



2014

PRAGMA 26 Workshop

4.9-4.11 Tainan, Taiwan



# Cyber-Learning Activities in Taiwan --- EM Education

Hsi-Ching Lin  
NCHC

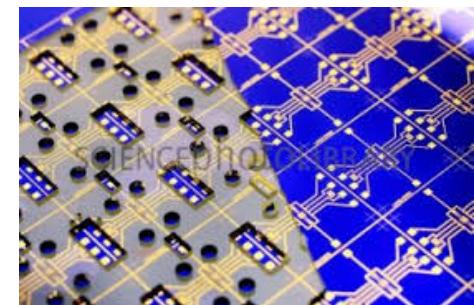
# Agenda

- Motivation
- Mission
- Organization
- The Role of the Platform by NCHC
- Conclusion & Future Work
- Q&A

# Motivations

## Importance of EM field theory

- From ELF to visible light
- From nano devices to ALMA.
- From communication to forecasting



# Motivations

## Challenges in EM educations

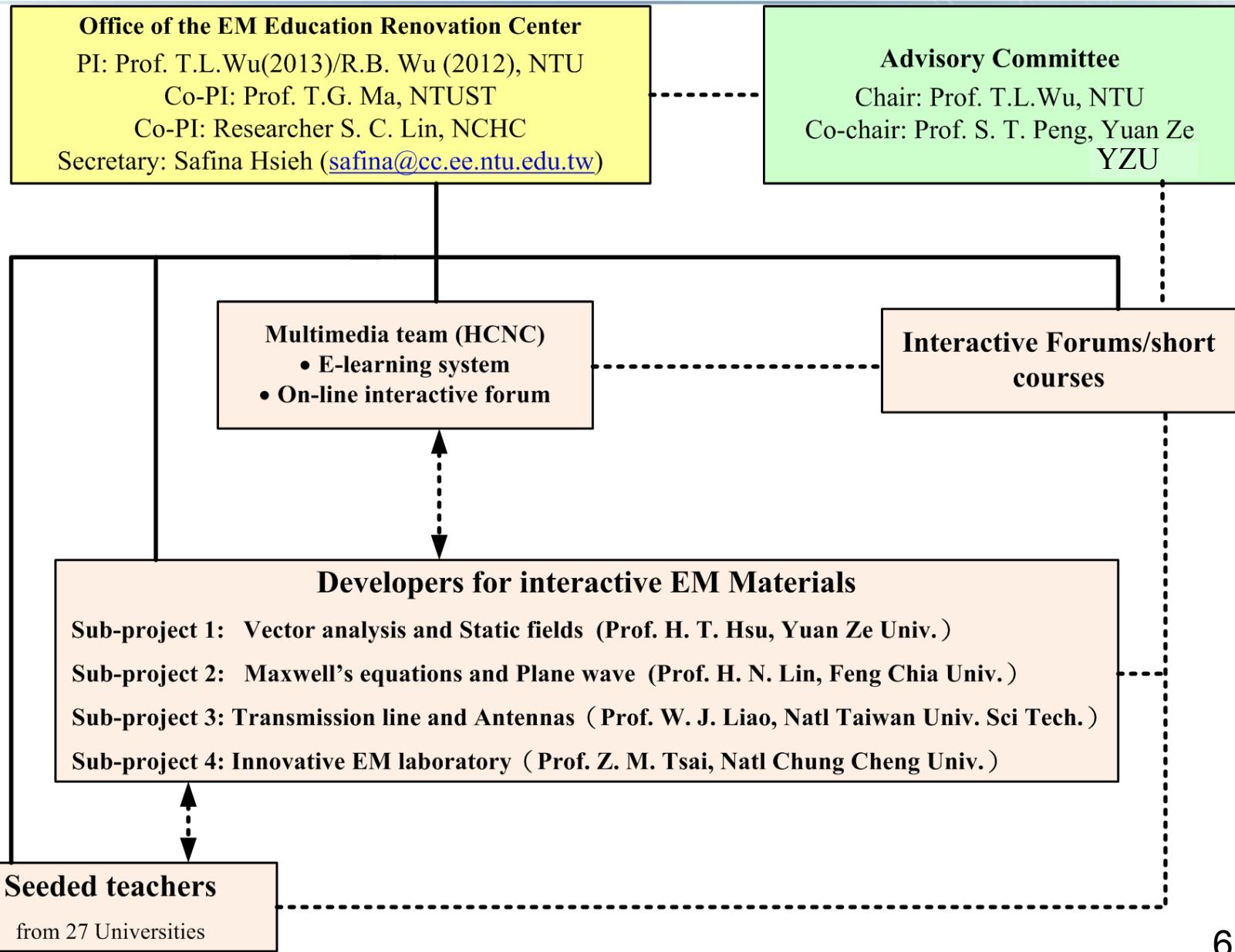
- The very first course in EE that simultaneously requires
  - Mathematical skills with vector calculus
  - Physical understanding of wave propagation
- Long history, but we have a very limited time.
- Challenges from the emergent new fields in EE.
- Tendency of downplaying in the curricula in many universities.

# Mission

## Project S A V E

- Simplicity
  - Accessibility
  - Visualization
  - Edutainment
- Initiated and inspired by Prof. Peng and Prof. Wu in 2011.

# Organization



# Budget

- Two-year grant sponsored by the Ministry of Education, Taiwan.
- Courseware development: NTD 16,000,000.
- Promotion Program: NTD 27,000,000  
(27 universities in Taiwan to evaluate the developed materials through trial teaching.)
  - ✓ Provide feedback from the students
  - ✓ to evaluate and enhance the quiz bank.

# The Platform base on the Main Principle

SIMPLICITY

ACCESSIBILITY

Cyber-Learning  
Platform for EM  
Education

VISUALIZATION

EDUTAINMENT

# Simplicity

- Redraw the roadmap for fundamental EM education in Taiwan.
- Comply with the goal of simplifying and condensing the contents.
- Not to reproduce what in existent textbooks, but to develop innovative teaching thoughts and approaches.

# Accessibility

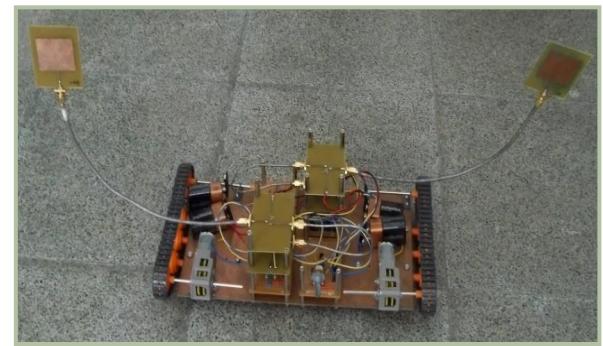
- Providing seamless accessibility regardless of the platforms.
- Taking advantage of modern mobile devices and high speed data links.
- Establishing tight connection with National Center for High-performance Computing (NCHC), Taiwan.

# Visualization

- A number of EM Animations to elaborate the physical phenomena in EM fields/waves.
  - ✓ Have received excellent feedbacks.
- Video chips for self-learning
  - ✓ Semi-open course ware.
  - ✓ 15-20 mins per chip.
  - ✓ Customized self-learning paths.
  - ✓ Adaptive learning curve.

# Edutainment

- Have fun with Creative “LEGO” Experiments.
  - ✓ to stimulate students’ curiosity and interest toward EM theory.
- Have fun with EM Animations.
  - ✓ It does work!
- Have fun with the Video Chips and
  - ✓ “Enjoy” a quiz bank with more than 2200 problems collected from experts in Taiwan.

