Essentials of Modern Spectrum Management

Are you fully up-to-speed on today’s modern spectrum management tools? As regulators move away from traditional spectrum management methods, introduce spectrum trading and consider opening up more spectrum to commons, do you understand the implications of these developments for your own networks?

This is the first book to describe and evaluate modern spectrum management tools. Expert authors offer you unique insights into the technical, economic and management issues involved. Auctions, administrative pricing, trading, property rights and spectrum commons are all explained. A series of real-world case studies from around the world is used to highlight the strengths and weaknesses of the various approaches adopted by different regulators, and valuable lessons are drawn from these.

This concise and authoritative resource is a must-have for telecom regulators, network planners, designers and technical managers at mobile and fixed operators and broadcasters, and academics involved in the technology and economics of radio spectrum.

Martin Cave is Professor and Director of the Centre for Management under Regulation at Warwick Business School. He is the author of the Cave Review commissioned by the Chancellor into spectrum management in the UK.

Chris Doyle is an Associate Fellow at the Centre for Management under Regulation at Warwick Business School.

William Webb is Head of Research and Development and Senior Technologist at Ofcom, a Visiting Professor at Surrey University and Fellow of the Royal Academy of Engineering.
The Cambridge Wireless Essentials Series

Series Editors

William Webb  Ofcom, UK
Sudhir Dixit  Nokia, US

A series of concise, practical guides for wireless industry professionals.


Forthcoming

Andy Wilton and Tim Charity, Essentials of Wireless Network Deployment
Chris Haslett, Essentials of Radiowave Propagation
Steve Methley, Essentials of Wireless Mesh Networking
Malcolm Macleod and Ian Proudler, Essentials of Smart Antennas and MIMO
Stephen Wood and Roberto Aiello, Essentials of Ultra-Wideband
David Crawford, Essentials of Mobile Television

For further information on any of these titles, the series itself and ordering information see www.cambridge.org/wirelessessentials
Essentials of Modern Spectrum Management

Martin Cave
Warwick Business School

Chris Doyle
Warwick Business School

William Webb
Ofcom, UK
## Contents

*Acknowledgements*  

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acknowledgements</td>
<td>xi</td>
</tr>
<tr>
<td>1 Emerging problems with the current spectrum management approach</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Why spectrum needs to be managed</td>
<td>3</td>
</tr>
<tr>
<td>1.2 The current management mechanisms</td>
<td>4</td>
</tr>
<tr>
<td>1.3 Shortcomings of the current system</td>
<td>6</td>
</tr>
<tr>
<td>1.4 Alternative management approaches</td>
<td>8</td>
</tr>
<tr>
<td>1.5 How this book addresses the new approaches</td>
<td>9</td>
</tr>
<tr>
<td>Reference</td>
<td>9</td>
</tr>
<tr>
<td>2 How changing technology is impacting spectrum management</td>
<td>11</td>
</tr>
<tr>
<td>2.1 Technology used to lend itself to discrete allocations</td>
<td>11</td>
</tr>
<tr>
<td>2.2 Multi-modal radios</td>
<td>12</td>
</tr>
<tr>
<td>2.3 Cognitive and software defined radios</td>
<td>13</td>
</tr>
<tr>
<td>2.4 Ultra-wideband</td>
<td>20</td>
</tr>
<tr>
<td>2.5 Summary</td>
<td>23</td>
</tr>
<tr>
<td>3 Alternative ways of dividing spectrum</td>
<td>25</td>
</tr>
<tr>
<td>3.1 Spectrum has been divided by frequency</td>
<td>25</td>
</tr>
<tr>
<td>3.2 UWB raises the possibility of division by power</td>
<td>26</td>
</tr>
<tr>
<td>3.3 Other divisions are also possible</td>
<td>33</td>
</tr>
<tr>
<td>3.4 Summary: in practice, changes to spectrum division would be minor</td>
<td>34</td>
</tr>
</tbody>
</table>
## Contents

### II Markets 35

4 Market solutions 37  
4.1 Introduction 37  
4.2 Market methods 38  
4.3 Market failures 40  
4.4 Conclusion 41  

5 Auctions 43  
5.1 Introduction 43  
5.2 Auctions versus administrative methods of assignment 46  
5.3 Theory of auctions 49  
5.4 Auction formats 51  
5.5 Auction logistics 76  
5.6 Conclusion 81  
References 82  

6 Spectrum trading: secondary markets 85  
6.1 Introduction 85  
6.2 Radio spectrum and market forces 87  
6.3 Spectrum trading, markets and efficiency 88  
6.4 Objections to spectrum trading 92  
6.5 The implementation of spectrum trading in the UK 94  
6.6 Trading in other countries 97  
6.7 Conclusion 103  
References 104  

7 Technical issues with property rights 105  
7.1 Introduction 105  
7.2 Key elements of property rights 106  
7.3 The problem of deployment density 110  
7.4 Calculating noise floor levels 112  
7.5 Making a property rights system work in practice 112
11.2 Economic efficiency and radio spectrum  169
11.3 Productive efficiency and radio spectrum  171
11.4 Pricing radio spectrum to achieve economic efficiency  174
11.5 The Smith–NERA method of calculating spectrum prices  175
11.6 Setting spectrum prices to achieve efficiency using the Smith–NERA method  178
11.7 The interaction between spectrum pricing and spectrum trading  181
11.8 Conclusion  184
References  185

