

# A Broadcast Engineering Tutorial for Non-Engineers

Skip Pizzi  
Graham Jones



Fourth Edition

 **NAB**<sup>®</sup>  
NATIONAL ASSOCIATION OF BROADCASTERS



# A BROADCAST ENGINEERING TUTORIAL FOR NON-ENGINEERS

Fourth Edition



 **Focal Press**  
Taylor & Francis Group  
NEW YORK AND LONDON

Third edition published 2005 by Focal Press

This edition published 2014

by Focal Press

70 Blanchard Road, Suite 402, Burlington, MA 01803

and by Focal Press

2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

*Focal Press is an imprint of the Taylor & Francis Group, an informa business*

© 2014 Taylor & Francis

The right of Skip Pizzi and Graham Jones to be identified as authors of this work has been asserted by them in accordance with sections 77 and 78 of the Copyright, Designs and Patents Act 1988.

All rights reserved. No part of this book may be reprinted or reproduced or utilised in any form or by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying and recording, or in any information storage or retrieval system, without permission in writing from the publishers.

#### Notices

Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods, professional practices, or medical treatment may become necessary.

Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds, or experiments described herein. In using such information or methods they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility.

Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation without intent to infringe.

#### *Library of Congress Cataloging in Publication Data*

Pizzi, Skip.

A broadcast engineering tutorial for non-engineers / Skip Pizzi, Graham Jones. — 4th edition.

pages cm

Includes index.

1. Radio—Transmitters and transmission. 2. Television—Transmitters and transmission.

3. Radio broadcasting. 4. Television broadcasting. I. Jones, Graham (Electrical engineer) II. Title.

TK6561.P59 2014

621.384—dc23

2013049657

ISBN: 978-0-415-73338-0 (hbk)

ISBN: 978-0-415-73339-7 (pbk)

ISBN: 978-1-315-84842-6 (ebk)

Typeset in Dante MT

By diacriTech, Chennai



Printed and bound in the United States of America  
by Edwards Brothers Malloy

# A BROADCAST ENGINEERING TUTORIAL FOR NON-ENGINEERS

**Skip Pizzi** is Senior Director of New Media Technologies at NAB, where he focuses on new methods for the creation and delivery of broadcast content. He is also Vice-Chair of ATSC *Technology Group 3* (TG3), which is developing standards for the next generation of digital television. Previously he worked in multimedia for 11 years at Microsoft, served as an editor and contributor to several broadcast technology books and journals, and consulted to the professional, educational, and government sectors of the media industry worldwide. He began his career as an engineer, manager, and technical trainer at NPR. He is a recipient of the Audio Engineering Society's Board of Governors Award, and a graduate of Georgetown University, where he studied Electrical Engineering, Fine Arts, and International Economics.

**Graham Jones** retired in 2010 from NAB, where he was a Senior Director working on advanced television issues. He is still active in ATSC, SCTE, and SMPTE standards committees. Previously he was Engineering Director for the Harris/PBS DTV Express, which introduced DTV to many U.S. broadcasters. He started his career with the BBC in London, and has worked as a consultant to broadcasters in many parts of the world. He holds a degree in Physics and is a chartered electrical engineer, a fellow of SMPTE, and a life member of the SBE and the Royal Television Society. He has been honored with the Bernard J. Lechner Outstanding Contributor Award from the ATSC and received a citation from SMPTE for outstanding service to the society.

# Preface

There are many people without engineering backgrounds who need to have a general understanding of broadcast engineering principles. Reaching a large range of devices from TV screens and clock radios to smartphones and digital dashboards, today's broadcasting brings together a wide range of professionals, both technical and non-technical, all working within its vast and omnipresent ecosystem. They may be broadcast managers, program producers, or others who deal with broadcast clients. It is important that they all share some level of knowledge about the workings of broadcast technology.

This tutorial is therefore intended to help such non-engineers seeking to learn about the technology of radio and television. It should also be useful for broadcast engineers in training, or those in technical occupations (such as IT) who find themselves involved with broadcast operations, or who simply want an overview of areas outside their primary expertise. This book explains the jargon of broadcasting and describes the underlying principles, standards, and equipment for broadcast facilities in terms a layperson can understand.

The fourth edition has been completely revised and updated to reflect the increasing use of digital and networking techniques in all aspects of television and radio broadcasting. New chapters have been added to provide an overview of new-media applications by broadcasters and emerging standards in the broadcast industry. The focus is on over-the-air broadcasting from U.S. radio and television stations, but other methods of program delivery to the home are also covered, along with some of the different standards and technologies used in other countries.