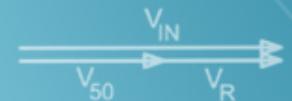
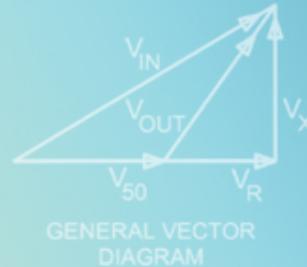


# Cyber-Learning Platform for EM Education

## ■ SAVE

- S: provide **simplicity** and understandability multimedia course material
- A: learning **accessibility** via internet
- V: provide **visualization** EM math equation animation and simulation to help students understand EM math equations
- E: learning through **edutainment** with multimedia course material, EM math equation animation and test bank





PURE RESISTIVE LOAD  
 $V_R = V_{OUT}$



PURE INDUCTIVE (OR CAPACITIVE) LOAD  
 $V_X = V_{OUT}$

$$V_R = \frac{V_{IN}^2 - V_{50}^2 - V_{OUT}^2}{2V_{50}}$$

$$V_X = \sqrt{V_{OUT}^2 - V_R^2}$$

$$I = \frac{V_{50}}{50}$$

$$SWR = \frac{A+B}{A-B}$$

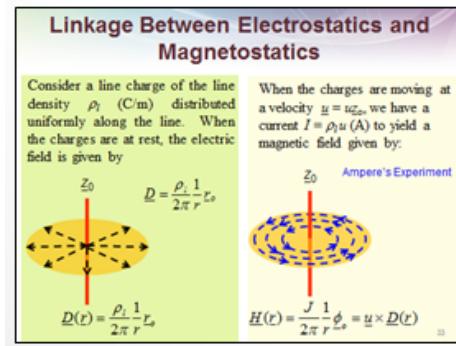
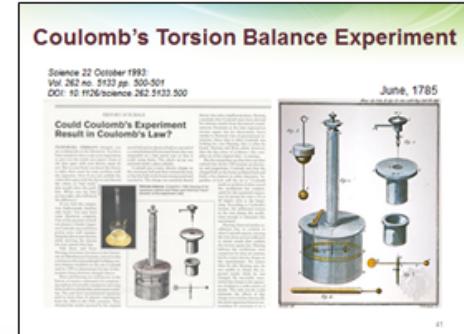
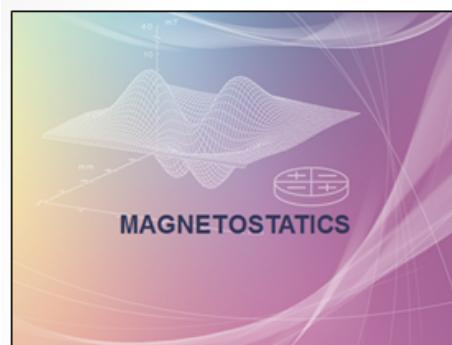
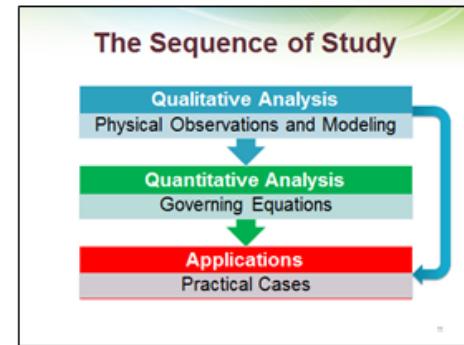
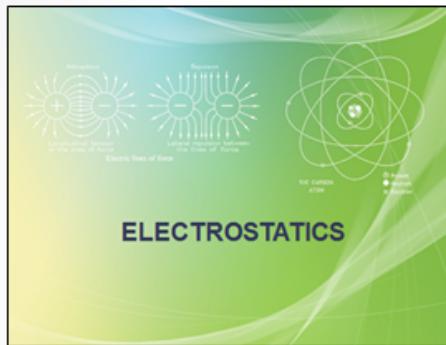
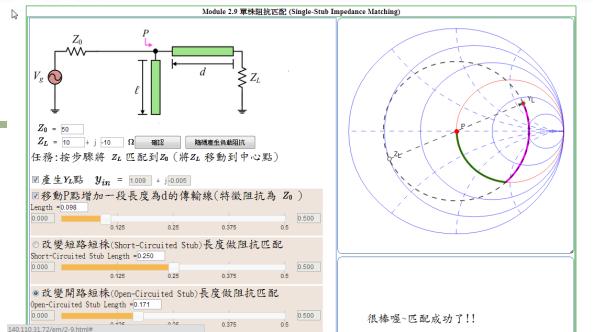
WHERE

$$A = \sqrt{(R+50)^2 + X^2}$$

$$B = \sqrt{(R-50)^2 + X^2}$$

# Simplicity Accessibility Visualization Edutainment

# Some samples of the slides



Magnetization and Equivalent Current Densities

Small Magnetic Dipole Moment:  $d\vec{M}(r) = \frac{\mu_0 M \times r}{4\pi r^3} dv$

Volume of Magnetic Dipole Moment:  $dV = \frac{\mu_0}{4\pi} \int_V M(r') \times \nabla' \frac{1}{r'} dv'$

Vector Identity:  $\vec{A}(r) = \frac{\mu_0}{4\pi} \int_V \left[ \frac{\nabla' \times M(r')}{r'} - \nabla' \times \frac{M(r')}{r'} \right] dv'$

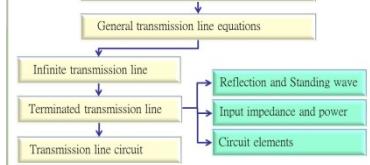
Generalized Stokes' Theorem:  $\vec{A}(r) = \frac{\mu_0}{4\pi} \int_V \frac{\nabla' \times M(r')}{r'} dv' + \int_S ds \cdot \frac{M(r') \times \hat{n}}{r}$

What is the difference btw lump circuit and transmission line?!

- In real life, without the radio or Internet, you only know that there is a traffic jam when you ran into one.
- As to transient signal in transmission line, signal gets reflected or attenuated when arrives on a discontinuity
- Transmission line is also referred as “distributed circuit” since EM fields are determined by local line properties



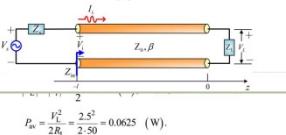
# Teaching Material Simplicity



Series resistance per unit length	R	Ohm/meter ( $\Omega/\text{m}$ )	$\text{MLT}^2\text{Q}^2$
Series inductance per unit length	L	Henry/meter ( $\text{H}/\text{m}$ )	$\text{MLQ}^2$
Shunt conductance per unit length	G	Siemens/meter ( $\text{S}/\text{m}$ )	$\text{M}^2\text{L}^2\text{TQ}^2$
Shunt capacitance per unit length	C	Farad/meter ( $\text{F}/\text{m}$ )	$\text{M}^2\text{L}^{-2}\text{TQ}^2$



$$\text{SWR} = \frac{1 + |\Gamma_s|}{1 - |\Gamma_s|} = \frac{1 + 0.422}{1 - 0.422} = 2.46.$$



**Definition of Scalar or Dot Product**

Consider a point charge,  $Q$ , in the free space.

For a vector  $\Delta$ , its components are  $\Delta_x, \Delta_y, \Delta_z$ .

1. The position vectors from the origin to the points  $P$  and  $Q$  are  $\Delta_P = \Delta_0 + \Delta_0^2 - \Delta_0$ , and  $\Delta_Q = \Delta_0^2 + \Delta_0^2 + \Delta_0^2$ , respectively.

Determine  $\Delta_P \cdot \Delta_Q$ .

2. Given vectors  $\Delta = \Delta_0^2 + \Delta_0^2 - \Delta_0^2 - \Delta_0^4$ ,  $\bar{\Delta} = -\Delta_0^3 - \Delta_0^2 + \Delta_0^3$ , find  $\Delta \cdot \bar{\Delta}$ .

3. A Vector  $\Delta$  starts at point  $(1, 0, 2)$  and ends at point  $(3, 2, 2)$  in rectangular coordinate system. Find the unit vector in the direction of  $\Delta$ .

4. A Vector field  $\vec{E}$  is given by  $\vec{E} = E_0 \cos \theta + E_0 \sin \theta \cos \phi + E_0 \sin \phi$  in spherical coordinate systems. Determine the component of  $\vec{E}$  tangential to the spherical surface  $r = 5$  at point  $P = (5, 60^\circ, 30^\circ)$ .

5. Given a vector  $\Delta = \Delta_0^2 - \Delta_0^3 - \Delta_0$ , find the unit vector of  $\Delta$ .

6. A set of 2D orthogonal vectors  $\Delta$  and  $\bar{\Delta}$  are given by  $\Delta$  and  $\bar{\Delta}$  is formed by rotating the  $x-y$  coordinate system counter-clockwise by  $\alpha$  degrees as shown. Given vector  $\Delta = \Delta_0^2 + \Delta_0^2 \Delta_0^4$  express in terms of  $\Delta$  and  $\bar{\Delta}$ .

Given vector  $\Delta = \Delta_0^2 + \Delta_0^2 \Delta_0^4$  express in terms of  $\Delta$  and  $\bar{\Delta}$ .

**Modeling of Coulomb's Force**

Consider a point charge,  $Q$ , in the free space.

For a vector  $\Delta$ , its components are  $\Delta_x, \Delta_y, \Delta_z$ .

