ECE320H1F: Fields and Waves
Laboratory 1: Waves On Transmission Lines

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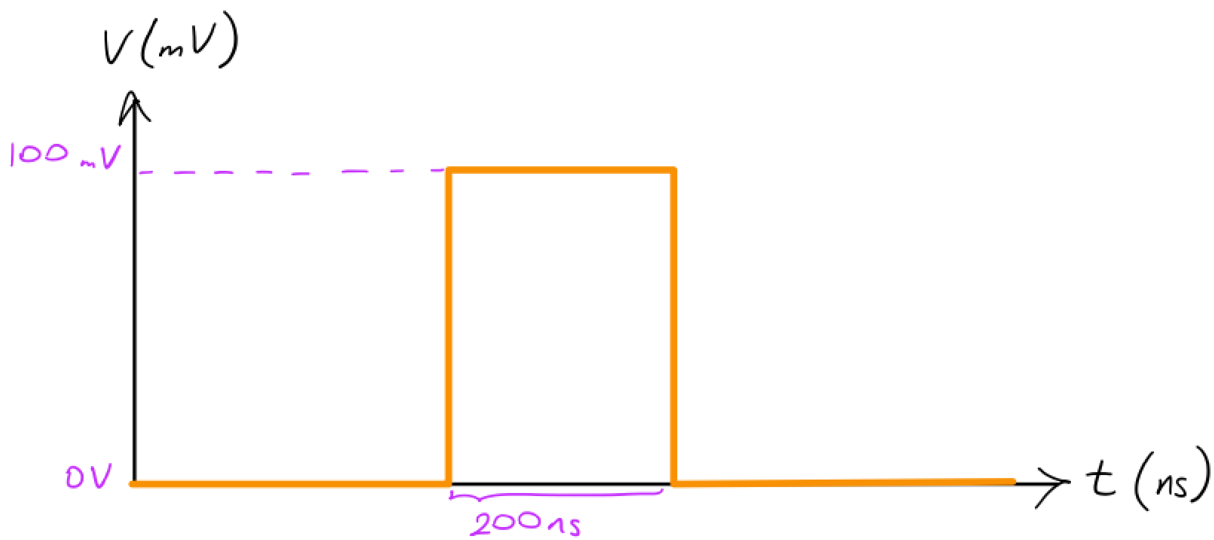
3.2 [3] Sketch of the waveform at point C when the line is terminated in *Z*0.



[2] *Z*0 found using the variable load.

Z0 is 50 Ω.

3.3 [5] $Z0 = v1(t, 0) / i1(t, 0)$ calculated using Ohm's law and measured voltages.

$v1(t, 0) =$ 51.25 mV
$i1(t, 0) =$ 1 mA

$Z0 = v1(t, 0) / i1(t, 0)$
$= (51.25\ \text{mV}) / 1\ \text{mA}$
$= 51.25\ \Omega.$

3.4 [5] **Measurement** *v* vs *t* graphs at C, D, E, and F for RL = 50 Ω.

At C at 0m

At D at 30m (C on Channel 1 and D on Channel 2)

At E at 60m (C on Channel 1 and E on Channel 2)

At F at 90m (C on Channel 1 and F on Channel 2)

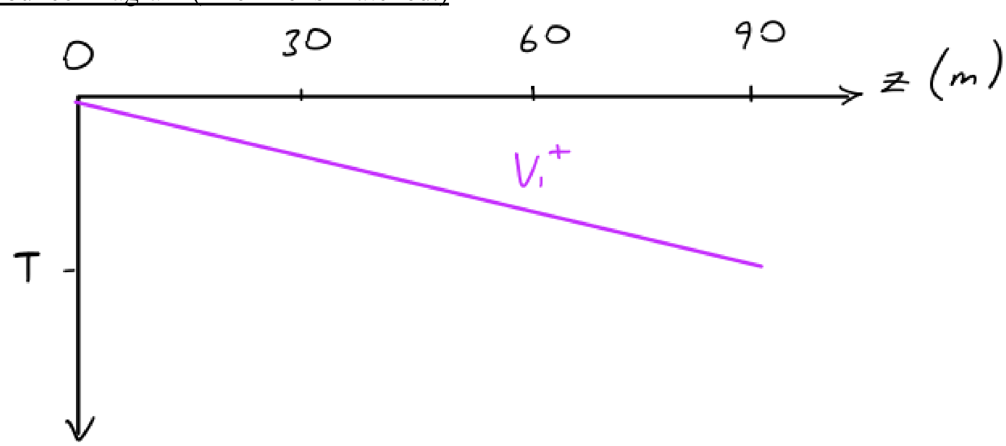
[3] Recorded time delay Δ*t* at points D, E, and F relative to the input signal.
At D: 114 ns
At E: 232 ns
At F: 354 ns

