ECE 526

PROTECTION OF POWER SYSTEMS II

SESSION no. 19

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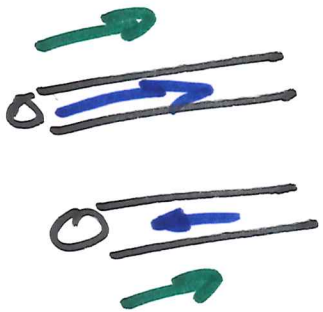
Propagation Constant, Attenuation, Phase and Velocity

Propagation Constant $\gamma = \alpha + j\beta$

Attenuation constant

Phase constant

Propagation velocity at a particular frequency ω



$$v(\omega) = \frac{\omega}{\beta}$$

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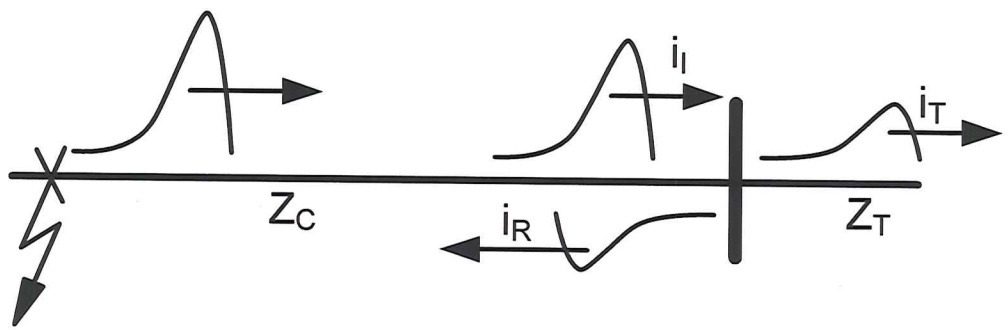
Incident, Reflected and Transmitted TWs



$$\frac{v}{i} = \frac{v_I + v_R}{i_I + i_R} = Z_T$$

$$v_R = \frac{Z_T - Z_C}{Z_T + Z_C} v_I = \Gamma_v v_I$$

VOLT REFLECTION COEF.

$$\Gamma_I = \frac{Z_C - Z_T}{Z_C + Z_T}$$

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Clarke Components Extract Aerial and Ground Modes

$$\begin{bmatrix} I_\alpha^A \\ I_\beta^A \\ I_0^A \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 2 & -1 & -1 \\ 0 & \sqrt{3} & -\sqrt{3} \\ 1 & 1 & 1 \end{bmatrix}\begin{bmatrix} I_A \\ I_B \\ I_C \end{bmatrix}$$

$$I_\alpha^A = I_A - I_0$$

$$I_\alpha^B = I_B - I_0$$

$$\begin{bmatrix} I_\alpha^B \\ I_\beta^B \\ I_0^B \end{bmatrix} = \frac{1}{3}\begin{bmatrix} -1 & 2 & -1 \\ -\sqrt{3} & 0 & \sqrt{3} \\ 1 & 1 & 1 \end{bmatrix}\begin{bmatrix} I_A \\ I_B \\ I_C \end{bmatrix}$$

$$\begin{bmatrix} I_\alpha^C \\ I_\beta^C \\ I_0^C \end{bmatrix} = \frac{1}{3}\begin{bmatrix} -1 & -1 & 2 \\ \sqrt{3} & -\sqrt{3} & 0 \\ 1 & 1 & 1 \end{bmatrix}\begin{bmatrix} I_A \\ I_B \\ I_C \end{bmatrix}$$

