

# Electromagnetics : Pedagogy and Research Trends

Sponsored by MHRD-TEQIP-KIT, CDEEP, IIT Bombay



*Post-Event Report*

## **Electromagnetics: Pedagogy and Research trends**



Indian Institute of Technology Bombay

Organised  
by  
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## 1. Introduction

The workshop entitled “Electromagnetics: Pedagogy and Research Trends” was organised by Prof. S. V. Kulkarni and CDEEP, IIT Bombay on 23<sup>rd</sup> and 24<sup>th</sup> of January 2015 at Victor Menezes Convention Centre (VMCC), IIT Bombay as an attempt to bring academicians, researchers and students possessing electromagnetics interests under one roof and thus creating a knowledge pool of electromagnetics experts. The workshop is funded by Technical Education Quality Improvement Programme (TEQIP) under Ministry of Human Resources Development (MHRD), Government of India. The field of Electromagnetics has diverse applications in medical, space exploration and power industries etc., and is often considered as a tough subject. Because of this myth, students generally develop a fear for the subject. It is understood that effective teaching methodologies can out-run the myth and make Electromagnetics a more enjoyable subject. Renowned professors and researchers were invited to the workshop to share their experiences with the audience. Participants were exposed to teaching aids like freeware FEM analysis softwares and critical EM applications in numerous fields.

The workshop was conducted over a span of two consecutive days and was divided into eight sessions. Each session was headed by the session chairman, who gave brief introduction about the session speakers. The following were some of the important outcomes of the workshop.

- ❖ Faculty members and students of various TEQIP funded institutions were exposed to various computational electromagnetics methods.
- ❖ Participants got glimpse of electromagnetic field distributions in machines and other power apparatus.
- ❖ End of the day, students acknowledged the fun in learning electromagnetics when taught using FEM software.
- ❖ Participants came up with different research proposals at both graduate and research level.

### ❖ Day 1:

The workshop started with an introductory speech of Prof. S. V. Kulkarni. The speech gave a head start to the workshop and created enthusiasm among the participants about the forthcoming sessions. Prof. S. V. Kulkarni spoke about the motivation in organising the workshop. After the speech, he felicitated the Chief Guest, Prof. R.K Shevgaonkar, Director, IIT Delhi and the Guest of Honour, Prof. A. Pramanik, College of Engineering Pune for their priceless contributions to the field of electromagnetics.

## I. Session I: Pedagogy

Session chairman, Prof. Himanshu Bahirat, IIT Bombay spoke about “Pedagogy” and introduced the session speakers. The gist of the lectures of the session are given in the forthcoming sections.

### a. “A journey with Electromagnetics”

– Prof. Ashutosh Pramanik, COEP.



Dr. Ashutosh Pramanik graduated in Electrical Engineering from Glasgow University after obtaining a degree in M.Sc from Nagpur University. He also holds an M.Sc and Ph.D from University of Birmingham. He was invited to the workshop and was requested to share his professional experiences in the field of electromagnetics, which he acquired from various organizations/ institutes across India and abroad. He shared with the audience, his experience in developing analytical solutions for three-dimensional eddy-current problems and also enumerated his various contributions in the field of electromagnetics. He patiently answered queries of participants.



## b. “The Breakdown of Kirchoff Laws”

– Prof. H. Ramachandran, IIT Madras.

Prof. Hari Ramachandran received his B.Tech. from IIT Bombay in 1982 and his Ph.D. from the University of California at Berkeley, both in Electrical Engineering. He was a research scientist in the Physics Department at the University of California, Los Angeles, for five years before returning to India. He was a scientist at the Institute for Plasma Research, Gandhinagar, from 1993 till 2001 and joined IIT Madras in November 2001.



During his talk, he pointed out the fact that the interests of students in electromagnetics is fading out because of very few topics are being taught at the UG level. He further emphasized that the way the syllabus is designed for electromagnetics has to be modified by keeping in mind the present day requirements of industrial community. He clearly brought forth differences between low frequency and high frequency circuits. He also explained the importance of skin depth and impedance matching in present day circuits which are being operated at GHz frequencies.

### c. “Innovative Laboratory Setups for Teaching Electromagnetics”

– Prof. B.N. Chaudhary, COEP.



