Master of Technology
(Wireless Communication)

Regulations, Curriculum and Syllabus

(Non CBCS)

(with effect from academic year 2018-2019)

i) Regulations for (Non – CBCS) M.Tech. (Wireless Communication)

Besides the Non - CBCS regulations specified by Pondicherry University in respect of engineering post graduate degree admission, evaluation and awarding degree, the following norms are applicable for this programme.

1. **Name of the Programme :** M.Tech. (Wireless Communication)

2. **Nature of the Programme :** Regular, Coming under Engineering Department.

3. **Programme Duration :** Two years (Four Semesters). However, one can complete the programme within maximum of eight semesters.

4. **Eligibility Criteria :** Candidates for admission to the first semester of four semester M.Tech (Wireless Communication) should have passed B.E / B.Tech in Electronics and communication Engineering / Telecommunication Engineering / Communication Engineering / Electronics and Telecommunication / Information Technology and other related branches, through regular course of study from an AICTE approved institution or an examination of any University or authority accepted by the Pondicherry University as equivalent thereto, with at least 55% marks in the degree examination or equivalent CGPA.

   Note:
   i. Candidates belonging to SC/ST who have a mere pass in the qualifying examination are eligible (as per university norms).
   ii. There is no age limit for M.Tech programmes.

5. **Admission Criteria :** The admission policy for various M.Tech programmes will be decided by the respective institutes offering M.Tech programmes subject to conforming to the relevant regulations of the Pondicherry University.

6. **Intake :** As per the sanctioned strength to the Institute by the Pondicherry University.

7. **Teaching and Learning Methods :** Lectures, tutorials and seminars are the main methods of course delivery, which would be supplemented by individual practical work, project work, simulation assignment, seminars and industrial visits.

8. Structure of M.Tech Programme :

8.1 The M.Tech Programmes is of semester pattern with 16 weeks of instruction in a semester.

8.2 The programme of instruction for each stream of specialization will consist of:

i. Core courses (Compulsory)
ii. Electives
iii. Laboratory
iv. Online course
v. Internship
vi. Project work

8.3 Credits will be assigned to the courses based on the following general pattern:

i. One credit for each lecture period
ii. One credit for each tutorial period
iii. One credit for Project literature survey
iv. Two credits for practical course
v. Two credits for Online course
vi. Two credits for Internship
vii. Twelve credits for Project work
viii. One teaching period shall be of 60 minutes duration including 10 minutes for discussion and movement.

8.4 Regulations, curriculum and syllabus of the M.Tech programme shall have the approval of Board of Studies and other Boards /Committees / Councils, prescribed by the Pondicherry University. The curriculum should be so drawn up that the minimum number of credits and other requirements for the successful completion of the programme will be as given in Table 1.

Table 1: Curriculum Details of the Programme

S. No.	Description	Requirements M.Tech (Full-Time)
1	Number of Semesters	4
2	Min. No. of credits of the Programme	74
3	Max. No. of credits of the Programme	74
4	Min. Cumulative Grade Point Average for pass	5
5	Min. period of completion of the Programme (consecutive Semesters)	4
6	Max. period for completing the Programme (consecutive Semesters)	8
7	Number of core and elective courses	18
8	Online course	1
9	Laboratory	2
10	Project work (semesters)	2
11	Internship	1

8.5 A core course is a course that a student admitted to the M.Tech. programme must successfully complete to receive the degree. A student must register for all the core courses listed in the curriculum.

8.6 Elective courses are required to be chosen from the courses offered by the department(s) in that particular semester from among the approved courses. A core course of one department may be chosen as an elective by a student from other department[***].

[***]Note: A candidate should successfully complete 7 electives for the award of degree. However, it is mandatory that the electives for each semester should be from the group of electives listed in curriculum.

8.7 Project work is envisaged to train a student to analyze independently any problem posed to him/her. The work may be analytical, experimental, design or a combination of both. The project report is expected to exhibit clarity of thought and expression.

8.8 The medium of instruction, examination, seminar and project work will be in English.

9. Requirements to appear for University Examination :

9.1 A candidate shall be permitted to appear for university examinations at the end of any semester only if he / she secures not less than 75% overall attendance arrived at by taking into account the total number of periods in all subjects put together offered by the institution for the semester under consideration. Candidates who secure overall attendance greater than 60% and less than 75% have to pay a condonation fee as prescribed by the University along with a medical certificate obtained from a medical officer not below the rank of Assistant Director to become eligible to appear for the examinations.

9.2 His / Her conduct should be satisfactory as certified by the Head of the institution.

10. Evaluation :

10.1 Theory Courses: 40% of marks for internal and 60% for end semester examinations.

The end semester question paper will have Part A ($6 \times 2 = 12$ Marks) consisting of six two mark questions and Part B ($4 \times 12 = 48$ Marks) consisting of six twelve mark descriptive questions of which one of them is compulsory and totally a candidate has to answer four out of six. For the end semester examination (University Semester Examination), the questions will be chosen only from the first four units of every theory subject of the programme to account end semester marks of 60 and internally (cumulatively) to assess a candidate's depth of knowledge in the concerned subject for 40 marks, a minimum of two internal tests (30 marks) shall be conducted. Further, the content of the fifth unit in each subject shall be considered to conduct seminars, tutorials, simulations, assignments, development of hardware models etc. for 10 marks as it is formulated at system level for all subjects of the programme. The question paper setter will be appointed by the Competent Authority of the University. However, the evaluation shall be a central evaluation that shall be carried out by Controller of Examinations, Pondicherry University.

10.2 Practical Courses: 50% of marks for internal and 50 % for the end semester examinations.

10.3 Internship / Seminar/ Workshop / Conference / FDP / Short term course / NPTEL/GIAN/MOOC Course: 100% of marks through internal assessment only.

It is optional to undergo internship in established industry or esteemed institution / Seminar/ Workshop / Conference / FDP / Short term course / NPTEL/GIAN/MOOC Course for a period of four weeks (20 working days) either in single or multiple spans by a candidate. Further, a presentation should be given regarding the training or programme underwent during the period with the submission of a report. There shall not be any end semester evaluation. However, the internal evaluation is done by the committee comprising of internal members and one external member from other department of the same institute constituted by Head of the Department for the award of appropriate grade to the candidate based on the performance. The distribution of marks will be decided by the committee. The internship / Seminar/ Workshop / Conference / FDP / Short term course / NPTEL/GIAN/MOOC Course can be completed at any period of the duration of M.Tech. programme to fulfill the partial requirements for the award of M.Tech. degree.

10.4 NPTEL/GIAN/MOOC Course:

It is mandatory to undergo one course related to the chosen programme for the minimum period of 30 hours either from NPTEL or GIAN or MOOC that is to be completed at any period of the duration of M.Tech. programme to fulfill the partial requirements for the award of M.Tech. degree. Absolute grade shall be awarded to a candidate based on the marks given in the certificate issued by the competent authority (NPTEL or GIAN or MOOC) for the chosen course.

10.5 Project - Literature Survey

100% of marks through internal assessment only.
It is mandatory to undergo a complete literature survey by a candidate on the area of project work in the third semester regularly. There will be two reviews for the candidate on the literature survey carried out. There shall not be any end semester evaluation. However, the internal evaluation is based on the presentation of the candidate with the submission of a report about the literature survey. It will be done by the committee comprising of internal members and one external member from other department of the same institute constituted by Head of the Department for the award of appropriate grade to the candidate based on the performance. The distribution of marks for the literature survey will be decided by the committee.

10.6 Project and Viva Voce
50% of marks for internal and 50% for end semester examinations.

The Project work shall be evaluated for a maximum of 100 marks. There shall be three assessments during the fourth semester by a review committee. The Head of the Department shall constitute the

review committee consisting of supervisor, project coordinator and another faculty member from the Department for the internal assessment (30 marks). The contribution by the respective supervisor of a student for 20 marks shall be accounted for the internal marks of 50. The end semester Project Viva Voce (for 50 marks) shall be conducted by the external member nominated by the competent Authority of the University. The distribution of the marks is shown in the Table given below.

Table 2: Allocation of marks

Allocation of Marks for Project and Viva Voce (100 Marks)					
Internal (50 Marks)				**External (50 Marks)**	**Total (100 Marks)**
Review Committee (30 Marks)			Supervisor (20 Marks)		
First Review	Second Review	Third Review			
10 Marks	10 Marks	10 Marks	20 Marks	50 Marks	100 Marks

10.7 Publication: Mandatory requirement for the completion of the programme.
It is mandatory to have a minimum of one submitted manuscript / accepted publication in reputed journal during the M.Tech. programme. However, the submitted manuscript / accepted paper is subject to the recommendation of the evaluating committee comprising of internal members from same Department constituted by Head of the Department and one external member (examiner) from other institute nominated by competent Authority of University for the acceptance of the quality of the manuscript /paper of the candidate. The publication can be made at any period of the duration of M.Tech. programme. However, it does not contribute any credits to the programme but mandatory to fulfill the partial requirements for the award of M.Tech. degree. This evaluation process may be carried out along with even end semester examination depending up on the status of the students.

10.8 The end-semester examination shall be conducted by the Pondicherry University for all the courses offered by the department. A model question paper, as approved by the Chairperson, BOS (ECE), Pondicherry University, for each course offered under the curriculum should be submitted to the University.

10.9 The University shall adopt the double valuation procedure for evaluating the end-semester examinations, grading and publication of the results. Each answer script shall be evaluated by two experts. If the difference between the total marks awarded by the two examiners is not more than 15% of end-semester examination maximum marks, then the average of the total marks awarded by the two examiners will be reckoned as the mark secured by the candidate; otherwise, a third examiner is to be invited to evaluate the answer scripts and his/her assessment shall be declared final.

10.10 Continuous assessment of students for theory courses shall be based on two tests (15 marks each) and one assignment (10 marks). A laboratory course carries an internal assessment mark of 50

distributed as follows: (i) Regular laboratory exercises and records – 20 marks (ii) Internal laboratory test– 20 marks and (iii) Internal viva-voce – 10 marks.

10.11 All eligible students shall appear for the University examination.

11. Grading **:** 11.1 The assessment of a course will be done on absolute marks basis. However, for the purpose of reporting the performance of a candidate, letter grades, each carrying stipulated points, will be awarded as per the range of total marks (out of 100) obtained by the candidate, as detailed below in Table 3.

Table 3: Letter Grade and the Corresponding Grade Point

Range of Total Marks	Letter Grade	Grade Point	Description
90 to 100	S	10	Excellent
80 to 89	A	9	Very Good
70 to 79	B	8	Good
60 to 69	C	7	Above Average
55 to 59	D	6	Average
50 to 54	E	5	Satisfactory
0 to 49	F	0	Failure
-	FA	-	Failure due to lack of attendance
-	AB	-	Failure by absence

11.2 A student is deemed to have completed a course successfully and earned the appropriate credit if and only if, he /she receives a grade of E or above. The student should obtain 40% of marks in the University examination in a subject to earn a successful grade.
A candidate shall be declared to have passed the examination in a subject of study only if he/she secures not less than 50% of the total marks (Internal assessment plus university examination marks).

11.3 A candidate who has been declared "Failed" in a course may reappear for that subject during the subsequent semester and secure a pass.

11.4 The internal assessment marks secured by a student in a theory course shall be considered only during the first appearance. For the subsequent attempts, the marks secured by the student in the University examination shall be scaled up to the total marks. Further, the marks secured by the student in the University examination in the latest attempt shall alone remain valid in total suppression of the University examination marks secured by the student in earlier attempts.

12. Declaration of Results, Rank and Issue of Grade Card :

12.1 The results will be declared and the grade cards will be issued to the students after completing the valuation process.

12.2 The grade cards will contain the following details:

i. The college in which the candidate is studying/has studied.
ii. The list of courses enrolled during the semester and the grades scored.
iii. The Grade Point Average (GPA) for the semester and the Cumulative Grade Point Average (CGPA) of all enrolled subjects from first semester onwards.

12.3 GPA is the ratio of the sum of the products of the number of Credits (C) of courses registered and the corresponding Grade Point (GP) scored in those courses, taken for all the courses and the sum of number of credits of all the courses

$$GPA = (\text{Sum of } (C \times GP) / \text{ Sum of } C)$$

The sum will cover all the courses the student has taken in that semester, including those in which he/she has secured F.

12.4 CGPA will be calculated in a similar manner, considering all the courses enrolled from first semester. FA grades are to be excluded for calculating GPA and CGPA. If a student has passed in a course after failing in earlier attempts, the grade secured by the student in the successful attempt only will be taken into account for computing CGPA.

12.5 To convert CGPA into percentage marks, the following formula shall be used:

$$\% \text{ Mark} = (CGPA - 0.5) \times 10$$

12.6 A candidate who satisfies the course requirements for all semesters and passes all the examinations prescribed for all the four semesters within a maximum period of eight (8) semesters reckoned from the commencement of the first semester to which the candidate was admitted, shall be declared to have qualified for the award of degree.

12.7 A candidate who qualifies for the award of the degree shall be declared to have passed the examination in FIRST CLASS with DISTINCTION upon fulfilling the following requirements:

i. Should have passed all the subjects pertaining to semesters 1 to 4 in his/her first appearance in 4 consecutive semesters starting from first semester to which the candidate was admitted.
ii. Should not have been prevented from writing examinations due to lack of attendance.
iii. Should have secured a CGPA of 8.50 and above from semesters 1 to 4.

12.8 A candidate who qualifies for the award of the degree by passing all the subjects relating to semesters 1 to 4 and secure CGPA not less than 6.5 shall be declared to have passed the

examination in FIRST CLASS. All other candidates who qualify for the award of degree shall be declared to have passed the examination in SECOND CLASS.

12.9 A student with CGPA less than 5.0 is not eligible for the award of degree.

12.10 For the award of University rank and gold medal, the CGPA secured from 1st to 4th semester should be considered and it is mandatory that the candidate should have passed all the subjects from 1st to 4th semester in the first appearance and he/she should not have been prevented from writing the examination due to lack of attendance and should not have withdrawn from writing the University examinations.

13. Provision for Withdrawal : A candidate may, for valid reasons, and on the recommendation of the Head of the Institution be granted permission by the University to withdraw from writing the entire semester examination as one UNIT. The withdrawal application shall be valid only if it is made earlier than the commencement of the last theory examination pertaining to that semester. Withdrawal shall be permitted only once during the entire programme. Other conditions being satisfactory, candidates who withdraw are also eligible to be awarded DISTINCTION whereas they are not eligible to be awarded a rank/gold medal.

14. Temporary Discontinuation from the Programme : If a candidate wishes to temporarily discontinue the programme for valid reasons, he/she shall apply through the Head of the Institution in advance and obtain a written order from the University permitting discontinuance. A candidate after temporary discontinuance may rejoin the programme only at the commencement of the semester at which he/she discontinued, provided he/she pays the prescribed fees to the University. The total period of completion of the programme reckoned from the commencement of the first semester to which the candidate was admitted shall not in any case exceed 4 years, including the period of discontinuance.

15. Revision of Regulations and Curriculum : The University may from time to time revise, amend or change the regulations of curriculum and syllabus as and when requirement for the same arises.

16. Power to Modify : 15.1 Notwithstanding anything contained in the foregoing, the Pondicherry University shall have the power to issue directions/ orders to remove any difficulty.

15.2 Nothing in the foregoing may be construed as limiting the power of the Pondicherry University to amend, modify or repeal any or all of the above.

17. Minimum number of credits to be acquired for successful completion of the programm : 74 (Seventy Four) Credits

ii) Curriculum for M.Tech. (Wireless Communication)

I Semester

Sl. No.	Course Code	Name of the Course	H/S	L-T-P	Credits
1	WCENG 510	Advanced Communication Laboratory - I	H	0-0-4	2
2	WCENG 511	Advanced Coding Techniques	H	3-1-0	4
3	WCENG 512	Advanced Engineering Mathematics	H	3-1-0	4
4	WCENG 513	Advanced Radiation Systems	H	3-1-0	4
5	WCENG 514	Advanced Wireless Communication	H	3-1-0	4
6		Elective I	S	2-1-0	3
7		Elective II	S	2-1-0	3
				Total Credits for Semester I	**24**

(H – Hard Core Course; S – Soft Core Course)

II Semester

Sl. No.	Course Code	Name of the Course	H/S	L-T-P	Credits
8	WCENG 520	Advanced Communication Laboratory - II	H	0-0-4	2
9	WCENG 521	Advanced Digital Signal Processing	H	3-1-0	4
10	WCENG 522	RF System Design	H	3-1-0	4
11	WCENG 523	Modeling and Simulation of Wireless Communication Systems	H	3-1-0	4
12	WCENG 524	Wireless IP Networks	H	3-1-0	4
13		Elective III	S	2-1-0	3
14		Elective IV	S	2-1-0	3
				Total Credits for Semester II	**24**

(H – Hard Core Course; S – Soft Core Course)

III Semester

Sl. No.	Course Code	Name of the Course	H/S	L-T-P	Credits
15.		Elective V	S	2-1-0	3
16.		Elective VI	S	2-1-0	3
17.		Elective VII	S	2-1-0	3
18.	WCENG 610	Internship/ Seminar/ Workshop / Conference / FDP / Short term course / NPTEL/GIAN/MOOC Course	H	0-0-2	2
19.	WCENG 611	NPTEL/GIAN/MOOC Course	H	0-2-0	2
20.	WCENG 612	Project – Literature Survey	H	0-0-1	1
				Total Credits for Semester III	**14**

(H – Hard Core Course; S – Soft Core Course)

IV Semester

Sl. No.	Course Code	Name of the Course	H/S	L-T-P	Credits
21.	WCENG 620	Project and Viva Voce	H	0-0-12	12
22.	WCENG 621	Publication	-	-	0
				Total Credits for Semester IV	**12**

(H – Hard Core Course; S – Soft Core Course)

Total number of credits required to complete

M.Tech. in Wireless Communication : 74 credits

Semester I – List of Electives

Sl. No.	Course Code	Name of the Course	L-T-P	Credits
1.	WCENG 530	Advanced Embedded System Design	2-1-0	3
2.	WCENG 531	Advanced Image Processing	2-1-0	3
3.	WCENG 532	Advanced Optical Communication	2-1-0	3
4.	WCENG 533	Advanced Satellite Communication	2-1-0	3
5.	WCENG 534	Communication Protocols	2-1-0	3
6.	WCENG 535	Electromagnetic Interference and Compatibility	2-1-0	3
7.	WCENG 536	Microwave Communication	2-1-0	3
8.	WCENG 537	Mobile Communication System	2-1-0	3
9.	WCENG 538	Optimization Techniques	2-1-0	3
10.	WCENG 539	Smart Antenna	2-1-0	3