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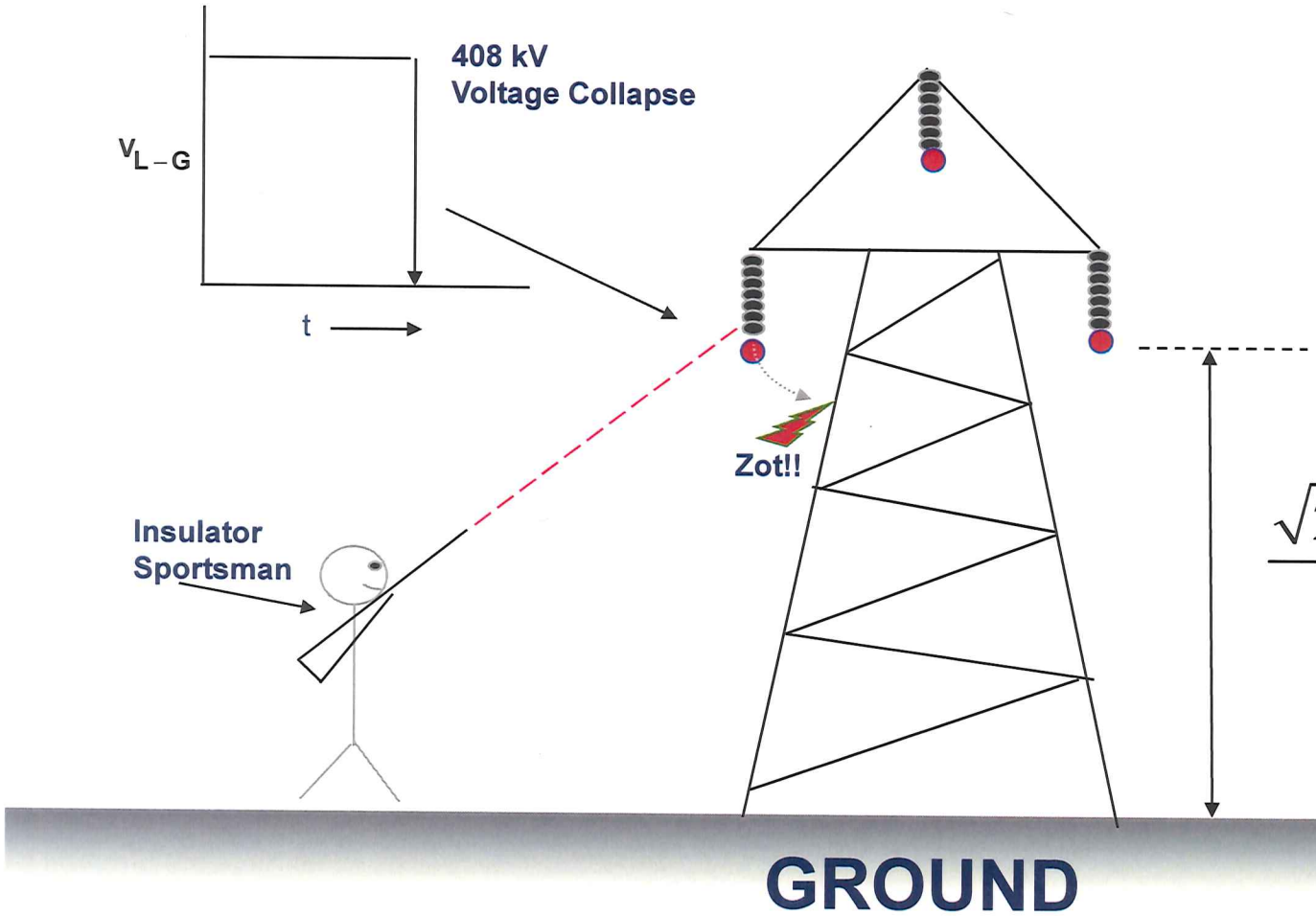
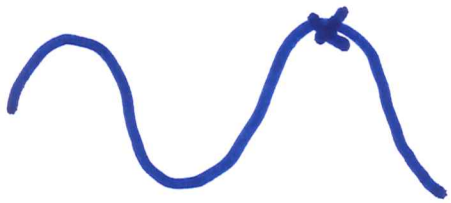
Out on the Power Line
(The birth of a traveling wave)