3.5 [2] Calculated average velocity of propagation *vavg* and relative permittivity *εr*.

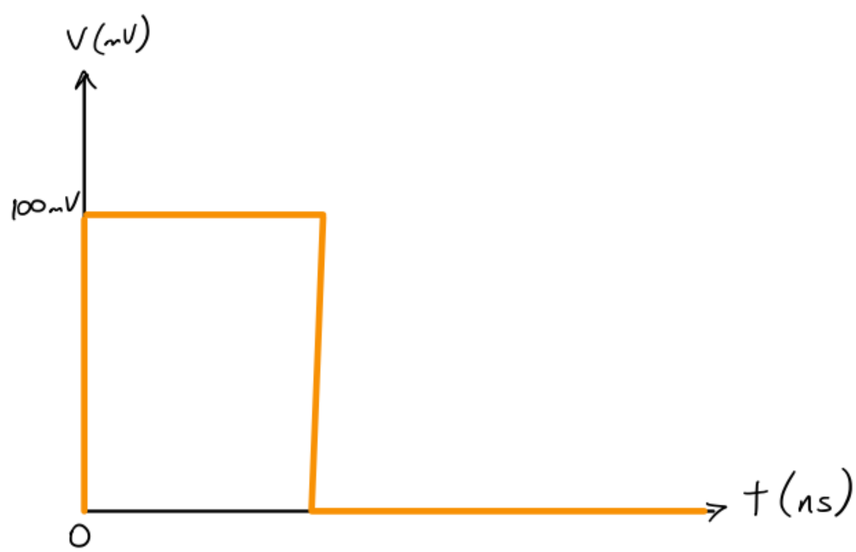
vavg: 2.631x10^8 m/s
εr: 1.30017

[10] Theoretical bounce diagram (2 marks) and corresponding *v* vs *t* graphs at C, D, E, and F (2 marks each). Compare with Section 3.4 measurement results.

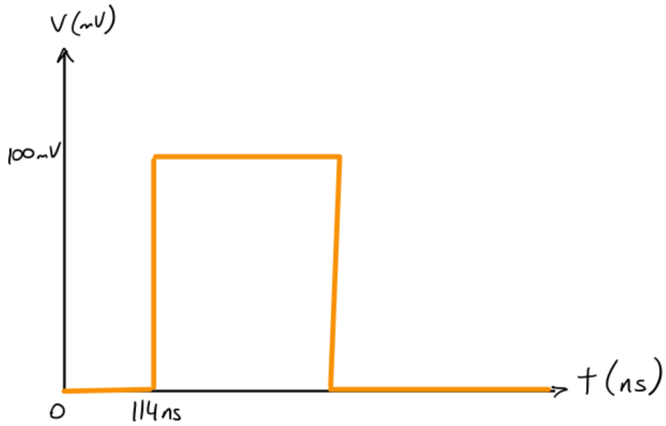
Bounce Diagram (The line is matched.)