Semester II - List of Electives

Sl. No.	Course Code	Name of the Course	L-T-P	Credits
1.	WCENG 550	Advanced Technologies in Wireless Networks	2-1-0	3
2.	WCENG 551	Antennas for Personal Area Communication	2-1-0	3
3.	WCENG 552	Cognitive Radio Technology	2-1-0	3
4.	WCENG 553	Free Space Optical Communication	2-1-0	3
5.	WCENG 554	Green Radio Communication Techniques	2-1-0	3
6.	WCENG 555	High Performance Communication Networks	2-1-0	3
7.	WCENG 556	Information and Network Security	2-1-0	3
8.	WCENG 557	Internet of Everything Things	2-1-0	3
9.	WCENG 558	Multicarrier Wireless Communication	2-1-0	3
10.	WCENG 559	Statistical Theory of Communication	2-1-0	3

Semester III - List of Electives

Sl. No.	Course Code	Name of the Course	L-T-P	Credits
1.	WCENG 630	Advanced Technologies in Wireless Reception	2-1-0	3
2.	WCENG 631	Convergence Technologies	2-1-0	3
3.	WCENG 632	Heterogeneous Network	2-1-0	3
4.	WCENG 633	High Speed Switching Architecture	2-1-0	3
5.	WCENG 634	Internetworking Multimedia Communication	2-1-0	3
6.	WCENG 635	Micro and Nano Electronic Engineering	2-1-0	3
7.	WCENG 636	MIMO Communication Systems	2-1-0	3
8.	WCENG 637	Multimedia Compression Techniques	2-1-0	3
9.	WCENG 638	Network Routing Algorithm	2-1-0	3
10.	WCENG 639	Pattern Recognition and Artificial Intelligence	2-1-0	3
11.	WCENG 640	RF System Design for Wireless Communication	2-1-0	3
12.	WCENG 641	Soft Computing	2-1-0	3
13.	WCENG 642	Audio Signal Processing	2-1-0	3
14.	WCENG 643	Ultra Wideband Communication Systems	2-1-0	3
15.	WCENG 644	Vehicular Ad-Hoc Networks (VANET)	2-1-0	3
16.	WCENG 645	VLSI for Wireless Communication	2-1-0	3
17.	WCENG 646	WDM Optical Networks	2-1-0	3
18.	WCENG 647	5G Wireless Networks	2-1-0	3

iii) Syllabus for M.Tech. (Wireless Communication)

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 510	ADVANCED COMMUNICATION LABORATORY-I	0	0	4	2	60

Objective : Hands on experience on hardware experiments in order to acquire sufficient knowledge and understand practical nuausence / implications of various communication techniques.

LIST OF EXPERIMENTS (Given list is only the minimum, however, the course teacher can decide the level of experiments)

1. Microcontroller Based Experiments
    a. Various Logic Operations
    b. Level and Edge Triggering Interrupts
    c. ADC/DAC
    d. Real time digital clock and alarm realization

2. DSP Based Experiments
    a. Wave form generation
    b. Linear and Circular convolution
    c. FIR filter implementation
    d. IIR filter implementation

3. Communication Based Experiments
    a. Design and analysis of GMSK modulator and demodulator
    b. Multiplexing, BER measurement and data transmission through optical fiber
    c. Characterization of Directional Coupler using micro strip trainer kit
    d. Characterization of power divider using microstrip trainer kit
    e. Measurement of radiation pattern of microstrip patch antenna
    f. Study of DPCM and ADPCM using Advanced Digital Modulator trainer kit

4. VLSI Based Experiments
    a. Synthesis of 8-bit adders
    b. Synthesis of 4-bit multiplier
    c. Synthesis of mod-13 counter
    d. Synthesis of FSM

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 511	ADVANCED CODING TECHNIQUES	3	1	0	4	60

Prerequisite: Knowledge in probability, calculus, Information theory and Coding.

Objective : To understand the concepts of various coding techniques with their applications.

Outcome : Students will be able to incorporate the various coding techniques in the field of wireless communications.

Unit I: Convolutional code **12 Hours**

Linear convolutional encoders – Structural properties of convolutional codes – State diagrams – Transparent convolutional codes – Receiver phase offset and Differential decoding – Trellis diagrams – Viterbi algorithm – Performance analysis – Design and Implementation of Viterbi decoder – Punctured convolutional codes.

Unit II: Decoders **12 Hours**

Tree diagrams – The Fano algorithm – The Stack algorithm – Performance analysis for Sequential decoders – Burst error correcting codes – Decoding of single burst error correcting cyclic codes – Fire interleaved codes – Phased burst error correcting codes – Concatenated codes.

Unit III: TCM and Turbo Codes **12 Hours**

M-ary signaling – One and Two-dimensional TCM – Multiple TCM – Decoding and performance analysis – Implementation considerations.
Turbo codes – Encoding – Performance Evaluation using bounding techniques – BCJR algorithm for decoding – Applications.

Unit IV: ARQ Protocols **12 Hours**

Pure ARQ Protocols – Noisy feedback channels – Type I Hybrid ARQ Protocols – Type II Hybrid ARQ Protocols and Packet combining.

Unit V: Instructional Activities **12 Hours**

Simulation of minimum of five coding techniques using related tools.

Reference Books:

1. Stephen B. Wicker, "Error control systems for Digital communication and storage", Prentice Hall Upper Saddle River, NJ, 1994.
2. Shu Lin, Daniel Costello, "Error control coding – Fundamentals and Applications", Second Edition, Prentice Hall, Upper Saddle River, NJ, 2004.
3. E. Biglieri, et al. "Introduction to Trellis coded modulation with Applications", Macmillan Publishers, 1991.
4. R. Johannesson and K.S. Zigangirov, "Fundamentals of Convolutional coding", IEEE Series on Digital and Mobile Communication, Wiley-IEEE Press, 1999.
5. K. Deergha Rao, "Channel Coding Techniques for Wireless Communications" Springer, 2015.

Hyperlinks:

1. nptel.ac.in/courses/117102062/
2. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.108.2560&rep=rep1&type=pdf
3. https://digitalcommons.lsu.edu/cgi/viewcontent.cgi?article=2897&context=gradschool_dissertations
4. https://wsl.stanford.edu/~ee359/mod_overview.pdf
5. http://www.tml.tkk.fi/Studies/Tik-110.300/1999/Wireless/channel_1.html

WCENG 511

Course Code	Name of the Course	Periods			Credits	Total Hours
WCENG 512	ADVANCED ENGINEERING MATHEMATICS	L	T	P	4	60
		3	1	0		

Prerequisite: Probability Theory

Objective : To make the students understand various mathematical concepts implied to Wireless Communication Engineering.

Outcome : The students will be able to apply these mathematical concepts to various applications of Wireless Communication Engineering.

Unit I: Random Variables **12 Hours**

Random variables: Probability axioms - Conditional probability - Discrete and continuous random variables, Cumulative Distribution Function (CDF) - Probability Mass Function (PMF) - Probability Density Function (PDF) - Conditional PMF/PDF - Expected value - Variance; Functions of a random variable; Expected value of the derived random variable.

Unit II: Multiple Random Variables **12 Hours**

Multiple random variables: Joint CDF/PMF/PDF - functions of multiple random variables - multiple functions of multiple random variables - independent/uncorrelated random variables - sums of random variables - moment generating function - random sums of random variables.

Unit III: Stochastic Processes **12 Hours**

Classification of stochastic process - stationary process (SSS and WSS) - ergodic process - independent increment process - counting process - narrowband process - normal process - Wiener process - shot noise process - autocorrelation function.

Unit IV: Finite Difference Time Domain Method **12 Hours**

Wave Equation: Dispersion and Stability ; The FDTD Method: Staggered Grids- One Space Dimension- Three Space Dimensions-Integral Interpretation of the FDTD Method- Dispersion Analysis in Three Dimensions ; Boundary Conditions for Open Regions: The Perfectly Matched Layer - near to far field transformation.

Unit V: Instructional Activities **12 Hours**

Response of LTI system's - probability distribution and density functions- Weiner and Shot noise process- Practical applications of wave scattering in FDTD using related platforms.

Reference Books:

1. Michel K.O, "Applied Probability and Stochastic Processes", John Wiley and Sons, 2008.
2. Paboulis A, Unnikrishna P S, "Probability, Random Variables and Stochastic Processes", 4th Edition, Tata McGraw Hill, 2002.
3. Anders B, Thomas R, Ingelstro P, "Computational Electromagnetics", 2nd Edition, Springer, 2013.
4. Steven K. "Intuitive Probability and Random Processes using MATLAB", Springer, 2006.
5. Sadiku M N O, "Numerical Techniques in Electromagnetics", 2nd Edition, CRC Press, 2000.
6. Sankaran K, "Accurate Domain Truncation Techniques for Time-Domain Conformal Methods", ETH Zurich, 2007.

Hyperlinks:

1. http://users.ece.utexas.edu/~gustavo/ee381j.html
2. http://www2.math.uu.se/research/telecom/software.html
3. http://www.ifp.illinois.edu/~hajek/Papers/randomprocesses.html
4. http://www.feynmanlectures.caltech.edu/II_toc.html
5. https://www.researchgate.net/publication/282120723_Accurate_domain_truncation_techniques_for_time-domain_conformal_methods

WCENG 512

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 513	ADVANCED RADIATION SYSTEM	3	1	0	4	60

Prerequisite : Electromagnetic and antenna theory.

Objective : To learn the antenna radiation concepts, different types of antenna and their design methodology.

Outcome : Students will be able to design different types of antenna for various applications.

Unit I: Concepts of Radiation and Antenna Fundamentals **12 Hours**

Physical Concept of Radiation: Radiation from surface and line current distributions - fundamental parameters of antennas - Friss Transmission Equation - radiation integrals and auxiliary potential functions - Near and Far Field regions - Reciprocity and Reaction Theorems - radiation hazards and solutions

Unit II: Aperture and Reflector Antennas **12 Hours**

Huygens's principle - radiation from rectangular and circular apertures - design considerations - Babinets principle - radiation from sectoral - pyramidal - conical and corrugated Horns - design concepts of parabolic reflectors and cassegrain antennas.

Unit III: Broadband Antennas **12 Hours**

Principles - frequency independent antennas - design and properties of log periodic - Yagi-Uda antennas - loop antennas - helical antennas - biconical antennas - broadcast antenna - spiral antenna and slot antennas.

Unit IV: Microstrip Antennas **12 Hours**

Microstrip Antennas: Radiation mechanism - parameters and applications - feeding methods - design of rectangular and circular patch - impedance matching of microstrip antennas - broadband - compact and tunable microstrip antennas.

Unit V: Instructional Activities **12 Hours**

Design, simulation and analysis of different antennas for wireless applications using related simulation tools.

Reference Books:

1. Jordan E C and Balmain K G, "Electromagnetic Waves and Radiating Systems", 2nd Edition, Pearson Education, 2015.
2. Balanis C A, "Antenna Theory: Analysis and Design", 4th Edition, John Wiley and Sons, New Jersey, 2016.
3. Kraus J D and Marhefka R J, "Antennas for All Applications", 3rd Edition, Tata McGraw Hill, 2002.
4. Elliot R S, "Antenna Theory and Design", Revised Edition, John Wiley and Sons, India, 2006.
5. Girish Kumar and Ray K P, "Broadband Microstrip Antennas", Artech House, 2003.

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2. http://www.nptel.ac.in/courses/108101092/
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WCENG 513

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 514	ADVANCED WIRELESS COMMUNICATION	3	1	0	4	60

Prerequisite: Basics of analog, digital and wireless communication.

Objective : To impart the new concepts in Advanced Wireless Communications.

Outcome : Students will able to understand the latest technologies used in advanced wireless communication systems.

Unit I: Introduction **12 Hours**

Introduction about wireless communication - technical challenges of wireless communication- applications; Cellular architecture - frequency reuse - channel assignment - handoff - coverage and capacity improvement; Multiple access - FDMA/CDMA/TDMA/SDMA

Unit II: Propagation principles **12 Hours**

Propagation Principles: Propagation mechanisms - channel modeling methods - radio channels- indoor channels - outdoor channels - fading channels ; Mobile Radio Propagation : Large scale path loss – path loss and propagation models - small scale fading - types of small scale fading- parameters of mobile multipath channels - statistical models for multipath fading channels

Unit III: Modulation and Detection **12 Hours**

Digital modulation: Structure of a wireless communication link - linear and constant envelope modulation techniques for wireless communication - error performance in fading channel; Transmission System; combined fast and slow fading - Equalization - different detection techniques used in wireless communication.

Unit IV: MIMO Systems **12 Hours**

Types of MIMO Systems: Beam forming - spatial multiplexing - basic space time code design principles- Alamouti scheme - orthogonal and quasi orthogonal space time block codes- space time trellis codes - representation of space - performance analysis for space-time trellis codes - comparison of space-time block and trellis codes.

Unit V: Instructional Activities **12 Hours**

Simulation of minimum of (2) modulation and multiple acess technique for wireless communication using related simulation tools.

Reference Books:

1. Andreas Molisch F, "Wireless Communications", John Wiley and Sons Ltd., 2011.
2. David Tse and PramodViswanath, "Fundamentals of Wireless Communication", Cambridge University Press, 2005.
3. Theodore S. Rappaport, "Wireless Communications: Principles and Practice", 2nd Edition, Prentice Hall of India, 2005.
4. Guillaume De La Roche, Andres Alayon Glazunov and Ben Allen, "LTE – Advanced and Next Generation Wireless Networks: Channel Modelling and Propagation", John Wiley and Sons Ltd., 2013
5. Andrea Goldsmith, "Wireless Communications", Cambridge University Press, 2005.
6. Michel DaoudYacoub, "Wireless Technology: Protocols, Standards, and Techniques", CRC Press, 2002.
7. Jafarkhani H, "Space-Time Coding: Theory & Practice", Cambridge University Press, 2005.

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4. http://ee.sharif.edu/~wireless.comm.net/references/Tse,%20Fundamentals%20of%20Wireless%20Communication.pdf
5. http://ee.sharif.edu/~pr.wireless.comm/references/Goldsmith.pdf

WCENG 514

Course Code	Name of the Course	Periods			Credits	Total Hours
WCENG 520	ADVANCED COMMUNICATION LABORATORY-II	L	T	P	2	60
		0	0	4		

Objective : Hands on experience on various simulation tools to design and analyse the various communication techniques.

LIST OF EXPERIMENTS: (Given the list is minimal, however, the course teacher can decide the level of experiments)

1. Simulation using MATLAB

a. Direct sequence spread spectrum system
b. Channel coding
c. Line coding
d. Filters
e. Modulation schemes
f. Security algorithm and authentication protocols

2. Simulation using VHDL/ Verilog

a. Flip Flops
b. Synchronous/ Asynchronous Counters
c. Registers
d. ROM/RAM
e. PRBS generator

3. Simulation using PSPICE

a. Analog circuits
b. Digital circuits
c. Communication circuits

4. Simulation using NetSim

a. Design and configure a simple network model, collect statistics and analyze network performance.
b. Design and analyse the Spanning tree algorithm.
c. Performance analysis of WiMAX/ WiFi network.
d. Performance analysis of convergence networks (WiMAX and LTE networks)

WCENG 520

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 521	ADVANCED DIGITAL SIGNAL PROCESSING	3	1	0	4	60

Prerequisite : Knowledge in Signal and Systems, and Digital Signal Processing.

Objective : To make the students to understand the concepts in signal processing mechanisms and power spectrum estimation methods

Outcome : Students will be able to analyze and implement advanced signal processing techniques for various applications

Unit I:Fundamentals of Signal Processing **12 Hours**

Introduction: Basic elements of Digital Signal Processing System- advantages of digital over analog signal processing; Classification of signals: Deterministic vs Random signals - Multi channel and Multi-dimensional signals; Down Sampling-decimation-up sampling- interpolation.

Unit II: Power spectrum estimation **12 Hours**

Estimation of spectra using the DFT from finite duration signals - non– parametric methods for power spectrum estimation: Welch- Bartlett methods; Parametric methods for power spectrum estimation: Yule-Walker method- Burg method for the ARM parameters- sequential estimation methods.

Unit III: Adaptive Signal processing **12 Hours**

FIR adaptive filters- steepest descent adaptive filter - LMS algorithm - convergence of LMS algorithms; Applications: Noise cancellation - channel equalization; Adaptive recursive filters - recursive least square estimation.

Unit IV: Wavelet Transform **12 Hours**

Introduction: Continuous Wavelet Transform - basic properties of wavelet transforms - Discrete Wavelet Transform: Haar scaling functions and function spaces- nested spaces - Haar wavelet function - orthogonality of $\varphi(t)$ and $\psi(t)$ - normalization of Haar bases at different scales; Daubechies wavelets - support of wavelet system.

Unit V: Instructional Activities **12 Hours**

EEG/ECG signal analysis for the real time environment; Echo cancellation using adaptive filters; Voice recognition and speech-to-text conversion using related tools.

Reference books:

1. Proakis J G and Manolkis D G, "Digital Signal Processing: Principles, Algorithms and Applications", 4th Edition, Prentice Hall of India, 2007.
2. Monson H H, "Statistical Digital Signal Processing and Modeling", Wiley, 2002.
3. Cristi R, "Modern Digital Signal Processing", Thomson Brooks/ Cole, 2004.
4. Lokenath D and Firdous A S, "Wavelet Transforms and Their Applications", 2nd Edition, Birkhauser, Springer, 2014.
5. Raghuveer R M, and Ajit S B, "Wavelet Transforms: Introduction to Theory and Applications", Pearson Education, New Delhi, 1998.

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1. www.ece.umd.edu/class/enee630.F2012.html
2. http://ar.book.org/s/?q=DSP+PROAKIS&yearFrom=&yearTo=&language=&extension=&t=0

WCENG 521

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 522	RF SYSTEM DESIGN	3	1	0	4	60

Prerequisite : Microwave engineering.

Objective : To impart RF system design for different applications.

Outcome : Students will be able to design different types of RF active components, devices and circuits.

Unit I: RF Passive Components and Transmission Line Analysis **12 Hours**

High Frequency Components: Resistors- capacitors and inductors ; Transmission line analysis - line equation - microstrip line - SWR - voltage reflection co– efficient - propagation constant - phase constant - phase velocity - Smith chart - parallel RL and RC circuits - ABCD parameters and S parameters.