$$\frac{\sqrt{2}\cdot 500}{\sqrt{3}}\text{kV} = 408\text{kV}$$

$Z = \frac{V}{I}$; $I = \frac{V}{Z}$

CHARAC. Z

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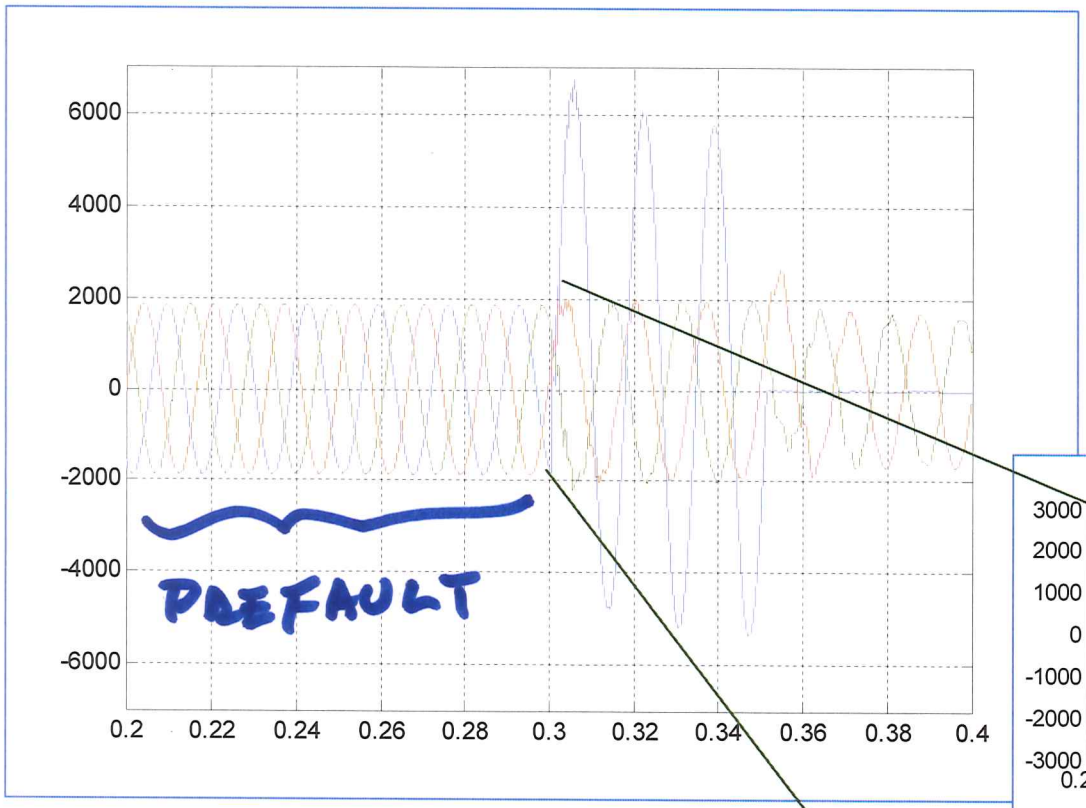
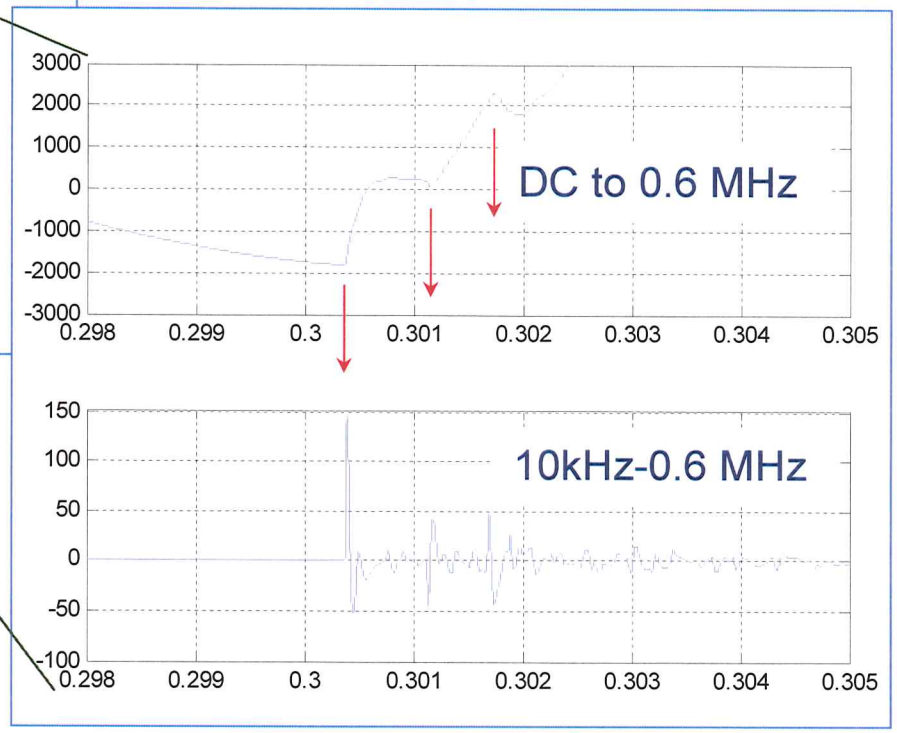
Transients Contain Fault Information

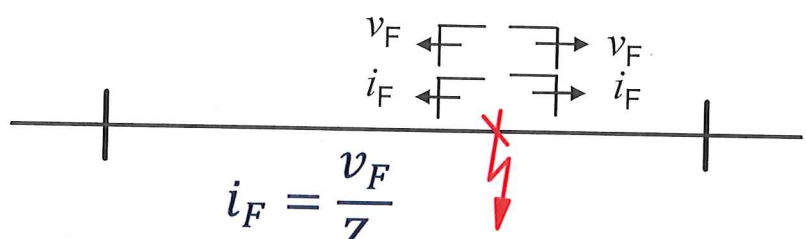


High frequency transients contain precise information about location of the fault



