



*If nature gives you free lunch you pay with your dinner.*

This second edition of Communication Engineering Principles is a painstaking and comprehensive revision of the original publication, including several new Chapters and a complete rewrite of some of the old Chapters. I have remained faithful to the approach and philosophy that made the first edition so successful. It is an Engineering-first approach inspired by an Engineering-is-fun philosophy. I have left no stone unturned to ensure complete clarity and to break complex concepts into their simple bite-sized components for the benefit and enjoyment of every reader and tutor.

Communication Engineering Principles is aimed at undergraduate courses in communication engineering, digital communications and signals and systems analysis. It is also suitable as preparatory material for MSc students and for researchers and practising engineers wishing to fully understand and apply the concepts and principles of the subject in their area of work. The book prioritises clarity and engineering insight above mathematical rigour, although Maths is an essential tool that is used when necessary. Analogies, graphs, heuristic arguments and numerous worked examples are used to deepen the reader's insight and hone their skills in problem solving and the correct interpretation and application of key concepts and principles.

Chapter 1 is a non-mathematical *overview of communication systems* that erects crucial

knowledge pegs needed to hang a more detailed treatment of the subject in subsequent chapters. It also presents a carefully selected review of our journey from telegraphy in 1837 to 5G in 2020 and a discussion of the main communication system elements and processes. This is an extensive update of the first Chapter of the first edition which went by the same name. In addition to a detailed update to reflect the state of the art of telecoms in 2020, new material has been added on circuit and packet switching, character coding, developments in transmission media and the digital era. It is in this Chapter that we discover that ATM is a slow-start sprinter whereas IP is an instant-start jogger and we learn the different attitudes of each technique towards sharing the community cake.

Chapter 2 on *Introduction to Signals and Systems* is a new Chapter that retains some of the material in the old Chapter 2 which was titled *Telecommunication Signals*. It is a must read for everyone, including those who already have some familiarity with some of the topics discussed. We lay a great foundation for dealing with signals and systems in engineering. This includes an exhaustive treatment of sinusoidal signals—the building block of all other signals—and an introduction to various system properties. It is also in this Chapter that we learn 10 logarithmic do's and don'ts. For example, did you know that you should never add together two dBW values, although you may subtract them?

Chapter 3 on *Time Domain Analysis of Signals and Systems* is a new Chapter that deals with various signal operations from time reversal and delay to convolution and autocorrelation. We use a graphical approach and various worked examples to make it easy to fully master these important operations. Random signals are also discussed and the statistical distributions that are most used for telecom systems and services analysis and modelling are fully covered. The last part of the Chapter is then devoted to learning how to characterise and analyse linear systems in the time domain.

Chapter 4 on *Frequency Domain Analysis of Signals and Systems* is new. Using a mix of heuristic, graphical and mathematical approaches we explore the topics of Fourier series, Fourier transform, and Discrete Fourier transform at a depth and breadth that are considered complete for the needs of modern engineering. We explore new applications of the tools and at all points emphasise the correct interpretation of results. The Chapter ends with careful coaching on the use of a frequency domain approach in system characterisation and analysis.

Chapter 5 on *Transmission Media* is new. A nonmathematical discussion of the characterisation, signal impairments and applications of metallic lines, optical fibre and radio is followed by a more in-depth analysis to develop the tools needed to calculate signal strength at various points in each medium. Transmission line theory is also covered in full.

Chapter 6 on *Noise in Communication Systems* is an update of the old Chapter 9 that went by the same title. The update includes new worked examples and improvements in presentation and discussion. We acquire a good grounding in the quantification of random noise and the assessment of their impact on digital and analogue communication systems. The design parameters that affect SNR in analogue systems and BER in digital systems are explored in detail.

Chapter 7 on *Amplitude Modulation* is an update of the old Chapter 3 that was similarly titled. It gives a comprehensive treatment of amplitude modulation and all its variants.

Chapter 8 on *Frequency and Phase Modulation* retains much of the material of the old Chapter 4 titled Angle Modulation. The treatment of noise effects using a phasor approach is improved. New worked examples are also included.

Chapter 9 on *Sampling* retains much of the old Chapter 5 that was similarly titled. The treatment of bandpass sampling is improved, and new graphical illustrations are employed.

Chapter 10 on *Digital Baseband Coding* is an extensive revision of the previous Chapter 6 titled Digital Baseband transmission. The treatment of quantisation and PCM is improved.

Chapter 11 on *Digital Modulated Transmission* is an extensive revision of the old Chapter 7 that was similarly titled. New material is introduced on signal orthogonality, signal space diagrams, bandwidth efficiency, design parameters and bit error ratios. New worked examples are also introduced.

Chapter 12 on *Pulse Shaping and Detection* is new. We develop various filtering measures for mitigating inter-symbol interference (ISI), evaluate the Shannon-Hartley information capacity law and derive the matched filter for optimum detection of a signal in additive white Gaussian noise. Various worked examples are also presented.

Chapter 13 on *Multiplexing Strategies* is an extensive revision of the previous Chapter 8 that was similarly titled. A new section on multiple access is introduced and the treatment of all topics, including wavelength division multiplexing, is updated and improved. New worked examples are also added.

Various useful materials are provided in a series of appendices, including *character code tables* in Appendix A, *trigonometric identities* in Appendix B, and *constants, SI units* and a *table of complementary error function and Q-function* in Appendix C.

The entire Chapter 1 and up to Section 5 of Chapter 2 is non-mathematical. This is in keeping with our Engineering-first approach.

We wanted Engineering, rather than Maths, to be our gatekeeper to welcome you to the beauty and fun of telecoms as presented in this volume. Beyond Section 2.5 it is assumed that you have a knowledge of calculus, although a lot of explanation of mathematical manipulations is provided as deemed necessary. In all cases however, we approach every concept and every problem solving by starting with engineering, bringing in Maths if necessary and then ending with engineering through a careful interpretation of any mathematical results.

I hope that you will enjoy using this book as much as I enjoyed writing it. I look forward to hearing how this book has helped your work, whether as student or tutor. Please visit my website at <https://professorifiokotung.com/> for further support including video clips and presentations that could help make your study easier and even more exciting.

## Acknowledgement

The communication engineering principles, technologies and standards covered in this book are the culmination of the efforts of many people and organisations over several generations. This book owes its very existence to these pillars of our subject and to the stellar work of the International Telecommunication Union (ITU) in developing many of the technical standards reflected within.

I am indebted to Simon Haykin whose writings played a significant role in guiding my first steps into communication systems theory in the 1980s. Since then, my journey in the subject has been further shaped through the contributions of others too numerous to mention. However, this book brings a unique approach born out of many years of teaching the subject matter to international cohorts of students and engineers with diverse

mathematical abilities. The book's style and attention to detail are motivated by a strong belief in simplicity and the necessity of clarity, and an uncompromising dedication to training competent engineers with a complete understanding of the underlying principles of the subject as well as excellent skills in communication system analysis and design.

I am grateful to generations of my undergraduate and postgraduate students, short course participants and users of the first edition of the book whose feedback and learning requirements helped in no small measure to shape the style and content of this second edition. I thank my colleagues, Dr Ali Roula and Professor Jonathan Rodriguez, for their support with some administrative and research responsibilities while the book was in preparation. I also thank my research student Ms Jinwara Surattanagul for her secretarial contributions to some parts of the later Chapters.

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Finally, I am grateful to God for granting me the privilege and ability to make this contribution to the education, training, career and reading pleasure of many.

*Ifiok Otung*  
*South Wales, United Kingdom*  
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