Unit II: RF Device and Circuit **12 Hours**

RF amplifier design- power gain equations - maximum gain design, low noise amplifier design, high power amplifier design- stability considerations; RF oscillator design -one – port and two – port negative resistance oscillators - oscillator design using large – signal measurements; RF Mixer Design: Single ended mixer – double ended mixer.

Unit III: RF feedback systems and Power amplifiers **12 Hours**

Stability of feedback systems: Gain and phase margin- root– locus techniques -time and frequency domain considerations - compensation ; General model – Class A, AB, B, C, D, E and F amplifiers - power amplifier linearization techniques - efficiency boosting techniques - ACPR metric- design considerations.

Unit IV: PLL and frequency synthesizers **12 Hours**

Linearised Model - noise properties - phase detectors - loop filters and charge pumps- integer-N frequency synthesizers - direct digital frequency synthesizers

Unit V: Instructional Activities **12 Hours**

Simulation of the frequency response of amplifier, oscillator and mixer for different applications using related tools.

References Books:

1. Reinhold Ludwig and Pavel Bretchko, “RF Circuit Design”, Pearson Education, 2007.
2. Josn Rogers and Calvin Plett, “Radio Frequency Integrated Circuit Design”, Artech House, 2002.
3. Ferri Losee, “RF systems, Components and Circuits Handbook”, Artech House, 2002.
4. Joseph J. Carr, “Secrets of RF Circuit Design”, Tata McGraw Hill, 2004.
5. Thomas Lee,” The Design of Radio Frequency CMOS Integrated Circuits”, Cambridge University Press, 2nd Edition, Cambridge, 2004.

Hyperlinks:

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WCENG 522

Course Code	Name of the Course	Periods			Credits	Total Hours
WCENG 523	MODELING AND SIMULATION OF WIRELESS COMMUNICATION SYSTEMS	L	T	P	4	60
		3	1	0		

Prerequisite : Knowledge of MATLAB programming, Digital Signal Processing and Digital Communication

Objective : To understand the modeling of wireless communication systems through simulation.

Outcome : Students will able to design and analyse the various concept of wireless communication systems.

Unit I: Introduction **12 Hours**

Role of Simulation: Examples of complexity - multidisciplinary aspects of simulation -models - deterministic and stochastic simulations; Simulation methodology - aspects of methodology - performance estimation; Fundamental Concepts: Sampling - quantizing - reconstruction and interpolation - simulation sampling frequency - complex envelope techniques.

Unit II: Generating and Processing Random Signals **12 Hours**

Stationary and Ergodic Processes: Uniform random number generators - mapping uniform random variables to an arbitrary PDF - generating uncorrelated and correlated Gaussian random numbers - PN sequence generators; Establishing a PDF and PSD Post Processing: Basic graphical techniques - estimation - coding.

Unit III: Methodology for Simulating a Wireless System **12 Hours**

Fundamental Concepts of Monte Carlo Simulation- applications and integration - two Monte Carlo examples; Semi Analytic Techniques System: Level simplifications and sampling rate considerations - overall methodology; Modeling and Simulation of Nonlinearities: Modeling and simulation of memory less nonlinearities - modeling and simulation of nonlinearities with memory - techniques for solving nonlinear differential equations.

Unit IV: Modeling and Simulation of Time-Varying Systems **12 Hours**

Introduction: Models for LTV systems - random process models - simulation models for LTV systems; Wired and guided wave - radio channels - multipath fading channels - Random process models - simulation methodology; Discrete Channel Models: Discrete memory less channel models - Markov models for discrete channels with memory- HMMs - Gilbert and Fritchman models - estimation of Markov model parameters.

Unit V: Instructional Activities **12 Hours**

Simulation of Generating PDF for the Gaussian and non-Gaussian distributions and Simulation of linear and non-linear systems using different techniques with the help of simulation tools

Reference Books:

1. William H T, Samshanmugan K, Rappaport T S and Kosbar K L, "Principles of Communication Systems Simulation with Wireless Applications", Pearson Education, 1st Edition, 2011.
2. Jeruchim M C, Philip B and Samshanmugam K, "Simulation of Communication Systems: Modeling Methodology and Techniques", 2nd Edition, Kluwer Academic Publisher, 2002.
3. Averill M L, "Simulation Modeling and Analysis", 5th Edition, McGraw Hill, 2014.
4. Hayes F J, "Modeling and Analysis of Computer Communication Networks", Springer, Plenum Press, 1984.
5. Banks J, Carson J S, Nelson L B and Nicol D M, "Discrete Event System Simulation", 4th Edition, Pearson Education, 2009.

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2. http://dspace.mit.edu/handle/1721.1/38950
3. http://www.mathworks.in/communications/wireless-wired-channel-modeling.html

WCENG 523

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 524	WIRELESS IP NETWORKS	3	1	0	4	60

Prerequisite : Wireless Networks.

Objective : To learn the next generation wireless network concepts, different types networks and their application.

Outcome : Students will be able to understand the different type of wireless networks and various applications.

Unit I:Wireless IP Network Architectures **12 Hours**

Evolution of Wireless Networks -.Introduction to 1G/2G/3G/4G Terminology- Current Wave of Mobile Data Services: High1Speed and Multimedia Mobile Internet Services. IP-Based Wireless Networks - 3GPP, 3GPP2.
3GPP Packet Data Networks - Network Architecture-3G PP2 Packet Data - MWIF All-IP Mobile Networks - Network Architectures - Access to MWIF Networks - Session Management.

Unit II: IP Multimedia Subsystems and Application **12 Hours**

Signaling in IP Networks 1Session Initiation Protocol (SIP) -Session Description Protocol (SDP) 3GPP IP Multimedia Subsystem (IMS) - IMS Architecture 3.2.2 Mobile Station Addressing for Accessing the IMS - Reference Interfaces - Service Architecture - Registration with the IMS - Deregistration with the IMS –End-to-End Signaling Flows for Session Control 3GPP2 IP Multimedia Subsystem (IMS)

Unit III: Mobility Management **12 Hours**

Basic Issues in Mobility Management - Mobility Management in IP Networks - Mobility Management in 3GPP Packet Networks - Mobility Management in 3GPP2 Packet Data Networks - Mobility Management in MWIF Networks - Comparison of Mobility Management in IP, 3GPP, and 3GPP2 Networks .

Unit IV: Quality of Service **12 Hours**

Internet QoS - QoS Challenges in Wireless IP Networks - QoS in 3GPP - QoS in 3GPP2 - 3GPP2 QoS Architecture - 3GPP2 QoS Management - 3GPP2QoS Classes – QoS Attributes (QoS Profile) - Management of End-to-End IP QoS.

Unit V:Instructional Activities **12 Hours**

Design, simulation and analysis of different wireless networks and their QoS service applications using related simulation tools.

Reference Books:

1. Jyh1Cheng Chen and Tao Zhang, "IP-Based Next1GenerationWireless Networks Systems, Architectures, and Protocols," John Wiley & Sons, Inc. Publication, 2006.
2. Crosspoint Boulevard, "Wireless and Mobile All1IP Networks," Wiley Publication, 2005.
3. Minoru Etoh, "Next Generation Mobile Systems3G and Beyond, "Wiley Publications, 2005.
4. Savo Glisic "Advanced Wireless Communications 4G Technologies, "Wiley Publications, 2004.
5. Yi-Bing Lin, Ai-Chun Pang, " Wireless and Mobile All-IP Networks", 1st Edition, Wiley Publications, 2005
6. Neill Wilkinson, "Next Generation Network Services: Technologies and Strategies", Wiley Publications, 2002

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3. http://nptel.ac.in/courses/117102062/
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6. http://www.analysysmason.com/services/Research/Telecoms-software/Next-Generation-Wireless-Networks/
7. https://www.wirelessweek.com/article/2015/10/5g-networks-next-generation-wireless

WCENG 524

Course Code	Name of the Course	Periods			Credits	Total Hours
WCENG 530	ADVANCED EMBEDDED SYSTEM DESIGN	L	T	P	3	45
		2	1	0		

Prerequisite : Fundamentals of Embedded system

Objective : To teach the fundamentals on design attributes of Hardware software partitioning in system design strategies for processor Communications and discuss on Co-Designs

Outcome : Understand the timing and interrupt in processor and apply co design methodology Solve the Co-Synthesis problem understand the memories and communication protocol in embedded field.

Unit I : **Introduction to Embedded Hardware and Software** **9 Hours**

Terminology – Gates – Timing diagram – Memory – Microprocessor buses – Direct memory access – Interrupts – Built interrupts – Interrupts basis – Shared data problems – Interrupt latency - Embedded system evolution trends – Interrupt routines in an RTOS environment.

Unit II: System Modeling and Co-Synthesis **9 Hours**

Embedded systems, Hardware/Software Co-Design, Co-Design for System Specification and modelling- Single-processor Architectures &,Multi-Processor Architectures, comparison of Co Design Approaches, Models of Computation, Requirements for Embedded System Specification, Hardware/Software Partitioning Problem, Hardware/Software Cost Estimation, Generation of Partitioning by Graphical modelling, Formulation of the HW/SW scheduling, Optimization. The Co-Synthesis Problem, State-Transition Graph, Refinement and Controller Generation, Distributed System Co-Synthesis.

Unit III: **Memory and Interfacing** **9 Hours**

Memory: Memory write ability and storage performance – Memory types – composing memory – Advance RAM interfacing communication basic – Microprocessor interfacing I/O addressing – Interrupts – Direct memory access – Arbitration multilevel bus architecture – Serial protocol – Parallel protocols – Wireless protocols – Digital camera example.

Unit IV : Concurrent Process Models and Co-Design **9 Hours**

Modes of operation – Finite state machines – Models – HCFSL and state charts language – state machine models – Concurrent process model – Concurrent process – Communication among process –Synchronization among process – Implementation – Data Flow model. Design technology – Automation synthesis – Hardware software co-simulation – IP cores – Design Process Model.

Unit V: Instructional Activities **9 Hours**

Simulation study of any (five) Embedded system design and their application using related tools.

References Books:

1. David. E. Simon, “An Embedded Software Primer”, Pearson Education, 2001.
2. Tammy Noergaard, ”Embedded System Architecture, A comprehensive Guide for Engineers and Programmers”, Elsevier, 2006
3. Raj Kamal, “Embedded Systems- Architecture, Programming and Design” Tata McGraw Hill, 2006.
4. Frank Vahid and Tony Gwargie, “Embedded System Design”, John Wiley & sons, 2002.
5. Steve Heath, “Embedded System Design”, Elsevier, Second Edition, 2004.
6. Ralf Niemann, “Hardware/Software Co-Design for Data Flow Dominated Embedded Systems”, Kluwer Academic Pub, 1998.
7. Jorgen Staunstrup, Wayne Wolf, “Harware/Software Co-Design:Principles and Practice”, Kluwer Academic Pub, 1997.
8. Giovanni De Micheli, Rolf Ernst Morgon, “Reading in Hardware/Software Co-Design” Kaufmann Publishers, 2001.

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1. www.vectorindia.org/embedded_coursecontent.html
2. www.cetpainfotech.com
3. http://nptel.ac.in/courses/117106030/35
4. https://link.springer.com

WCENG 530

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 531	ADVANCED IMAGE PROCESSING	2	1	0	3	45

Prerequisite : Fundamentals of Signals and Systems

Objective : Make the students to understand the concepts used in image processing techniques and its analysis.

Outcome : Students will be able to work with various image processing techniques for real time applications

Unit I: Digital Image Fundamentals **9 Hours**

Image fundamentals: Image acquisition - sampling and quantization - image resolution- basic relationship between pixels - color images - RGB, HSI and other models; Transform based models (DFT, DCT, DWT); Image Enhancement: Spatial and frequency averaging - smoothening and sharpening filters.

Unit II: Segmentation and Denoising **9 Hours**

Image Segmentation: Edge detection - edge linking via Hough transform - thresholding- region based segmentation; Denoising: Maximum likelihood estimation - Bayesian estimators - model selection (MDL principle) - transform based denoising - adaptive wiener filtering - soft shrinkage and hard thresholding.

Unit III: Image Compression **9 Hours**

Image compression: Basics of source coding theory (lossless and lossy) - Vector quantization - codebook design - transform and sub band coding.

Unit IV: Image security and forensic **9 Hours**

Image Security: cryptography and steganography techniques- Chaos based and Non-Chaos based methods; Image Forensics: Key photographic techniques-detection techniques for crime scene analysis.

Unit V: Instructional Activities **9 Hours**

Simulation of preprocessing techniques-implementation of image processing techniques for real time applications-forensic analysis using related tools.

Reference Books:

1. Rafael C Gonzalez and Richard E Woods, "Digital Image Processing", 2nd Edition, Pearson Education, 2004.
2. Anil K Jain, "Fundamentals of Digital Image Processing", 3rd Edition, Pearson Education, 2002.
3. William K Pratt, "Digital Image Processing", 2nd Edition, John Wiley, 2002.
4. Milan Sonka et al, "Image Processing, Analysis and Machine Vision", 2nd Edition, Vikas Publishing House, 1999.
5. Prabat K Andleigh and Kiran Thakrar, "Multimedia Systems and Design", Prentice Hall India, 2007.
6. Tay Vaughan, "Multimedia Making It Work", McGraw Hill, 2011.
7. Parekh R, "Principles of Multimedia",Tata McGraw-Hill, 2006.
8. Robinson and Edward, "Introduction to Crime Scene Photography", Elsevier/Academia Press, 2012.
9. Herbert Blitzer, Karen Stein-Ferguson and Jeffrey Huang, "Understanding Forensic Digital Imaging", 1st edition, Acadamic Press, 2008.

Hyperlinks:

1. www.imageprocessingplace.com/DIP-3E/dip3e_main_page.html
2. https://www.tutorialspoint.com/dip/
3. https://homepages.inf.ed.ac.uk/rbf/HIPR2/glossary.htm

WCENG 531

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 532	ADVANCED OPTICAL COMMUNICATION	2	1	0	3	45

Prerequisite : Sound knowledge on basic optics, optical communication, various modulation and detection schemes in optical communication

Objective : To impart the concepts of multilevel modulation schemes, OFDM and MIMO for optical communication systems and nonlinear optics.

Outcome : Students will able to understand the potential of physical layer of optical system and its applications.

Unit I: Introduction **9 Hours**

Prologue: Historical perspective - light sources - modulators, fiber losses - signal dispersion - signal propagation - multi channel propagation - optical solutions- photonic crystal and Photonic Band Gap (PBG); Introduction to second order nonlinear optics: Second Harmonic Generation (SHG) - Sum Frequency Generation (SFG) - Difference Frequency Generation (DFG); Third order nonlinear optics: Third Harmonic Generation (THG) - Four Wave Mixing (FWM) - Self Focusing (SF).

Unit II: Modulation schemes **9 Hours**

Noise sources - channel impairments - optical transmission system - advanced modulation formats - multilevel modulation schemes - OFDM for optical communications - MIMO optical communication - polarization multiplexing - constrained (line or modulation) coding - soliton based communication.

Unit III: Detection schemes **9 Hours**

Coherent detection of optical signals - optical coherent detection schemes - optical heterodyne detection - optical homodyne detection - optical intradyne detection - DPSK photonic systems - optical channel equalization - coherent optical OFDM detection - optical MIMO detection.

Unit IV: Optical Channel Estimation **9 Hours**

Optical channel capacity - calculation of information capacity - information capacity of systems with direct detection - capacity of optical OFDM systems - capacity of optical MIMO systems.

Unit V: Instructional Activities **9 Hours**

Simulation of two dimensional photonic crystal, ring resonator and Y-shaped waveguide using 32-bit OPTIFDTD (freeware); Also analyze second order nonlinearity and four-wave mixing through simulation using the same FDTD tools.

Reference Books:

1. Keiser G, "Optical Fiber Communication", 4th Edition, McGraw Hill, 2008.
2. Agrawal G P, "Fiber Optics Communication Systems", 4th Edition, Wiley, 2010.
3. Binh L N, "Advanced Digital Optical Communications", 2nd Edition, CRC Press, 2015.
4. William S and Ivan D, "OFDM for Optical Communications", Academic Press: Elsevier, 2010.
5. Ivan P K, Tingye L, and Alan E W, "Optical Fiber Communications VIB: Systems and Networks", 6th Edition, Academic Press: Elsevier, 2013.
6. Milorad C and Ivan B D, "Advanced Optical Communication Systems and Networks", Artech House, 2012.
7. Pierre L, "Fiber - Optic Communications", John Wiley and Sons, 2008.
8. Enrico F, "Optical Communication Theory and Techniques", Springer, 2006.
9. James N D, "Fiber-Optic Communications", Thomson Delmar Learning, 2005.
10. Rogers A J, "Understanding Optical Fiber Communications", Artech House, 2001.
11. Robert W Boyd, "Nonlinear Optics", 3rd edition, Academic Press, 2008.

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3. https://optiwave.com/resources/academia/free-fdtd-download/

WCENG 532

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 533	ADVANCED SATELLITE COMMUNICATION	2	1	0	3	45

Prerequisite : Basics of digital and satellite communication

Objective : To impart the orbital mechanics, space craft sub-systems and satellite link design

Outcome : Students will be able to analyze the advanced technical details behind the satellite link.

Unit I: Introduction and Satellite Access: 9 Hours

Orbits of Satellite: Low - medium – geo synchronous - angle period - returning period – orbital spacing - delay transponder - earth stations - antennas and earth coverage - altitude and eclipses; Multiple Access: Demand assigned FDMA - spade system - TDMA - satellite switched TDMA - CDMA.

Unit II: Space Segment and Earth Segment 9 Hours

Space Segment: Power supply - altitude control - station keeping - thermal control - TT and C subsystem - transponders; Earth Segment: Receive only home TV system - outdoor unit - indoor unit - master antenna TV system - community antenna TV system.

Unit III: Satellite Link Design 9 Hours

Link Design: System noise temperature and G/T ratio - C/N design of uplink and downlink - error control for digital satellite link.

Unit IV: VSAT Systems 9 Hours

VSAT Systems: Network architectures – access control protocols - earth station engineering - antennas - link margins - system design procedure.

Unit V: Instructional Activities 9 Hours

Simulation of link budget for two satellite systems - simulation of Transponders and Antenna system using related tools.

