ECE 3300 SPECIAL CASES OF TRANSMISSION LINES

Motivation: Recall that a "capacitor " does not function as a capacitor , and an "inductor" does not function as an inductor at microwave frequencies. But if we want to build a filter, for instance, at microwave frequencies, we need C and L. How do we get them? We will see that lengths of shorted or open transmission lines can be used for C and L.

SPECIAL CASES OF TRANSMISSION LINES

Short-Circuited Line

For a short-circuited transmission line:

$Z_L = 0$

$\Gamma = [\, Z_L - Zo \,] / [\, Z_L + Zo \,] = -1 = 1 \angle 180°$

S (standing wave ratio) = $|V|max / |V|min = \infty$

$V_{sc}(z) = Vo^+ [\, e^{-j\beta z} - e^{j\beta z}] = -2j\ Vo^+ \sin(\beta z)$ volts

$I_{sc}(z) = (Vo^+ / Zo)\ [\, e^{-j\beta z} + e^{j\beta z}] = 2\ (\ Vo^+ / Zo)\ \cos(\beta z)$ amps

If you think of this from "ordinary" circuit perspective, what should $V_{sc}(z)$ be on the load?

ZERO!

For z=0 $V_{sc}(0) = -2j\ Vo^+ \sin(\beta 0) = 0!$

What should $I_{sc}(z)$ be?

MAXIMUM!

$I_{sc}(0) = 2\ (\ Vo^+ / Zo)\ \cos(\beta 0\ )$ amps $= 2\ (\ Vo^+ / Zo)$

Input Impedance (impedance at input terminals)

$Z_{in}^{sc} = V_{sc}(z=-l) / I_{sc}(z=-l) = j\ Zo\ \tan(\beta l)$ ← Strictly reactive

Other reactive impedances:

Capacitor	$Z_C = 1 / (j\omega C) = -j / \omega C$
Inductor	$Z_L = j\omega L$

So, if Zin has POSITIVE reactive value, it can act like an equivalent inductor Leq

If it has NEGATIVE reactive value, it acts like an equivalent capacitor Ceq

Equivalent Inductor:

$j\omega Leq = jZo \tan(\beta l)$ if $\tan(\beta l) \geq 0$

$Leq = Zo \tan(\beta l) / \omega$ henries

To create an equivalent inductor, we use the shortest possible line:
$lmin = (1/\beta) \tan^{-1} (\omega Leq / Zo)$ meters

Equivalent Capacitor
$1 / (j\omega Ceq) = jZo \tan(\beta l)$ if $\tan(\beta l) \leq 0$
$Ceq = -1 / [Zo\ \omega \tan(\beta l)]$ farads

To create an equivalent capacitor, we use the shortest possible line (must have positive physical length):
$lmin = (1/\beta) [\pi - \tan^{-1} (\omega Ceq / Zo)]$ meters

Example (book has example of capacitance)

Create a stub-line which will act as an equivalent inductance of 1 nHenry
Given: Zo = 50 ohms, F = 3 GHz, air-filled line

$\lambda = c / f = 3 \times 10^8 / 3 \times 10^9 = 10$ cm
$\beta = 2\pi / \lambda = 62.83$ rad/m
$\omega = 2\pi F = 1.88 \times 10^{10}$ rad/meter

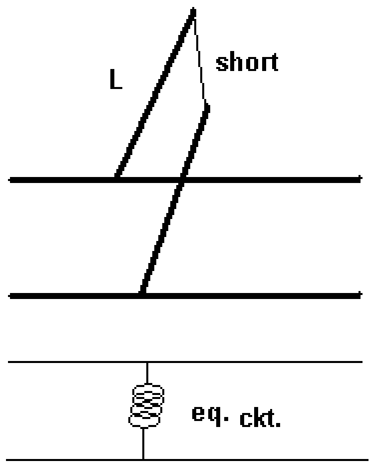
$lmin = (1/\beta) \tan^{-1} (\omega Leq / Zo)$ meters

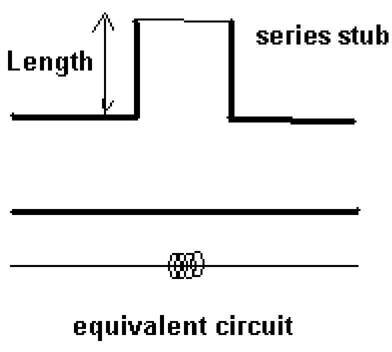
$= (1/ 62.83 \text{ rad/m}) \tan^{-1} (1.88 \times 10^{10} \text{ rad/meter} * 1 \text{ nHenry} / 50 \text{ ohms})$

= 5.7mm

Connection of parallel and series stubs (not covered in text)

How do you connect these things?





What controls whether a stub is capacitive or

How do you tell if a stub is capacitive or inductive?

The LENGTH

Open-circuited line

$\Gamma=1$

$V_{oc}(z) = Vo^{+} [e^{-j\beta z} + e^{j\beta z}] = 2\, Vo^{+}\cos(\beta z)$ volts

$I_{oc}(z) = (Vo^{+} / Zo) [e^{-j\beta z} - e^{j\beta z}] = -2j\, (Vo^{+} / Zo) \sin(\beta z)$ amps

$Z_{in}^{oc} = V_{oc}(z=-1) / I_{oc}(z=-1) =- j\, Zo \cot(\beta l)$ ← Strictly reactive

Open circuited line can ALSO be used to create inductance and capacitance.
In practice this is rarely done, because an "open" line is difficult to create. Fringing fields (fields fringing around the edges of an open end) create capacitance at the end of the open.

Measurement Techniques using Open and Shorts

How do you measure the characteristic impedance Zo? (We BUY lines with this spec.)

$Z_{in}^{oc} = V_{oc}(z{=}-1) \,/\, I_{oc}(z{=}-1) = -\,j\ Zo \cot(\beta l)$

$Z_{in}^{sc} = V_{sc}(z{=}-1) \,/\, I_{sc}(z{=}-1) = j\ Zo \tan(\beta l)$

$Z_{in}^{oc}\, Z_{in}^{sc} = Zo^2$ (multiplying equations)

$Zo = \sqrt{Z_{in}^{oc}\, Z_{in}^{sc}}$

$\tan(\beta l) = \sqrt{-\, Z_{in}^{sc} \,/\, Z_{in}^{oc}}$