Prof. B. N. Chaudhary of College of Engineering, Pune (COEP) is a well-known academician. He played a crucial role in setting up a state-of-the-art basic electrical engineering laboratory at COEP. He explained the principle and operation of an all-in-one rotating-machines test bed, a multipurpose three limb transformer model, a synchronous machine based FHP dynamometer, a 5 kW Generalized AC-DC-AC Power Conditioner and some other interesting equipment in electromagnetics. He also briefed about their ongoing projects at COEP like Industrial Load Emulator, micro-grid etc.

#### d. “Teaching Electromagnetics at Anna University”

– Prof. S. Usa, Anna University.



Dr. S. Usa is a Professor in Electrical Engineering Department, Anna University. Her research interests are in the field of high voltage engineering. In her speech, she discussed many applications of electromagnetics like Maglev trains, Hall Effect sensors, etc. She explained the importance of vector calculus in electromagnetics study and unfolded the physical interpretations of curl, divergence and gradient. She briefed about the teaching methodologies she adopts to teach electromagnetics at Anna University. She further showed various field plots obtained using different FEM software.



## II. Session II: Electromagnetic Systems in Research Organizations

The session “Electromagnetic Systems in Research Organizations” was headed by Chairman Prof. Jayanta Mukherjee. The objective of this session was to expose the audience the applications of electromagnetics in research organisations like BARC, IPR, and DRDO etc.

### a. “High Power RF and Microwave Systems”

– Dr. Pramod Sharma, IPR and Mr. Harish Dixit, VCET.



Mr. Harish V. Dixit is a faculty in Vidyavardhini’s College of Engineering and Technology, Vasai. His speech for the session was on “High Power RF and Microwave Systems”. In his talk, he emphasised the necessity to look for alternate sources of energy generation like nuclear fission rather than conventional generation using fossil fuels like coal. He elaborated the principles of nuclear fission and Tokamak low hybrid current drive. He further shared his views on challenges and research opportunities in microwave engineering.

b. “High Frequency Electromagnetic Systems for Particle Accelerators and Multi-Physics Simulations for Superconducting Magnets”

– Mr. Vikas Teotia, BARC and Mr. S. Sundar Rajan, BARC.



Mr. Vikas Teotia and Mr. S. Sundar Rajan of BARC helped the audience understand the importance of electromagnetics in research and defence organisations. Mr. Vikas Teotia spoke about “High Frequency Electromagnetic Systems for Particle Accelerators” and Mr. S. Sundar Rajan talked on “Multi-Physics Simulations for Superconducting Magnets”. Mr. Vikas, in his presentation, covered topics like introduction to RF linac, components of accelerators, accelerator driven subcritical system, drift tube linac (DTL) cavity, studies and measurements for a prototype DTL cavity, and focusing lens design. Mr. Sundar covered the physics behind superconducting solenoid magnets and QUENCH. He also compared capabilities of existing FEM software.

### c. “Electromagnetic Launchers for Naval Applications”

– Dr. Arbind Kumar and Shri PM Kurulkar, RDE(E), DRDO, Pune.



Dr. Arbind Kumar and Shri P. M. Kurulkar of DRDO, Pune, shared with the audience the physics behind electromagnetic launchers for naval applications. They briefly explained that electromagnetic launchers are required in situation where the runway of aircraft carriers falls short of the range. The electromagnetic launchers gives extra throttle to the aircrafts, with which the aircrafts can take-off with less runway. They patiently answered questions raised by the audience and made the presentation very interactive.



### III. Session III:

#### Electromagnetics -Innovations and Product Development in industries

The session “Electromagnetics -Innovations and Product Development in Industries” was headed by Chairman Prof. B. Muralidharan. The objective of this session was to expose the audience the applications of electromagnetics in industries.

##### a. “Electromagnetics at GE: Research and Product Development”

—Dr. Ravindra Bhide, GE Global Research Center, Bangalore.



Dr. Ravindra Bhide, an alumnus of IIT Bombay and an erstwhile PhD student of Prof. Kulkarni, is currently working in GE Global Research Centre, Bangalore. His research interests include low frequency electromagnetics, finite element modelling, coupled power electronic circuit-field computations, power electronic devices: modelling and simulation, rectifier and interphase transformers: modelling and analysis, and thermal models for rectifier transformers. He inspired the audience by giving insights into some of his ongoing research at GE. He emphasised the fact that electromagnetics has lots of scope in coming years.