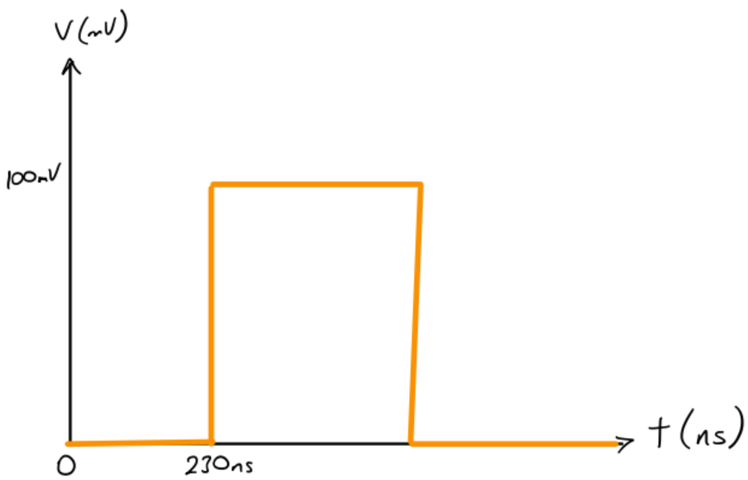
v vs t graph at C



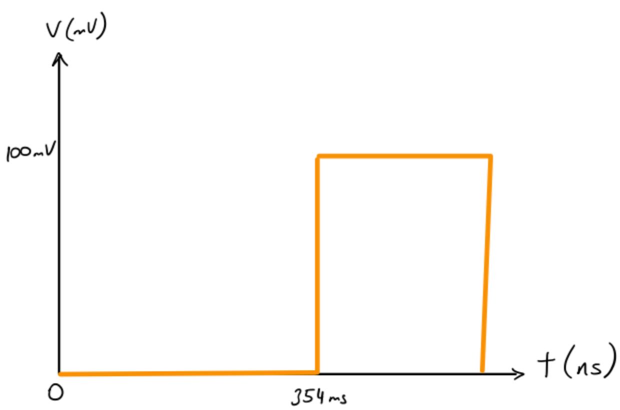
v vs t graph at D



v vs t graph at E



v vs t graph at F



3.6 [1] Compare calculated and measured ΓL.