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Determine  $\Delta_P + \Delta_Q$ .

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**Moving Circuit in Time-Varying Magnetic Field**

1. The position vectors from the origin to the points  $P$  and  $Q$  are  $\Delta_P = \Delta_0 + \Delta_0^2 - \Delta_0$ , and  $\Delta_Q = \Delta_0^2 + \Delta_0^2 + \Delta_0^2$ , respectively.

Determine  $\Delta_P + \Delta_Q$ .

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Given vector  $\Delta = \Delta_0^2 + \Delta_0^2 \Delta_0^4$  express in terms of  $\Delta$  and  $\bar{\Delta}$ .

Divide the full teaching material (ppt) into several short teaching materials.

# Content Management System

**Definition of Scalar or Dot Product**

Given two vectors :

$$\vec{A} = x_1 \hat{x}_1 + y_1 \hat{y}_1 + z_1 \hat{z}_1$$
$$\vec{B} = x_2 \hat{x}_2 + y_2 \hat{y}_2 + z_2 \hat{z}_2$$

The angle between them :  $\theta_{AB}$

The scalar or dot product of the two vectors is defined as:

$$\vec{A} \cdot \vec{B} = \vec{B} \cdot \vec{A} = |\vec{A}| |\vec{B}| \cos \theta_{AB}$$

**Modeling of Coulomb's Force**

Consider a point charge,  $Q$ , in the free space.

- ✓ For a test charge at a point on the spherical surface with its center at the location of the charge,  $Q$ , the Coulomb's force must be in the radial direction.
- ✓ From geometrical consideration, the Coulomb's force must distribute uniformly over the spherical surface, as shown below.

**Moving Circuit in Time-Varying Magnetic Field**

$\vec{E}' = \vec{E} + \vec{u} \times \vec{B}$   
 $\Rightarrow \vec{E} = \vec{E}' - \vec{u} \times \vec{B}$

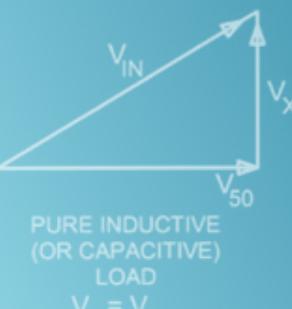
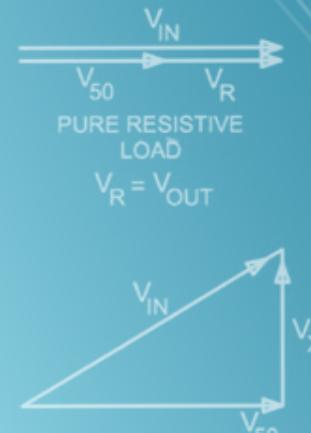
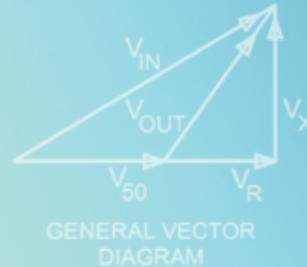
since  $\int_C \vec{E} \cdot d\vec{l} = - \int_S \frac{\partial \vec{B}}{\partial t} \cdot d\vec{s} + \int_C (\vec{u} \times \vec{B}) \cdot d\vec{l}$

emf induced in loop due to time variation of magnetic field  
motion and due to moving circuit in magnetic field

Contents and  
Interactive Animations

Test Bank

Content Management System



# Simplicity Accessibility Visualization Edutainment

$$V_R = \frac{V_{IN}^2 - V_{50}^2 - V_{OUT}^2}{2V_{50}}$$

$$V_X = \sqrt{V_{OUT}^2 - V_R^2}$$

$$I = \frac{V_{50}}{50}$$

$$SWR = \frac{A+B}{A-B}$$

WHERE

$$A = \sqrt{(R+50)^2 + X^2}$$

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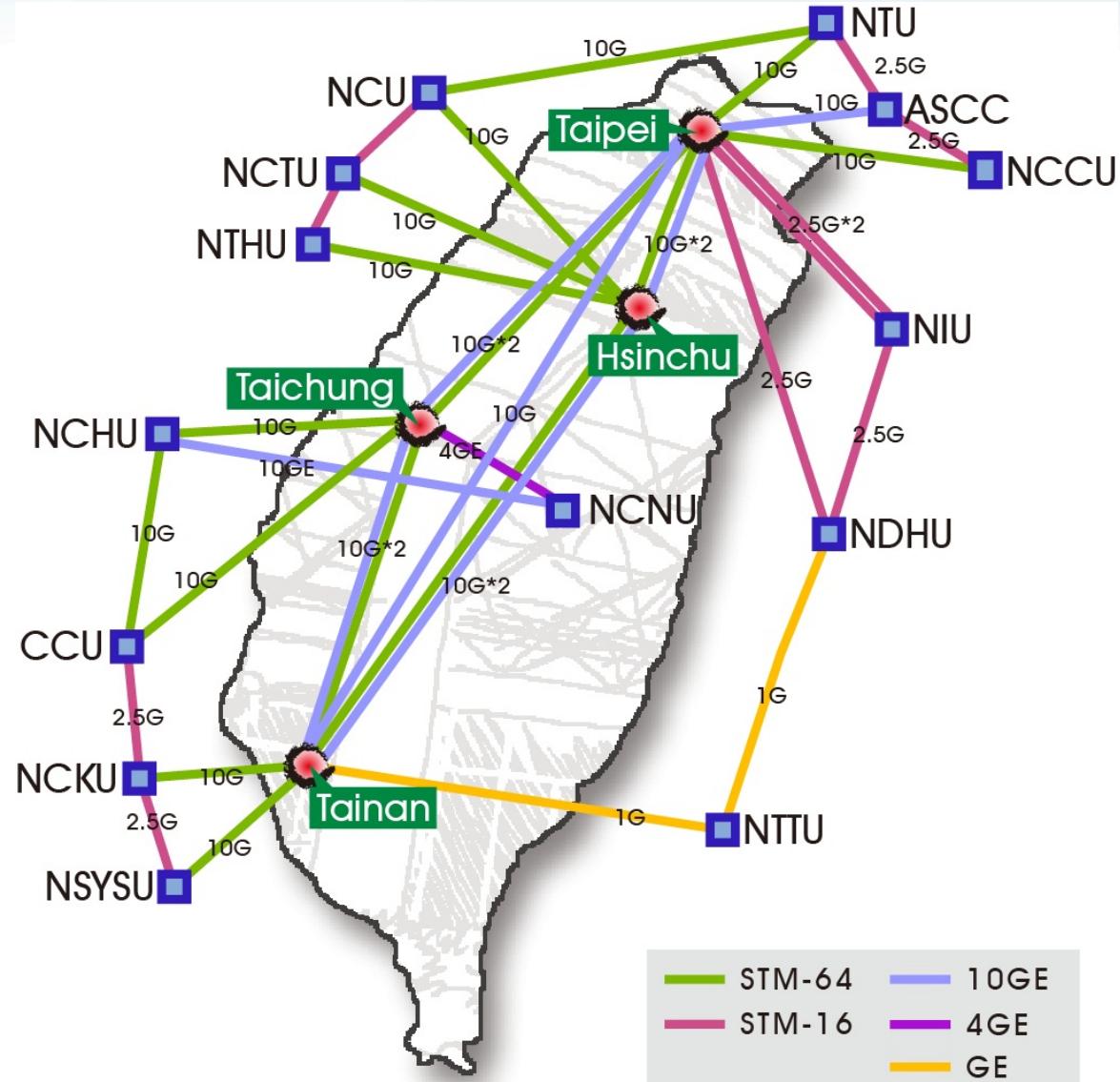
# TWAREN Backbone Map

