STUDENT NAME:
STUDENT ID:
DATE:

LAB WORKBOOK
TEM TRANSMISSION LINE – PART #1 (INCIDENT WAVES)

- Submit for marking at the end of the 3-hour session!
- Write your name and student ID on each page (see top of page)!

PRETEST

(Write answers immediately below respective questions.)

1. If you measure the signal magnitudes at two points, V_{m1} and V_{m2}, along a lossy transmission line, and the distance between the two points is $D_{1,2}$, how can you calculate the attenuation constant α of the line in Np/m?

2. Repeat problem #1 this time for the attenuation α in dB/m.

3. In a TEM transmission line, the medium is characterized by relative permittivity $\varepsilon_r = 1$, relative permeability $\mu_r = 1$ and nonzero specific conductivity, $\sigma \neq 0$. Write the formula for the attenuation constant α of this line.

4. In a TEM transmission line, the medium is characterized by relative permittivity $\varepsilon_r = 1$, relative permeability $\mu_r = 1$ and nonzero specific conductivity, $\sigma \neq 0$. Write the formula for the phase constant β of this line.

5. What is the relation between the wavelength λ and the phase constant β?

6. What is the relation between the phase constant β and the phase velocity v_p?

7. What is the relation between the phase constant β and the group velocity v_g?

8. Assume we know the speed v and the frequency f of a sinusoidal TEM plane wave. How can we calculate the distance between two points P_1 and P_2 if we have measured the phase difference (phase delay) $\Delta\varphi_{12}$ between the signals recorded at the two points.

9. What is the main reason for signal (pulse) distortion in TEM transmission lines?

10. Write the phase velocity of a TEM line in terms of its capacitance per unit length and its inductance per unit length.

11. Draw the equivalent circuit of a TEM transmission line. Explain its components very briefly.

ADDITIONAL NOTES AND COMMENTS:

STUDENT NAME:
STUDENT ID:
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PRACTICE AND EXPERIMENTS

Experiment #1: Propagation of a Gaussian Pulse in a Matched Lossless Line

Step 1: Project Geometry

TABLE 1: STRUCTURE DESCRIPTION

Common Parameters		Transmission Line Geometry		
ΔL	1 mm		# of cells N_L	Physical size $N_L \Delta L$, mm
Δt	2.35865 ps	Width		
ε_r	1	Length		
σ	0 S/m	Probe 1 – Probe 2		
# probes	3	Probe 2 – Probe 3		

Step 2: Field Animation Observations

Q1: Does the pulse shape change as the pulse moves along the line? (circle one answer)

(a) YES (b) NO

Q2: The Gaussian pulse as a function of time has the general form $g(t) = g_m \exp(-\alpha t)$ where g_m and α are positive real constants. The Gaussian pulse that you observe, however, is a function of time and space and it moves with some constant velocity v along the line (the z-axis). Having in mind which way the positive z axis runs and which way the pulse runs, choose the expression which represents correctly the observed pulse.

(a) $g(t,z) = g_m \exp\left[-\alpha(t + z / v)\right]$ (b) $g(t,z) = g_m \exp\left[-\alpha(t - z / v)\right]$

(c) $g(t,z) = g_m \exp\left(-\alpha t + z / v\right)$ (d) $g(t,z) = g_m \exp\left(-\alpha t - z / v\right)$

Step 3: The Excitation Function

Q3: How many samples in time are used by the simulator to represent the Gaussian pulse of bandwidth 40 GHz?

(a) about 58 (b) about 100

Q4: Using the sampling time step Δt from TABLE 1, find the pulse duration for the 40-GHz Gaussian pulse:

(a) about 137 ps (b) about 236 ps

Q5: The Gaussian pulse $g(t) = g_m \exp(-\alpha t)$ is centered at $t = 0$, i.e., its maximum value g_m corresponds to $t = 0$. The 40-GHz Gaussian pulse that you observe is not centered at $t = 0$. What is the time t_0 at which it is centered?

(a) $t_0 = 68.4$ ps (b) 118 ps

STUDENT NAME:
STUDENT ID:
DATE:

Q6: Choose the formula which best describes the observed Gaussian pulse.

(a) $g(t) = 0.707 \exp\left[-\alpha(t + t_0)\right]$

(b) $g(t) = 0.707 \exp\left[-\alpha(t - t_0)\right]$

Q7: How long in time is the 20-GHz Gaussian pulse as compared with the 40-GHz Gaussian pulse?

(a) about the same

(b) twice shorter

(c) twice longer

(d) three times longer

Q8: Is the time duration of the pulse related to its bandwidth? Why?

Step 4: Measuring the Velocity of Propagation

TABLE 2: VELOCITY OF PROPAGATION

Probe 1 maximum at:		time-steps
Probe 2 maximum at:		time-steps
Delay in time steps, N_d :		time-steps
Physical delay, $D_t = N_d \Delta t$		10^{-12} seconds
Physical distance Probe 1 to Probe 2		mm
Velocity (calculated)		m/s
Velocity (theory)		m/s

*Check with TABLE 1 for the values of ΔL and Δt as well as the distance between Probes 1 and 2.

Q9: How did you calculate the theoretical pulse velocity in TABLE 2?

