Course Type	Course Code	Name of Course	L	T	P	Credit
DE	NECD525	Metamaterials and CRLH Transmission Lines	3	0	0	3

Course Objective

The objective of this course is to introduce the students to the metamaterials and CRLH transmission lines.

Learning Outcomes

Upon successful completion of this course, the students will:

- Understand the fundamentals of metamaterials and their theoretical backgrounds
- Learn some interesting properties of metamaterials, which are not commonly available in nature
- Able to design and analyze artificially engineered metamaterial structures using composite right-left-handed transmission line (CRLH-TL) approach
- Able to design different guided-wave and radiated wave structures using CRLH-TL metamaterial structures

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Introduction to Metamaterials**: Definition of metamaterials (MTMs) and left-handed (LH) materialsand its novelty, Transmission line approach, Composite right-left-handed (CRLH) MTMs, Metamaterials and photonic band gap (PBG) structures.	04	The students will be introduced to the basic concepts of metamaterials, their backward wave characteristics, and a way to artificially engineering them.
2	**Fundamentals of Metamaterials:** Concept of left-handedness, Boundary conditions, Reversal of Doppler effect, Vavilov-Cerenkov radiation, Snells law, Focusing by flat lenses, Fresnel's coefficients, Goos-Hanchen effect, Convergence and divergence in convex and concave lenses.	07	The students will learn the theoretical background of left-handed materials and some of the interesting properties of such materials.
3	**Transmission line theory of metamaterials:** Fundamentals of CRLH transmission lines, Equivalent MTM constitutive parameters, Balanced and unbalanced resonances.	07	The students will learn the basic fundamentals of CRLH transmission lines
4	**Analysis of CRLH transmission Lines:** LC-network implementation, Transmission line matrix analysis, Input impedance, cut-off frequencies, Bloch impedance.	08	The students will learn the implementation and analysis of CRLH transmission lines
5	**Guided wave applications of CRLH transmission lines:** Dual-band properties of CRLH transmission lines, Enhanced bandwidth components, Negative and zeroth order resonator.	08	The students will learn some guided-wave applications of CRLH transmission lines.
6	**Radiated wave applicationsof CRLH transmission lines:** Principle of leakage radiation, Uniform and periodic leaky-wave structures, Back-to-end fire leaky-wave antenna, ZOR Antenna.	08	The students will learn some radiated-wave applications of CRLH transmission lines.
	Total	**42**	

Text Book:

1. Christophe Caloz and Tatsuo Itoh, "Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications", John Wiley and sons, New York, 2006

Reference Books:

1. Nader Engheta and Richard W. Ziolkowski, "Metamaterials: Physics and Engineering Explorations", Wiley-IEEE Press, 2006.
2. Tie Jun Cui, David Smith, and Ruopeng Liu, "Metamaterials: Theory, Design, and Applications", Springer, 2010.
3. Balamati Choudhury, "Metamaterial Inspired Electromagnetic Applications: Role of Intelligent Systems", Springer, 2017.
4. Pankaj K. Choudhury, "Metamaterials Technology and Applications" CRC Press, 2021.