## ■ four core nodes

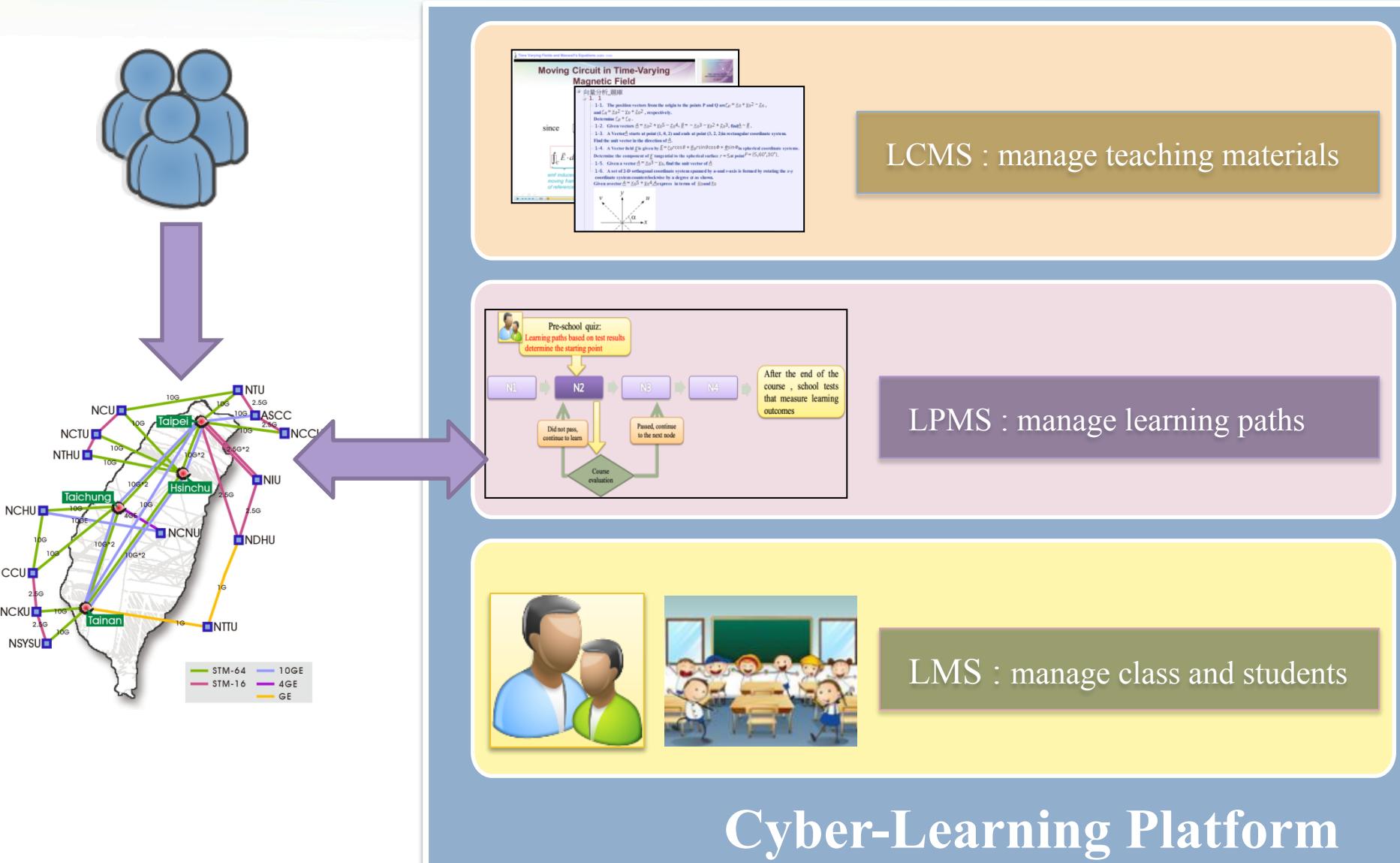
- The Taipei Node: Taipei Technology Building
- The Hsinchu Node: Hsinchu Headquarter, NCHC
- The Tainan Node: Southern Business Unit, NCHC
- The Taichung Node: Central Business Unit, NCHC

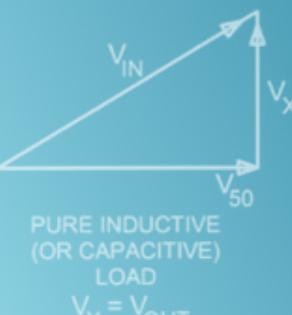
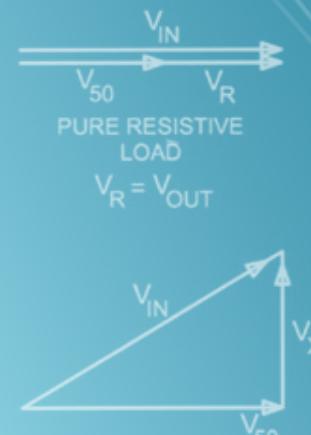
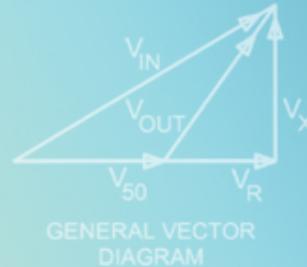
## ■ 12 regional network centers (a.k.a. GigaPOPs.)

## ■ 1 access node



# Cyber-Learning Platform for EM Education





# Simplicity Accessibility Visualization Edutainment

$$V_R = \frac{V_{IN}^2 - V_{50}^2 - V_{OUT}^2}{2V_{50}}$$

$$V_X = \sqrt{V_{OUT}^2 - V_R^2}$$

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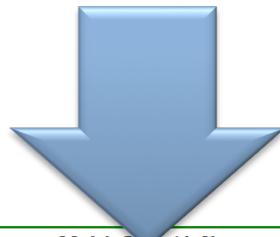
$$A = \sqrt{(R+50)^2 + X^2}$$

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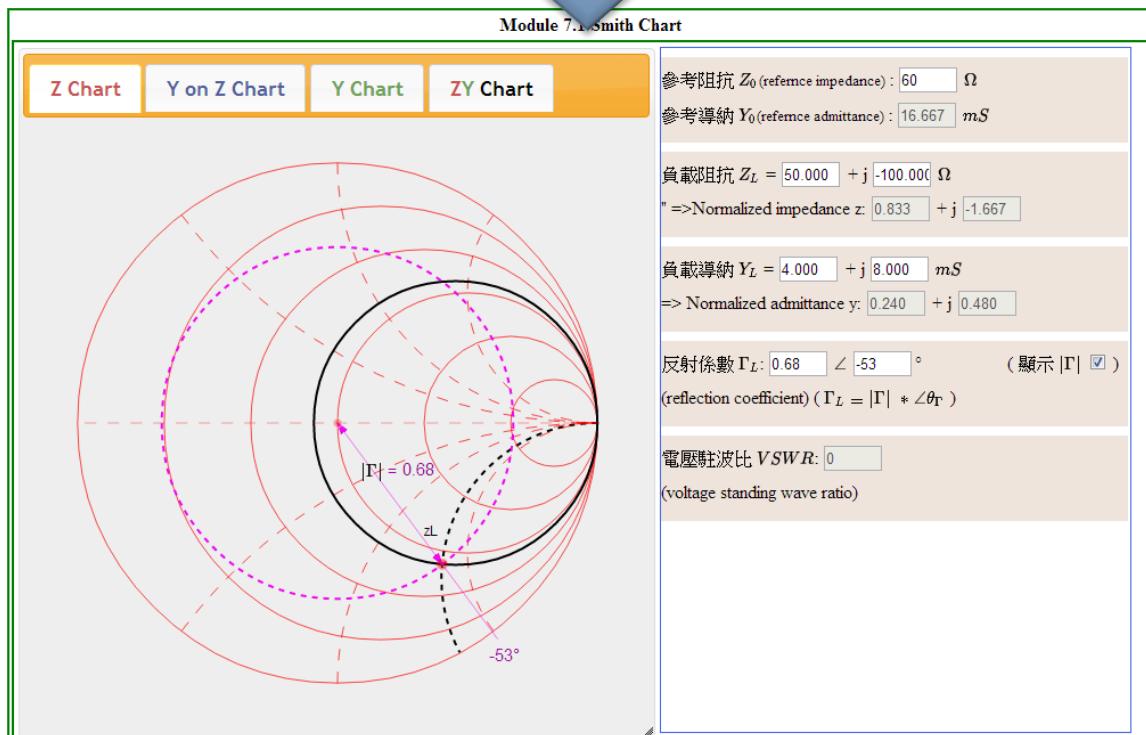
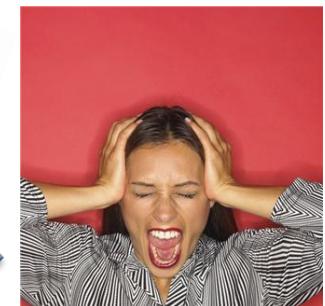
# EM Math Equation Animation

$$Z_{in}(z') = Z_0 \frac{Z_L + jZ_0 \tan(\beta z')}{Z_0 + jZ_L \tan(\beta z')}$$

$$\Gamma(z') = \Gamma_L e^{-2\gamma z'} = \frac{Z_{in}(z') - Z_0}{Z_{in}(z') + Z_0}$$



