

RADIO SPECTRUM MANAGEMENT

POLICIES, REGULATIONS AND TECHNIQUES

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To my mother Suzanne (Sévilia) Madjar and to my wife Nitza (Ben-Shemesh) Mazar

About the Author

Dr. Haim Mazar (Madjar) has more than 45 years of experience in wireless communications (including broadcasting, mobile, fixed, radiolocation, satellite and public services) and RF spectrum management. In addition to contributing to ITU-D and ITU-T Study Groups, Haim has contributed to all ITU-R Study Groups (and their associated Working Parties), in total, more than 180 technical contributions. Elected by 88 countries at the ITU Radio Assembly 2015, he serves as Vice Chair of ITU-R Study Group 5 (Terrestrial Services). Dr. Mazar is a consultant for national administrations and industries around the world on spectrum management, the ruling of Short Range Devices and RF Human Hazards. He holds a BSc EE, from the Technion Israel Institute of Technology in 1971; an MBA from Bar Ilan University in 1988; and a PhD from Middlesex University, London, UK, in 2008, focusing on regulatory frameworks for wireless communications. He is currently a radio communications lecturer and since January 2016, a guest professor at Xihua University, Chengdu, China.

Foreword

Mr. Mazar has been involved extensively in ITU activities since 1991 and is well known and appreciated within the wireless regulatory community. This book is intended to provide engineers, lawyers and economists involved in wireless communications a valuable source of information and inspiration for professional activities in this field.

I am sure that all professionals involved in regulatory and standardization activities relating to wireless communications will appreciate this book.

François Rancy
*Director, Radiocommunication
Bureau International Telecommunication Union*

Preface

An understanding of the policies, regulations, standards and techniques of radio spectrum management is useful to those who manage and administrate it, to operators, to equipment providers and to the users of wireless communication (i.e., all of us). For many years the author has been deeply involved in ruling the RF spectrum at the national, regional and global levels. The book is based on the professional experience of the author, his academic courses, presentations and tutorials in five continents. The book reflects this legacy and will be of use to engineers, lawyers and economists, who serve the global industry of the wireless world; in it they may find solutions to the problems they frequently encounter.

The book provides the background and an overall view, evaluating the regulatory framework for wireless communications of most administrations. The European idea to transfer national regulatory power to an intergovernmental authority may be repeated in other continents, to assist many developed and developing countries. Rather than creating new regulations and standards, administrations worldwide may follow the European, North American or Asian rules.

The regulation of the RF spectrum is concerned with the following features: regulating uncertain risks, harmful interference, the security of life services, and placing on the market new wireless technologies. Unwanted emissions and human hazards are problems that require world-views and values to guide their regulation.

The nine chapters of the book explore the administrative, engineering, legal and economic aspects of wireless communications; then the main international and regional organizations influencing the regulation and standardization of the RF spectrum are detailed. The national regulations and standards of China, France, the UK and the USA serve as case studies. Other topics discussed are the proliferation of cellular base stations, the public dislike of large antenna structures, and the growing concern about electromagnetic pollution. These topics oblige regulators to be involved, therefore, human exposure to RF is emphasized.

Chapter 1 explores wireless communications, by giving a short historical overview, depicting the basic communication channels and detailing the RF bands. Chapter 2 examines the main regulated radio services. The broadcasting delivery and technical parameters of analog and digital sound (radio) and video (television) are detailed; the analog radio FM and digital DVB-T are emphasized. Due to its importance and the continuous need for additional RF to provide capacity and coverage, a section focuses on the cellular service. Fixed point-to-point and point-to-multipoint are radiocommunication services between specified fixed stations; therefore, the fixed service can be provided by alternative cable or satellite systems. However, line-of-sight and non-line-of-sight links provide quick cost-effective broadband solutions. Satellites are used for commerce, government purposes, science, research and astronomy; therefore, satellite orbits, plus services and equipment are specified.

As regulators and the public are very concerned about Short Range Devices (SRDs), Chapter 3 provides their technical and operating parameters; SRDs are not considered a “radiocommunication service”; thus they operate normally on this basis: unlicensed, unprotected and with non-interference with other radio equipment. The roaming of SRDs obliges regional and global harmonization. The global success of Wi-Fi can be compared to the triumph of GSM. Wi-Fi, RFID and the citizens’ band 26.96–27.28 MHz serve as case studies.