Reference Books:

1. Timothy Pratt and Charles W. Bostain, "Satellite Communications", 2nd Edition, Wiley, 2012.
2. D. Roddy, "Satellite Communication", 4th Edition (Reprint), McGraw Hill, 2009.
3. Wilbur L. Pritchard, Hendri G. Suyderhoud and Robert A. Nelson, "Satellite Communication Systems Engineering", Prentice Hall/ Pearson, 2007.
4. Tri T. Ha, "Digital Satellite Communication", 2nd Edition, McGraw Hill, 1990.
5. Brian Ackroyd, "World Satellite Communication and Earth Station Design", BSP Professional Books, 1990.

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2. http://ece564web.groups.et.byu.net
3. http://personal.stevens.edu/~yyao/syllabus-674.html
4. http://staff.um.edu.mt/carl.debono/lectures.html

WCENG 533

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 534	COMMUNICATION PROTOCOLS	2	1	0	3	45

Prerequisite : Fundamentals of communication

Objective : This subject aims to teach various communications Protocol for wireless communication.

Outcome : Understand the fundamental of communication protocols in wireless communication for real time application.

Unit I: Network Reference Model and Specifications **9 Hours**

Communication model-software, subsystems – protocol - protocol development methods -Protocol engineering process - Layered architecture - Network services and Interfaces - Protocol functions - OSI model - TCP/IP protocol suite.
Components of protocol - Specifications of Communication service - Protocol entity – Interface – Interactions - Multimedia protocol - Internet protocol -, SDL - SDL based protocol - other protocol specification languages.

Unit II: Verification and Validation **9 Hours**

Protocol verification - Verification of a protocol using finite state machines - Protocol validation - protocol design errors - Protocol validation approaches - SDL based protocol verification and validation.

Unit III: Conformance and Performance Testing **9 Hours**

Conformance testing – methodology - frame work – architectures -Test sequence generation- Distributed architecture - Conformance testing with TTCN - RIP,SDL based tools for conformance testing, SDL based: conformance testing of MPLS - performance testing of TCP and OSPF- Interoperability testing -SDL based interoperability testing of CSMA/CD and CSMA/CA protocol.

Unit IV: Protocol Synthesis and Implementation **9 Hours**

Protocol synthesis - Interactive synthesis algorithm - Automatic synthesis algorithm - Automatic synthesis of SDL from MSC -, Protocol Re-synthesis - Requirements of protocol implementation - Object based approach to protocol implementation - Protocol compilers - Tool for protocol engineering.

Unit V: Instructional Activities **9 Hours**

Simulation study of any (five) communication protocols and their application using related tools.

Reference Books:

1. PallapaVenkataram and SunilkumarS.Manvi, "Communication protocol engineering", Prentice Hall of India, 2004.
2. Richard Lai and AjinJirachiefpattana, "Communication Protocol Specification and Verification", Kluwer Publishers, Boston, 1998.
3. Tarnay, K., "Protocol Specification and Testing", Springer, 1991.
4. 4. Mohamed G. Gouda, "Elements of Network Protocol Design", Wiley-Interscience, New York, 1998.
5. V.Ahuja, "Design and Analysis of Computer Communication networks", McGraw-Hill, London, 1982.
6. G.J.Holtzmann, "Design and validation of Computer protocols", Prentice Hall, New York.

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WCENG 534

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 535	ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY	2	1	0	3	45

Prerequisite : Electromagnetic theory.

Objective : To expose the students on the fundamentals of electromagnetic interference and compatibility in the electronic system design.

Outcome : Students will able to know the EMI environment, coupling principles, specifications, standards and limits, measurements and control techniques, and EMC design of PCBs.

Unit I: EMI Environment **9 Hours**

EMI/ EMC Concepts and Definitions: Sources of EMI - conducted and radiated EMI- transient EMI - time domain vs frequency domain EMI - units of measurement parameters.

Unit II: EMI Coupling Principles and Standards **9 Hours**

Principles: Conducted, radiated and transient coupling - common impedance ground coupling- radiated common mode and ground loop coupling - radiated differential mode coupling - Near and Far Field cable to cable coupling - power mains and power supply coupling - units of specifications; Civilian Standards: FCC - CISPR - IEC - EN; Military Standards: MIL STD461D/ 462.

Unit III: EMI Measurements **9 Hours**

EMI Test Instruments/ Systems: EMI shielded chamber - open area test site - TEM cell - sensors/ Injectors/ Couplers - test beds for ESD and EFT.

Unit IV: EMI Control Techniques **9 Hours**

Techniques: Shielding - filtering - grounding - bonding - isolation transformer - transient suppressors - cable routing - signal control - component selection and mounting.

Unit V: Instructional Activities **9 Hours**

Simulation of minimum of two EMI coupling methods and controlling techniques with their performance analysis using related tools.

Reference Books:

1. V. P. Kodali, “Engineering EMC Principles, Measurements and Technologies”, IEEE Press, 2001.
2. Henry W. Ott, “Noise Reduction Techniques in Electronic Systems”, Wiley, 1988.
3. C. R. Paul, “Introduction to Electromagnetic Compatibility”, Wiley, 2006.
4. Bernhard Keiser, “Principles of Electromagnetic Compatibility”, 3rd Edition, Artech house, 1986.

Hyperlinks:

5. http://www.nptel.iitm.ac.in/syllabus/syllabus.php?subjectId=117108043.
6. http://www.ieee.li/emc/

WCENG 535

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 536	MICROWAVE COMMUNICATION	2	1	0	3	45

Prerequisite: Fundamentals of Electronics and communication

Objective : To enable the student to understand the basic principles of microwave amplifiers and oscillators, passive component characteristics, resonators and filters, antennas and microwave radio link characterization.

Outcome : The student would be able to design a microwave system taking into account the path losses and fading channel characteristics, carry out measurements and interpret results obtained.

Unit I: Microwave Active Devices **9 Hours**

Microwave Active Devices: Gunn diode and its mode – PIN modulator - IMPATT and TRAPATT diodes - Bipolar transistor – FET – Transferred electron oscillators – Avalanche diode oscillators – Parametric amplifiers - Two cavity klystron amplifier – Power and efficiency considerations – Reflex Klystron oscillators – Modes and efficiency considerations – Magnetrons – TWT.

Unit II: S Parameters **9 Hours**

S Parameters: Scattering parameters, properties of S matrix, Conversion of ABCD and S matrix, S matrix representation of Waveguide corners, bends, twists, Directional couplers, Circulators, Isolators, Attenuators, Wave guide Tee, Hybrid Tee, Hybrid rings (rat-race) and Terminator

Unit III: Microwave Measurements **9 Hours**

Microwave Measurements: VSWR, power, impedance, insertion loss, scattering parameters and dielectric constant measurement. And Antenna Measurements: Radiation pattern, gain, directivity, phase and polarization measurement

Unit IV: Satellite Microwave Systems **9 Hours**

Satellite Microwave Systems: Satellite orbits and dynamics, Frequency allocation and satellite footprints, Earth stations and satellite transponders, Noise considerations. Link budget calculations. Multiple access methods, Mobile satellite systems, their uses and illustrative systems.

Unit V: Instructional Activities **9 Hours**

Simulation study of any (five) microwave communication circuits or standards using related tools.

Reference Books:

1. Roddy D., "Microwave Technology" Reston Publications.1986.
2. Chatterjee R. "Microwave Engineering "East West Press. 1988.
3. Rizzi P."Microwave Engineering Passive circuits". Prentice Hall.1987
4. Tomasi.W "Advanced Electronic communication systems "Prentice Hall.1987.
5. Clock.P.N. "Microwave Principles and Systems" Prentice Hall.1986.
6. Combes, Graffewil and Sauterean "Microwave Components, Devices and Active Circuits". John wiley.198
7. Annapurana Das. Sisir.K.Das,"Microwave Engineering" Tata McGraw Hill, 2000
8. Cloud Computing Bible, Barrie Sosinsky, Wiley-India, 2010
9. George Kizer, "Digital Microwave Communication: Engineering Point–to–Point Microwave Systems", Wiley Publications, 2013
10. Joseph Carr, "Microwave and Wireless Communications Technology", 1st Edition, Elsevier, 1996.

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1. http://science.jrank.org/pages/4326/Microwave-Communication.html
2. http://www.daenotes.com/electronics/microwave-radar/microwave-communication-system
3. http://www.commscope.com/Docs/Microwave Communication Basics eBook

WCENG 536

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 537	MOBILE COMMUNICATION SYSTEM	2	1	0	3	45

Prerequisite : Fundamentals of analog and digital communication systems.

Objective : To learn the architecture and working principles of mobile communication systems

Outcome : The students will be able to understand the design principles and techniques of Mobile Communication Systems.

Unit I: Introduction to cellular concepts **9 Hours**

Evolution of mobile radio communications - trends in cellular radio and personal communication; Basics of cellular concepts – Types and components of mobile communication - Operation of cellular system Systems- handoff – radio channel characterization - Multiple Access schemes.

Unit II: Mobile standards **9 Hours**

System architecture and working principle: GSM - SCSD - GPRS - EDGE - CDMA digital cellular standard - 3G CDMA 2000 - 3G W-CDMA - IMT-2000 - 4G LTE- 5G.

Unit III: Mobile IP network and transport layer **9 Hours**

Introduction to Mobile IP: Requirements, IP packet delivery- agent discovery- registration, tunneling and encapsulation- optimization- reverse tunneling; Mobile adhoc networks - routing - destination sequence distance vector - dynamic source routing and alternative metrics; Traditional TCP - congestion control- slow start- fast retransmit - fast recovery- implications of mobility; Classical TCP improvements – methods of mobile TCP: Indirect TCP - snooping TCP - mobile TCP - fast retransmit.

Unit IV: Diversity Schemes **9 Hours**

Realization of independent fading paths - Receiver Diversity - Selection Combing -Threshold Combing - Maximal– Ratio Combing - Equal – Gain Combing ; Transmitter Diversity - channel known at transmitter - channel unknown at transmitter - transmit and receive Diversity for MIMO Systems.

Unit V: Instructional Activities **9 Hours**

Simulation study of any (five) mobile communication standards using related tools.

References Books:

1. Mullett, "Introduction to Wireless Telecommunication Systems & Networks", Cengage Learning, 2008.
2. Theodore S. Rappaport, "Wireless Communications Principles & Practice", PHI, 2007.
3. Schiller J, "Mobile Communications", Pearson Education, 2007.
4. Mark J W, Jhuang W, "Wireless Communications & Networking", PHI, 2006.
5. Krzysztof Wesolowski, "Mobile Communication Systems", Wiley, 2002.
6. Ramjee Prasad, Werner Mohr, Walter Konhäuser, "Third Generation Mobile Communication Systems", Artech House universal personal communications series, 2nd Edition, Artech House, 2000.
7. Man Young Rhee, "Mobile Communication Systems and Security", John Wiley & Sons, 2009.
8. John David Parsons, "Mobile Communication Systems", Springer Science & Business Media, 2012.
9. Raj Pandya, "Mobile and Personal Communication Systems and Services", IEEE Series on Digital & Mobile Communication, Volume 13, John Wiley & Sons, 2004.
10. Panagopoulos, Athanasios D, "Handbook of Research on Next Generation Mobile Communication Systems", Advances in Wireless Technologies and Telecommunication, IGI Global, 2015.
11. Francisco Rodrigo Porto Cavalcanti, SörenAndersson, "Optimizing Wireless Communication Systems", Springer Science & Business Media, 2009

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3. http://www.etsi.org/technologies-clusters/technologies/mobile/umts

WCENG 537

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 538	OPTIMIZATION TECHNIQUES	2	1	0	3	45

Prerequisite : Fundamentals of optimization and communication

Objective : This subject aims to teach various optimization techniques for wireless communication.

Outcome : Understand the fundamental of optimization techniques in wireless communication for real time application.

Unit I: Introduction / Linear Programming **9 Hours**

Linear Programming: Graphical method, simplex method, Non-Simplex Method, revised simplex method, Big-M method, 2- phase method, alternate optimal solutions, unbounded LPs, degeneracy and convergence, duality in linear programming, sensitivity analysis, dual simplex method, Transportation, assignment and other applications.

Unit II: Non-Linear Programming **9 Hours**

Non-Linear Programming: Nonlinear Programming - Elimination methods, Interpolation methods, Unconstrained optimization techniques - Direct search methods - Indirect search methods, Constrained Optimization methods – Direct methods, Indirect methods.

Unit III: Dynamic Programming **9 Hours**

Dynamic Programming Multistage decision process, Concept of sub optimization and principle of optimality, computational procedure in dynamic programming

Unit IV: Optimization Methods **9 Hours**

Optimization Methods 09 Simulated annealing, Particle Swarm optimization, Ant colony optimization, Bee colony optimization, Cuckoo Search, Bat Algorithms, Firefly Algorithms

Unit V: Instructional Activities **9 Hours**

Simulation study of any (five) optimization techniques in wireless communication using related tools.

References Books:

1. Singiresu S Rao, “Engineering Optimization: Theory and Practice”, 4th Edition, John Wiley and Sons, 2009
2. Xin-Sie Yang, “Nature Inspired Optimization Techniques”, Elsevier, 2014.
3. Edwin K P Chong and Stanislaw S Zak, “An Introduction to Optimization”, Fourth Edition, John Wiley and Sons, 2013
4. Stanislaw H. Zak Edwin K.P. Chong, “An Introduction to Optimization”, Wiley Publications, 2010
5. Chander Mohan, “Optimization Techniques”, New Age International (P) Limited, Publishers 2009.

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3. https://www.cines.fr/wp-content/uploads/2014/10/lesson3_slides.pdf

WCENG 538

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 539	SMART ANTENNA	2	1	0	3	45

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Prerequisite: Fundamentals of Antenna

Objective : This subject aims to teach Propagation and modeling, spatial processing, techniques for CDMA system and RF positioning for the smart antennas.

Outcome : Understand the fundamental parameters of antenna and use of cellular concepts and able to integrate smart antenna technology with overall communication system design, principle and its performance.

Unit I: Introduction / DOA Estimation **9 Hours**

Need for Smart Antennas, Smart Antenna Configurations, Switched-Beam Antennas, Adaptive Antenna Approach, Space Division Multiple Accesses (SDMA), Architecture of a Smart Antenna System, Receiver, Transmitter, Benefits and Drawbacks, Mutual Coupling Effects.
Introduction The Array Response Vector, Received Signal Model, The Subspace-Based Data Model, Signal Auto covariance Matrices ,Conventional DOA Estimation Methods, Conventional Beam forming Method, Capon's Minimum Variance Method, Subspace Approach to DOA Estimation ,The MUSIC Algorithm, The ESPRIT Algorithm, Uniqueness of DOA Estimates

Unit III: Beam forming fundamentals **9 Hours**

The Classical Beam former-Statistically Optimum Beam forming Weight Vectors, The Maximum SNR Beam former, The Multiple Sidelobe Canceller and the Maximum, SINR Beam former-Minimum Mean Square Error (MMSE),Direct Matrix Inversion (DMI), Linearly Constrained Minimum Variance (LCMV) , Adaptive Algorithms for Beam forming ,The Least Mean-Square (LMS) Algorithm, The Recursive Least-Squares (RLS) Algorithm

Unit IV: Space–Time Processing **9 Hours**

Introduction, Discrete Space–Time Channel and Signal Models, Space–Time Beam forming, Intersymbol and Co-Channel Suppression, ISI Suppression, CCI Suppression, Joint ISI and CCI Suppression, Space–Time Processing for DS-CDMA, Capacity and Data Rates in MIMO Systems, Single-User Data Rate Limits, Multiple-Users Data Rate Limits, Data Rate Limits Within a Cellular System, MIMO in Wireless Local Area Networks

Unit V: Mobile Stations Smart Antennas **9 Hours**

Introduction -Multiple-Antenna MS Design, Combining Techniques, Selection (Switched) Diversity, Maximal Ratio Combining, Adaptive Beam forming or Optimum Combining, RAKE Receiver Size, Mutual Coupling Effects, Dual-Antenna Performance Improvements, Downlink Capacity Gains.

Unit V: Instructional Activities **9 Hours**

Simulation study of any (five) smart antennas design and their application using related tools.

Reference Books:

1. Constantine A. Balanis, Panayiotis I. Ioannides, Introduction to Smart Antennas Morgan & Claypool Publishers
2. Ahmed El Zooghby, Smart Antenna Engineering, Artech House
3. M.J. Bronzel, Smart Antennas, John Wiley, 2004
4. T.S.Rappaport &J.C.Liberti, Smart Antennas for Wireless Communication, Prentice Hall (PTR), 1999.
5. R.Janaswamy, Radio Wave Propagation and Smart Antennas for Wireless Communication, Kluwer, 2001
6. Frank Gross , "Smart Antennas with MATLAB", Second Edition, McGraw-Hill Education, 2015.
7. A. Balanis, I. Ioannides, "Introduction to Smart Antennas", Morgan and clay publishers, 2007.

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3. http://www.microwaves101.com/encyclopedia/
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WCENG 539

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 550	ADVANCED TECHNOLOGIES IN WIRELESS NETWORKS	2	1	0	3	45

Prerequisite : Basics knowledge of computer and wireless networks

Objective : To learn about the advanced topics in wireless networks with their architectures

Outcome : Students will able to understand the various technologies in wireless networks.

Unit I: Wireless Area Networks **9 Hours**

WPAN: System model - protocol stack of IEEE 802.15; Bluetooth: Network architecture - operation - specification and application models; Radio Frequency Identification (RFID): Types and specifications; ZIGBEE and WBAN: Standard and architecture; WLAN: Network architecture - protocol stack of IEEE 802.11 - physical layer and MAC layer mechanism; WiMAX: BWA - issues and challenges of WiMAX - network architecture - protocol stack of IEEE 802.16 - differences between IEEE 802.11 and IEEE 802.16

Unit II: Wireless Internet **9 Hours**

IP for wireless domain - mobile IP - IPv6 advancements - mobility management functions - location management - registration and handoffs; TCP in wireless domain: TCP over wireless - types - mobile transaction - impact of mobility; Wireless security and standards.

Unit III: Wireless Sensor Network **9 Hours**

Issues - design challenges - characteristics and architecture of wireless sensor network - classification - MAC protocols - routing schemes - security - enabling technologies for sensor network.

Unit IV: Wideband Wireless Technologies **9 Hours**

UWB Radio Communication: Fundamentals of UWB - major issues - operation of UWB systems - comparisons with other technologies - advantages and disadvantages; LTE: System architecture - frame structure - LTE FDD vs TDD comparison; LTE advanced: Network architecture - frame structure and its characteristics; 5G networks: Technical challenges- architecture.