$$VSWR = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

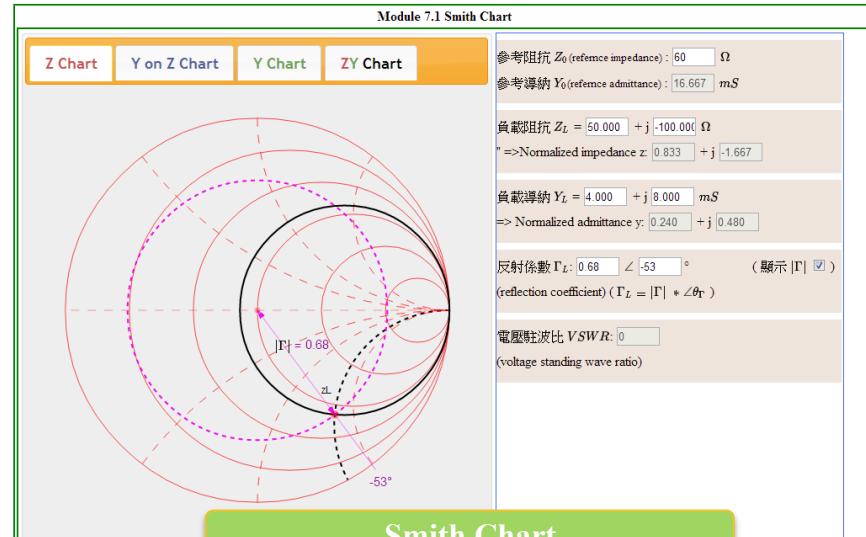
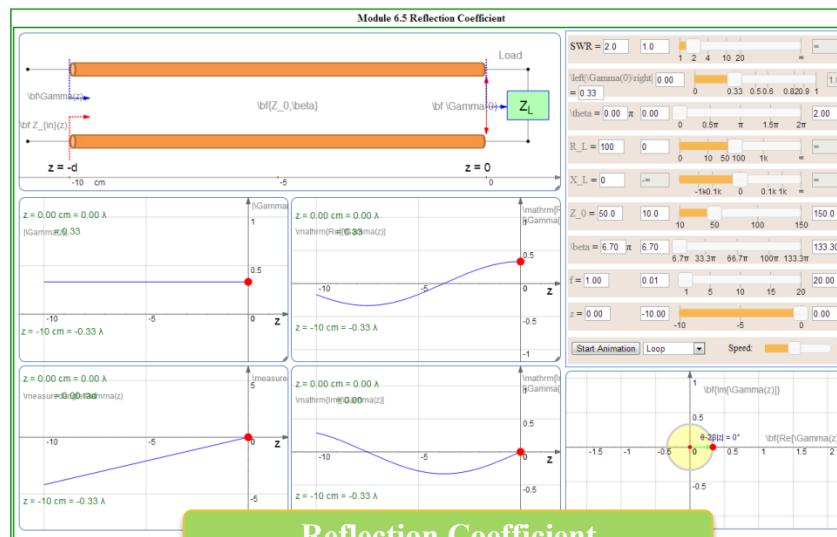
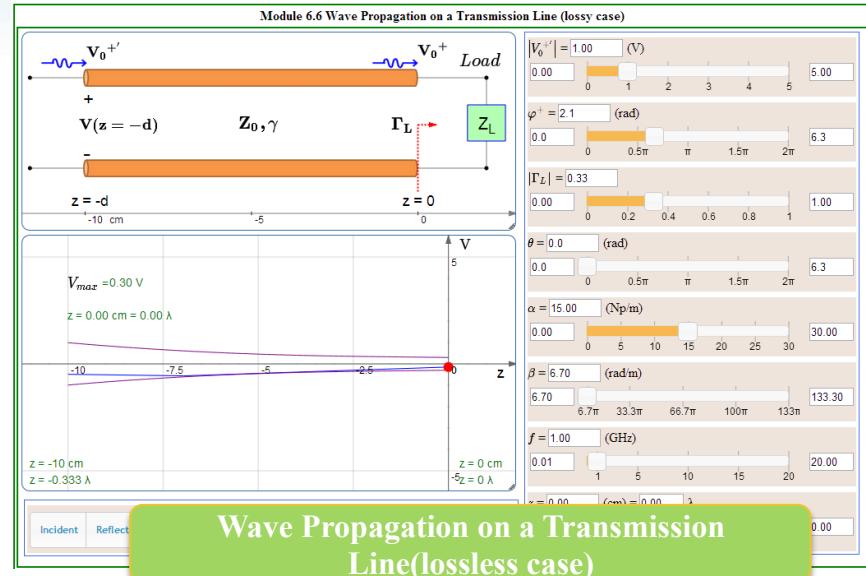
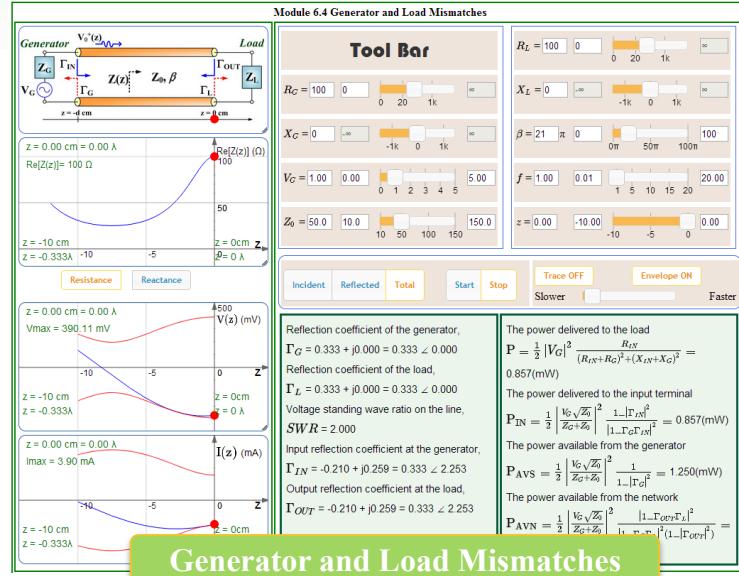


# EM Math Equation Animation

- HTML5
- JavaScript
- CSS

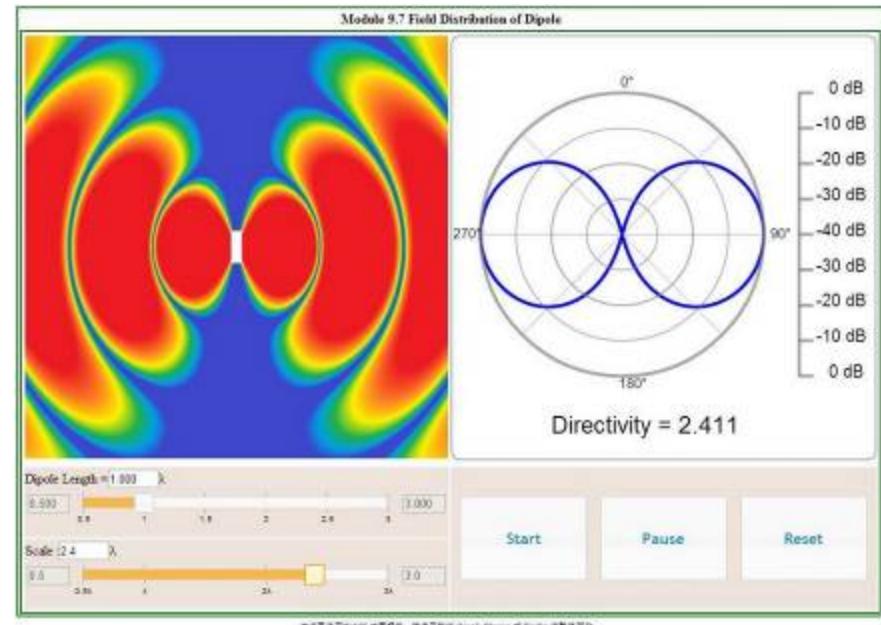
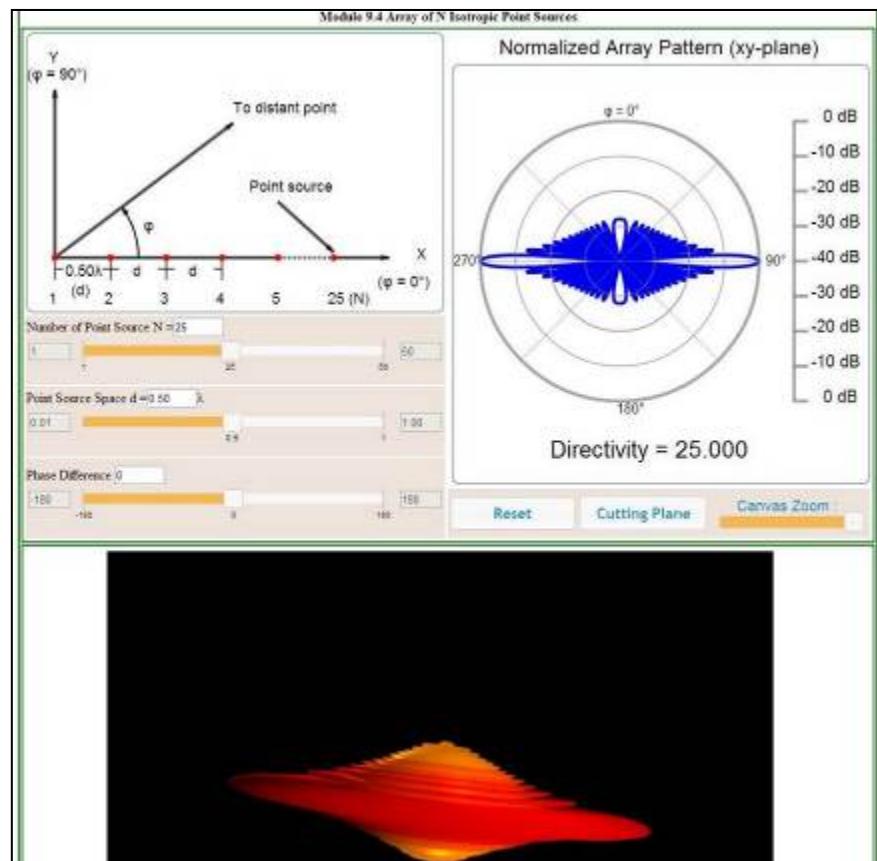