## b. “FEM Analysis for Optimization and Quality Enhancement”

– Mr. Saravanan Selvaraj, CG Global R&D, Mumbai.



Mr. Saravanan Selvaraj received his B.E. Degree in Electrical Engineering from Madras University, Tamilnadu in 2002 and M.E. Degree in High Voltage Engineering from Anna University, Tamilnadu in 2005. He joined Global R&D Centre, Crompton Greaves Ltd., India in 2005. He is engaged in High Voltage insulation design, Electromagnetic Analysis and Coupled Field Analysis of Transformers and Switchgears. In his talk, he shared his experiences in designing transformers using FEM techniques. He said that FEM techniques helped him in choosing materials and their dimensions to make efficient designs of transformers.

## IV. Session IV: Plenary Session

### a. “Teaching Electromagnetic Waves in an Effective Way”

—Prof. R. K. Shevgaonkar, Director, IIT Delhi.



Prof. R. K. Shevgaonkar is the Director of IIT Delhi and also a faculty at IIT Bombay. He was invited to the workshop as the Chief Guest and as a speaker. He inspired and educated the teachers and other participants of the workshop with his speech. He explained the ways in which a complex subject like electromagnetics can be taught in an enjoyable fashion. He suggested the participants to read ‘Lecture series by Feynman’ to get the real glimpse of electromagnetics. He further pointed out a few topics in electromagnetics which need to be taught carefully since these topics can generate curiosity in students to learn and pursue research in electromagnetics.

## V. Session V: Panel Discussion

Panel Discussion: 'Promoting Electromagnetics Education and Research in India: The Way Forward'. The discussion was highly interactive with participants and invited speakers exchanged their thoughts about challenges in teaching electromagnetics and solutions/innovative techniques for overcoming them.