Unit V: Instructional Activities **9 Hours**

Simulation of minimum of five wireless networks standards using related tools.

Reference Books:

1. Siva Ram Murthy C and Manoj B S, "Ad-hoc Wireless Networks-Architecture and Protocols", 2nd Edition, Pearson education, 2007.
2. KavehPahlavan and Prashant Krishnamurthy, "Principle of Wireless Networks - A Unified Approach", Prentice Hall of India, 2006.
3. William Stallings, "Wireless Communication and Networks", 2nd Edition, Prentice Hall, 2005.
4. Clint Smith and Daniel Collins, "3G Wireless Networks", 2nd Edition, Tata McGraw Hill, 2007.
5. Vijay Garg K, "Wireless Communications and Networks", 2nd Edition, Morgan Kaufmann Publishers (Elsevier), 2007.
6. AmitabhaGhosh and RapeepatRatasuk, "Essentials of LTE and LTE-A," Cambridge University Press, 2011.

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2. www.tutorialspoint.com/wimax/
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WCENG 550

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 551	ANTENNAS FOR PERSONAL AREA COMMUNICATION	3	0	0	3	45

Prerequisite : Fundamentals of Antenna and communication

Objective : To understand about Wearable Antennas , Printed Antennas , Integrated Antennas and to apply the Reconfigurability function in Antenna Design and to study about different array technique

Outcome : Antenna Theory is central for all Radio Systems, and this course will enable the learners to understand different Radio Antennas and their usage.

UNIT I: Printed Antennas **9 Hours**

Concepts of Printed Antennas, Broadband Microstrip Patch Antennas, Circularly polarized planar antennas, Enhanced Gain Patch Antennas, Wideband Compact Patch Antennas, Microstrip Slot Antennas, Microstrip Planar Monopole Antenna, Patch Antennas for Multiband Applications.

UNIT II: Wearable Antennas **9 Hours**

Overview of Wearable Systems and its Characteristics, Antennas for Wearable Devices, Design Requirements, Modeling and Characterization of Wearable Antennas, WBAN Radio Channel Characterization and Effect of Wearable Antennas, Domains of Operation, Sources on the Human Body, Compact Wearable Antenna for Healthcare Sensors.

UNIT III: Active Integrated Antennas **9 Hours**

Active Wearable Antenna Modules-Features, Electromagnetic Characterization of Fabrics and Flexible Foam Materials, Matrix-Pencil Two-Line Method, Small-Band Inverse Planar Antenna Resonator Method, Active Antenna Modules for Wearable Textile Systems, Substrate Integrated Waveguide Technology.

UNIT IV: Reconfigurable and Array Antennas **9 Hours**

Reconfigurable methodologies, Design Considerations for Reconfigurable systems, Reconfigurable Planar/printed antenna configurations, Active reconfigurable systems. Linear and planar array fundamentals, Mutual Coupling in Arrays, Multidimensional Arrays, Switched beam and Phased Arrays, Array Feeding Techniques, Array optimization techniques

Unit V: Instructional Activities **9 Hours**

Simulation of minimum of five personal area communication with suitable antenna using related tools

Reference Books:

1. Debatosh Guha, Yahia M.M. Antar, "Microstrip and Printed Antennas", 1stEdition, John Wiley & Sons, 2011.
2. Taming the Borg, "Moving Wearables into the Mainstream", Springer, 2008.
3. Eng Hock Lim, Kwok Wa Leung, "Compact Multifunctional Antennas for Wireless Systems", John Wiley & Sons, 2012.
4. Zhi Ning Chen, "Antennas for Portable Devices", John Wiley & Sons, 2007.
5. Apostolos Georgiadis, Hendrik Rogier, Luca Roselli, Paolo Arcioni, "Microwave & Millimeter Wave Circuits & Systems", First Edition, John Wiley & Sons, 2013.
6. Warren L Stutzman, Gary A.Thiele, "Antenna Theory and Design " 3rdedition, ", John Wiley & Sons, 2013
7. Kazimierz Siwiak, Yasaman Bahreini, "Radiowave Propagation and Antennas for Personal Communications", Artech House, 2007.
8. Zhi Ning Chen, Kwai-Man Luk, "Antennas for Base Stations in Wireless Communications", McGraw Hill Professional, 2009.

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3. https://www.hindawi.com/journals/ijap/2012/243191/
4. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4579845/
5. https://www.calvin.edu/~pribeiro/courses/engr302/Samples/kisraels_302_paper.pdf

WCENG 551

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 552	COGNITIVE RADIO TECHNOLOGY	3	0	0	3	45

Prerequisite : Fundamentals in Wireless Networks

Objective : To understand the requirements in designing software defined radios and cognitive radio and its functionalities

Outcome : Students will be able to design the wireless network based on cognitive radio technology

Unit I: Introduction **9 Hours**

Fundamentals of Communication Networks: New challenges - multiple access schemes - cross layer design and optimization; Multicarrier modulation and equalization - ISI; RF spectrum and regulation: Regulatory issues of cognitive access.

Unit II: SDR Architecture **9 Hours**

Software Defined Radio: Evolution - essential functions of the Software Defined Radio - architecture goals - quantifying degrees of programmability - top level component topology - computational properties of functional components - interface topologies among plug and play modules - architecture partitions - merits and demerits of SDR - problems faced by SDR.

Unit III: CR Architecture **9 Hours**

Cognitive radio network architectures: Architectures for spectrum sharing - network optimization - topology aware CRN architectures - Haykin dynamic spectrum architecture.

Unit IV: CRN Security **9 Hours**

Primary user emulation attacks - security vulnerabilities in IEEE 802.22 - security threats to the radio software.

Unit V: Instructional Activities **9 Hours**

Simulation of CR & SDC network using related tools.

Reference Books:

1. Alexander M. Wyglinski, MaziarNekovee, and Thomas Hou Y, "Cognitive Radio Communications and Networks - Principles and Practice", Elsevier Inc., 2010.
2. Kwang-Cheng Chen and Ramjee Prasad, "Cognitive Radio Networks", John Wiley & Sons Ltd, 2009.
3. Khattab, Ahmed, Perkins, Dmitri, Bayoumi, Magdy, "Cognitive Radio Networks - From Theory to Practice", Springer Series: Analog Circuits and Signal Processing, 2009.
4. Mitola J, "Cognitive Radio: An Integrated Agent Architecture for software defined radio", Doctor of Technology thesis, Royal Inst. Technology, Sweden 2000.
5. Simon Haykin, "Cognitive Radio: Brain –empowered wireless communications", IEEE Journal on selected areas in communications, Feb 2005, page no.201-220, volume 23, no.2.
6. Ian F. Akyildiz, Won – Yeol Lee, Mehmet C. Vuran, ShantidevMohanty, "NeXt generation / dynamic spectrum access / cognitive radio wireless networks: A Survey Elsevier Computer Networks", May 2006, page no.2127-2159, volume 50.
7. Arslan H, "Cognitive Radio, Software Defined Radio and Adaptive Wireless Systems", University of South Florida, USA, Springer, 2007.

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2 http://www.sciencedirect.com/science/book/9780123747150
3 http://www.xgtechnology.com/innovations/cognitive-radio-networks/

WCENG 552

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 553	FREE SPACE OPTICAL COMMUNICATION	3	0	0	3	45

Prerequisite : Basics knowledge of optics and communication

Objective : To learn about the advanced topics in optical communication

Outcome : Students will able to understand the various technologies in optical communication.

Unit I: Fundamentals of FSO Technology and Networks **9 Hours**

Introduction – Electromagnetic wave propagation in free space - alternate bandwidth technologies – Fiber Vs FSO1 Fiber Access – Overview of FSO Optical Transmitters – Receivers – Subsystems – Pointing, Acquisition and Tracking. The Role of FSO in the network – factors affecting FSO – line of sight (LOS) – selecting transmission wave integration of FSO in Optical networks – installation of FSO systems

Unit II: Long Distance FSO Communication **9 Hours**

The FSO model – Applications – System descriptions and design – Introduction to Laser Satellite Communications – Characteristics, Modulation Techniques and Radiation effects – Laser Sources.

Unit III: Optical Components **9 Hours**

Optical Components for FSO Optical waveguides – Optical Filters, Couplers, Amplifiers, Switches, Antennas, Interconnecting Equipments, and etc – Optical integrated circuits – semiconductor integrated optic devices.

Unit IV: Optical Signal Processing **9 Hours**

Analog and Discrete systems – Noise and Stochastic processes – Filters – Power spectra estimation – Ambiguity function, Wigner distribution function and triple correlations.

Unit V: Instructional Activities **9 Hours**

Simulation of minimum of five free space optical communication standards using related tools.

Reference Books:

1. Heinz, Phd. Willebrand, "Free Space Optics," Sams, 1st Ed., 2001.
2. Morris Katzman, "Laser Satellite Communication," Prentice Hall Inc., New York, 1991.
3. Hiroshi Nishihara, "Optical Integrated Circuits," McGraw Hill, New York, 1992.
4. Pankaj K. Das, "Optical Signal Processing," Narosa Pub. House, 1993.
5. Kaushal, Hemani, Jain, V.K., Kar, Subrat , "Free Space Optical Communication", Springer 2017
6. Olivier Bouchet, Hervé Sizun, Christian Boisrobert, Frédérique de Fornel, Pierre-Noël Favennec, "Free-Space Optics: Propagation and Communication", ISTE Ltd, 2006.

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WCENG 553

Course Code	Name of the Course	Periods			Credits	Total Hours
WCENG 554	GREEN RADIO COMMUNICATION TECHNIQUES	L	T	P	3	45
		3	0	0		

Prerequisite : Fundamentals of computer communication and wireless networks.

Objective : To impart the importance of energy conservation, CO_2 emission and inculcate green conceptsfor designing energy efficient next generation wireless networks.

Outcome : Students will be able to design green radio communication networks with energy efficient techniques.

Unit I: Introduction **9 Hours**

Fundamental tradeoffs on the design of green radio networks: Insight from Shannon's capacity formula - impact of practical constraints - algorithms for energy harvesting wireless networks: Energy harvesting technologies - PHY and MAC layer optimization for energy harvesting wireless networks –Vertical Handoff and its types.

Unit II: Green Modulation and Co-operative Techniques **9 Hours**

Modulation and coding schemes with energy optimized techniques for wireless networks - co-operative techniques for energy efficient wireless communications: Energy efficiency metrics for wireless networks - co-operative networks - optimizing the energy efficiency performance of co-operative networks - energy efficiency in co-operative base stations.

Unit III: Base Station Power Management Techniques **9 Hours**

Base station power management techniques: Opportunistic spectrum and load management - energy saving techniques in cellular wireless base stations - power management for base stations in a smart grid environment.

Unit IV: Wireless Access Techniques **9 Hours**

Cross layer design: Adaptive packet scheduling for green radio networks - energy efficient relaying for cooperative cellular wireless networks - energy performance in TDD CDMA multihop cellular networks - resource allocation for green communication in relay based cellular networks.

Unit V: Instructional Activities **9 Hours**

Survey about minimum of four green communication networks and carry out simulation of those networks.

References Books:

1. EkramHossain, Vijay Bhargava K and Gerhard Fettweis P, "Green Radio Communication Networks", Cambridge University Press, New York, 2012.
2. Richard Yu F, Zhang Xi and Victor Leung C M, "Green Communications and Networking", 1st Edition, CRC press, 2012.
3. Mazin Al Noor, "Green Radio Communication Networks Applying Radio-Over-Fibre Technology for Wireless Access", GRINVerlag, 2012.
4. Mohammad Obaidat S, AlaganAnpalagan and Isaac Woungang, "Handbook of Green Information and Communication Systems", 1st Edition, Academic Press, 2012.
5. Jinsong Wu, SundeepRangan and Honggang Zhang, "Green Communications: Theoretical Fundamentals, Algorithms and Applications", CRC Press, 2016.
6. Ramjee Prasad, Shingo Ohmori and Dina Simunic, "Towards Green ICT", River Publishers, 2010.

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2. http://home.ku.edu.tr/~nwcl/green.html
3. http://mypage.zju.edu.cn/en/honggangzhang/607861.html

WCENG 554

Course Code	Name of the Course	Periods			Credits	Total Hours
WCENG 555	HIGH PERFORMANCE COMMUNICATION NETWORKS	L	T	P	3	45
		3	0	0		

Prerequisite : Fundamentals of computer networks and wireless networks.

Objective : To learn the architecture and uniqueness of high performance networks

Outcome : Students will be able to understand the various topologies, services offered by broadband, WiFi, WiMAX, UWB and LTE networks.

Unit I: Introduction **9 Hours**

Communication Networks: Telephone and computer networks - cable television networks - wireless networks - networking principles - digitalization - network externalities - service integration; Layered Architecture: - network bottlenecks - network elements - network mechanisms - traffic characterization and QoS.

Unit II: MANET **9 Hours**

Multihop wireless broadband networks - mesh networks; MANET architecture - classification of routing protocols in MANET -routing metrics; packet scheduling algorithms - power control mechanism.

Unit III: Internet and TCP / IP Networks **9 Hours**

Internet Protocol (IP): Technology trends in IP networks - IP packet communications in mobile communication networks; TCP and UDP - performance of TCP/ IP networks; Circuit Switched Networks: SONET- DWDM - fiber to the home - DSL; Intelligent Network (IN) scheme - comparison with conventional systems - merits of the IN scheme; CATV and layered network - services over CATV.

Unit IV: Enabling Networks **9 Hours**

WiFi: overview - architecture - PHY an d MAC layer; WiMAX overview - system architecture - frame structure - PMP mode - mesh mode - multihop relay mode; UWB overview - time hopping UWB - direct sequence UWB - multiband UWB; LTE and LTE- A overview - system model - frame structure - comparison with broadband technologies.

Unit V: Instructional Activities **9 Hours**

Simulation of WiFi network - Simulation of WiMAX network in mesh mode and multihop relay mode - Simulation of integration of LTE - A and WiMAX network with single IP network.

Reference Books:

1. Jean Warland and Pravin Varaiya, "High Performance Communication Networks", 2nd Edition, Harcourt and Morgan Kanffman Publishers, London, 2008.
2. Leon Gracia and Widjaja, "Communication Networks", Tata McGraw Hill, 2008.
3. Lumit Kasera and Pankaj Sethi, "ATM Networks: Concepts and Protocols", Tata McGraw Hill, 2007.
4. Jeffrey G. Andrews, Arunabha Ghosh and Rias Muhamed, "Fundamentals of WiMAX Understanding Broadband Wireless Networking", Prentice Hall of India, 2008.
5. AmitabhaGhosh and RapeepatRatasuk, "Essentials of LTE and LTE-A", Cambridge University, 2011.
6. David Tung Chong Wong, Peng-Yong Kong, Ying-Chang Liang, Kee Chaing Chua and Jon W. Mark, "Wireless Broadband Networks", John Wiley and Sons, 2009.
7. Ada Gavrilovska, "Attaining High Performance Communications: A Vertical Approach", CRC Press, 2016.
8. Dimitris N. Chorafas, "High-Performance Networks, Personal Communications and Mobile Computing", Springer, 2016.

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1. http:// www.ece.gmu.edu/.../high performance communication networks_1.pdf
2. http://www.ee.columbia.edu/~bbathula/courses/HPCN/lecture01.pdf
3. https://www.scribd.com/document/159305769/AN1630-High-Performance-Communication-Networks

WCENG 555

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 556	INFORMATION AND NETWORK SECURITY	2	1	0	3	45

Prerequisite : Analog and Digital Communication

Objective : To study the various security attacks- data security and network security algorithms and wireless security mechanism.

Outcome : Students will understand the various symmetric and asymmetric cryptographic techniques- authentication mechanism and network security.

Unit I: Introduction to Cryptography **9 Hours**

Security issues: Security problems in computing - attacks - security services - security mechanism - OSI security architecture - standard setting organizations; Need for Cryptographic techniques- Substitution - Transposition - Block ciphers

Unit II: Data Security and Authentication **9 Hours**

Triple DES with two keys - stream cipher- RC4 - RSA algorithm - elliptical curve cryptography algorithm; MD5 - HASH algorithm-SHA 512 logic–digital signatures standards.

Unit III: Network Security **9 Hours**

Network Security: IP security overview - IP security architecture - authentication header- encapsulating security payload - combining security association - key management- web security considerations - secure socket layer and transport layer security - secure electronic transaction - security in GSM - security in 3G and 4G.

Unit IV: System Security **9 Hours**

Intruders and intrusion detection: Malicious software - viruses and related threats - virus counter measures - distributed denial of service attack - firewalls design principles- trusted systems.

Unit V: Instructional Activities **9 Hours**

Simulation of minimum of three public key and private key cryptography algorithms using related simulation tools.

Reference Books:

1. Bernard S and Pabitra K R, "Digital Communications: Fundamentals and Applications", 2nd Edition, Pearson Edition, 2009.
2. Stallings W, "Cryptography and Network Security", 4th Edition, Prentice Hall, 2006.
3. Thomas S, Cover M and Joy A T, "Elements of Information Theory", 2nd Edition, John Wiley & Sons, 2006.
4. MacKay J C D, "Information Theory, Inference and Learning Algorithms", 2nd Edition, Cambridge University Press, 2003.
5. McEliece J R, "The Theory of Information and Coding", 2nd Edition, Cambridge University Press, 2002.

Hyperlinks:

1. https://www.cl.cam.ac.uk/teaching/1314/InfoTheory
2. http://gva.noekeon.org/QCandSKD/QCandSKD-introduction.html

WCENG 556

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 557	INTERNET OF EVERYTHING THINGS	2	1	0	3	45

Prerequisite : Basics of computer communication networks and wireless sensor networks

Objective : To study the architecture and security principles of IOE

Outcome : Students will be able to design efficient IOE based projects.

Unit I: Introduction **9 Hours**

IoT: Architectural overview - main design principles - standards considerations; M2M and IoT technology fundamentals: devices and gateways - data management - business processes in IoT - everything as a service (XaaS) - M2M and IoT analytics - knowledge management.

Unit II: IoE Sensors **9 Hours**

Sensors for IoE: Wireless sensor structure - energy storage module - power management module - RF Module - sensing module.

Unit III: IoE Security **9 Hours**

Security requirements in IoE architecture - security in enabling technologies - security concerns in IoE applications: Architecture - insufficient authentication/authorization - insecure access control - threats to access control, privacy, and availability - attacks Specific to IoE.