Although later chapters build on information in earlier sections, this book can also be consulted for discrete information about a particular topic, and is copiously cross-referenced. However it is used, the overall goal of this book is to help readers further their understanding of the broadcast industry, and thus enhance their ability to perform the broadcast-related functions of their jobs.

Skip Pizzi  
NAB Technology Department

# Contents

<i>Preface</i>	xi
<b>1</b> Introduction	1
<b>BROADCASTING BASICS</b>	<b>3</b>
<b>2</b> Types of Broadcasting	5
Analog Radio	5
Digital Radio	6
Satellite Radio	8
Analog Television	9
Digital Television	10
Mobile Digital Television	12
Cable Television	15
Satellite Television	16
Telco Television	18
IPTV	19
Internet Radio and Television	19
Stations, Groups, and Networks	21
<b>3</b> Sound and Vision	25
Sound, Audio, and Hearing	25
Light, Video, and Vision	27
Baseband	29
<b>4</b> Analog Color Television	31
NTSC	31
PAL and SECAM	39
HD Analog Video	40
<b>5</b> Digital Audio and Video	41
Digital Audio	41

	SD and HD Digital Video	48
	Audio and Video Data Compression	58
<b>6</b>	Information Technology	61
	Binary	61
	Computers	64
	Storage	66
	Computer Networks	68
<b>7</b>	Radio Frequency Waves	75
	Electromagnetic Waves	75
	Frequencies, Bands, and Channels	77
	RF Over Wires and Cables	79
	Modulation	79
	<b>STUDIOS, PRODUCTION, AND PLAYOUT FACILITIES</b>	<b>85</b>
<b>8</b>	Radio Studios	87
	Types of Studios	87
	Studio Operations	88
	System Considerations	91
	Audio Mixing Consoles	94
	Microphones	98
	Loudspeakers and Headphones	100
	CD Players	102
	Hard Disk Recorders and Audio Workstations	103
	Radio Program Automation	105
	Digital Record/Playback Devices	106
	Analog Devices	108
	Telephone Hybrids	110
	Remote Sources	111
	Audio Delay Units	111
	Emergency Alert System	112
	Audio Processing Equipment	113
	Signal Distribution	115
	IP-Based Studio Infrastructure ("Audio Over IP")	118
	Ancillary Systems	118
	Radio Master Control	119
	Facilities for IBOC Operations	119
	Radio Data Services	120
	Internet Radio Operations	121
	Other Considerations	122
<b>9</b>	Television Studios and Playout Facilities	123
	Station and Network Operations	123
	Types of Studios	125

Studio Characteristics	125
System Considerations	129
Studio System	130
Post-Production Edit Suites	131
Picture and Waveform Monitoring	134
Television Cameras	136
Film in Television	140
Video Recording	142
Video Editing	152
SMPTE Timecode	152
Video Servers	153
Nonlinear Editing	155
Character Generators and Computer Graphics	156
Electronic Newsroom	157
Signal Distribution	157
Video Timing	159
File-Based Workflows	160
Audio for Television	160
Ancillary Systems	164
Ingest and Conversion	165
IP-Based Studio Infrastructure	166
Television Master Control	167
Television Automation	170
ATSC Encoding and Multiplexing	172
Multicasting Operations	172
Closed Captioning	172
Video Description	173
Alternate Language Audio	173
PSIP Generator	174
Data Broadcasting Equipment	174
Advanced Programming Services	174
Bitstream Distribution and Splicing	176
Signal Delivery to MVPD Headends	177
Internet TV Services	177
<b>10</b> Remote Broadcasting	179
Radio News Gathering	179
Radio Remote Production	181
Television News Gathering	182
Television Remote Production	184
<b>11</b> Links	187
Link Architectures	187
Contribution Links for Radio	190
Contribution Links for Television	193



Network Distribution Links for Radio and Television	196
Studio-Transmitter Links for Radio and Television	197

## **TRANSMISSION STANDARDS AND SYSTEMS** **201**

<b>12</b>	Analog Radio	203
	AM Transmission	203
	Emissions Masks	205
	FM Transmission	206
	Stereo Coding	207
	Subcarriers	211
<b>13</b>	IBOC Digital Radio	213
	Phased IBOC Introduction	213
	Carriers and Channels for IBOC	214
	Modulation and Forward Error Correction	214
	Audio Data Compression	215
	AM IBOC	215
	FM IBOC	217
	Program and Service Data (PSD)	218
	Digital Radio Data Broadcasting	219
	Advanced Services	219
	HD Radio Standardization	219
<b>14</b>	Alternate Radio Delivery Systems	221
	Internet Radio Streaming	221
	Audio Podcasting	224
	Mobile Radio "APPS"	224
	Converged Receivers: "Connected Cars" and Radios in Smartphones	224
	Hybrid Radio	226
	Audio-Only Service Via DTV	227
<b>15</b>	NTSC Analog Television	229
	Carriers and Channels for Analog TV	229
	Video Signal	230
	Audio Signal	231
	Vertical Blanking Interval (VBI) Ancillary Information	232
	Closed Captioning and Content Advisory Ratings	232
	Analog TV Receiver	233
<b>16</b>	ATSC Digital Television	235
	ATSC and the FCC	235
	The U.S. Digital TV Transition	236
	DTV System	238
	Carriers and Channels for DTV	239
	8-VSB Modulation	240
	ATSC Compressed Bitstream	242