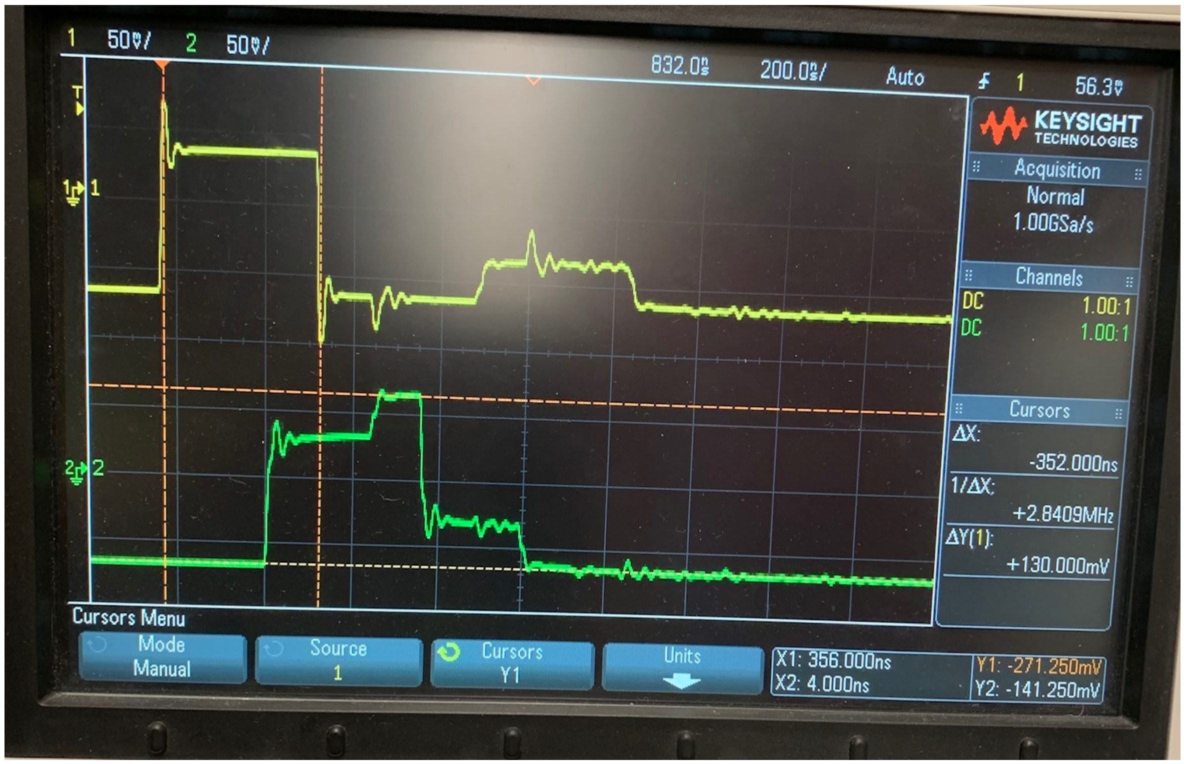
Calculated ΓL: 0.333
Measured ΓL: 0.3

[4] **Measurement** *v* vs *t* graphs at C and F for *R*L = 100 Ω.
Measurement at C and F (Channel 1 at C and Channel 2 at F)

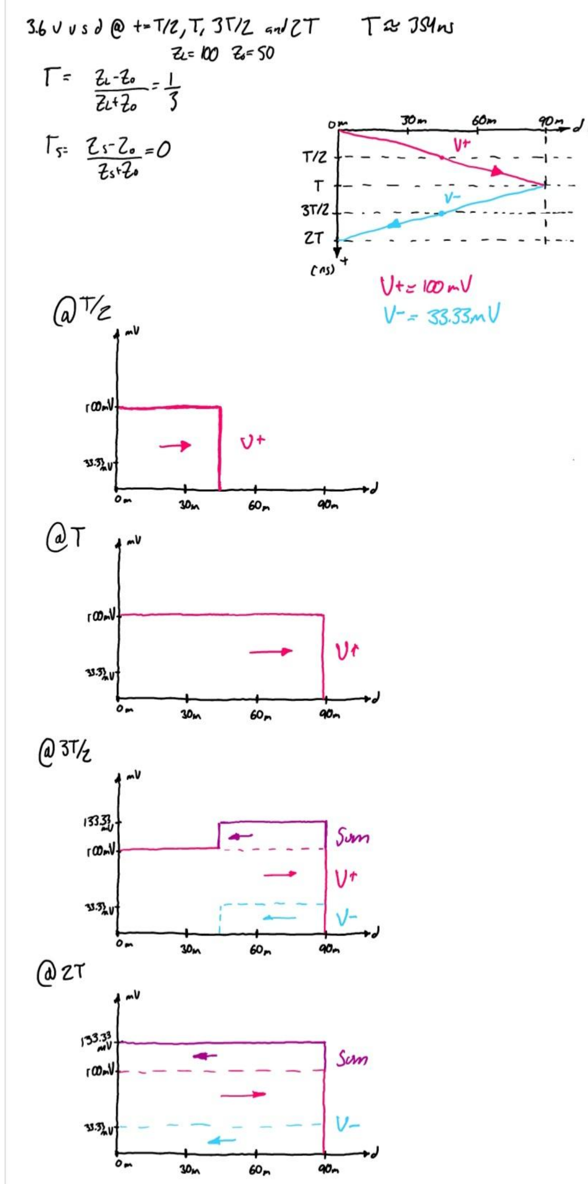
[2] Discuss the relationship between the pulses at C and F.

From the graphs we can see that the pulse of F is delayed compared to C. This is because point F is at 90m on the transmission line so that it takes more time for the wave to receive that point. We can also observe that the pulses add up as they travel in opposite directions. Such process can be seen more clearly below:

<u>Measurement at D vs C to observe reflective wave adding up on the initial wave</u>



[10] Theoretical *v* vs *d* graphs at *t* = *T* /2, *T*, 3 *T* /2, and 2 *T* where *T* = pulsewidth.



[2] Discuss the pulse propagation along the line with a mismatch at the load.

With a mismatch at the load we get reflections that bounce back and forth adding or subtracting from the initial wave until a convergence is reached.

3.7 [4] **Measurement** *v* vs *t* graphs at C and F for *R*source = (50 + 100) Ω and *R*L = 20 Ω for pulse widths of *T* and 10 *T*.