Unit IV: IoE Testbed **9 Hours**

ACOEM Eagle - EnOcean Push Button - NEST Sensor - Ninja Blocks Focus on wearable electronics.

Unit V: Instructional Activities **9 Hours**

Simulation of (minimum of any five) IoE applications - home and office infrastructures - security - Home appliances and other IoE electronic equipment- interfacing of sensor with sensor Node using any Embedded target boards (Raspberry Pi / Intel Galileo/ARM Cortex/ Arduino).

Reference Books:

1. Asoke K Talukder and Roopa R Yavagal, "Mobile Computing: Technology, Application and Service Creation", Tata McGraw Hill, 2010.
2. William Stallings, "Data and Computer Communications", 8th Edition, Pearson Education Pte. Ltd., 2009.
3. Adelstein F and Gupta S.K.S, "Fundamentals of Mobile and Pervasive Computing", McGraw Hill, 2009.
4. Barrie Sosinsky, "Cloud Computing Bible", Wiley-India, 2010.
5. Arshdeep Bahga, Vijay Madisetti, "Internet of Things – A hands-on approach", Universities Press, 2015.
6. Manoel Carlos Ramon, "Intel® Galileo and Intel® Galileo Gen 2: API Features and Arduino Projects for Linux Programmers", Apress, 2014.
7. Marco Schwartz, "Internet of Things with the Arduino Yun", Packt Publishing, 2014.

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2. https://www.codeproject.com/Learn/IoT/
3. https://www.edureka.co/blog/iot-tutorial/
4. https://www.bbvaopenmind.com/en/the-internet-of-everything-ioe/

WCENG 557

Course Code	Name of the Course	Periods			Credits	Total Hours
WCENG 558	MULTICARRIER WIRELESSS COMMUNICATION	L	T	P	3	45
		2	1	0		

Prerequisite : Fundamentals of communication systems.

Objective : To impart OFDM transmitter and receiver system

Outcome : Students will be able to understand the importance of OFDM techniques for wireless systems

Unit I: OFDM Principles **9 Hours**

System Model: Block diagram of OFDM system - generation of sub carrier using IFFT - guard time - cyclic extensions - windowing - choice of OFDM parameters - signal processing - bandwidth efficiency - peak to average power ratio - peak power problem - PAPR properties of OFDM signals; PAPR reduction techniques: Signal distortion techniques - multiple signaling and probabilistic techniques - coding techniques.

Unit II: OFDM Time and Frequency Domain Synchronization **9 Hours**

System performance with frequency and timing errors; Synchronization algorithms - comparison of frequency acquisition algorithms - BER performance with frequency synchronization

Unit III: Adaptive Single and Multiuser OFDM Techniques **9 Hours**

Adaptive modulation for OFDM : Adaptive OFDM speech system - pre-equalization ; Comparison of adaptive techniques - near optimum power and bit allocation in OFDM - multiuser AOFDM - Multiuser systems - Maximum likelihood enhanced sphere decoding of MIMO OFDM.

Unit IV: Channel Estimation in OFDM systems **9 Hours**

Pilot Based OFDM Channel Estimation-Example; Comb Type Pilot (CTP) Transmission - example; Channel estimation in time/ frequency domain; Frequency Domain Equalization (FDE).

Unit V: Instructional Activities **9 Hours**

BER Vs Eb/N0 for OFDM in AWGN channel- OFDM channel estimation using LS, LMMSE, and lower complexity LMMSE methods.

Reference Books:

1. Ramjee P, “OFDM for Wireless Communication Systems”, Artech House, 2004.
2. Hanzo L and Keller T, “OFDM and MC-CDMA: A Primer”, John Wiley & Sons, 2006.
3. Henrik S and Christian L, “Theory and Applications of OFDM and CDMA: Wideband Wireless Communications”, John Wiley & Sons, 2005.
4. Bahai Ahmad R S, Burton R S and Mustafa E, “Multi-Carrier Digital Communications: Theory and Applications of OFDM”, 2nd Edition, Springer, 2004.
5. Rahmatallah Y and Mohan S, “Peak-to-Average Power Ratio Reduction in OFDM System: A Survey and Taxonomy”, IEEE Communication Surveys and Tutorials, vol. 15, no. 5, pp. 1567-1592, 2013.
6. Steven M K, "Fundamentals of Statistical Signal Processing: Estimation Theory ", Volume I, Prentice Hall, 1993.

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2. http://www.morganclaypool.com/doi/abs/10.2200/S00255ED1V01Y201002ASE005
3. http://ethesis.nitrkl.ac.in/4380/
4. http://wncg.org/interference-mitigation-in-wireless-ofdm-communication-systems.html

WCENG 558

Course Code	Name of the Course	Periods			Credits	Total Hours
WCENG 559	STATISTICAL THEORY OF COMMUNICATION	L	T	P	3	45
		2	1	0		

Prerequisite : Representation of Random Processes

Objective : To develop decision, estimation and modulation theories to demonstrate how they can be used to solve a practical problems in many diverse physical situations.

Outcome : The course presents a unified approach to the problem of detection, estimation and modulation theory, which are common tools used in many applications of communication systems, signal processing and system theory.

Unit I – Detection and Estimation Theory **9 Hours**

Introduction – Simple binary hypothesis tests – M Hypothesis – Estimation theory – Composite hypothesis – General Gaussian problem – Performance bounds and approximations.

Unit II – Detection and Estimation of Signal Parameters **9 Hours**

Detection and Estimation in White Gaussian and Non-White Gaussian noise – Signals with unwanted parameters: The Composite hypothesis problem – Multiple channels – Multiple parameter estimation.

Unit III – Estimation of Continuous Waveforms **9 Hours**

Derivation of Estimator equations – A Lower bound on the mean square estimation error – Multidimensional waveform estimation – Non random waveform estimation.

Unit IV - Linear Estimation **9 Hours**

Properties of Optimum processors – Realizable Linear filters: Stationary processes, Infinite past: Wiener filters – Kalman-Bucy filters – Linear Modulation: Communications context - Fundamental role of the Optimum linear filter.

Unit V: Instructional Activities **9 Hours**

Develop the design steps for RADAR signal detection and estimation by various prediction techniques and filters. Comment on the same by simulating the design using MATLAB.

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Reference Books:

1. Harry L. Van Trees, “Detection, Estimation and Modulation theory”– Part I/ Edition 2, John Wiley & Sons, NY, USA, 2013.
2. M.D. Srinath, P.K. Rajasekaran and R. Viswanathan, "Introduction to Statistical Signal Processing with Applications,” Pearson Education (Asia) Pte. Ltd. / Prentice Hall of India, 2003.
3. Steven M. Kay, “Fundamentals of Statistical Signal Processing ," Volume I: "Estimation Theory", Prentice Hall, USA, 1998;
4. Steven M. Kay, "Fundamentals of Statistical Signal Processing”, Volume II: "Detection Theory," Prentice Hall, USA, 1998.
5. K Sam Shanmugam, Arthur M Breipohl, “Random Signals: Detection, Estimation and Data Analysis”, John Wiley & Sons, 1998
6. P. Eugene Xavier, “Statistical theory of Communication”, New Age International Ltd. Publishers, New Delhi, 2007.
7. Prof. B.R. Levin, “Statistical communication theory and its applications”, MIR Publishers, Moscow, 1982.
8. Lee, Yuk Wing,” Statistical theory of communication”, Wiley, 1960

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1. http://nptel.ac.in/syllabus/117105083/
2. http://iopscience.iop.org
3. http://www.ece.iisc.ernet.in

WCENG 559

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 630	ADVANCED TECHNIQUES FOR WIRELESS RECEPTION	2	1	0	3	45

Prerequisite : Fundamentals of Wireless techniques in receiver side of wireless communication

Objective : To teach the advanced techniques for wireless reception.

Outcome : The students will come out with a complete knowledge of advanced techniques in wireless reception for real- time application.

Unit I: Blind Multiuser Detection **9 Hours**

Wireless signaling environment. Basic signal processing for wireless reception. Linear receivers for synchronous CDMA. Blind and group-blind multiuser detection methods. Performance issues.
Linear group blind MUD for synchronous CDMA, Group blind multiuser detection in multipath channels- Linear group blind detectors. Robust multiuser detection for non Gaussian channels; asymptotic performance, implementation aspects.

Unit II: Space-Time MUD **9 Hours**

Adaptive array processing in TDMA systems. Optimum space-time multiuser detection. Sub-space based training algorithm and extension to dispersive channels Turbo multiuser detection for synchronous and turbo coded CDMA.

Unit III: NBI Suppression **9 Hours**

Linear and nonlinear predictive techniques. Non-linear predictive techniques-ACM filter, Adaptive non-linear predictor, Non-linear interpolating filters and HMM based methods. Code- aided techniques. Performance comparison.

Unit IV: Signal Processing for Wireless Reception **9 Hours**

Bayesian and sequential Montecarlo signal processing. Blind adaptive equalization of MIMO channels .Signal processing for fading channels. Coherent detection based on the EM algorithm. Decision-feedback differential detection. Signal processing for coded OFDM systems.

Unit V: Instructional Activities **9 Hours**

Design the steps of Monte Carlo sampling methods for Bayesian filtering. Develop a general variational Bayesian framework for iterative data and parameter estimation for coherent detection is introduced as a generalization of the EM-algorithm.

Reference Books:

1. X. Wang and H. V. Poor, Wireless Communication Systems, Pearson, 2004.
2. R. Janaswamy, Radio Wave Propagation and Smart Antennas for Wireless Communication, Kluwer, 2001.
3. Mohamed Ibnkahla, Signal Processing for Mobile Communications, CRC Press, 2005.
4. A.V.H. Sheikh, Wireless Communications Theory & Techniques, Kluwer Academic Publications, 2004.
5. A. Paulraj et.al, Introduction to Space -time Wireless Communications, Cambridge

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1. docwiki.cisco.com/wiki/Wireless Technologies
2. http://dl.acm.org/citation.cfm?id=1593080

WCENG 630

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 631	CONVERGENCE TECHNOLOGIES	2	1	0	3	45

Prerequisite : Basics of wireless networks, elementary concepts in probability, optimization related to communication systems.

Objective : To gain expertise in the convergence technologies in respect of network design and performance measures

Outcome : Students will be able to enumerate the functions and importance of internetworking/ interoperability of advanced wireless technologies

Unit I: Introduction **9 Hours**

Evolution towards convergence: Next generation network concept - framework for examining next generation and evolving networks - examples of application of framework - enabling mobile network technologies - opportunities and threats to the mobile converging service market

Unit II: Switching Networks and convergence standards **9 Hours**

Switching Networks: Packet switched networks - Circuit switched networks; Convergence Standards: VOIP convergence - H.323 protocol - SIP - Media Gateway Control Protocol (MGCP) – MEGACO; Wireless standards: IEEE 802.11 - HYPERLAN - IEEE 802.16 - wireless ATM - wireless convergence - sensor networks - ZigBee and RFID.

Unit III: IP Telephony **9 Hours**

IP Telephony : Network architecture - IP Voice - VoIP call signaling protocols - IP cablecom - media networking - broadband infrastructure - IP TV - cloud computing- interoperability among multicasting/broadcasting systems - QoS.

Unit IV: Software Methodologies for Converged Networks and Services **9 Hours**

Development of software methodologies for ICT: Software processes in the NGN framework - high level design and analysis methods - enterprise and business modeling notation - object and data definition language - dynamic modeling notations - component and interface notations - distributed systems - creating a unified framework

Unit V: Instructional Activities **9 Hours**

Simulation of minimum four convergence technologies for various applications using related tools.

Reference Books:

1. Hu Hanrahan, "Network Convergence: Services, Applications, Transport, and Operations Support", John Wiley and Sons, 2007.
2. Jeffrey Bannister, Paul Mather and Sebastian Coope, "Convergence Technologies for 3G Networks", John Wiley and Sons, 2008.
3. David Tung Chong Wong, Peng-Yong Kong, Ying-Chang Liang, KeeChaing Chua and Jon W. Mark,"Wireless Broadband Networks", John Wiley and Sons, 2009.
4. Vijay Garg, "Wireless Network Evolution: 2G to 3G", Prentice Hall of India, 2001.
5. Jyh-Cheng Chen and Tao Zhang, "IP Based Next Generation Wireless Networks - Systems, Architecture and Protocols", John Wiley and Sons, 2003.
6. Guillaume De La Roche, Andres Alayon Glazunov and Ben Allen, "LTE – Advanced and Next Generation Wireless Networks: Channel Modeling and Propagation", John Wiley and Sons, 2013.
7. C. Siva Ram Murthy and B.S. Manoj, "Ad Hoc Wireless Network: Architectures and Protocols", Pearson Education, 2007.
8. Jerry D. Gibson, "Multimedia Communications: Directions and Innovations", Academic Press, 2000.

Hyperlinks:

1. www.radio-electronics.com/info/wireless/
2. www.radio-electronics.com/info/telecommunication_networks/
3. http://www.explainthatstuff.com/how-iptv-works.html
4. http://www.computerweekly.com/feature/Converged-networks-The-VoIP-revolution

WCENG 631

Course Code	Name of the Course	Periods			Credits	Total Hours
WCENG 632	HETEROGENEOUS NETWORK	L	T	P	3	45
		2	1	0		

Prerequisite : Knowledge of Wireless networks, Protocols, Transmission Media, Knowledge of Computer Network Operating Systems.

Objective : The objective of this course is based on understanding Overview, Technology, Management and Application of Heterogeneous networks.

Outcome : Students will be able to understand the concepts and functionality of heterogeneous communication systems and its applications.

Unit I: Introduction and overview **9 Hours**

Motivations for Heterogeneous Networks-Definitions of Heterogeneous Networks-Heterogeneous Networks Use Scenarios-Aspects of Heterogeneous Network Technology-Heterogeneous cellular network nodes-Introduction to 3GPP LTE advanced heterogeneous cellular networks.

Unit II: Multi-tier Network Architecture **9 Hours**

Heterogeneous Network Deployment Scenarios:-OSG scenario-CSG scenario-Interference Management-Multi-radio techniques-Cross-tier interference-Deployment Scenarios for LTE - Advanced HetNet: Macro-Femto Scenario-Macro-Pico Scenario.

Unit III: interference, Mobility Management **9 Hours**

Introduction-Conventional inter-cell interference Coordination-Enhanced inter-cell Interference Coordination-Interference Scenarios. Mobility Management in RRC- connected state-Mobility Management in RRC-idle state-Mobility Management in heterogeneous cellular networks.

Unit IV: Cell Selection Modes **9 Hours**

Distinction of cells-Access Control-Access Control Scenarios-Access Control Executor-Access Control Mechanism-Cell Selection and Cell Reselection-Cell Reselection in Macro-Femto cells.

Unit V: Instructional Activities **9 Hours**

Survey minimum of four heterogeneous networks concepts for wireless communication networks and carry out simulation of those networks.

References Books:

1. Heterogeneous Cellular Networks.–Rose Qing Hu, Yi Qian–Wiley Publication, IEE Press
2. Heterogeneous Cellular Networks –Theory, Simulation and Deployment, By: Xiaoli Chu, David Lopez-Perez, Yang Yang, Fedrik Gunnarsson-Cambridge University Press.
3. Heterogeneous Wireless Access Networks –Ekram Hossain –Springer.
4. Rong**,** B., Qiu**,** X., Kadoch**,** M., Sun**,** S., Li, W, "5G Heterogeneous Networks", Springer, 2016
5. Rong**,** B., Qiu**,** X., Kadoch**,** M., Sun**,** S., Li, W, "5G Heterogeneous Networks", Springer, 2016
6. Joydeep Acharya, Long Gao and Sudhanshu Gaur , "Heterogeneous Networks in LTE-Advanced", 1st Edition, Wiley Publication.

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2. http://ieeexplore.ieee.org/document/6413904/
3. https://link.springer.com/chapter/10.1007/978-3-319-18038-0_3
4. https://arxiv.org/abs/0906.2212
5. https://www.cs.cornell.edu/home/kleinber/wsdm12-links.pdf

WCENG 632

Course Code	Name of the Course	Periods			Credits	Total Hours
WCENG 633	HIGH SPEED SWITCHING ARCHITECTURE	L	T	P	3	45
		3	0	0		

Prerequisite : Fundamentals of Computer Network and Communication

Objective : To impart High Speed Switching Architecture Concepts

Outcome : Students will be able to understand the importance of High Speed Switching Network wireless systems

Unit I: Basic Switching Concepts **9 Hours**

Switching Concepts – Hierarchy of switching networks – Switching in telecommunication networks – An overview, Evolution of networks – Introduction to B- ISDN. ATM Standards, ATM adaptation layers.

Unit II: LAN Switching Technology **9 Hours**

Switch Forwarding Techniques, Switch Path Control, LAN Switching, Cut through Forwarding, Store and forward, and Virtual LANs.

Unit III: Architectures and Signaling Standards **9 Hours**

Switching architectures – Issues and performance analysis – Banyan and knockout switches – Single & Multistage networks – Shuffle switch tandem banyan.
Signaling – SS7 Signaling - Traffic and queuing models – Performance analysis of Input, Output & Multiple shared Queuing.

Unit IV: IP Switching **9 Hours**

Addressing Model, IP switching types, Flow driven and topology driven solutions, IP over ATM, Address and next hop resolution, Multicasting, IP v6 over ATM.

Unit V: Instructional Activities **9 Hours**

Simulation of minimum four High Speed Network Architectures Algorithm for various applications using related tools

Reference Books:

1. Achille Pattavina, "Switching Theory Architectures and performance in Broadband ATM networks", John wiley & sons Ltd. New York, 1998.
2. Christopher Y Metz, "Switching protocols & Architectures", McGraw Hill Professional Publishing, New York, 1998.
3. Ranier Handel. Manfred N Huber, Stefab Schrodder, ATM Networks – Concepts, Protocols, Applications, 3rd Edition, Adisson Wesley, New York 1999.
4. Thiggarajan Viswanathan, "Tele Communication Switching System and Networks", Prentice Hall of India, Pvt. Ltd., New Delhi, 1995.
5. Spaniol, Otto, Danthine, Andre, Effelsberg, Wolfgang, "Architecture and Protocols for High-Speed Networks", Springer 1994
6. H. Jonathan Chao, Bin Liu, "High Performance Switches and Routers", 1st Edition, Wiley Publication, 2007.