ATSC Video Formats	243
Aspect Ratio Management	244
MPEG-2 Compression	246
Advanced Video Codecs	252
Compression Artifacts	253
AC-3 Audio	253
Advanced Audio Codecs	257
Multiplexing	258
Multicasting	258
Closed Captions	260
Program and System Information Protocol (PSIP)	260
Data Broadcasting and Interactive Television	262
Content Protection (Conditional Access)	265
Advanced ATSC Services	265
<b>17</b> Alternate Television Delivery Systems	267
Internet Television Streaming and Downloading	267
Connected Television	271
Video Podcasting	272
Mobile Television “APPS”	272
Second Screen and Social TV	272
Hybrid TV	274
<b>18</b> Next-Generation Broadcast Television Systems	275
Proposed Differences from Current Systems	275
System Proposals around the World	278
New Directions in Audience Measurement	280
<b>19</b> Transmitter Site Facilities	281
Incoming Feeds	282
Processing Equipment	283
Exciters	284
Power Amplifiers	286
Transmission Lines and Other Equipment	289
AM Antenna Systems	290
FM and TV Antennas	293
Towers	296
Translators and Repeaters	297
Transmitter Remote Control	297
Backup Systems	299
<b>20</b> Radio Wave Propagation and Broadcast Regulation	301
AM Propagation	301
FM Propagation	304
IBOC Considerations	305
TV VHF and UHF Propagation	306
Spectrum Allocation	307

---

	FCC Rules	308
	Spectrum Auctions	312
<b>21</b>	Conclusion	315
	Further Information	316
	<i>Index</i>	317

## CHAPTER 1

# Introduction

Broadcasting is a communications service that possesses two fundamental and unique attributes: (1) Broadcasting is a *point-to-multipoint* service, meaning that a broadcast service originates from a single transmitter but is receivable by an unlimited number of receivers within the coverage zone of that transmitter. (Compare this to a *point-to-point* communications system, such as telephony, in which one device typically connects only to a single device at any given time.) (2) Broadcasting is a *unidirectional* service, meaning that it carries content only in a one-way path—from the broadcast station's transmitter to the listener's or viewer's receiver—with no provision for carrying signals back the other way. (Compare this to a *bidirectional* communications system, such as telephony, in which each user's device serves as both a transmitter and a receiver, and content can flow between users in both directions simultaneously.) These two characteristics have defined broadcasting since its origin and continue to do so today. Thus, all the systems described in this book will possess these two essential qualities.

Meanwhile, the *business* of Broadcasting has evolved to include its own two primary functions: (1) The *generation* of audio or audiovisual media content, and (2) the *delivery* of such content to audiences. All broadcasting facilities are organized around one or both of these two processes. Radio and television stations typically include one of each type of facilities. Often these are placed at two different physical locations, but occasionally they are collocated.

Therefore, in its simplest form, a radio or television broadcast station consists of two basic facilities: the studio site and the transmitter site. The studio is where the content is generated. The transmitter site is where the content is sent out over the air, in a point-to-multipoint, unidirectional fashion. If those two facilities are not physically in the same place, between them is a connection called the studio-transmitter link (or "studio-to-transmitter link"), often abbreviated as "STL." But there are many individual components in each of these facilities that make up the chain from content generation to the reception of broadcast

services by the viewer or listener. This tutorial provides an introduction to the technologies and equipment that make up these chains, and thereby constitute modern broadcasting systems.

Traditionally, broadcasting was based on *analog* techniques, but for the past quarter-century or so, there has been a steady migration to *digital* systems, which provide many technical and operational benefits for broadcasting processes. The increasing use of computer-based systems has revolutionized both radio and television studios, increasing the quality and efficiency of audio and visual media content creation. More recently, new standards have evolved that also allow application of digital techniques to the transmission of content to end users of both radio and television, improving the efficiency and quality of media content delivery, as well.

All types of broadcast stations used for domestic broadcasting (AM and FM radio, and television) are covered in this tutorial, with descriptions of both analog and digital studio and transmission systems. For completeness, satellite, cable, and Internet delivery are also briefly described, although this book does not cover them in detail.