# EM Math Equation Animation



# EM Math Equation Animation

■ New EM math equation animation will use WebGL to develop



# EM Math Equation Animation

## ■ Ch5. Time Domain Transmission Line

- 5.1 Bouncing Signal in T. Line w/ DC Source
- 5.2 Bouncing Signal in T. Line w/ Impulse Source
- 5.3 Bouncing Signals in 3 Sec. T.-Line w/ Pulse Source
- 5.4 Bouncing Signal in a T.-Line System w Shunt/Series Discontinuity

## ■ Ch6. Transmission Lines

- 6.1 Wave Propagation on a Transmission Line(lossless case)
- 6.2 Standing Wave Pattern(lossless case)
- 6.3 Input Impedance
- 6.4 Generator and Load Mismatches
- 6.5 Reflection Coefficient
- 6.6 Wave Propagation on a Transmission Line (lossy case)
- 6.7 Standing Wave Pattern (lossy case)

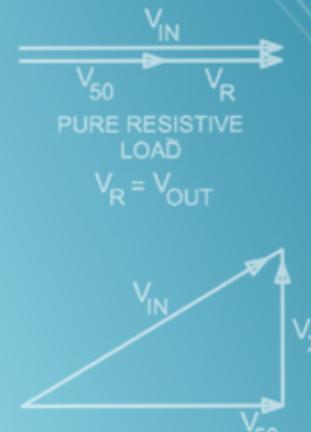
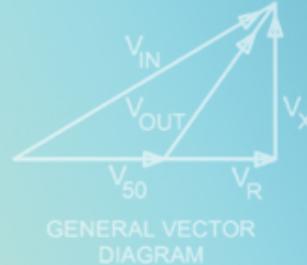
# EM Math Equation Animation

## ■ Ch7. Smith Chart

- 7.1 Smith Chart
- 7.2 Smith Chart and Transmission Lines
- 7.3 Quarter-wavelength Transformer
- 7.4 Single-Stub Impedance Matching
- 7.5 Double-Stub Impedance Matching (八分之一波長)
- 7.6 Double-Stub Impedance Matching (十六分之一波長)

## ■ Ch9. Antennas

- 9.1 Linear Polarization
- 9.2 Circular Polarization
- 9.3 Elliptical Polarization



# Simplicity Accessibility Visualization Edutainment

$$V_R = \frac{V_{IN}^2 - V_{50}^2 - V_{OUT}^2}{2V_{50}}$$

$$V_X = \sqrt{V_{OUT}^2 - V_R^2}$$

$$I = \frac{V_{50}}{50}$$

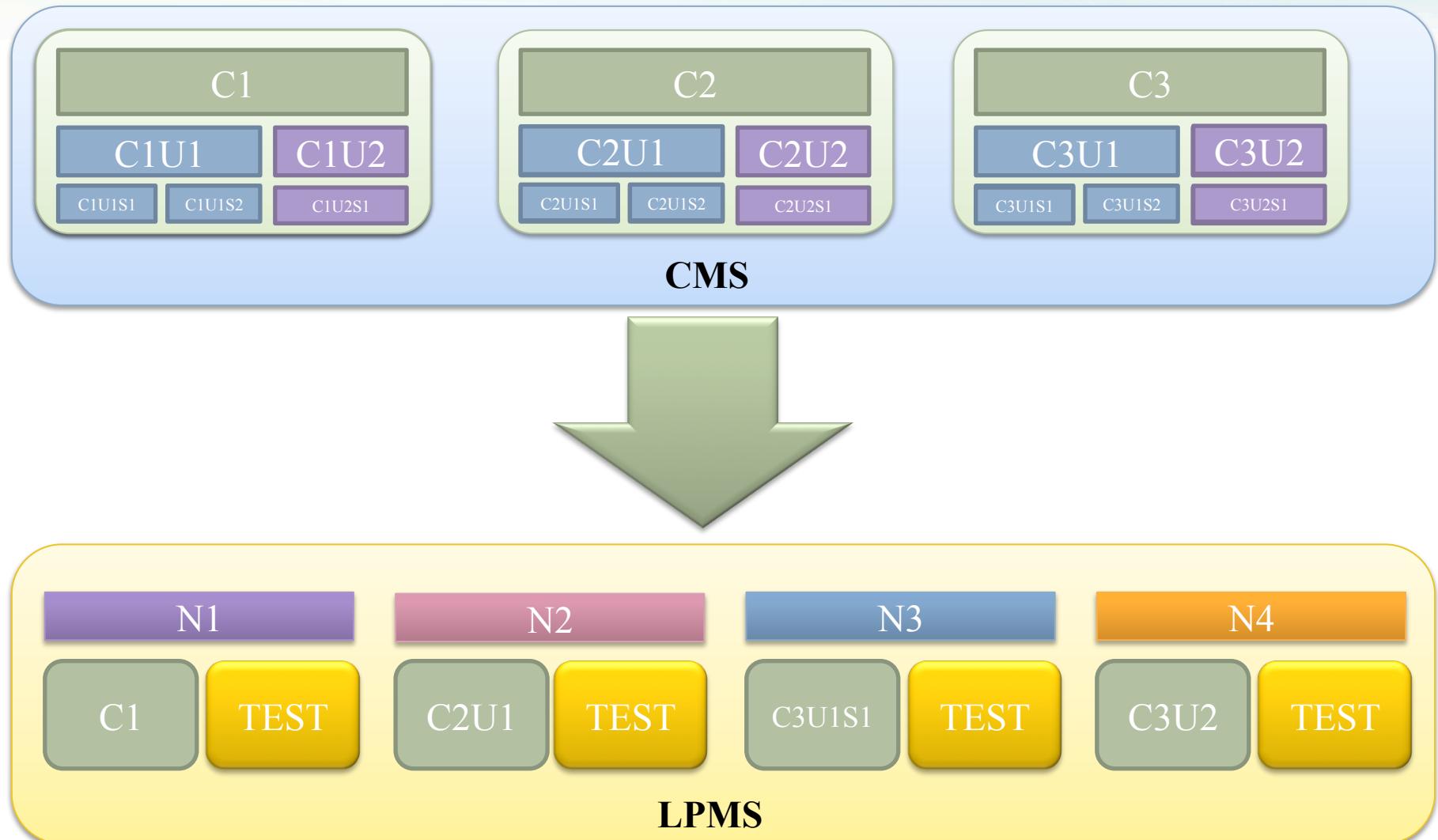
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WHERE

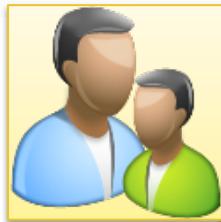
$$A = \sqrt{(R+50)^2 + X^2}$$

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# Dynamic Learning Path Management

