Unit 219 Telecommunication systems engineering

Unit summary
This unit addresses the underlying principles of telecommunication systems.

Aims
The unit aims to develop an understanding of modern digital communications principles by breaking down the complex signal processing that takes place in a transceiver into its component parts. The emphasis is on transmission.

Prerequisites
It is expected that candidates will have a working knowledge of the materials in the four compulsory papers of the Certificate examination and with mathematical methods, statistics and queuing

Learning outcomes
There are **five** outcomes to this unit. The candidate will be able to:

- Demonstrate an overview of modern digital communication systems
- Describe signals in the time, frequency and statistical domains, translate freely between these domains and evaluate the effect of transmission through a linear system
- Demonstrate an understanding the principles of digital transmission, line coding and modulation
- Demonstrate knowledge of elementary information theory and describe the purpose and principles of source coding and error control coding
- Demonstrate an understanding of noise and link budgets

Guided learning hours
It is recommended that 300 hours should be allocated for this unit. 120 of those hours are actual taught hours. This may be on a full time or part time basis.

Key Skills
No Key Skills were identified for this unit.

Occupational Standards
This unit has been mapped to the following National Occupational Standards:

1.1.1 Identify the requirements of clients for engineering products or processes
1.1.2 Produce specifications for engineering products or processes
2.1.1 Determine the production requirements of engineering products and processes
3.1.1 Determine the installation requirements for engineering products or processes
4.1.1 Determine the operational requirements of engineering products or processes
6.1.1 Analyse the risks arising from engineering products and processes
8.1.1 Maintain and develop own engineering expertise

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Outcome 1 Demonstrate an overview of modern digital communication systems

Knowledge requirements
The candidate knows how to:

1 describe the historical development of telecommunications services

2 describe the purpose of the following digital communications processes

- a sampling and anti-aliasing filtering
- b quantization/reconstruction filtering
- c pulse code modulation/demodulation
- d source coding/decoding
- e encryption/deciphering
- f error control coding/decoding
- g multiplexing/demultiplexing
- h line coding/decoding
- i pulse shaping/matched filtering
- j bandpass modulation/demodulation
- k multiple accessing
- l equalization

3 compare and contrast the advantages and disadvantages of line and radio transmission

4 describe the compare the transmission characteristics of twisted pair, coaxial cable and optical fibre transmission lines

5 describe and compare the dominant propagation mechanisms, noise processes and nominal ranges of different bands of the radio spectrum

6 suggest, and comment on, the advantages of digital communications compared with analogue communications

7 describe a range of telecommunication network applications

8 explain the fundamental network problem

9 distinguish between broadcast and switched networks

10 distinguish between LANs, MANs and WANs

11 describe a range of network structures (including star, tree, mesh, bus, ring) and represent them, where appropriate, using a connection matrix

12 explain the following network switching philosophies

- a circuit switching
- b message switching
- c packet switching

13 explain the principles and advantages of a layered network architecture

14 describe the ISO-OSI 7-layer model of a communications system

15 describe the use of repeaters, bridges, routers and gateways to extend and interconnect networks

16 describe the structure of a national PSTN

17 explain what is meant by the transmission system, the switching system and the signalling system of a network

18 explain what is meant by the terms core network, access network, bearer network and service (or functional) networks

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Outcome 2 Describe signals in the time, frequency and statistical domains, translate freely between these domains and evaluate the effect of transmission through a linear system

Knowledge requirements
The candidate knows how to:

1 recognise and distinguish between periodic and non-periodic signals

2 recognise and distinguish between deterministic and random signals

3 recognise and distinguish between transient and non-transient signals

4 use analytical formulas to represent common periodic and transient signals in time and frequency domains

5 use probability distributions and statistics to describe random signals

6 translate simple signals between time and frequency domains using the fourier series and fourier transform

7 translate signals between time and frequency domains using tables of Fourier series, Fourier transforms and Fourier transform theorems

8 calculate the power spectra and autocorrelation functions of signals

9 relate power spectra and autocorrelation functions using the Wiener-Kintchine theorem

10 explain what is meant by cross-correlation function and correlation coefficient and calculate these for simple signals and random variables

11 describe the effect of a linear system using frequency response and/or impulse response, especially in the context of pulse transmission

12 relate the frequency response and impulse response of a linear system

13 describe the origin, effects and mitigating techniques for the following types of distortion

- a loss
- b amplitude distortion
- c phase and group delay

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Outcome 3 Demonstrate an understanding the principles of digital transmission, line coding and modulation

Knowledge requirements
The candidate knows how to:

1 state, and apply, Nyquist's sampling theorem

2 break the process of analog-to-digital conversion into sampling, quantization and pulse code modulation

3 explain the process and significance of quantization

4 explain what is meant by quantization noise

5 calculate signal to quantization-noise ratios (SN_qR) for signals with uniform pdf

6 describe pulse code modulation (PCM)

7 explain the advantages of PCM

8 calculate the signal-to-noise ratio (SNR) of a demodulated PCM signal

9 explain the process and advantages of non-linear quantization and companding

10 quantify the benefits of A-law companding

11 describe centre point detection (CPD) as applied in simple baseband receivers

12 derive and calculate the bit error ratio (BER) for a baseband CPD system in the presence of Gaussian noise

13 explain what is meant digital signal regeneration and describe how it is achieved

14 calculate the effect of error accumulation over multi-hop links using linear amplifiers or regenerative repeaters between hops

15 describe the purpose and requirements of a line code

16 describe the general properties of unipolar, polar, dipolar and bipolar (AMI) line codes

17 distinguish between return-to-zero and non-return-to-zero line codes

18 describe HDB3, CMI and *n*B*m*T line codes

19 explain the purpose of band-pass modulation

20 describe the basic binary forms of digital modulation

- a amplitude shift keying (ASK)
- b frequency shift keying (FSK)
- c phase shift keying (PSK)

21 sketch example waveforms, spectra and constellation diagrams for each of the binary modulation schemes

22 show how each ASK, FSK and PSK signals could be generated in principle

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Outcome 4 Demonstrate knowledge of elementary information theory and describe the purpose and principles of source coding and error control coding

Knowledge requirements
The candidate knows how to:

1 summarize elementary information theory

- a explain and define the basic measures of information (bits, nats and hartleys)
- b explain and define entropy, redundancy and transmission (or code) efficiency
- c apply measures of information, entropy, redundancy and transmission efficiency to simple numerical problems

2 explain the purpose and principles of source coding

- a implement a Huffman code
- b describe source coding for speech, music (Hi-Fi), facsimile, pictures (JPEG) and video (MPEG)
- c define channel capacity (Shannon-Hartley law)
- d comment on the limiting factors of channel capacity (error rate due to noise and bit rate due to bandwidth) and the possible trade-off between these factors

3 explain the purpose and principles of error control coding

- a define Hamming distance and codeword weight
- b explain the principles of (n, k) block codes and the use of parity check digits
- c define the error detection and correction capability of a code
- d implement nearest neighbour and syndrome decoding of a block code
- e explain what is meant by a cyclic code and, in particular, the special case of a Hamming code
- f explain the meaning and significance of interleaving

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Outcome 5 Demonstrate an understanding of noise and link budgets

Knowledge requirements
The candidate knows how to:

1 explain what is meant by additive noise, white noise and Gaussian noise

2 explain why thermal noise can normally be assumed to be additive, white and Gaussian

3 explain origin and characteristics of shot noise

4 distinguish between internal and external receiver noise

5 define noise temperature and noise figure and convert freely between the two

6 calculate the overall noise temperature and noise figure of a system comprising multiple subsystems connected in cascade

7 explain what is meant by antenna noise temperature

8 sketch the typical noise temperature of a narrow beam antenna as a function of frequency for low and high elevation angles

9 explain the origin of the dominant antenna noise at different frequencies

10 explain and define antenna directivity, gain and effective area

11 explain and define spreading loss, free-space path loss, plane Earth path loss and interference patterns due to ground reflection

12 construct simple microwave or millimeter-wave link budgets for point-to-point terrestrial links

13 describe what is meant by multipath fading and diversity reception in the context of a radio link

14 explain the principles of optical fibre transmission including fibre contruction, propagation modes and their characteristics

15 give an elementary account of optical sources, detectors and amplifiers

16 construct simple optical fibre link budgets

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Recommended reading list

Core texts	Author(s)	Publisher	ISBN
Digital Communications	Glover, Grant	Prentice-Hall	0130893994
Telecommunication switching, Traffic and Networks	Flood	Pearson Education	0130893994
Transmissions Systems	Flood, Cochrane	Peregrinus	0863413102
Other useful texts			
Communication Systems	Carlson	McGrawHill	007009960
Telecommunication Engineering	Dunlop, Smith	Chapman Hall	0-412562707
Digital Communications	Proakis	McGraw Hill	007-2321113
Digital Communications	Sklar	Prentice Hall	0130847887
Introduction to Communication Systems	Stremler	Addison Wesley	0201516519
Optical Communication	Sibley	McMillan	0-333-61792-4
Modern Digital and Analogue Communication Systems	Lathi	Oxford University Press	0195110099