<u>Measurement at C on Channel 2 for pulse width T</u> (Vg on Channel 1)

<u>Measurement at F on Channel 2 for pulse width T</u> (C on Channel 1)

Measurement at probably C and F for pulse width 10T (C on Channel 1 and F on Channel 2)

[2] Calculated and measured ΓS and ΓL.

Calculated: $\Gamma L = (ZL - Zo) / (ZL + Zo) = (20 - 50) / (20 + 50) = -3/7 = -0.4286$

$\Gamma S = (ZL - ZS) / (ZL + ZS) = (20 - 150) / (20 + 150) = -13/17 = -0.7647$

Measured: $(1 + \Gamma L) * Vo = 29.375$ where $Vo = 50.625$ V
$\Gamma L = -0.419$

$Vo * \Gamma L * \Gamma S * (1 - \Gamma L) = 9$
$(50.625) * (-0.419) * (\Gamma S) * (1 - 0.419) = 9$
$\Gamma S = 9 / [(50.625) * (-0.419) * (1 - 0.419)]$
$\Gamma S = -0.7303$

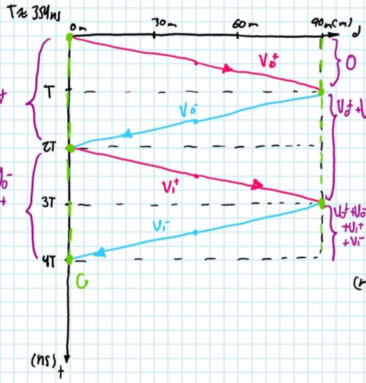
[20] Calculate the corresponding theoretical bounce diagram diagram for pulse widths of *T* and 10 *T* (5 marks each) and plot the theoretical *v* vs *t* graphs for each case at C and F (2.5 marks each).

3.7 Bounce diagrams of T and 10T, v vs t

@ C=0m

@ F=90m

T



$\Gamma_L = -0.4286$

$\Gamma_S = -0.7647$

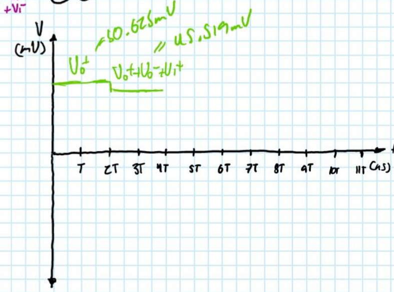
$V_0^+ = 50.625\,mV$

$V_0^- = \Gamma_L(50.625\,mV) = -21.698\,mV$

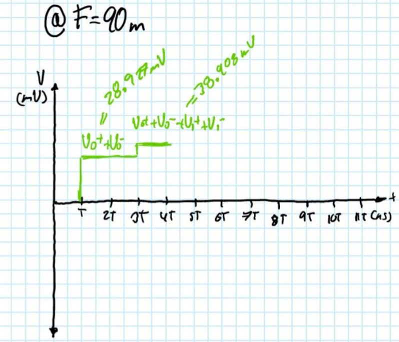
$V_1^+ = \Gamma_S(21.698\,mV) = 16.592\,mV$