At the Instant of Voltage Collapse

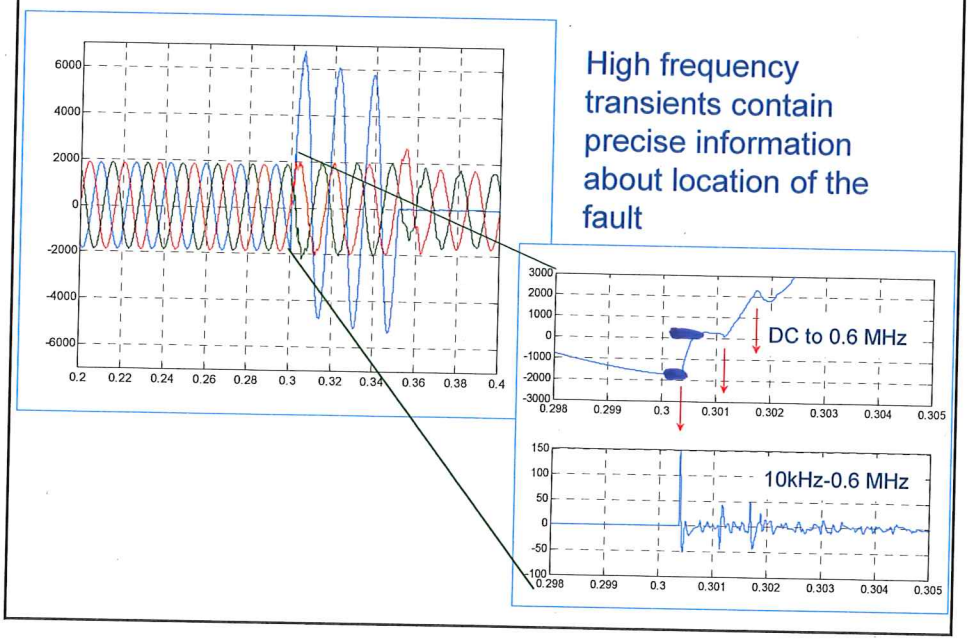
- A traveling 408 kV wave front emanates in both directions on the faulted conductor
- Current waves are con"currently*" produced



$$i_F = \frac{v_F}{Z_c}$$

$-\frac{1}{2}$ d volt on other 2 phases
curr
due

Transients Contain Fault Information



High frequency transients contain precise information about location of the fault

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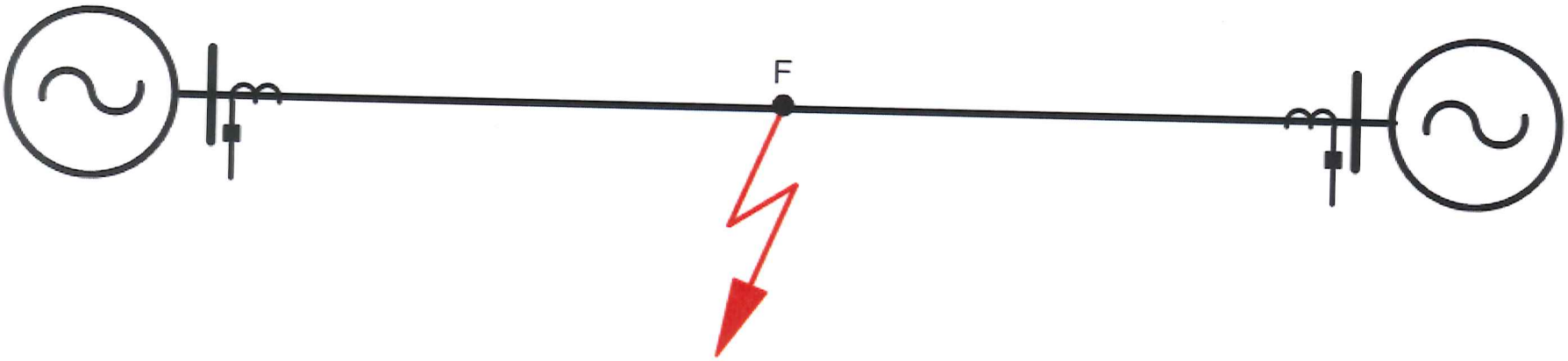
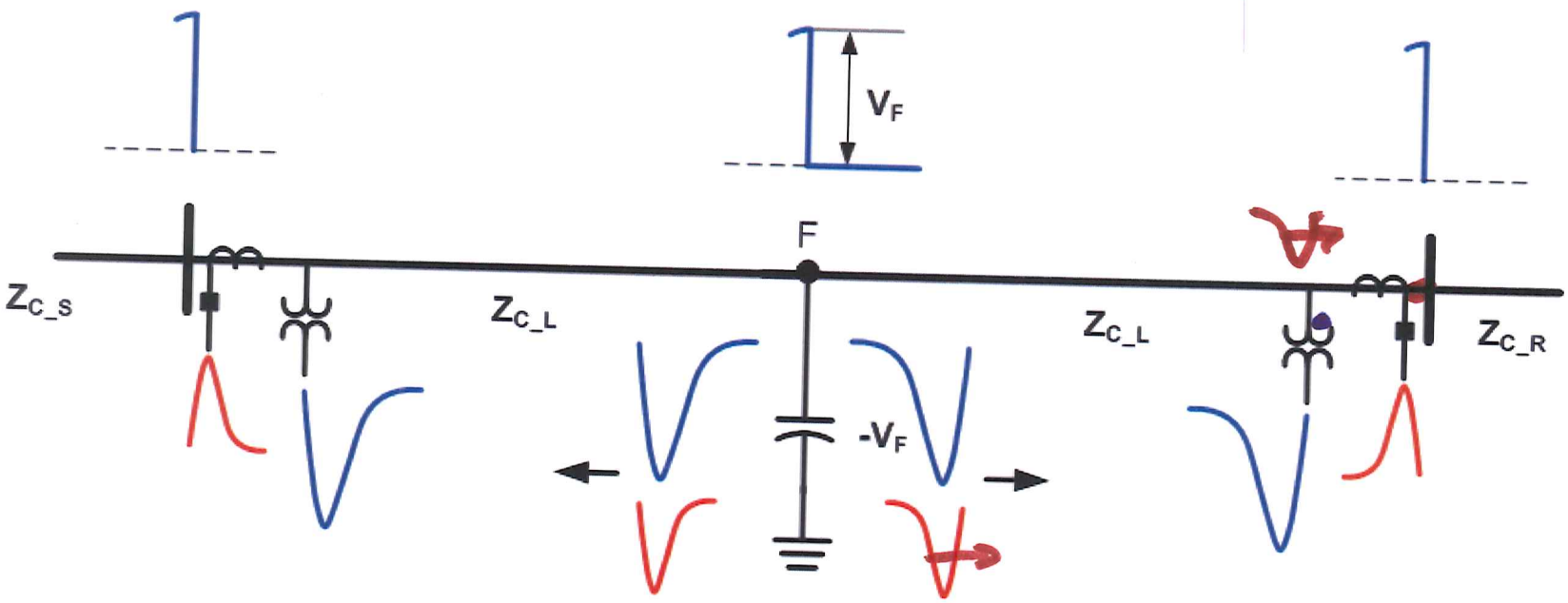
TW Polarities as Seen by the Relays