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2. https://www.cse.wustl.edu/~jain/cis788-97/ftp/gigabit_nets/index.html#1.-Introduction
3. http://www.cs.columbia.edu/dcc/research/isochronets/isochronets.html

WCENG 633

Course Code	Name of the Course	Periods			Credits	Total Hours
WCENG 634	INTERNETWORKING MULTIMEDIA COMMUNICATION	L	T	P	3	45
		2	1	0		

Prerequisite : Fundamentals of Communication and interworking

Objective : To familiarize the salient approaches in multimedia communication based on internetworking

Outcome : Students will be able to apply concepts of internetworking in multimedia communication

Unit I: Multimedia Networking **9 Hours**

Digital sound, video and graphics, basic multimedia networking, multimedia characteristics, evolution of Internet services model, network requirements for audio/video transform, multimedia coding and compression for text, image, audio and video.

Unit II: Broad Band Network Technology **9 Hours**

Broadband services, ATM and IP, IPV6, High speed switching, resource reservation, Buffer management, traffic shaping, caching, scheduling and policing, throughput, delay and jitter performance.

Unit III: Multicast and Transport Protocol **9 Hours**

Multicast over shared media network, multicast routing and addressing, scalping multicast and NBMA networks, Reliable transport protocols, TCP adaptation algorithm, RTP, RTCP.

Unit IV: Media - On – Demand **9 Hours**

Storage and media servers, voice and video over IP, MPEG over ATM/IP, indexing synchronization of requests, recording and remote control.
MIME, Peer-to-peer computing, shared application, video conferencing, centralized and distributed conference control, distributed virtual reality, light weight session philosophy.

Unit V: Instructional Activities **9 Hours**

Simulation of Internetworking Multimedia Communication concepts using related tools

Reference Books:

1. Jon Crowcroft, Mark Handley, Ian Wake man. Internetworking Multimedia, Harcourt Asia Pvt.Ltd. Singapore, 1998.
2. B.O. Szuprowicz, Multimedia Networking, McGraw Hill, New York. 1995
3. Tay Vaughan, Multimedia making it to work, 4ed, Tata Mc Graw Hill, New Delhi, 2000.

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1. https://www.cl.cam.ac.uk/~jac22/out/mm.pdf
2. https://www.scribd.com/document/145363542/CU9255-Internetworking-Multimedia
3. https://www.scribd.com/document/145363542/CU9226

WCENG 634

Course Code	Name of the Course	Periods			Credits	Total Hours
WCENG 635	MICRO AND NANO ELECTRONICS ENGINEERING	L	T	P	3	45
		2	1	0		

Prerequisite : Knowledge in basic sensors, actuators and various fabrication techniques

Objective : To teach the principles in respect of micro and nano electronics, and MEMS /NEMS.

Outcome : The students will come out with a complete knowledge of micro and nano fabrication concepts, micro and nano sensors. MEMS/NEMS for real- time application.

Unit I: MEMS **9 Hours**

Introduction: Need for miniaturization technology - from perception to realization - overall MEMS market size - MEMS market character - MEMS based on Si- Non-Silicon MEMS - MEMS versus Traditional Precision Engineering.

Unit II: Micro Sensors and Actuators **9 Hours**

Sensing and actuation - case studies of real devices; Sensing mechanisms: piezoelectric - piezoresistive - capacitive; Actuation mechanisms: piezoelectric - electrostatic - magnetic and thermal; Physical sensors - opto– fluids - sensors for turbulence measurement and control – micro– actuators for flow control.

Unit III: Nanomaterials and Nanodevices **9 Hours**

Introduction to nanomaterials : properties of nanomaterials - role of size in nanomaterials and nanoparticles - semiconducting nanoparticles; Nanowires - nanoclusters - quantum wells - conductivity - Carbon Nanotube (CNT): structure of CNT and its properties; Nanosensors- structure- applications

Unit IV: Micro and Nano Fabrication Techniques **9 Hours**

Introduction to Lithography: Pattern transfer with different techniques - E beam lithography; Micromachining: Size effect in micromachining - mechanical micromachining; Oxidation - CVD of nanostructures - CVD diamond technology for NEMS and MEMS applications - nano crystals - nanowires - nanolithography - etching techniques.

Unit V: Instructional Activities **9 Hours**

Simulation of minimum of five MEMS/ NEMS using related tools.

References Books:

1. Marc J M, "Fundamentals of Micro fabrication: The Science of Miniaturization", 2nd Edition, CRC Press, 2002.
2. Groffrey A O, Andre C A and Ludovico C , "Nanochemistry: A chemical approach to nanomaterials", 2nd Edition, RSC Publishing, 2009.
3. Schmidt G, "Nanoparticles: From theory to applications", Wiley, 2006.
4. Jackson M J, "Microfabrication and Nanomanufacturing", CRC Press, 2005.
5. Nadim M and Williams K, "An Introduction to Microelectromechanical Systems Engineering", 2nd Edition, Artech House, 2004.
6. Stephen B, Graham E, Michael K and Neil W, "MEMS Mechancial Sensors", Artech House, 2004.
7. Stephen D S, "Microsystem Design", Kluwer Academic Publishers, 2002.
8. Michael J O, "Carbon Nanotubes: Properties and Applications", CRC Press, 2006.
9. Rao C N R and Govindaraj A, "Nanotubes and Nanowires", RCS Publishing, 2005.
10. Kouroush K, Benjamin F, "Nanotechnology enabled sensors", Springer, 2008.
11. Jackson M J, "Micro fabrication and Nanomanufacturing", CRC press, 2005.
12. Cao G and Wang Y, "Nanostructures and Nanomaterials: Synthesis, properties and applications", 2nd Edition, World Scientific, 2011.

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2. http://www.lithoguru.com/scientist/CHE323/
3. http://www.iap.uni-jena.de/iapmedia/de/Lecture/Micro_+and+Nano_Technology1505685600/MNT2017_1_Introduction.pdf

WCENG 635

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 636	MIMO COMMUNICATION SYSTEMS	2	1	0	3	45

Prerequisite : Fundamentals of Information Theory and Wireless Communication.

Objective : To study the MIMO concepts of communication systems, the various types STBC and STTC codes for wireless communication.

Outcome : Students will be able to understand the concepts of MIMO communication systems and its applications.

Unit I: Information Theoretic aspects **9 Hours**

Review of SISO fading communication channels, MIMO channel models, Classical i.i.d. and extended channels, Frequency selective and correlated channel models, Capacity of MIMO channels, Ergodic and outage capacity, Capacity bounds and Influence of channel properties on the capacity.

Unit II: Diversity and Spatial Multiplexing **9 Hours**

Sources and types of diversity, analysis under Rayleigh fading, Diversity and channel knowledge. Alamouti space time code, MIMO spatial multiplexing. Space time receivers. ML, ZF, MMSE and Sphere decoding, BLAST receivers and Diversity multiplexing trade-off.

Unit III: Space Time Block Codes **9 Hours**

Space time block codes on real and complex orthogonal designs, Code design criteria for quasi-static channels (Rank, determinant and Euclidean distance), orthogonal designs, Generalized orthogonal designs, Quasi-orthogonal designs and Performance analysis.

Unit IV: Space Time Trellis Codes **9 Hours**

Representation of STTC, shift register, generator matrix, state-transition diagram, trellis diagram, Code construction, Delay diversity as a special case of STTC and Performance analysis.

Unit V: Instructional Activities **9 Hours**

Survey minimum of four MIMO concepts for wireless communication networks and carry out simulation of those networks.

References Books:

1. David Tse and Pramod Viswanath, “Fundamentals of Wireless Communication”, Cambridge University Press 2005
2. Hamid Jafarkhani, “Space-Time Coding: Theory and Practice”, Cambridge University Press 2005
3. Paulraj, R. Nabar and D. Gore, “ Introduction to Space-Time Wireless Communications”, Cambridge University Press 2003
4. E.G. Larsson and P. Stoica, “Space-Time Block Coding for Wireless Communications”, Cambridge University Press 2008
5. Ezio Biglieri , Robert Calderbank et al “MIMO Wireless Communications” Cambridge University Press 2007
6. Tolga M. Duman, Ali Ghrayeb, “Coding for MIMO Communication Systems”, Wiley 2007
7. Huang**,** Howard, Papadias**,** Constantinos B., Venkatesan, Sivarama, “MIMO Communication for Cellular Networks”, Springer 2012.

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1. https://web.stanford.edu/~dntse/wireless_book.html
2. http://ieeexplore.ieee.org/document/4777623/?reload=true
3. http://file.scirp.org/pdf/IJCNS20101200001_56363952.pdf
4. https://onlinecourses.nptel.ac.in/noc16_ec11/preview

WCENG 636

Course Code	Name of the Course	Periods			Credits	Total Hours
WCENG 637	MULTIMEDIA COMPRESSION TECHNIQUES	L	T	P	3	45
		2	1	0		

Prerequisite : Basics of Information theory

Objective : To expose the students on the fundamentals of source coding and Compression techniques.

Outcome : The students will able to know the different multimedia compression techniques so far used in the Practical wireless communication.

Unit I: Introduction **9 Hours**

Introduction to Multimedia – components of multimedia6 overview of multimedia software tools6Graphics and Image Data Representations –Graphics/image data types, popular file formats 6Fundamental Concepts in Video – analog and digital video. Basics of Digital Audio – Storage requirements for multimedia applications 6Need for Compression 6 Taxonomy of compression techniques

Unit II: Data Compression / Audio Compression **9 Hours**

Huffman coding, Arithmetic coding – Adaptive method s – Adaptive Huffman Coding — Adaptive Arithmetic Coding – Dictionary Methods– LZW algorithm.
Digital audio6 audio compression techniques 6 O Lawand A Law companding, ADPCM. Speech compression6 waveform codecs6source codecs6 hybrid codecs6 Shorten compressor MPEG61 audio layers.

Unit III: Image Compression **9 Hours**

Image Transforms – orthogonal transforms6 DCT, JPEG , progressive image compression6 JBIG, JBIG2 standards , Vector quantization, Differential lossless compression –DPCM Wavelet based compression6 Filter banks, DWT, Multi resolution decomposition, SPIHT and EZW Coders, JPEG 2000 standard .

Unit IV: Video Compression **9 Hours**

Video signal components 6 Video compression techniques – MPEG Video Coding– Motion Compensation – H.261, H.263 Standard, .MPEG4 and H.264 codecs.

Unit V: Instructional Activities **9 Hours**

Simulation of minimum of five multimedia compression techniques using related tools.

References Books:

1. Mark S.Drew and Ze6Nian Li: Fundamentals of Multimedia, 1stEdition, Prentice Hall of India, 2008.
2. David Salomon, "Data Compression – The Complete Reference" 3rd Edition, Springer Verlag New York Inc., 2008.
3. L. Hanzo, P. J. Cherriman and J. Streit "Video Compression and Communications From Basics to H.261, H.263, H.264,MPEG4 for DVB and HSDPA6Style Adaptive Turbo6Transceivers" 2 nd Edition, IEEE Communications Society, John Wiley &Sons, 2007.
4. Peter Symes, "Digital Video Compression," Tata McGraw Hill, 2004.
5. Mark Nelson, "Data compression," BPB Publishers, New Delhi, 2008.
6. Yun Q. Shi, Huifang Sun: Image and Video Compression for Multimedia Engineering - Fundamentals, Algorithms & Standards, CRC press, 2003.
7. Watkinson, J: Compression in Video and Audio, Focal press, London.1995.
8. Jan Vozer: Video Compression for Multimedia, AP Profes, NewYork, 1995
9. Gonzalez and Woods, Digital Image Processing, 3rd Ed, PHI

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1. http://nptel.ac.in/syllabus/117105083/
2. https://eclass.uoa.gr/modules/document/file.php/D246/Lectures/compression.pdf
3. http://www.snscourseware.org/snsct/files/CW_594b40b2d7948/compression.pdf
4. http://wikieducator.org/Multimedia_Systems/Compression_Techniques_%26_its_Principles

WCENG637

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 638	NETWORK ROUTING ALGORITHM	2	1	0	3	45

Prerequisite : Fundamentals of Computer Network and Communication

Objective : To impart Network Routing Algorithm

Outcome : Students will be able to understand the importance of Network Routing Algorithm for wireless systems

Unit I: Network Routing **9 Hours**

Network Routing - An Introduction, Basics and Foundation, Shortest path and Widest Path, Framework and Principles, Network Flow Modeling.

Unit II: Routing in IP Networks **9 Hours**

Routing IP Networks-IP Routing and Distance vector routing Protocol family, OSPF and Integrated IS-IS, IP traffic Engineering, BGP, Internet Routing Architectures.

Unit III: Routing in PSTN **9 Hours**

Routing in the PSTN- Hierarchical and Dynamic Call routing, Traffic engineering, SS7, PSTN architecture and routing.

Unit IV: Router Architectures / Next Generation Routing **9 Hours**

Router Architectures-IP addresses Look-Up Algorithms, IP Packet Filtering and Classification. Towards Next Generation - QoS routing, MPLS and GMPLS, Routing and Traffic Engineering with MPLS, VoIP Routing, Interoperability through IP and PSTN.

Unit V: Instructional Activities **9 Hours**

Simulation of minimum four Network Routing Algorithm for various applications using related tools

Reference:

1. Deepankar Medhi and Karthikeyan Ramasamy, "Network Routing: Algorithms, Protocols, and Architectures", Elsevier, 2007.
2. Martha Steen Strup, "Routing in Communication Networks", Prentice Hall, 1995.
3. William Stallings, "Data and Computer Communications", Pearson Education, 2006
4. Palesi**,** Maurizio**,** Daneshtalab**,** Masoud**, "**Routing Algorithms in Networks-on-Chip", Springer,2014
5. Deep Medhi, Karthik Ramasamy, "Network Routing: Algorithms, Protocols, and Architectures", Elsevier, 2017.

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1. http://nptel.ac.in/syllabus/117105083/
2. http://nptel.ac.in/courses/IITMADRAS/Computer_Networks/pdf/Lecture32_RoutingAlgorithmsDV.pdf
3. http://cs.gettysburg.edu/~jfink/courses/cs322slides/3-19.pdf

WCENG 638

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 639	PATTERN RECOGNITION AND ARTIFICIAL INTELLIGENCE	2	1	0	3	45

Prerequisite : Basic concepts of probability theory and random process.

Objective : To help the students to gain in-depth knowledge in pattern recognition and artificial intelligence

Outcome : Students will be able to apply pattern recognition and artificial intelligence techniques for signal and image processing application.

Unit I: Introduction to Pattern Recognition **9 Hours**

Introduction: Probability- statistical decision making- nonparametric decision making- patterns and features - training and learning in pattern recognition - pattern recognition approach- different types of pattern recognition.

Unit II: Clustering **9 Hours**

Unsupervised learning: Hierarchical clustering- graph theories approach to pattern clustering- fuzzy pattern classifier- application of pattern recognition in medicine.

Unit III: Artificial Intelligence **9 Hours**

Artificial Intelligence: Intelligent agents- perception and language processing- problem solving- searching- heuristic searching- game playing- Logics- logical reasoning.

Unit IV: Basic solving methods **9 Hours**

Expert Systems- Components- Production rules- Backwards vs Forward reasoning- statistical reasoning- certainty factors- measure of belief and disbelief- Meta level knowledge- Introspection.

Unit V: Instructional Activities **9 Hours**

Range images generation- extraction of geometric elements- automatic scene generation- scene recognition- geometrical hashing using related tools.

Reference Books:

1. MacKay D.J.C, "Information Theory, Inference, and Learning Algorithms", Cambridge University Press, 2003.
2. Devi, Susheela V, Murty, Narasimha M, "Pattern Recognition: An Introduction", Universities Press, Hyderabad, 2011.
3. Theodoridis S and Koutroumbas K, "Pattern Recognition", 4th Edition. Academic Press, 2009.
4. Mishra R B, "Artificial Intelligence", PHI, India, 2010.
5. Russell S and Norvig N, "Artificial Intelligence: A Modern Approach", Prentice Hall Series in Artificial Intelligence. 2003.
6. Bishop, C M, "Pattern Recognition and Machine Learning", Springer. 2007.

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1. https://www.tutorialspoint.com/biometrics/pattern_recognition_and_biometrics.htm
2. http://www.cedar.buffalo.edu/~srihari/CSE555/
3. https://www.ibm.com/developerworks/library/cc-beginner-guide-machine-learning-ai-cognitive/index.html

WCENG 639

Course Code	Name of the Course	Periods			Credits	Total Hours
WCENG 640	RF SYSTEM DESIGN FOR WIRELESS COMMUNICATION	L	T	P	3	45
		2	1	0		

Prerequisite : Fundamentals of radio frequency concepts and wireless communication

Objective : To learn the RF system design for wireless communication

Outcome : Students will be able to understand the RF system design in wireless communication for real time applications.

Unit I: Fundamentals of System Design **9 Hours**

Linear Systems and Transformations -Nonlinear System Representation and Analysis Approaches - Noise and Random Process - Elements of Digital Base -Band System.

Unit II: Radio Architectures and Design **9 Hours**

Super heterodyne Architecture - Direct Conversion (Zero IF) Architecture - Low IF Architecture – Band-Pass Sampling Radio Architecture.

Unit III: Receiver System Analysis and Design **9 Hours**

Introduction - Sensitivity and Noise Figure of Receiver - Intermodulation Characteristics -Single Tone Desensitization - Adjacent/Alternate Channel Selectivity and Blocking Characteristics - Receiver Dynamic Range and AGC System - System Design and Performance Evaluation

Unit IV: Transmitter System Analysis and Design **9 Hours**

Introduction - Transmission Power and Spectrum - Modulation Accuracy – Adjacent and Alternate Channel Power - Noise Emission Calculation - Some Important Considerations in System Design. System Design -Multimode and Multiband Super heterodyne Transceiver- Direct Conversion Transceiver.