Chapter 4 describes policies, the legal and economic frameworks to manage the RF spectrum; the central planning (*ex-ante* and *a-priori*) approach is compared and contrasted with the market-based (*ex-post* and *a-posteriori*) style. The main objectives of spectrum control are listed. The two different legal traditions (civil law and common law) characterize the legislative environment; the importance of the radiocommunications law to the legal framework is specified; the property rights of the license holders are discussed; international, regional and national legislation is reviewed. The economic aspects of the RF are also analyzed; the benefits of wireless communications to economic welfare and to increase productivity are indicated; countries include the RF spectrum as a non-produced asset in their national cost accounting. License fees are evaluated by secondary trading, auctions and lotteries; the annual fees are quantified; international, regional and national frequency allocation tables are explained; redeployment and refarming are economic tools to optimize RF use.

Chapter 5 studies end-to-end wireless communication; power and unwanted emissions of transmitters are examined for RF sharing. Since receivers can be interfered with, their selectivity, noise and sensitivity are assessed. As there is no RF signal without antennas, a section details their fundamental parameters (aperture, beamwidth and gain; polarization, bandwidth, insertion loss and impedance). Because the attenuation of the RF signal is fundamental to the RF environment, free-space propagation loss and Maxwell’s equations are presented, Fresnel zones are proved, near-field and far-field are compared. The frequency dependency when penetrating walls and bypassing obstacles explains why traditional cellular systems operate below 6 GHz. Non-linear and linear RF interference and spectrum sharing are calculated, and mitigation techniques are proposed to decrease interference.

Chapter 6 explores the international spectrum management and standardization by cataloging the relevant players and detailing how rules and standards are developed and implemented. The three ITU sectors of Development ITU-D BDT, Telecommunications ITU-T TSB and Radio ITU-R BR are surveyed. Readers may learn about bilateral and multilateral agreements between administrations, cross-border coordination and mitigation techniques to avoid interference.

Chapter 7, on regional RF spectrum management, details the exceptional European model, as a result of which the EU countries relinquish some of their sovereignty. European regulation, the main players, intergovernmental and international regulatory relationships, the legislation on the spectrum, computerized tools and harmonized activities are described. The main regional American players are OAS, CITELE and CAN. Regulation and standardization in the two major camps (Europe and North America) are compared and summarized. Regulation is explored in Asia, the (ex-Russian) Regional Commonwealth in the field of communications (RCC), the Arab countries and Africa (African Telecommunications Union, the West African states, the East African community and the South African region).

Chapter 8 details the national spectrum management: roles, objectives, basic functions, guidelines and practices to optimally manage the RF spectrum. Administrative trends in spectrum management, smarter technologies and wireless innovation modernize the ruling. The chapter discusses how China, France, the UK and the USA manage their spectrum.

Chapter 9 presents RF health risks as a social story; the electromagnetic hypersensitivity and electrophobia are explained; international, regional and national thresholds are compared; power density and field-strength are simulated and measured to define safety distances around base stations. The impact of RF hazards limits on mobile network planning is quantified; policies and mitigation techniques to reduce human exposure are proposed.

Acknowledgments

As this book extends over a wide area of subjects and many regulatory bodies I wish to acknowledge the contribution of a large number of colleagues who reviewed the text and suggested valuable editions. In view of the diversified nature of the material on the one hand and the focused nature of most contributors, I believe that the best way to recognize the assistance by these contributors is by way of the following table.

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Acronyms and Abbreviations

1G	First Generation
2G	Second Generation
3G	Third Generation
3GPP	Third Generation Partnership Project
3GPP2	Third Generation Partnership Project 2
4G	Fourth Generation
ABU	Asia-Pacific Broadcasting Union
AF	Annual Fee
AHCIET	<i>Asociación Iberoamericana de Centros de Investigación y Empresas de Telecomunicaciones</i> (Ibero-American Association of Telecommunications Research and Enterprises)
AICTO	Arab Information and Communication Technology Organization
AM	Amplitude Modulation
ANFR	<i>Agence Nationale des Fréquences</i> (France)
ANSI	American National Standards Institute (USA)
APT	Asia-Pacific Telecommunity
ARCEP	<i>Autorité de Régulation des Communications Electroniques et des Postes</i> (France)
ARCTEL-CPLP	<i>Associação de Reguladores de Comunicações e Telecomunicações da Comunidade dos Países de Língua Portuguesa</i> (Association of Communications and Telecommunications Regulators of the Community of Portuguese-Speaking Countries)
AREGNET	Arab Regulators Network
ARIB	Association of Radio Industries and Businesses (Japan)
ARRL	American Radio Relay League Incorporated
ASETA	Association of Andean Community Telecommunications Enterprises
ASK	Amplitude Shift Keying
ASMG	Arab States Spectrum Management Group
AT-DMB	Advanced Terrestrial Digital Multimedia Broadcasting (South Korea)
ATIS	Alliance for Telecommunications Industry Solutions
ATSC	Advanced Television Systems Committee (USA and Canada)
ATU	African Telecommunications Union
AWG	APT Wireless Group
BASK	Binary Amplitude Shift Keying
BBC	British Broadcasting Corporation (UK)
BDT	Telecommunications Development Bureau (ITU)
BER	Bit Error Rate
BEREC	Body of European Regulators for Electronic Communications
BFSK	Binary Frequency Shift Keying