12 Incentive based spectrum pricing: practicalities  187
12.1 Introduction  187
12.2 Applying administrative incentive prices: some issues  188
12.3 Calculating AIP in practice: case study of fixed links in the UK  193
12.4 Incentive based spectrum charges in other countries  199
12.5 Conclusion  200
References  202

13 How the commons works  203
13.1 Introduction  203
13.2 The economics of the commons  204
13.3 The likelihood of congestion in radio spectrum  209
13.4 Quasi-commons: UWB and cognitive radio  220
13.5 Summary  220
References  221

14 Commons or non-commons?  223
14.1 Introduction  223
14.2 The use of market mechanisms to determine the amount of spectrum commons  223
Acknowledgements

Martin Cave
I am very grateful to a number of people from whom I have learnt about spectrum economics, including William Lehr, Tom Hazlett, Robert Pepper, Evan Kwerel, Michael Goddard, David Hendon and Adele Morris – but they bear no responsibility for the result; I am especially grateful to my co-authors.

Chris Doyle
Over the years I have been fortunate to work with Peter Cramton, Eric van Damme and Paul Milgrom on a number of spectrum assignments and am grateful for their invaluable insights on auctions and spectrum pricing in particular. I am grateful to Phillipa Marks and Brian Williamson of Indepen Economic Consultants, John Burns of Aegis Systems Limited and Charles Chambers formerly of Quotient Associates. I am also grateful to my co-authors for comments. Finally, I should like to thank my wife, Jennifer Smith, who has helped my work in this area.

William Webb
In writing this book I have drawn upon all my experience gained over my years in the industry. I have learnt something from almost everyone I have come into contact with and would thank all of those with whom I have had discussions. Special thanks are due to a number of key individuals. During my time at Multiple Access Communications, Professor Ray Steele, Professor Lajos Hanzo, Dr Ian Wassell and Dr John Williams amongst others have taught me much about the workings of mobile radio systems. At Smith System Engineering (now Detica), Richard Shenton, Dr Glyn Carter and Mike Shannon have
provided valuable knowledge as have contacts with a number of others in the industry including Michel Mouly, Mike Watkins, Jim Norton and Phillipa Marks (Indepen). At Motorola I had tremendous guidance from a range of individuals including Sandra Cook, Raghu Rau, John Thode and the immense privilege of discussions with Bob Galvin, ex-CEO. In my work with Institutions I have been privileged to work with John Forrest CBE, Sir David Brown, Walter Tuttlebee, Peter Grant and many more. At Ofcom Peter Ingram, Mike Goddard, those in my R&D team and others have provided invaluable guidance. Finally, as always, thanks to Alison, my wife, who supports all my endeavours to write books with good humour and understanding.

Disclaimer

Note that the views and opinions presented in this book are those of the authors and not necessarily of the organisations which employ them. These views should in no way be assumed to imply any particular strategic direction or policy recommendation within the organisations thus represented.
This page intentionally left blank. Essentials of Modern Spectrum Management. Are you fully up-to-speed on todayâ€™s modern spectrum management tools? As regulators move away from traditional spectrum management methods, introduce spectrum trading and consider opening up more spectrum to commons, do you understand the implications of these developments for your own networks? This is the first book to describe and evaluate modern spectrum management tools. Current spectrum management methods and their shortcomings 1.1 Why spectrum needs to be managed 1.2 The current management mechanisms 1.3 Shortcomings of the current system 1.4 Alternative management approaches 1.5 How this book addresses the new approaches Reference. 3 3 4 6 8 9 9. Spectrum management is the process of regulating the use of radio frequencies to promote efficient use and gain a net social benefit. The term radio spectrum typically refers to the full frequency range from 3 kHz to 300 GHz that may be used for wireless communication. Increasing demand for services such as mobile telephones and many others has required changes in the philosophy of spectrum management. Demand for wireless broadband has soared due to technological innovation, such as 3G and 4G mobile. This spectrum management training course delivers the essential technical foundations needed to support modern approaches while bringing attendees up to speed with the latest thinking in a range of other areas. Who should participate? The course is aimed at people who either work for regulators or a commercial organisation which needs to understand the principles of spectrum management. PT Publishing produces PolicyTracker, the journal of spectrum management as well as the Spectrum Research Service, business reports and bespoke research. LS telcom is a worldwide market leader in the provision of strategic and technical consulting; training on technologies, regulation and policy; automated spectrum management and monitoring systems; and planning and optimisation software. Learn more about Essentials of Modern Spectrum Management on GlobalSpec. Offering insights into the technical, economic and management issues involved in modern spectrum management tools, this book provides real-world case studies to highlight the strengths and weaknesses of the approaches adopted by different regulators. Table of contents. Essentials of Modern Spectrum Management. Part I: Emerging Problems with the Current Spectrum Management Approach.