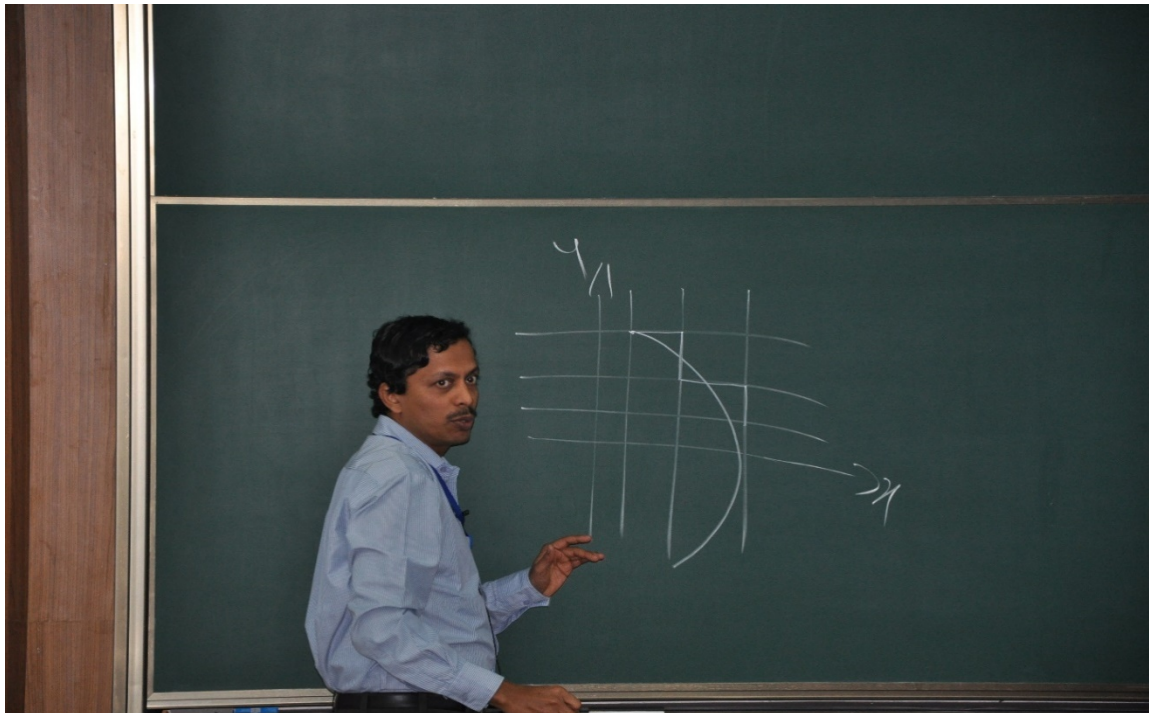
### 2. Day 2

#### I. Session I: Overview of Numerical Techniques and Coupled Field computations

The session "Overview of Numerical Techniques and Coupled Field computations" was headed by Chairman Prof. RPRC Aiyar. The objective of this session was to expose the audience the applications of numerical techniques and coupled field computations in electromagnetic field analysis.

##### a. "An Overview of Computational Electromagnetics"

– Prof. Udaya Kumar, IISc Bangalore.



Dr. Udaya kumar is Professor at IISc Bangalore. His area of expertise includes high voltage engineering, electromagnetic fields, lightning and measurements. He is a member of the working group of CIGRE WG C4.26 on "Evaluation of Lightning Shielding Analysis Methods for EHV and UHV DC and AC Transmission Lines" and WG C4.37 "Electromagnetic Computation Methods for Lightning Surge Studies with Emphasis on the FDTD Method. He delivered his



lecture on the second day of workshop and taught the audience about computational electromagnetics. His talk included the need for evaluating EM fields, limitations of analytical models and overview of numerical methods.

## b. “Finite Element Analysis of Electromagnetic and Coupled Systems”

– Prof. G. B. Kumbhar, IIT Roorkee.



Prof. G. B. Kumbhar is an alumnus of IIT Bombay and is currently working as Assistant Professor at IIT Roorkee. His area of expertise is in electromagnetic fields and high voltage engineering. He was invited to the workshop as a speaker to share his knowledge on finite element modelling. His lecture included the history of FEM, problem formulation, and applications of FEM. He also explained about coupled field-circuit models for transformers.



### c. "Use of Freeware FEM Software for Teaching"

– Prof. Ketan Badgujar, IITRAM.



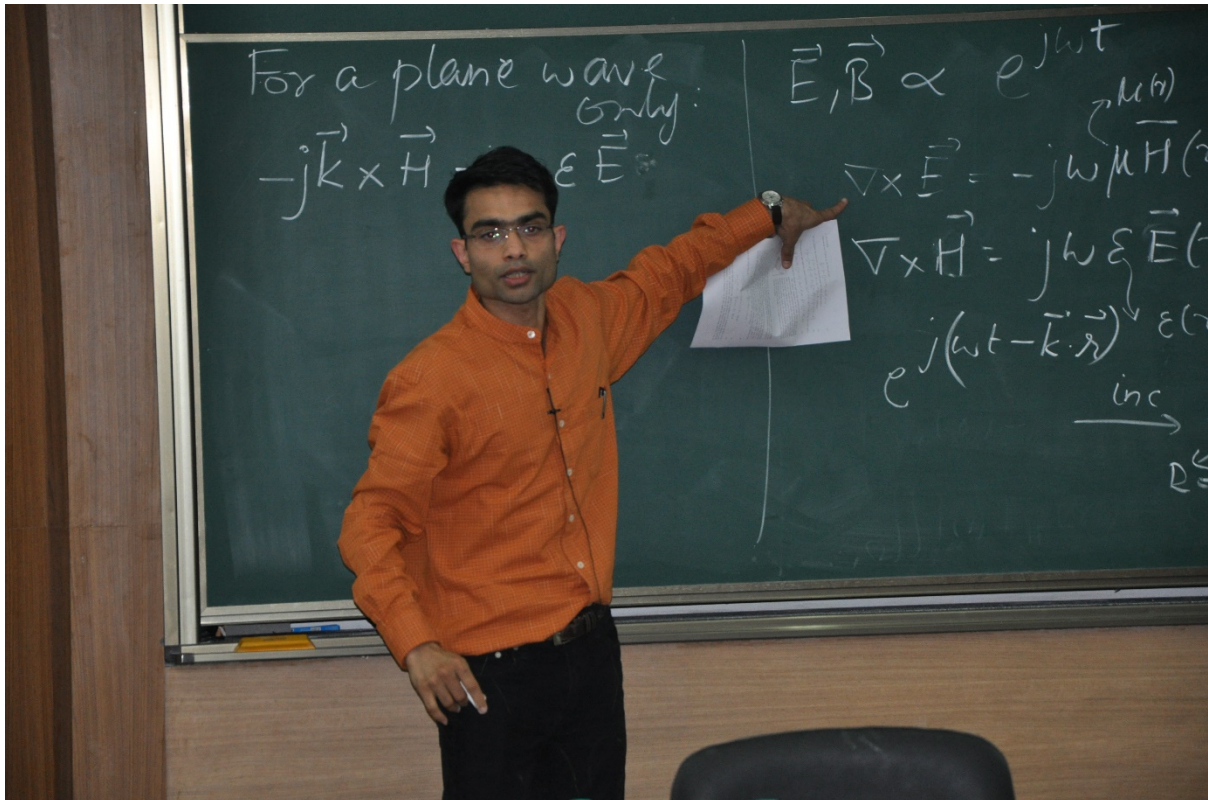
Prof. Ketan Badgujar, an M.tech gold medallist from IISC Bangalore is also an alumnus of IIT Bombay. He has done his Ph.D under Prof. S. V. Kulkarni, where he worked extensively on air core models for determining frequency response of transformer coils. These days, he is working as Professor at IITRAM. He was invited to speak on freeware finite element modelling (FEM) software which can be used as a great aid to demonstrate the field patterns and other plots in the class. He taught the audience how to run simulations in freeware software 'FEMM' and also shared with the audience an extensive list of freeware FEM packages.