BIPM	<i>Bureau International des Poids et Mesures</i>
BIS	Business, Innovation and Skills (UK Department)
Bps	Bits Per Second, also termed bit/s
BPSK	Binary Phase Shift Keying
BR	Bureau Radio (ITU)
BSS	Broadcasting-Satellite Service
BW	Band Width
BWA	Broad Wireless Access
C/A	Coarse/Acquisition (civilian code of GPS)
CA	Channel Arrangement
CAATEL	<i>Comité Andino de Autoridades de Telecomunicaciones</i> (Andean Committee of Telecommunications)
CAN	<i>Comunidad Andina de Naciones</i>
CANTO	Caribbean Association of National Telecommunication Organizations
CAPTEF	<i>Conférence des Administrations des Postes et Télécommunications des pays d'Expression Française</i>
CATV	Cable TV
CCA	Combinatorial Clock Auction
CCSA	China Communications Standards Association
CDMA	Code Division Multiple Access
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CEPT	European Conference of Postal and Telecoms Administrations
CFR	Code of Federal Regulations (USA)
C/I	Carrier to Interference
CISPR	International Special Committee on Radio Interference
CITEL	<i>Comisión Interamericana de Telecomunicaciones</i> (Inter-American Commission of Telecommunications)
CJK	China, Japan and South Korea
C/N	Carrier to Noise (interchangeable with S/N)
CNR	Carrier to Noise Ratio (interchangeable with SNR)
COPANT	Pan American Standards Commission
COSPAS-SARSAT	International Satellite System for Search and Rescue
CPCE	<i>Code des postes et des communications électroniques</i> (France)
CPG	Conference Preparatory Group (CEPT)
CRAF	Committee on Radio Astronomy Frequencies (Europe)
CRASA	Communication Regulators' Association of Southern Africa
CRS	Cognitive Radio System
CS	Constitution and Convention (ITU)
CSA	<i>Conseil Supérieur de l'Audiovisuel</i> (France)
CTO	Commonwealth Telecoms Organisation
CTU	Caribbean Telecommunications Union
DAA	Detect And Avoid
DAB	Digital Audio Broadcasting
DAS	Dynamic Access to Spectrum
dB	decibel
dBd	dB relative to half Dipole antenna
dB _i	dB relative to Isotropic antenna
dBm	dB relative to 1 mW

DBS	Direct Broadcast Satellite
dBW	dB relative to 1 W
DCMS	Department for Culture, Media and Sport (UK)
DD	Digital-Dividend
DFS	Dynamic Frequency Selection
DGPS	Differential Global Positioning System
DL	Down Link (downlink)
DMB-T/H	Digital Media TV Broadcasting-Terrestrial/Handheld) (South Korea); see also T-DMB and AT-DMB
DRM	<i>Digital Radio Mondiale</i>
DSB	Digital Sound Broadcasting
DTH	Direct To Home
DTMB	Digital Terrestrial Multimedia Broadcast (China)
DTT	Digital Terrestrial Television
DTTB	Digital Terrestrial TV Broadcasting
DVB-H	Digital Video Broadcasting – Handheld
DVB-T	Digital Video Broadcasting – Terrestrial
EAC	East African Community
EACO	East African Communications Organization
EASA	European Aviation Safety Agency
EBU	European Broadcasting Union
EC	European Commission
ECC	Electronic Communications Committee (Europe)
E_c/I_0	Energy of Carrier over Interference reference
ECO	European Communications Office
ECOWAS	Economic Community of West African States
ECTEL	Eastern Caribbean Telecommunications Authority
EDGE	Enhanced Data rates for Global Evolution
EEA	European Economic Area
EFTA	European Free Trade Association
EHF	Extremely High Frequency (30–300 GHz)
EHS	Electromagnetic HyperSensitivity
E.I.R.P.	Equivalent Isotropically Radiated Power
EMF	Electro Magnetic Fields
EN	European Standard
EPRA	European Platform of Regulatory Authorities
ERC	European Radiocommunications Committee
E.R.P.	Effective Radiated Power
ESA	European Space Agency
ETSI	European Telecommunications Standards Institute
EU	European Union and European Commission
FAA	Federal Aviation Administration (USA)
FCC	Federal Communications Commission (USA)
FDD	Frequency Division Duplexing
FDMA	Frequency Division Multiple Access
FHSS	Frequency Hopping Spread Spectrum
FM	Frequency Modulation
FRATEL	<i>réseau FRAncophone des régulateurs des TÉLécommunications</i> (France) (Francophone Telecoms Regulatory Network)