Step 5: Computing Distance from Phase Delay

TABLE 3: DISTANCE FROM PHASE DELAY

Frequency	φ_1, deg	φ_2, deg	$\Delta\varphi_{12}$, deg	D_{12} from $\Delta\varphi_{12}$, mm	D_{12} from TABLE 1, mm
10 GHz					

Q10: How did you calculate D_{12} from $\Delta\varphi_{12}$?

STUDENT NAME:
STUDENT ID:
DATE:

Experiment #2: Propagation of a Sinusoidal Wave in a Lossless Line

Step 1: Defining the Sinusoidal Source Waveform

Q11: From the plot of the 6-GHz sinusoidal waveform, how many time steps (time samples) there are in one period?

(a) 35
(b) 70
(c) 105
(d) 140

Q12: Calculate the period T of the waveform using Δt from TABLE 1 and your answer in Q11.

$T =$

Q13: Calculate T from the known frequency $f = 6$ GHz and compare the result with the calculation in Q12.

$T =$

Step 2: Field Animation Observations

Q14: How many wavelengths of the sinusoidal wave fit in the observed section of the transmission line:

(a) about 1 λ
(b) about 2 λ
(c) about 2.25 λ
(d) about 3 λ

Q15: Which expression describes correctly the observed sinusoidal wave?

(a) $\sim Me^{-\alpha z}\sin(\omega t + \beta z)$, $\alpha \neq 0$
(b) $\sim M\sin(\omega t + \beta z)$
(c) $\sim Me^{-\alpha z}\sin(\omega t - \beta z)$, $\alpha \neq 0$
(d) $\sim M\sin(\omega t - \beta z)$

Step 3: Observing the Envelope of the Traveling Wave

Q16: What is the value of the maximum voltage $V_{\max}$ of the wave envelope along the transmission line?

(a) 0.1 V
(b) 1 V
(c) 100 V
(d) 10 V

Q17: What is the value of the minimum voltage $V_{\min}$ of the wave envelope along the transmission line?

(a) 0.1 V
(b) 1 V
(c) 100 V
(d) 10 V

Q18: What is the standing wave ratio (SWR) for the observed wave?

(a) 2
(b) 0.1
(c) 1
(d) 10 V

Q19: What type of wave is the observed voltage wave?

(a) standing
(b) mixed
(c) traveling
(d) none of the above

Step 4: Measuring the Frequency and the Wavelength of a Traveling Wave

TABLE 4: FREQUENCY AND WAVELENGTH MEASUREMENTS

	Set-up/Theory	Measured
Frequency, GHz		
Wavelength, mm		

Q20: How did you calculate the wavelength from the frequency in TABLE 4?

Experiment #3: Propagation of a Sine Wave in a Lossy Line

Step 1: Observation and Measurement of the Attenuation of the Sinusoidal Wave

Q21: From your observations of the wave animation and the probe outputs, what can you conclude about the magnitude of the sine wave as it travels down the lossy line?

(a) stays the same
(b) decreases
(c) increases

TABLE 5: ATTENUATION CONSTANT

V_{m1}, V	V_{m3}, V	$D_{1,3}$, m	α, Np/m	α, Np/m, theory

Q22: How did you compute the attenuation constant α from V_{m1}, V_{m3} and $D_{1,3}$?

$\alpha =$

STUDENT NAME:
STUDENT ID:
DATE:

Q23: How did you compute the theoretical attenuation constant α from the medium constitutive parameters ε, σ, and μ?

$\alpha =$

Q24: Calculate α in dB/m.

$\alpha =$

Step 2: Observation of the Envelope of Attenuated Sinusoidal Wave

TABLE 6: MEASUREMENT OF THE ATTENUATION CONSTANT FROM THE ENVELOPE

	Magnitude, V	Position, mm	Distance $D_{1,2}$, mm	α, Np/m
V_{m1}				
V_{m2}				

Q25: Is the value of α in TABLE 6 similar to that in TABLE 5?

Step 3: Measurement of the Wavelength of the Attenuated Sinusoidal Wave

TABLE 7: WAVELENGTH IN THE LOSSY LINE

	Measured	Theory
Wavelength, mm		

Q26: How did you calculate the theoretical wavelength in TABLE 7?

STUDENT NAME:
STUDENT ID:
DATE:

Experiment #4: Propagation of a Gaussian Pulse in a Lossy Line

Step 1: Observation of the Attenuated Traveling Pulse

Q27: Which of the three pulses recorded by the probes is delayed in time the most?

(a) that of Probe 1
(b) that of Probe 2
(c) that of Probe 3
(d) they all have the same delay

Q28: Which of the three pulses is the weakest?

(a) that of Probe 1
(b) that of Probe 2
(c) that of Probe 3
(d) they all have the same magnitude

Step 2: Measuring the Attenuation of the Pulse

TABLE 8: MEASUREMENT OF THE PULSE ATTENUATION

	Magnitude, V	Position, mm	Distance $D_{1,2}$, mm	α, Np/m
V_{m1}				
V_{m2}				

Q29: Is there agreement between the attenuation of the Gaussian pulse and the sinusoidal wave? Why?

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