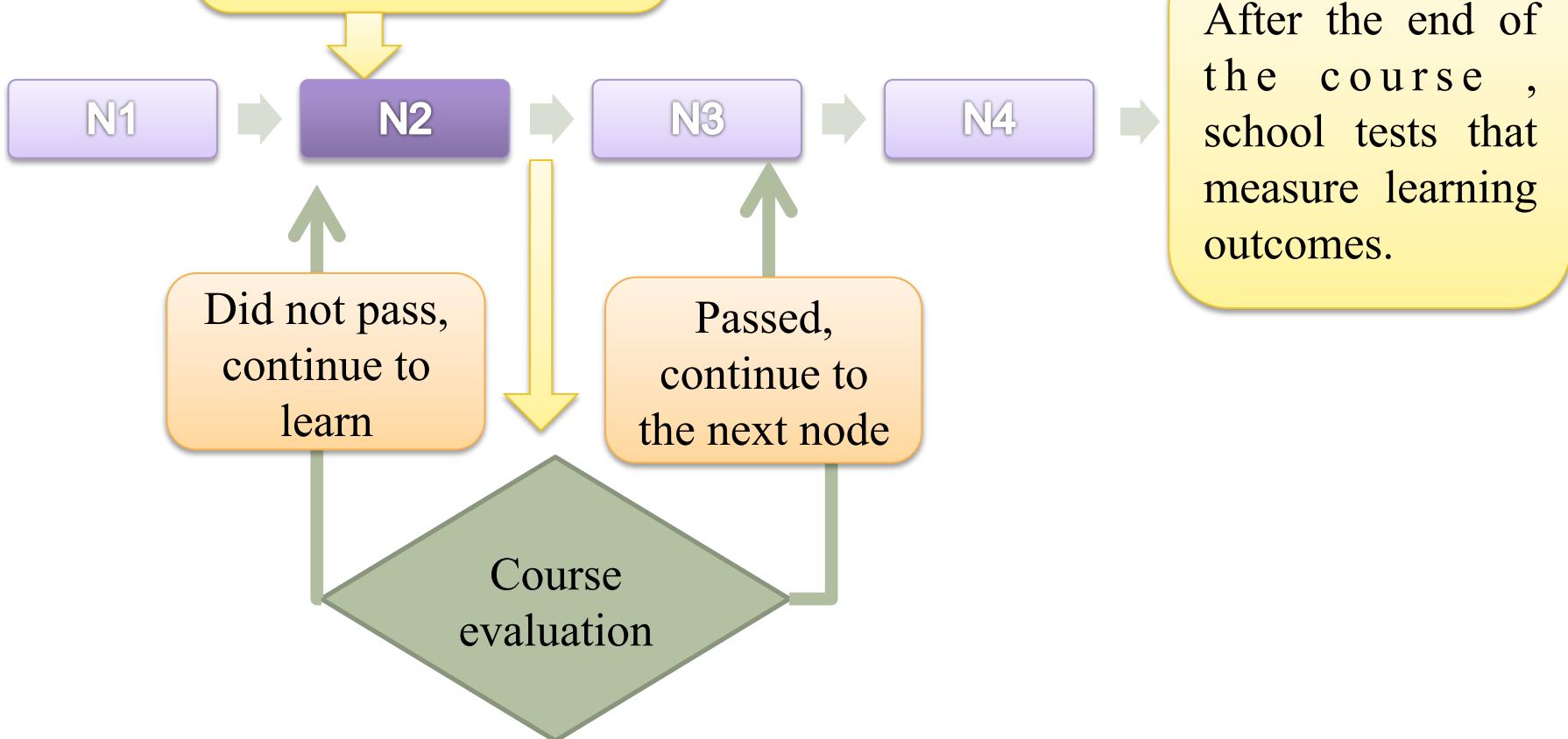


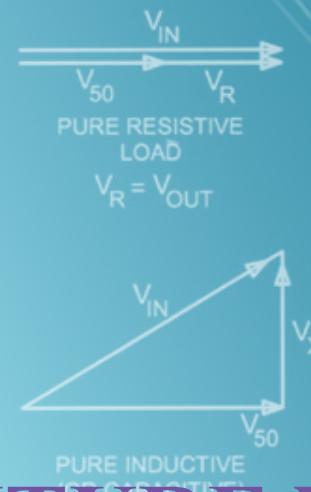
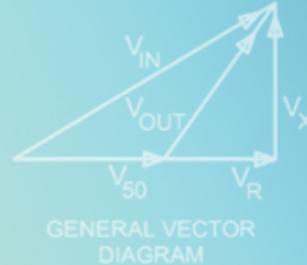
# Dynamic Learning Path



Pre-school quiz:

Learning paths based on test results determine the starting point





$$V_R = \frac{V_{IN}^2 - V_{50}^2 - V_{OUT}^2}{2V_{50}}$$

$$V_X = \sqrt{V_{OUT}^2 - V_R^2}$$

$$I = \frac{V_{50}}{50}$$

$$SWR = \frac{A+B}{A-B}$$

WHERE

$$A = \sqrt{\frac{(R+50)^2 + X^2}{(R-50)^2 + X^2}}$$

# CONCLUSION & FUTURE WORK

# Conclusion

## ■ Cyber-learning Platform

- LCMS, LMPS, LMS, ...

## ■ Content

- Test Bank (3,835 tests)
- Learning Path (207 paths)
- 9 courses (60 hours)
- 29 math equation animations

## ■ Activity

- 28 university/college, 125 classes, 169 teachers, 3,894 students, 230 lectures

# Future Work

## ■ Increase the Content

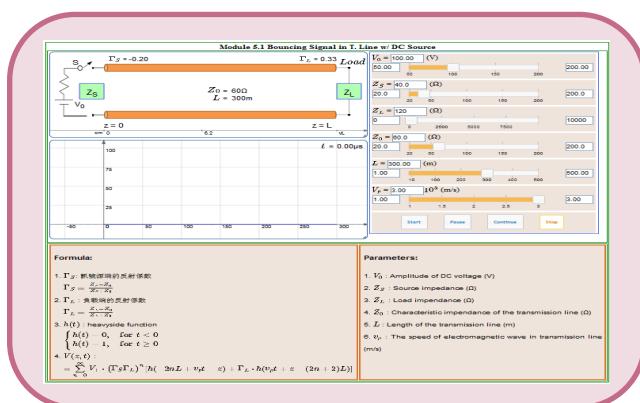
- Test bank
- Animation
- Course set

## ■ Provide the learning platform on mobile devices(android, iOS)

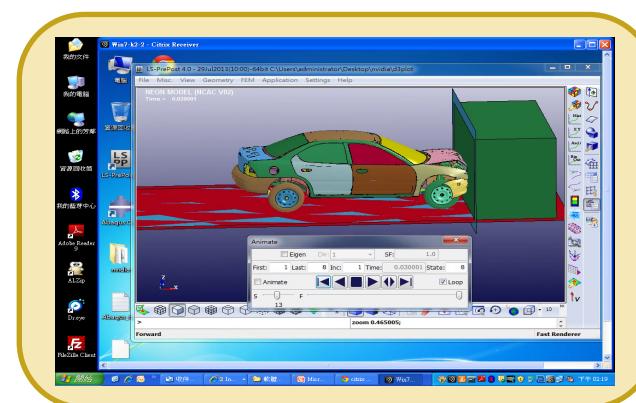
## ■ Create the Simulation-base Learning System

# Future Work

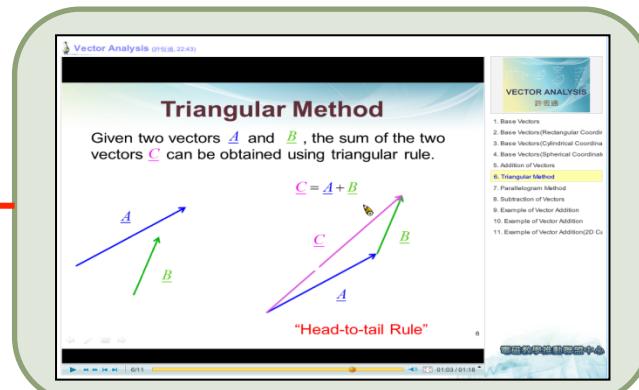
## Multimedia-base learning (GUI run on local)