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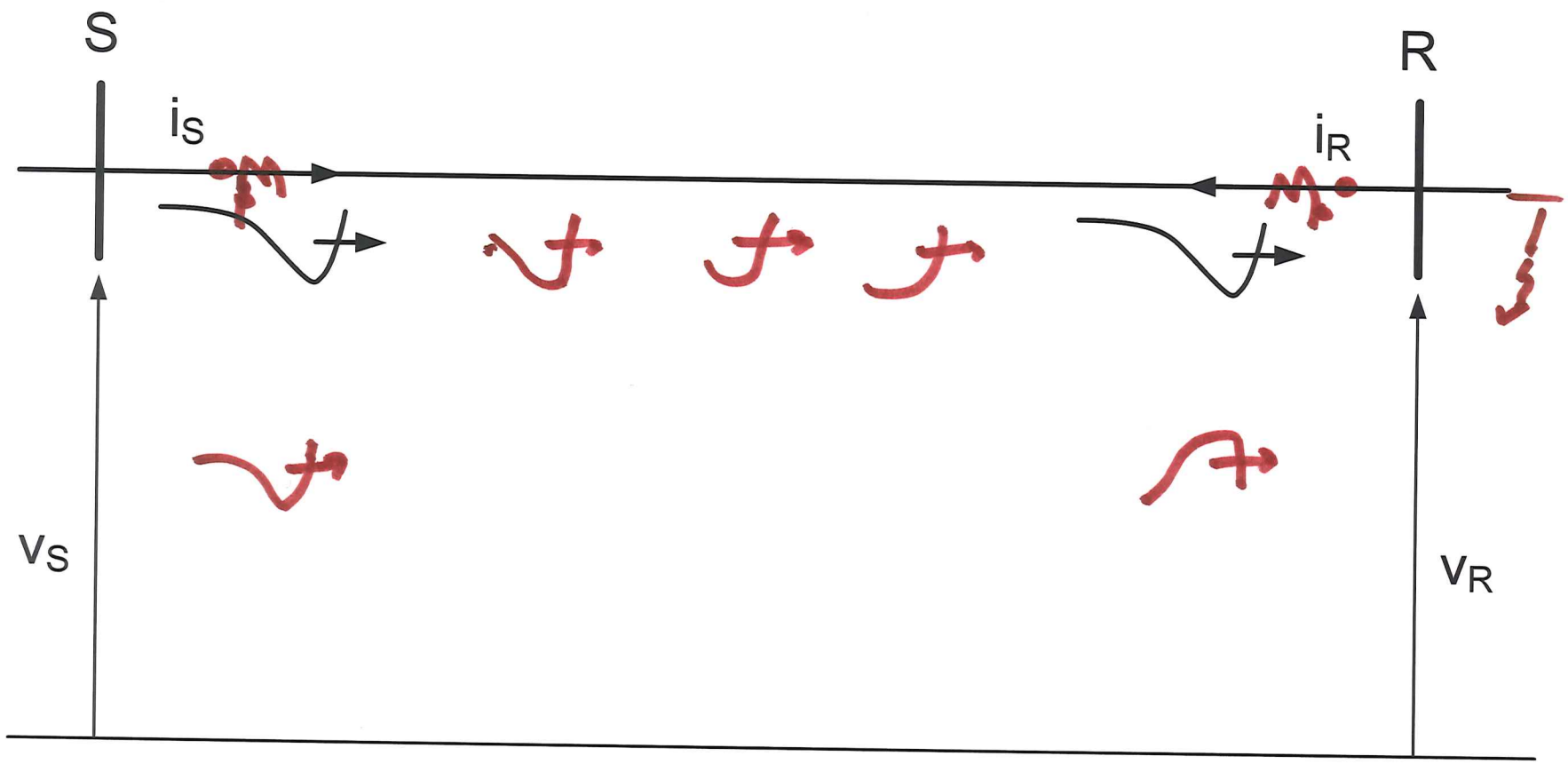
Current Only TW Differential Principle