$V_1^- = \Gamma_L(16.592) = -7.111\,mV$

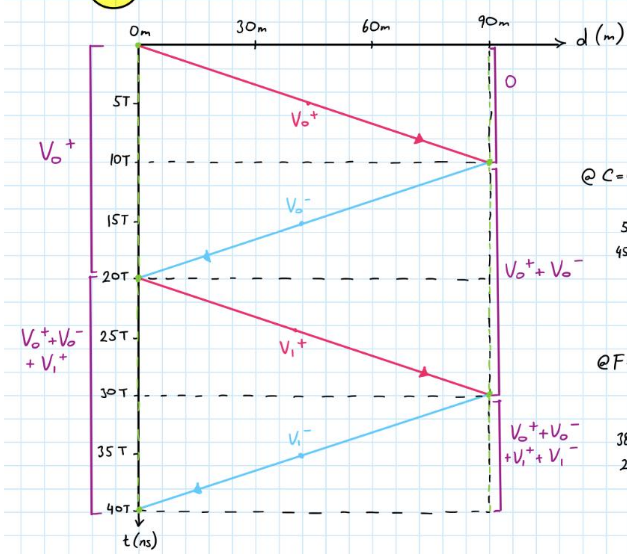
@C=0m



@F=90m



10T



$\Gamma_L = -0.4286$ $T \approx 354\,ns$

$\Gamma_S = -0.7647$ $10\,T \approx 3540\,ns$

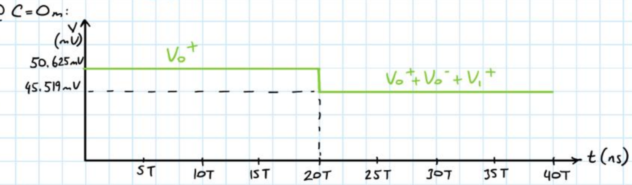
$V_0^+ = 50.625\,mV$

$V_0^- = \Gamma_L(50.625\,mV) = -21.698\,mV$

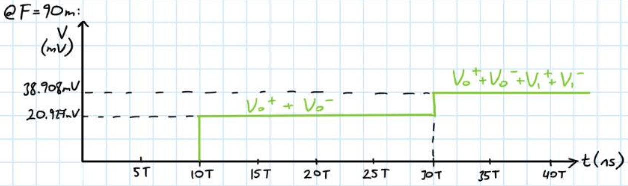
$V_1^+ = \Gamma_S(21.698\,mV) = 16.592\,mV$

$V_1^- = \Gamma_L(16.592\,mV) = 7.111\,mV$

@ C=0m:



@F=90m:



[3] Discuss how the measured results compare to the theoretically calculated ones.

Measure results are almost equal to the calculated results. The small differences could be caused by estimations, device measurement accuracy and cursor placement.

3.8 [3] Find three *v*1 minimum frequencies for the short circuit load.

1. 1.3MHz
2. 2.7MHz
3. 4.1MHz

[5] Explain why minimum voltages are obtained and discuss the effect on input current.

These minimum voltages are obtained at periodic intervals from the load due to the relationship between β and d (distance) and how they relate to λ at different frequencies, as these are the ones we are varying. When the load is short circuited the current is maximum and the voltage is minimum (the opposite can be argued for an open circuit equivalent where the current has minimum and voltage has a maximum).

[3] Find three *v*1 minimum frequencies for the capacitive load.

1. 1.4MHz
2. 2.8MHz
3. 4.2MHz

[6] Discuss how and why the results for the short circuit and the capacitor are different.