Unit V: Instructional Activities **9 Hours**

Simulation of minimum of five RF system design for wireless communication with suitable application using related tools

Reference Books:

1. Gu, Qizheng, "RF System Design of Transceivers for Wireless Communications," 1st ed. Corr. 2nd printing, 2005, XIV, 479 p. 125 illus., Hardcover, Springer, and ISBN: 978101387124161
2. D.K.Misra, "Radio Frequency and Microwave Communication Circuits, Analysis and Design", John wiley & Sons. Inc, 2004, kundli.
3. Pozar,D.M, "Microwave Engineering," Adison Wesley, 3rdEdition, 1990

Hyperlinks:

1. http://www.nptel.iitm.ac.in
2. http://freevideolectures.com/Course/2329/Wireless-Communication

WCENG 640

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 641	SOFT COMPUTING	2	1	0	3	45

Prerequisite : Computer Networks

Objective : To familiarize the salient approaches in soft computing based on artificial neural networks, fuzzy logic, and genetic algorithms

Outcome : Students will be able to apply concepts of artificial neural networks, fuzzy logic, and genetic algorithm for real time application

Unit I : Neural Network **9 Hours**

Basic concept - mathematical model - properties of neural networks - architectures - different learning methods - common activation functions - application of neural networks; Neuron architecture: Algorithms - McCullo h-Pitts - Back propagation NN - ADALINE - MADALINE - Discrete Hopfield net - BAM - Maxnet.

Unit II: Fuzzy Sets & Logic **9 Hours**

Fuzzy versus Crisp - fuzzy sets - fuzzy relations - laws of propositional logic - inference - Predicate logic fuzzy logic - quantifiers - inference - defuzzification methods.

Unit III: Genetic Algorithm **9 Hours**

Role of GA - fitness function - selection of initial population - cross over (different types) - mutation - inversion - deletion - constraints handling and applications of travelling salesman and graph coloring.

Unit IV: Hybrid Systems **9 Hours**

Hybrid Systems: GA based BPNN (Weight determination) - Neuro fuzzy systems - Fuzzy BPNN - fuzzy neuron - architecture - learning - Fuzzy logic controlled genetic algorithm.

Unit V:Instructional Activities **9 Hours**

Simulation of PSD - HSA and ACO related to either wireless networking or Antenna or Image Processing using related tools.

References Books:

1. S.N. Sivanandam, S.N. Deepa, "Principles of Soft Computing", 2nd Edition, John Wiley India, 2012.
2. S. Haykin, "Neural Networks - A Comprehensive Foundation", 2nd Edition, Pearson Education, 2005.
3. T.S. Rajasekaran, G.A. VijaylakshmiPai, "Neural Networks, Fuzzy Logic and Genetic Algorithms: Synthesis and Applications", Prentice-Hall India, 2003.
4. Sanchez, Takanori, Zadeh, "Genetic Algorithm and Fuzzy Logic System", World Scientific, 1997.
5. Goldberg David, "Genetic Algorithms", Pearson Education, 2006.
6. Zimmermann H. J, "Fuzzy Set Theory and Its Applications", Allied Publishers Ltd, 1991.
7. Stamatios V. Kartolopoulos, "Understanding neural networks and fuzzy logic: Basic concepts and Applications", Wiley IEEE press.

Hyperlinks:

1. https://www.tutorialspoint.com/biometrics/pattern_recognition_and_biometrics.htm
2. http://www.cedar.buffalo.edu/~srihari/CSE555/
3. https://www.ibm.com/developerworks/library/cc-beginner-guide-machine-learning-ai-cognitive/index.html

WCENG 641

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 642	AUDIO SIGNAL PROCESSING	2	1	0	3	45

Prerequisite : Fundamentals of Speech and Audio signal

Objective : To study the basic concepts of speech and audio and to analysis of various M-band filter banks for audio coding and to learn various transform coders for audio coding.

Outcome : The students will come out with a complete knowledge of Speech and Audio signal processing.

Unit I: Mechanics of Speech **9 Hours**

Speech production mechanism – Nature of Speech signal – Discrete time modelling of Speech production – Representation of Speech signals – Classification of Speech sounds– Phones – Phonemes – Phonetic and Phonemic alphabets – Articulatory features. Music production – Auditory perception – Anatomical pathways from the ear to the perception of sound – Peripheral auditory system – Psycho acoustics.

Unit II: Time and Frequency Domain Methods for Speech Processing **9 Hours**

Time domain parameters of Speech signal – Methods for extracting the parameters Energy, Average Magnitude – Zero crossing Rate – Silence Discrimination using ZCR and energy – Short Time Auto Correlation Function – Pitch period estimation using Auto Correlation Function.
Short Time Fourier analysis – Filter bank analysis – Formant extraction - Pitch Extraction – Analysis by Synthesis- Analysis synthesis systems- Phase Vocoder - Channel Vocoder. Homomorphic speech analysis: Cepstral analysis of Speech – Formant and Pitch Estimation – Homomorphic Vocoders.

Unit III: Linear Predictive Analysis of Speech **9 Hours**

Formulation of Linear Prediction problem in Time Domain – Basic Principle – Autocorrelation method – Covariance method – Solution of LPC equations – Cholesky method – Durbin's Recursive algorithm – lattice formation and solutions – Comparison of different methods – Application of LPC parameters – Pitch detection using LPC parameters – Formant analysis – VELP – CELP.

Unit IV: Application of Speech and Audio Signal Processing **9 Hours**

Algorithms: Spectral Estimation, dynamic time warping, hidden Markov model – Music analysis – Pitch Detection – Feature analysis for recognition – Music synthesis –Automatic Speech Recognition – Feature Extraction for ASR – Deterministic sequence recognition – Statistical Sequence recognition – ASR systems – Speaker identification and verification – Voice response system – Speech Synthesis: Text to speech, voice over IP.

Unit V: Instructional Activities **9 Hours**

Simulation of minimum of five speech and audio signal processing techniques using related tools.

Reference Books:

1. Ben Gold and Nelson Morgan, Speech and Audio Signal Processing, John Wiley and Sons Inc., Singapore, 2004
2. L.R.Rabiner and R.W.Schaffer – Digital Processing of Speech signals – Prentice Hall -1978
3. Quatieri – Discrete-time Speech Signal Processing – Prentice Hall – 2001.
4. J.L.Flanagan – Speech analysis: Synthesis and Perception – 2nd edition – Berlin –1972
5. I.H.Witten – Principles of Computer Speech – Academic Press – 1982.
6. A.R. Jayan, "Speech and Audio Signal Processing", PHI Learning Pvt. Ltd.
7. Ogunfunmi**,** Tokunbo, Togneri**,** Roberto, Narasimha**,** Madihally Sim, "Speech and Audio Processing for Coding, Enhancement and Recognition", Springer, 2015.

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2. https://dl.acm.org/citation.cfm?id=2073536
3. http://home.iitk.ac.in/~nnaik/pdf/PPT_AudioSpeech.pdf
4. https://www.ee.iitb.ac.in/student/~daplab/publications/chapter9-prao.pdf

WCENG 642

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 643	ULTRA WIDEBAND COMMUNICATION SYSTEMS	2	1	0	3	45

Prerequisite : Communication theory and wireless communications

Objective : To impart the concepts of the UWB communication systems.

Outcome : Students will be able to design sub-modules of UWB system.

Unit I: UWB Signals and Systems **9 Hours**

Introduction: Comparison of UWB with other wideband communication system – power spectral density – pulse shape – pulse trains – UWB spectrum and spectral masks – multipath and penetration characteristics – spatial and spectral capacities – speed of data transmission – Gaussian waveforms – designing waveforms for specific spectral masks – practical constraints and effects of imperfections – applications of UWB systems.

Unit II: UWB Pulse Generation and Processing **9 Hours**

UWB signal generation: UWB modulation schemes – transmitter and receiver – multiple access techniques – capacity – interference and coexistence of UWB with other systems – Hermite pulses – Orthogonal prolate spheroidal wave functions – wavelet packets in UWB PSM – signal processing: effects of a lossy medium on a UWB transmitted signal – time domain analysis – frequency domain techniques.

Unit III: UWB Channel Modeling **9 Hours**

IEEE proposals for UWB channel models – simplified UWB multipath channel model – path loss model – two-ray UWB propagation model – frequency domain autoregressive model – MIMO for UWB systems – self interference in high data-rate UWB communications – coexistence of UWB with WIMAX and other short range wireless radios.

Unit IV: UWB Antennas and Filters **9 Hours**

Antenna fundamentals – antenna radiation for UWB signals – conventional antennas and impulse antennas for UWB systems – beam forming for UWB signals – UWB filters – prototype – characteristics – filtering techniques – wireless positioning and location – GPS techniques – positioning techniques – time resolution issues – UWB positioning and communications.

Unit V: Instructional Activities **9 Hours**

Simulation of UWB: Pulse generation and processing – channel modeling – antennas using EM – MIMO for UWB systems using related tools.

Reference books:

1. Ghavami M, Michael L B and Kohno R, "Ultra Wideband Signals and Systems in Communication Engineering", 2nd Edition, John Wiley and Sons, NY, USA, 2007.
2. Reed J H, "An Introduction to Ultra Wideband Communication Systems", Prentice Hall PTR, 2005.
3. Faranak N, "Ultra-Wideband Communications: Fundamentals and Applications", Prentice Hall PTR, 2011.
4. Ranjit G and Peter K, "Ultra Wide Band: Circuits, Transceivers and Systems", Springer, NY, USA, 2008.

Hyper Links:

1. https://en.wikipedia.org/wiki/Ultra-wideband
2. https://en.wikipedia.org/wiki/List_of_UWB_channels

WCENG 643

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 644	VEHICULAR AD-HOC NETWORKS (VANET)	2	1	0	3	45

Prerequisites: Wireless communications and network, and mobile ad-hoc networks

Objective : To introduce the students with the emerging technologies and their standards with applications for vehicular communication systems

Outcome : Students will able to understand the basic principles, standards, and system architecture of Vehicular Ad-hoc Networks.

Unit I: Introduction **9 Hours**

Basic principles and challenges - past and ongoing VANET Activities; Cooperative vehicular safety applications: Introduction - enabling technologies - cooperative system architecture.

Unit II: Vehicular Mobility Models **9 Hours**

Introduction - notation description - random models - flow models - traffic models - behavioral models - trace or survey based models - integration with network simulators - design framework for realistic vehicular mobility models.

Unit III: Routing Protocols **9 Hours**

Routing protocols: Opportunistic packet forwarding - topology based routing - geographic routing; Standards: Protocol stack - DSRC regulations and standard.

Unit IV: Security **9 Hours**

Requirement - challenges - adversaries - VANET supporting properties - message authentication and integrity using digital signatures - detection of malicious data and secure position verification.

Unit V: Instructional Activities **9 Hours**

Simulation of Vehicle to Vehicle Communication - Vehicle to infrastructure and infrastructure to vehicle communication using related tools

Reference Books:

1. Sommer C, Dressler F, "Vehicular Networking", Cambridge University Press, 2015.
2. Emmelmann M, Bochow B and Kellum C. C, "Vehicular Networking: Automotive Applications and Beyond", Wiley, 2010.
3. Watfa M, "Advances in Vehicular Ad-Hoc Networks: Development and Challenges", Information Science Reference, 2010.
4. Moustafa H, Zhang Y, "Vehicular Networks: Techniques, Standards, and Applications", CRC Press, 2009.
5. Hartenstein H and Laberteaux K. P, "VANET: Vehicular Applications and Inter Networking Technologies", Wiley, 2010.

Hyperlinks:

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2. https://en.wikipedia.org/wiki/Vehicular_ad_hoc_network
3. http://comp.ist.utl.pt/~rmr/WSN/CaseStudies2007-no/WSN_Transportation

WCENG 644

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 645	VLSI FOR WIRELESS COMMUNICATION	2	1	0	3	45

Prerequisite : Fundamentals of VLSI and Wireless Communication.

Objective : To study the design concepts of low noise amplifiers, the various types of mixers and design PLL and VCO for wireless communication.

Outcome : Students will be able to design VLSI circuits for wireless communication applications.

Unit I Components and Devices **9 Hours**

Integrated inductors, resistors, MOSFET and BJT AMPLIFIER DESIGN: Low Noise Amplifier Design -Wideband LNA-Design Narrowband LNA-Impedance Matching-Automatic Gain Control Amplifiers–Power Amplifiers

Unit II Mixers **9 Hours**

Balancing Mixer - Qualitative Description of the Gilbert Mixer-Conversion Gain–distortion-Low Frequency Case: Analysis of Gilbert Mixer–Distortion-High-Frequency Case–Noise-A Complete Active Mixer. Switching Mixer –Noise- Sampling Mixer- Noise.

Unit III Frequency Synthesizers **9 Hours**

Phase Locked Loops-Voltage Controlled Oscillators-Phase Detector–Analog Phase Detectors–Digital Phase Detectors-Frequency Dividers-LC Oscillators-Ring Oscillators-Phase Noise-A Complete Synthesizer Design Example (DECT Application).

Unit IV Sub Systems and Implementations **9 Hours**

Data converters in communications, adaptive Filters, equalizers and transceivers
VLSI architecture for Multitier Wireless System - Hardware Design Issues for a Next generation CDMA System.

Unit V: Instructional Activities **9 Hours**

Survey minimum of four VLSI Circuit design for wireless communication networks and carry out simulation of those networks.

References Books:

1. B.Razavi,"RF Microelectronics", Prentice-Hall, 1998.
2. Bosco H Leung "VLSI for Wireless Communication", Pearson Education, 2002.
3. Thomas H.Lee, "The Design of CMOS Radio Frequency Integrated Circuits', Cambridge University Press, 2003.
4. Emad N Farag and Mohamed I Elmasry, "Mixed Signal VLSI Wireless Design Circuits and Systems", Kluwer Academic Publishers, 2000.
5. Behzad Razavi, "Design of Analog CMOS Integrated Circuits" McGraw Hill, 1999.
6. J. Crols and M. Steyaert, "CMOS Wireless Transceiver Design," Boston, Kluwer Academic Pub., 1997.

Hyperlinks:

1. https://www.electronic-engineering.ch/study/phd/General_MIMO_Poster.pdf
2. https://archive.org/stream/Bosco_Leung_VLSI_for_Wireless_Communication/Bosco_Leung_VLSI_for_Wireless_Communication_djvu.txt
3. http://www.ece.iisc.ernet.in/~banerjee/course_E3237/Upload_files/E3%20237_L1.pdf
4. https://pdfs.semanticscholar.org/19e2/81a115c4023e915e0f416bae74475b8f1c43.pdf

WCENG 645

Course Code	Name of the Course	Periods			Credits	Total Hours
		L	T	P		
WCENG 646	WDM OPTICAL NETWORKS	2	1	0	3	45

Prerequisite : Fundamentals of optics

Objective : To expose the students on the fundamentals of optical network

Outcome : The students will able to know the different optical network and techniques used in the Practical wireless communication

Unit I: Optical Networks **9 Hours**

Optical Networks: Why optical networks? Conventional optical networks, SONET/SDH, FDDI, IEEE 802.3, DQDB, Multiple access optical networks, WDM optical networks architectures and issues in wavelength routed networks

Unit II: Optical Fibers & Signal Degradation/Digital Transmission Systems **9 Hours**

Optical Fibers & Signal Degradation: Basics of optical fibers. Attenuation and dispersion effects in single mode and multimode optical fibers. Control of dispersion in single mode & multimode fibers. Non linear effects in single mode fibers and their control.
Digital Transmission Systems: Point to Point link, system considerations, link power, budget & rise time budget analysis. Line coding techniques, NRZ, RZ, Manchester etc. eye pattern analysis

Unit III: WDM Base Optical Communication System **9 Hours**

WDM Base Optical Communication System: Introduction to wavelength division multiple access. Receiver & transmitter requirements in WDM networks. Repeaters & amplifiers, Erbium doped fiber amplifier (EDFA).

Unit IV: Passive Components for WDM Based Systems **9 Hours**

Passive Components for WDM Based Systems: Couplers & splitters, FBT couplers, WDM multiplexer & demultiplexers fixed & tunable filters, isolators, circulators & attenuators. Optical switches & wavelength converters.

Unit V: Instructional Activities **9 Hours**

Simulation study of any (five) optical networks design using related tools

Reference Books:

1. G. Keiser, Optical Fiber Communications, McGraw Hill
2. D.K. Myanbaev and Lowell L. Scheiner," Fiber Optic Communication Technology, Pearson Education Asia.
3. G.P. Agrawal, " Nonlinear Fiber Optics , Academic Press
4. J.M. Senior, Optical Fiber Communications, Prentice Hall, India
5. C. Siva Ram Murthy and Mohan Gurusamy, "WDM Optical Networks: Concepts Design and algorithm", Pearson Publication, 2015
6. Biswanath Mukherjee, "Optical WDM Networks", Springer 2006

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1. https://www.tutorialspoint.com/optical_networks/optical_networks_wdm_technology.htm
2. http://www.fiber-optical-networking.com/category/wdm-optical-network
3. http://www.informit.com/articles/article.aspx?p=26931&seqNum=7

WCENG 646

Course Code	Name of the Course	Periods			Credits	Total Hours
WCENG 647	5G WIRELESS NETWORKS	L	T	P	3	45
		2	1	0		

Prerequisite : Fundamentals of Information Theory and Wireless Networks.

Objective : To study the concepts of wireless networks for the future communication systems.

Outcome : Students will be able to understand the concepts of next generation communication systems and its applications.

Unit I: Multi-gigabit wireless networks **9 Hours**

Next generation (5G) wireless technologies- Upper Gigahertz and Terahertz wireless communications: Millimeter wave networking- Directionality and beam forming- Mobility and signal blockage- IEEE 802.11ad (60 GHz WLAN) MAC and PHY overview: Visible light communication- High-speed networking using LEDs - IEEE 802.15.7 PHY and MAC overview Sensing through visible light- Visible light indoor localization and positioning

Unit II: Indoor localization and RF sensing **9 Hours**

Smartphone localization - WiFi fingerprinting - protocols and challenges - Non-WiFi localization - Device-free sensing with radio frequency - Mining wireless PHY channel state information- Device-free localization and indoor human tracking - Activity and gesture recognition through RF.

Unit III: Low-power networking **9 Hours**

Backscatter communication - Radio Frequency Identification (RFID) technology overview - Energy harvesting tags and applications- Internet-of-Things (IoT) - IoT protocol overview - CoAP and MQTT - IPv6 networking in low-power PANs (6LoWPAN)

Unit IV: Future mobile networks **9 Hours**

Drone networking - Multi-UAV networks, architectures and civilian applications-Communication challenges and protocols for micro UAVs- Connected and autonomous cars - Wireless technologies for Vehicle-to-Infrastructure (V2I) and Vehicle-to-Vehicle (V2V) communications - Automotive surrounding sensing with GHz and THz signals.

Unit V: Instructional Activities **9 Hours**

Survey minimum of four 5G wireless networks for wireless communication and carry out simulation of those networks.

References Books:

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