$$i_{RT1(t)} = \left| i_{S(t)} - i_{R(t-\tau)} \right|$$

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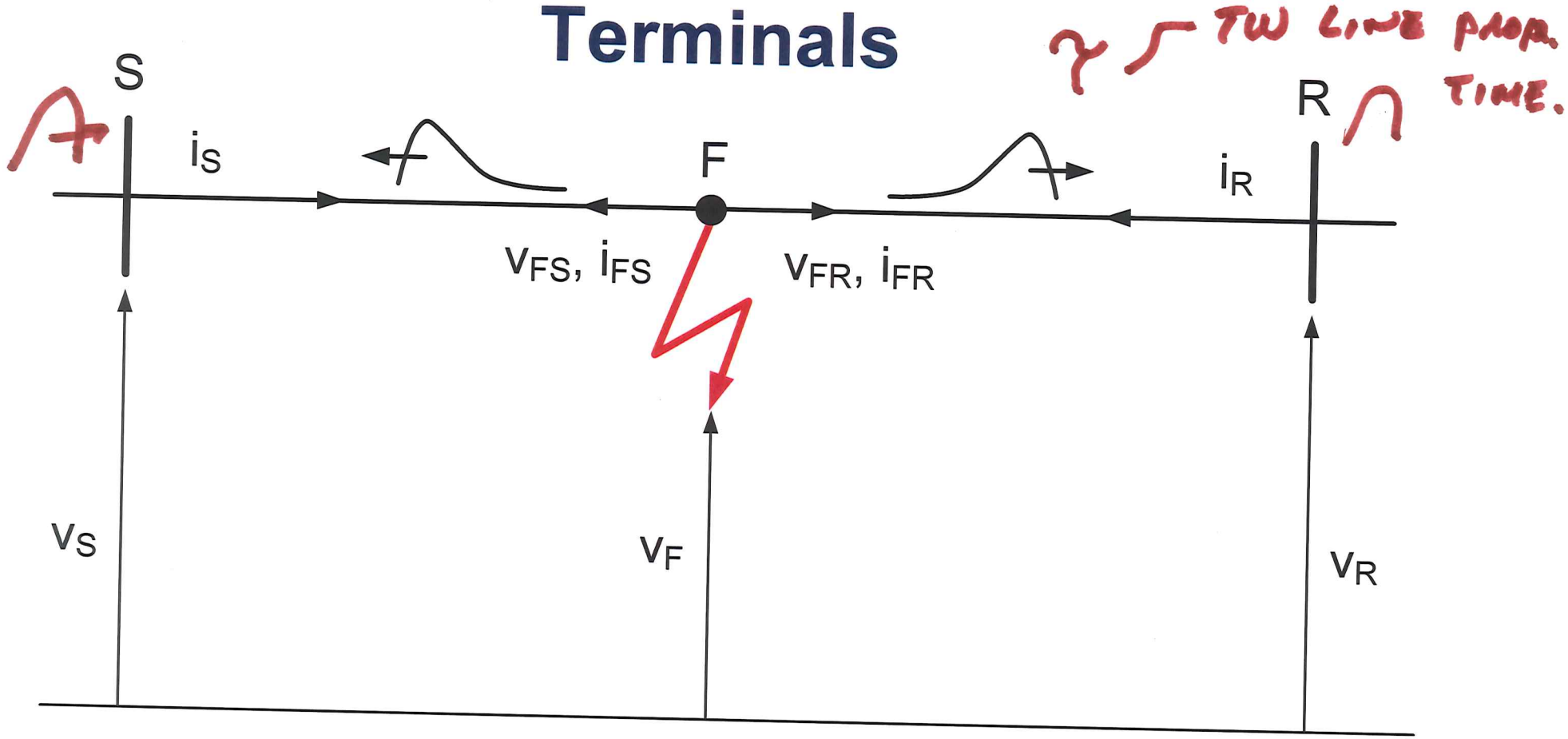
Waves Traveling Toward the Line Terminals