## II. Session II: High Frequency Electromagnetics

The session “High Frequency Electromagnetics” was chaired by Prof. KP Ray. The objective of this session was to teach the audience the applications of numerical techniques and FEM techniques in high frequency electromagnetic field analysis.

### a. “Vector Based Formulations of the Finite Element Method in Computational Electromagnetics”

– Prof. Uday Khankhoje, IIT Delhi.



Dr. Uday Khankhoje has done his graduation in Electrical Engineering at IIT Bombay and later he completed his MS and Ph.D from California Institute of Technology. His research interests include computational electromagnetics, nano-photonics, inverse-imaging and remote sensing. In the workshop, he spoke about “Vector based formulations of the finite element method in computational electromagnetics”. He explained a way to solve Maxwell’s equations using first order vector based elements.

b. “High Frequency Electromagnetics: Pedagogical Aspects & Research trends”

—Prof. M. Jaleel Akhtar, IIT Kanpur.



Dr. M. Jaleel Akhtar is working as a faculty member at IIT Kanpur. His research interests include microwaves: imaging, characterization and non-destructive testing, RF and Microwave Sensors, UWB Antennas, etc. In his talk, he spoke about pedagogical aspects in high frequency electromagnetics and meta-materials. He also showed the virtual lab developed at IIT Kanpur. Further, he also explained radar cross section reduction techniques for stealth applications.



- c. “Simulations of Beam Transmission through an RF resonating Structure “  
– Mrs. Kumud Singh, BARC.



Mrs. Kumud Singh of BARC has vast experience in dealing with RF circuits. In her talk, she explained the structure of klystron, a typical resonating structure. She also explained the dynamics of an electron beam, in which she covered the concepts of Brillouin Flow focusing, and confined flow focusing. She also covered electrostatic design of cathode gun and electromagnetic design of focussing lens.



### 3. Conclusions:

The following points were recommended for further action based on the deliberations in the workshop.

- ❖ Similar workshops on Electromagnetics should be held at different locations so that students and staff of nearby colleges can attend them.
- ❖ The faculty of electromagnetic fields should take special efforts, prepare notes/presentations and develop tools to make concepts clear and easy to the students.
- ❖ It was also advised not to include too much mathematics in electromagnetics; applications should be explained simultaneously after theory. It should be kept in mind that electromagnetics is not a maths subject.
- ❖ Teachers should use freeware FEM software to simulate and demonstrate field distributions. This will enhance the students' understanding of the subject.
- ❖ Innovative techniques such as Virtual Laboratory should be developed for students of remote areas where teaching resources are inadequate.