Chapters in the first section of the book, “Broadcasting Basics,” discuss the main methods used for radio and television broadcasting and explain some of the basic science and the terms used later in the book. Chapters in the second section, “Studios, Production, and Playout Facilities,” describe radio and television studios and remote operations, covering the main items of equipment used and how they work together. Chapters in the third section, “Transmission Standards and Systems,” discuss the standards and technologies used for U.S. radio and television transmission and cover transmitter-site facilities and equipment. The penultimate chapter of this section discusses radio wave propagation and regulation of broadcasting by governmental authorities.

In each section or chapter, audio and radio topics are generally treated first, followed by video and television subjects.

Jargon words and phrases are shown in *italics* when these are used for first time in each section. The words and phrases may be defined in each section or covered in detail in other chapters. Some jargon words are unique to broadcasting, but some are regular words used in a special way that will be explained in each case.

# **BROADCASTING BASICS**



## CHAPTER 2

# Types of Broadcasting

For many years, the term *broadcasting* meant the transmission of audio or video content via radio-frequency (RF) waves, often referred to as “over-the-air.” More recently, with developments in advanced digital technology, the term applies to many different types of content distribution. Let’s start with a summary of the main types of broadcasting in use today in the United States and elsewhere.

Many of the systems mentioned below differ only in the particular method of transmission or distribution used, whereas the studio systems used for generations of radio and television content have fewer variations. Don’t worry if you don’t fully understand all of the terms used in this chapter. They will be explained later in the appropriate sections.

### **ANALOG RADIO**

Traditional radio broadcasting for local stations in the United States and throughout the world generally falls into two main types: AM and FM—standing for *amplitude modulation* and *frequency modulation*, respectively. These are the particular methods of radio transmission used for many years in broadcasting audio signals to home, car, and portable receivers. In North America, AM is used in the *medium frequency* (MF)—also known as *medium wave band*—whereas FM uses the *very high-frequency* (VHF) band.

In the United States, a given radio station frequently feeds only one transmitter and therefore is referred to as an AM station or an FM station. It is, however, quite possible for a station to feed both AM and FM transmitters in the same area, or to feed more than one transmitter covering different areas, in which case the term AM or FM may refer only to a particular transmitter and not to the station as a whole. The latter arrangement is more frequently encountered outside the United States, but is becoming increasingly common in the United States.

In some countries, AM radio also uses the *long wave band*, with frequencies somewhat lower than the MF band, and having slightly different propagation



characteristics, better for broadcasting over wide areas. AM is also used for *shortwave* radio broadcasting—also known as “HF” for the *high-frequency* band that is used. This is used for broadcasting over very long distances (usually internationally).

We cover analog radio in more detail in Chapter 12.

## DIGITAL RADIO

There are four standards for over-the-air digital radio systems in the world, all different from each other in several respects. They are commonly referred to by their acronyms: IBOC, DAB, ISDB-TSB, and DRM.

### IBOC (In-Band On-Channel)

Digital radio broadcasting for local stations in the United States uses a system called In-Band On-Channel (IBOC, often pronounced “EYE-bock”). The IBOC digital radio system was developed and continues to be managed by a single company, iBiquity Digital Corporation, referring to its implementation of IBOC by the trademarked name of *HD Radio*. For this reason, the two terms are essentially interchangeable in most practical parlance, and so today, the HD Radio label is more commonly applied to the format. (The HD Radio trade name has led many to assume that the “HD” stands for high definition, but in fact, iBiquity Digital specifies that it is not an acronym and simply an identifier.)

The technology is called In-Band On-Channel because it places a radio station’s digital signal within the same band (AM or FM) as the station’s original analog system, and within the station’s existing analog channel in each case. For this reason, IBOC digital radio does not require any additional spectrum, unlike most other digital broadcasting systems. Today’s IBOC station therefore transmits two versions of its primary content—one analog and one digital—thereby serving both legacy and new receivers via the same broadcast channel. (The IBOC system also provides the capability of eliminating the analog component and moving to an all-digital channel, but this mode of operation is not currently allowed by FCC rules).

There are two variants of IBOC: one for AM radio services and one for FM. The major advantage for AM radio is a qualitative improvement in received audio and freedom from the ever-growing impact of audible interference that plagues AM reception. The FM IBOC system also provides better audio quality than traditional analog FM service, but with less noticeable effect since analog FM audio quality is already relatively good to begin with. The primary improvement with FM IBOC is *quantitative*, in that it also allows a station to include multiple audio services within the same broadcast channel (called “multicast services,” but often referred to as “HD-2” or “HD-3” services, owing to how