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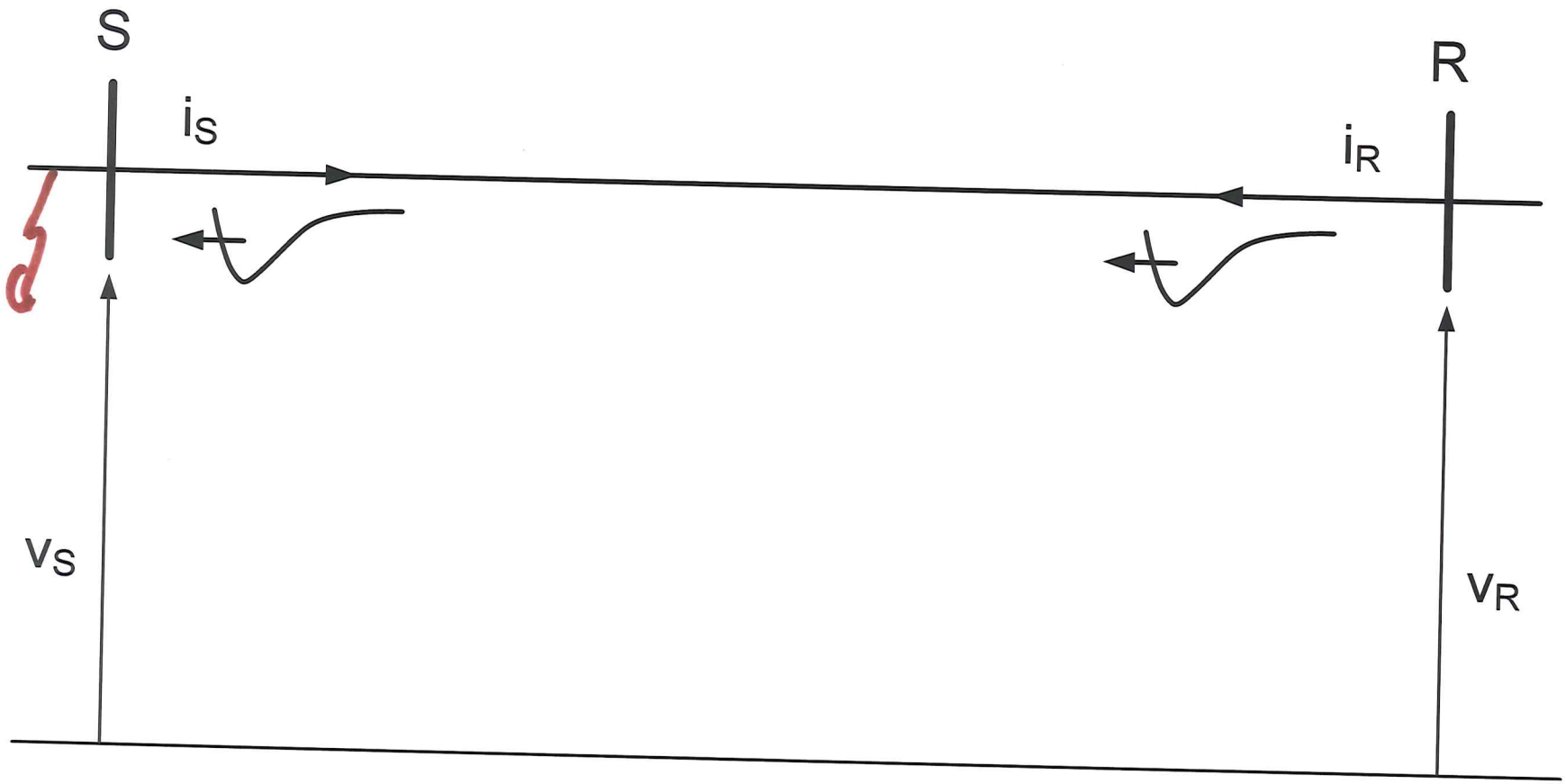
Current Only TW Differential Principle