FS	Fixed Service
FSK	Frequency Shift Keying
FSS	Fixed Satellite Service
FWS	Fixed Wireless Systems
GDP	Gross Domestic Product
GE-89	Regional Agreement for the African TV Broadcasting Area (Geneva 1989)
GE-2006	Regional Radio Conference 2006; also called RRC-06 Agreement
GEO	GEostationary Orbit (equivalent to GSO)
GLONASS	<i>Глобальные Навигационные Спутниковые Системы</i> (Russian GPS) <i>ГЛОНАСС, Global'naya Navigatsionnaya Sputnikovaya Sistema</i> (GNSS)
GMDSS	Global Maritime Distress and Safety System
GPS	Global Positioning System
GS1	Global Standards One
GSM	<i>Groupe Spéciale Mobile</i> (Global System for Mobile communications)
GSMA	GSM Association
GSO	Geostationary Satellite Orbit (equivalent to GEO)
G/T	Gain to noise Temperature
HCM	Harmonized Calculation Method (Europe)
HDTV	High Definition TV
HEO	High Earth Orbit, Highly Elliptical Orbit or Highly Eccentric Orbit (low under 1,000 km, high up to 40,000 km)
HF	High Frequency (3–30 MHz)
HFCC	High Frequency Co-ordination Conference
HRP	Hypothetical Reference Path
HRX	Hypothetical Reference Connection
Hz	Hertz (the base unit of frequency)
IAF	International Astronautical Federation
IARC	International Agency for Research on Cancer
IARU	International Amateur Radio Union
IATA	International Air Transport Association
IAU	International Astronomical Union
IBB	Integrated Broadcast-Broadband
IBOC	In Band On Channel
ICAO	International Civil Aviation Organization
ICNIRP	International Commission on Non-Ionizing Radiation Protection
ICT	Information and Communication Technologies
IEC	International Electrotechnical Commission
IEEE-SA	Institute of Electrical and Electronics Engineers – Standards Association
IIRSA	South American Regional Infrastructure Integration
IMO	International Maritime Organization
IMP	Inter Modulation Products
IMSO	International Mobile Satellite Organization
IMT	International Mobile Telecommunications
I/N	Interference to Noise
IP	Internet Protocol
IP3	3rd order Intercept Point
IRG	Independent Regulators Group (pan-European body)
ISDB-T	Integrated Services Digital Broadcasting Terrestrial
ISM	Industrial, Scientific and Medical

ISO	International Organization for Standardization
ITSO	International Telecommunications Satellite Organization
ITU	International Telecommunication Union
ITU-D	ITU – Development Sector
ITU-R	ITU – Radiocommunications Sector
ITU-T	ITU – Telecommunications Sector
LBT	Listen Before Talk
LEO	Low-altitude Earth Orbit (about 1,000 km above sea level)
LF	Low Frequency
LoS	Line-of-Sight
LSA	Licensed Shared Access
LTE	Long-Term Evolution
MEO	Medium-altitude Earth orbit (about 10,000 km above sea level)
MERCOSUR	<i>Mercado Común del Sur</i> (Common South American Market)
MF	Medium Frequency
MFN	Multi Frequency Network
MIFR	Master International Frequency Register
MIIT	Ministry of Industry and Information Technology (China)
MIMO	Multiple Input and Multiple Output
MMN	Man-Made Noise
MOD	Ministry of Defence (UK)
MoU	Memorandum of Understanding
MPE	Maximum Permissible Exposure
MPEG	Moving Picture Experts Group
MSS	Mobile Satellite Service
NABA	North American Broadcasters Association
NAFTA	North American Free Trade Agreement
NATO	North Atlantic Treaty Organization
NF	Noise Figure
NGSO	Non Geo-Stationary Orbit (also termed non-GSO or non-GEO)
NIR	Non Ionizing Radiation
NLoS	Non-Line-of-Sight
NOI	Notice of Inquiry (USA FCC)
NRA	National Regulatory Authority
NSM	National Spectrum Management
NTIA	National Telecommunications and Information Administration (USA)
NTSC	National Television System Committee (originated by USA, 1954)
OAS	Organization of American States
OECD	Organisation for Economic Co-operation and Development
OET	Office of Engineering and Technology (USA FCC)
Ofcom	Office of Communications (UK)
OFDMA	Orthogonal Frequency Division Multiple Access
PAL	Phase Alternation by Line (originated by Germany and UK, 1967)
PED	Personal Electronic Device
PIM	Passive Inter Modulation
P-MP	Point-to-Multi-Point
P-P	Point-to-Point
PR	Protection Ratio
PRN	Pseudo Random Numbers (used in GPS)