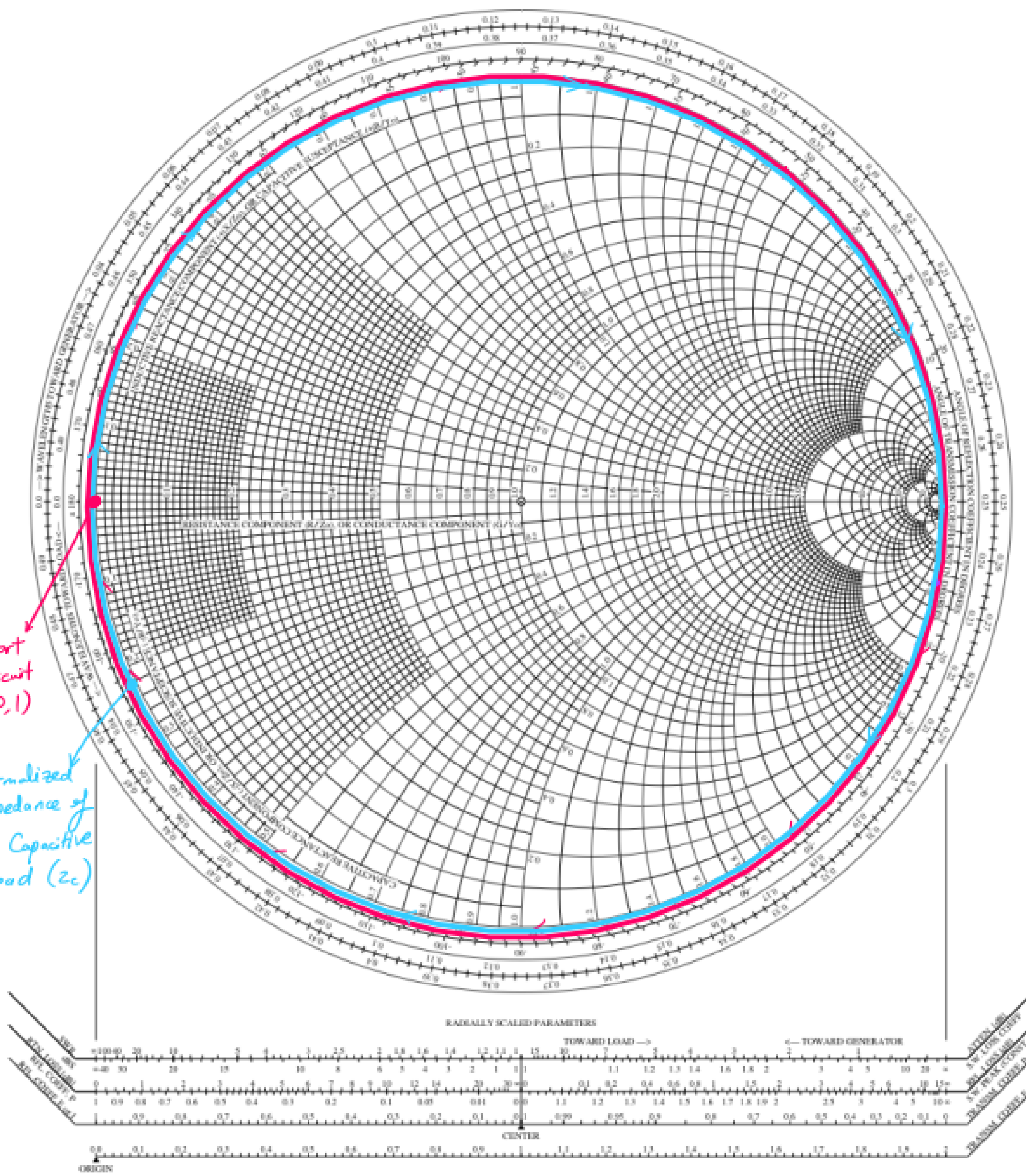
For the short circuit load our frequency is 1.4MHz meaning that we get a minimum v1 value every T = 0.877 μs. From the Smith Chart below, we can observe the outermost circle crosses the short circuit point (0,1) periodically as we loop around that circle.

For the capacitive load of capacitance C = 0.01 μF, our frequency is 1.4 as well, meaning that we get a minimum v1 value every T = 0.877. As Zc = 1/jωC we can conclude that the normalized impedance (zc) of the capacitive load will also have no real part and is purely reactive. Therefore it will also be on the same circle as the short circuit point which also has a real part of 0, in the Smith Chart. With this information we can conclude that the short circuit load and the capacitive load have repeated voltage minimas with the same span of time, as in the Smith Chart both are on the same circle with 0 resistance.

Although the frequency of occurrence is the same for both the short circuit and the capacitor case, we have different values for where the minimas occur. This is because the short circuit point and the capacitive load will be close but in different places in the Smith Chart, as they have different reactances. Therefore we can conclude that the frequencies would be similar but not the same.

The Complete Smith Chart

Black Magic Design



Capacitive Load $C = 0.01\ \mu F$

$$Z_c = \frac{1}{j\omega C} = \frac{1}{j2\pi f\, C} = \frac{1}{j2\pi\, 1.4\cdot 10^6 \cdot 0.01 \cdot 10^{-6}}$$

$$= \frac{1}{j\,0.088} = \frac{-j}{0.088} = -11.368j\ \Omega$$

$$z = \frac{Z_c}{Z_0} = \frac{-11.368j}{50} = -0.227j\ \Omega$$

Short Circuit $z_{sc} = 0 + 1j\ \Omega$

[5] Presentation and neatness.

[ ] Indicates the number of marks out of 100 total marks