$$i_{RT2(t)} = \left| i_{R(t)} - i_{S(t-\tau)} \right|$$

$$i_{RT} = MAX(I_{RT1}, I_{RT2})$$

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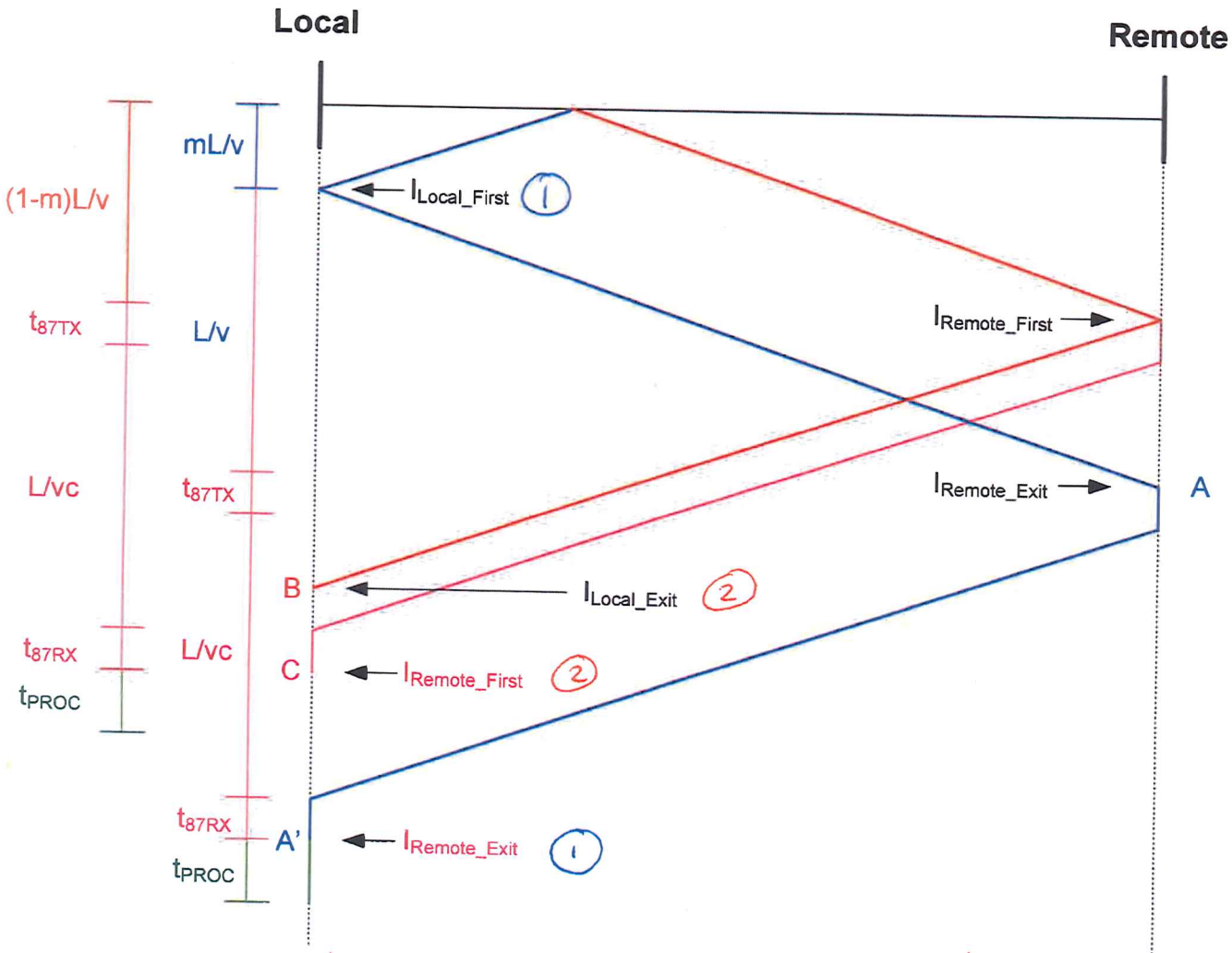

$I_{op} = |I_{LOCAL\_FIRST} + I_{REMOTE\_FIRST}|$

$I_{RT1} = |I_{LOCAL\_FIRST} - I_{REMOTE\_EXIT}|$

$I_{RT2} = |I_{REMOTE\_FIRST} - I_{LOCAL\_EXIT}|$

$I_{RT} = MAX(I_{RT1}, I_{RT2})$

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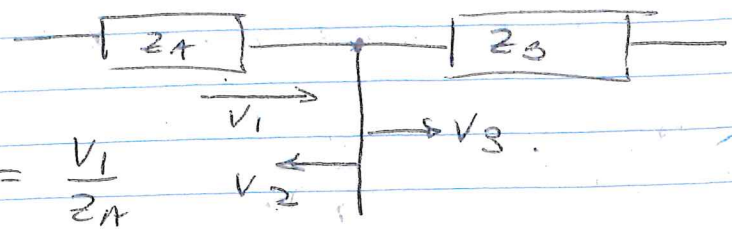
$Z_A > Z_B$



INCIDENT $I_1 = \frac{V_1}{Z_A}$

REFLECTED $I_2 = -\frac{V_2}{Z_A}$

REFRACTED WAVES $I_3 = \frac{V_3}{Z_B}$

$V_1 + V_2 = V_3$

$I_1 + I_2 = I_3$

REFLECTION COEF VOLTAGES

$$\Gamma_V = \frac{Z_B - Z_A}{Z_A + Z_B}$$

REFRACTION COEF

$$\gamma_V = \frac{2 \cdot Z_B}{Z_B + Z_A}$$

$$\Gamma_i = \frac{Z_A - Z_B}{Z_A + Z_B}$$

$$\gamma_i = \frac{2 \cdot Z_A}{Z_A + Z_B}$$