} = \frac{2\pi}{\lambda}; \text{ Another expression for } \beta \text{ (phase constant)}$$

Rewriting the equation above ...

$$V_0(z,t) = V_0 \cos \left(\omega t - 2\pi \underbrace{\frac{z}{\lambda}}_{\text{Electric length}} \right)$$

This term is referred to as the "electrical length"
In this form, it is expressed in radians.

Electrical Length is the portion of a wavelength (λ) that a distance z represents, or simply $\left(\frac{z}{\lambda}\right)$.

Electrical Length

From before....

$$\beta = \frac{2\pi}{\lambda} \quad (\text{phase constant})$$

$$\beta z = 2\pi \left(\frac{z}{\lambda}\right) \xrightarrow{\substack{\text{the portion of one wavelength that} \\ \text{the distance } z \text{ represents. (dimensionless)}}}$$

electrical length. (expressed here in radians) (Also "E" or "θ" in some texts)

$$E = 2\pi \frac{z}{\lambda} \quad (\text{in radians})$$

$$E = 360^\circ \frac{z}{\lambda} \quad (\text{in degrees})$$

OR

$$E = \frac{z}{\lambda} \quad (\text{As a fraction of a wavelength})$$

3 ways of expressing the
same thing

When the length of a component or conductor pair is a significant portion of a wavelength, the component is considered a distributed element and the conductor pair is considered to be a transmission line.

What is "a significant portion"?

Lumped vs Distributed (cont.)

Back to the "significant portion" question . . .

From before, $V(z,t) = V_0 \cos(\omega t - \beta z)$ and by substitution,

$$= V_0 \cos\left(\omega t - \frac{2\pi}{\lambda} z\right)$$

$$= V_0 \cos\left(\omega t - 2\pi \underbrace{\left(\frac{z}{\lambda}\right)}_{\text{electrical length}}\right)$$

electrical length

So whenever z is comparable to λ the voltage begins differs across that distance z . In other words, this is a distributed environment.

If distributed elements exist, you are in a T-line scenario.

Three factors place us in that environment

- frequency of the signal (or frequencies contained therein) $(\lambda = \frac{V_p}{f})$
- velocity of propagation $(\lambda = \frac{V_p}{f})$
- length of the element or conductor $(\frac{z}{\lambda})$

Now, let's develop 3 ways to answer our question.