## Simulation-base learning (GUI run on remote)

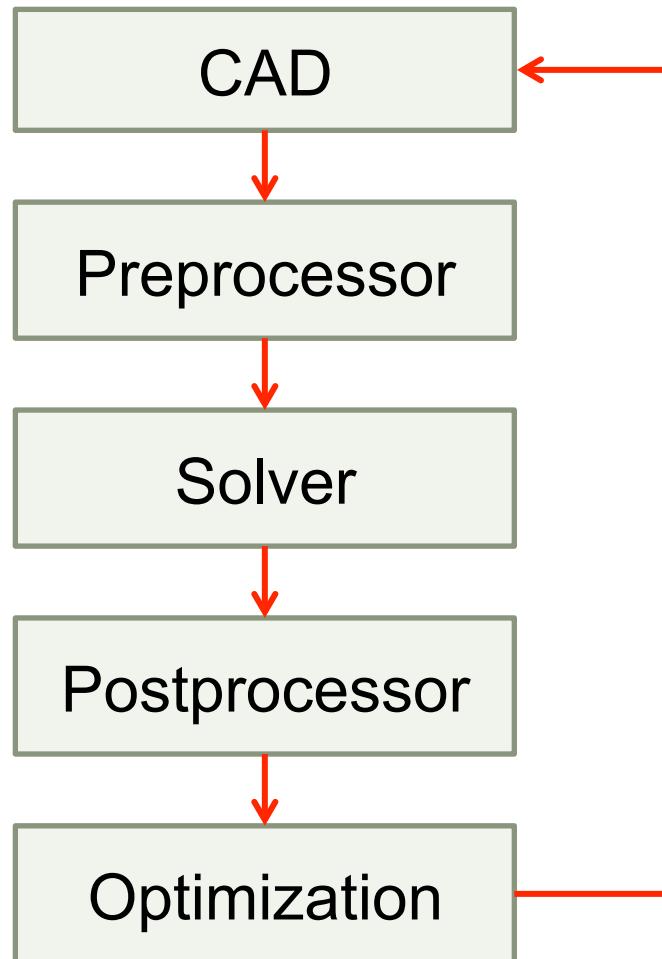


Digital material  
Powerpoint, video/audio



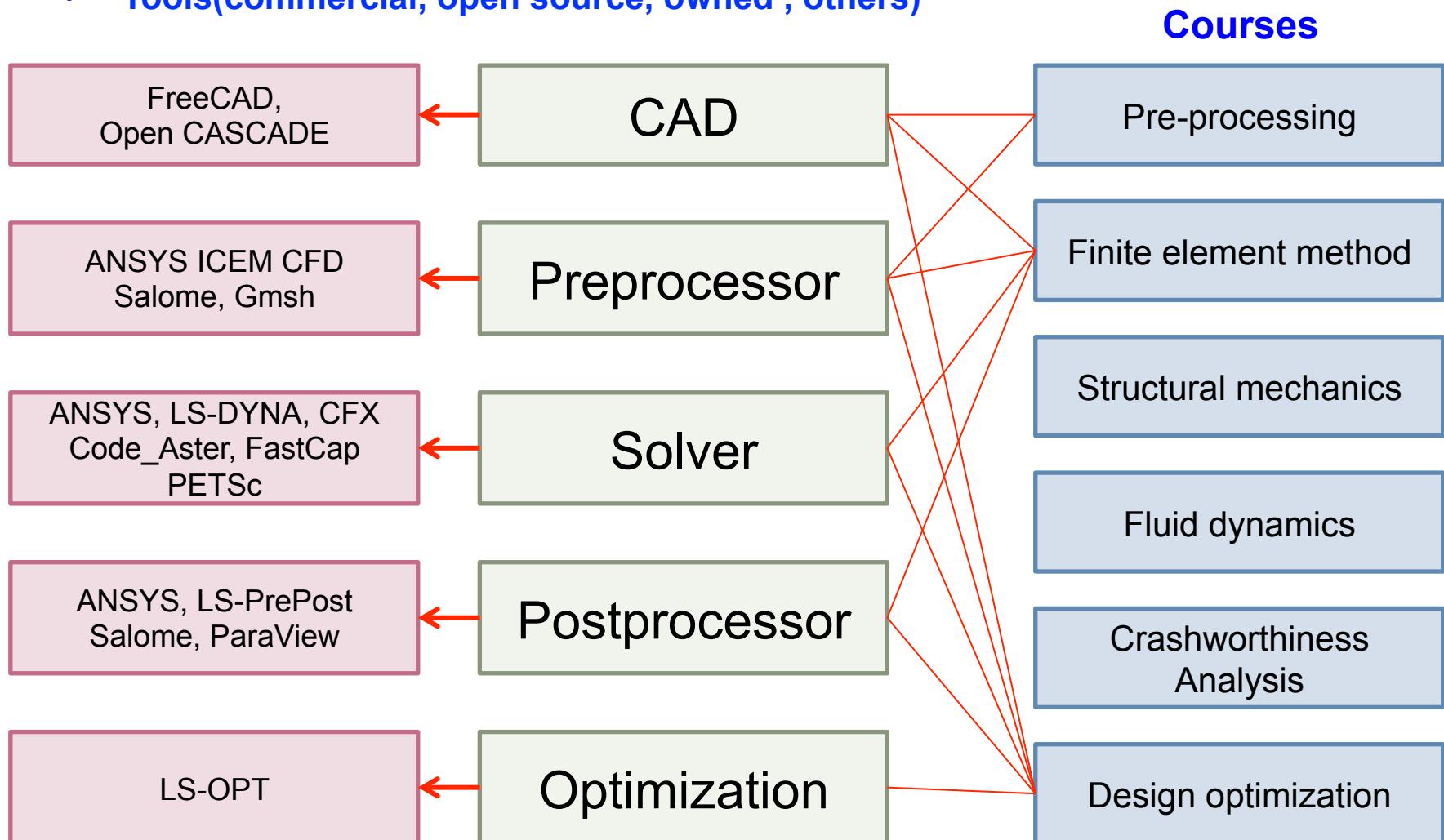
# Future Work

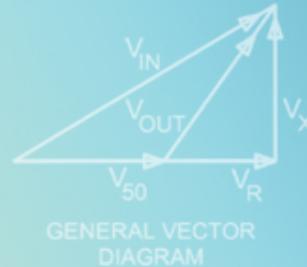
- **Numerical simulation**



# Future Work

- Tools(commercial, open source, owned , others)





# Q & A



PURE INDUCTIVE  
(OR CAPACITIVE)  
LOAD  
 $V_X = V_{OUT}$



$$V_R = \frac{V_{IN}^2 - V_{50}^2 - V_{OUT}^2}{2V_{50}}$$

$$V_X = \sqrt{V_{OUT}^2 - V_R^2}$$

$$I = \frac{V_{50}}{50}$$

$$SWR = \frac{A+B}{A-B}$$

WHERE

$$A = \sqrt{(R+50)^2 + X^2}$$

$$B = \sqrt{(R-50)^2 + X^2}$$

# TEACHING MATERIAL QUANTITIES DEVELOPED IN COURSE MODULES OF THREE WORKGROUPS.

Course Modules		Developed Teaching Materials	
Workgroup #1	Vector Analysis	Module Details	Workgroup Summary
		206 slides, 202 problems, 10 hrs video clips, 2 interactive labs	587 slides, 632 problems, 26 hrs video clips, 4 interactive labs
Workgroup #2	Static Electrics	213 slides, 212 problems, 8 hrs video clips, 1 interactive labs	
	Static Magnetics	168 slides, 216 problems, 8 hrs video clips, 1 interactive labs	
	Maxwell Equations	81 slides, 171 problems, 11 hrs video clips, 1 interactive labs	394 slides, 446 problems, 22.5 hrs video clips, 5 interactive labs
Workgroup #3	Waveguides	175 slides, 64 problems, 2.5 hrs video clips, 2 interactive labs	
	Uniform Plane Wave	138 slides, 211 problems, 12 hrs video clips, 2 interactive labs	
	Transmission Line in Freq. Domain	82 slides, 285 problems, 7.5 hrs video clips, 7 interactive labs	353 slides, 840 problems, 18.5 hrs video clips, 28 interactive labs
WG #4	Smith Chart	61 slides, 191 problems, 6 hrs video clips, 7 interactive labs	
	Transmission Line in Time Domain	102 slides, 210 problems, 5 hrs video clips, 7 interactive labs	
	Antenna	110 slides, 154 problems, 7 interactive labs	
EM Laboratories		360 slides, 160 pages lab manual, 39 problems, 4 sample lab designs	