

**FUNDAMENTALS OF
DIGITAL TELEVISION
TRANSMISSION**

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GW Collins Consulting



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*To **God**
who created the electromagnetic force
and
the law that governs its operation in communications systems
and*

*To my beautiful wife **Wilma**
who, after 39 years of marriage,
still wonders why I'm thinking about my work!*

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PREFACE

Many engineers familiar with analog television broadcast systems are now faced with designing, operating, and maintaining digital television systems. A major reason for this introductory book is to make the transition from analog to digital television broadcasting as painless as possible for these engineers. The emphasis is on radio-frequency (RF) transmission, those elements of the system concerned with transmitting and propagating the digitally modulated signal. I begin with the digital signal as it emerges from the transport layer and end with the RF signal as it arrives at the receiver. The emphasis is on factors affecting broadcast system performance.

The scope of this book is necessarily limited; some topics, such as studio-to-transmitter links and receivers are not covered. It is intended as a self-study resource by the broadcast system engineer, as well as a reference for the design engineer, system engineer, and engineering manager. An index is included to make it a more useful resource for future reference. It may be used as a text for a formal training class.

Most people would agree that a useful engineering tool must include some mathematics. For this reason, and to make the presentation as clear as possible, concepts have been described verbally, mathematically, and in many cases, graphically. The mathematics used include algebra, trigonometry, and a small amount of calculus. For those not interested in the mathematical formulation, the charts and graphs should be sufficient to grasp the key points.

For those who wish to probe further, extensive footnotes are provided. These not only provide much more detail but are my attempt to give credit to the many workers who have brought digital television to its present state of maturity. Even with ample footnotes, I may have failed to give credit to all who deserve it. This is by no means intentional; the references included are simply those sources of which I am aware.

To the extent possible I have used the mathematical symbols most commonly used for the quantities discussed. However, the literature for the many subsystems comprising a digital television transmission system use common symbols to represent a large number of the quantities. To avoid confusion, I have added subscripts and used alternative type fonts to distinguish such quantities where necessary. When I found it necessary to use a nonstandard symbol, I attempted to make the relationship between the quantity and its symbol as intuitive as possible.

To the extent that information was available to me, I have discussed the American ATSC, the European DVB-T system, and Japan's ISDB-T system. My personal experience and library are heavily biased in the direction of the ATSC and DVB-T systems, however, a fact that will readily be apparent to the reader. The information presented should not be considered an endorsement of a specific system for any particular country or group of countries. There are many factors to be considered when selecting a transmission system, not all of which are determined by performance parameters such as transmitter peak-to-average ratio or threshold carrier-to-noise ratio. These include the type of network, program and service considerations, and the extent of the use of mobile receivers, as well as language, industrial policy, and other issues. The information presented is factual to the best of my understanding. Readers are left to draw the appropriate conclusions for their applications.

My personal design background is in antennas, analog transmitter systems, passive RF components, and propagation. When the transition to digital television began, it became necessary to educate myself with regard to digital modulation techniques, system design, and testing. This has required collaboration with many experts and the study of many reports and papers. This book is the result of that effort. If in some respect the presentation of any topic is incomplete, I take full responsibility.

The implementation of digital television is a process that will continue for many years to come. The transition periods will take up to 15 years in some countries. The process will not start in Japan until after 2003. In the United States the transition period has started and is mandated to be short. However, stations whose initial channel is outside the core spectrum will be required to move to a core channel after the transition. Those whose analog and digital channel is inside the core will be permitted to choose their permanent channel. It is hoped that this book will be helpful to those who are designing and implementing these systems, both now and in the future.

JERRY COLLINS
December 1999

ACKNOWLEDGMENTS

I most certainly do not claim originality for much of the material included in this book. In fact, the story of digital television builds on the many contributions of workers since the beginning of radio and television transmission. Rather, this book represents the result of my own attempt to understand and manage the development of digital television broadcast equipment since 1989. I am especially grateful to my former colleagues and the management of Harris Corporation Broadcast Division for their outstanding efforts. Together we participated in the process of developing digital television standards, designing equipment, and testing broadcast systems. It is to them that I owe so very much.

In naming some, I'm sure I will miss some important contributors. However, I must mention the very beginning of our work when Bob Plonka, Jim Keller, I, and others worked with Charlie Rhodes of the ATTC to develop the RF test bed by which the proponent transmission systems were tested. Bob and Jim have continued their work developing, implementing, and testing new designs and production equipment for Harris. Charlie's name is almost synonymous with DTV transmission. As soon as it was clear that the 8 VSB system would be the standard for the United States, I involved others in my R&D group in the development of the first series of 8 VSB exciters. These fine engineers included Dave Danielsons, Ed Twitchell, Paul Mizwicki, Dave Nickell, Dave Blickhan, Bruce Merideth, and Joe Seccia. The system engineering skills of Bob Davis were vital. We started the work on power amplifier development soon after the exciter. This could not have been accomplished without the able contributions of the engineers at our sister facility in Cambridge, England, under the leadership of Dave Crawford and Barry Tew. Dmitri Borodulin joined us in Quincy, Illinois for

solid state PA development, along with Jim Pickard who made many contributions to the design of the IOT amplifier. I wish to emphasize the role of Harris management—especially my good friend Bob Weirather—in the development process. Without their support and encouragement we would have accomplished very little. Finally, my sincere thanks to Bob for his review of the manuscript and his constructive comments.