Microwave Communication

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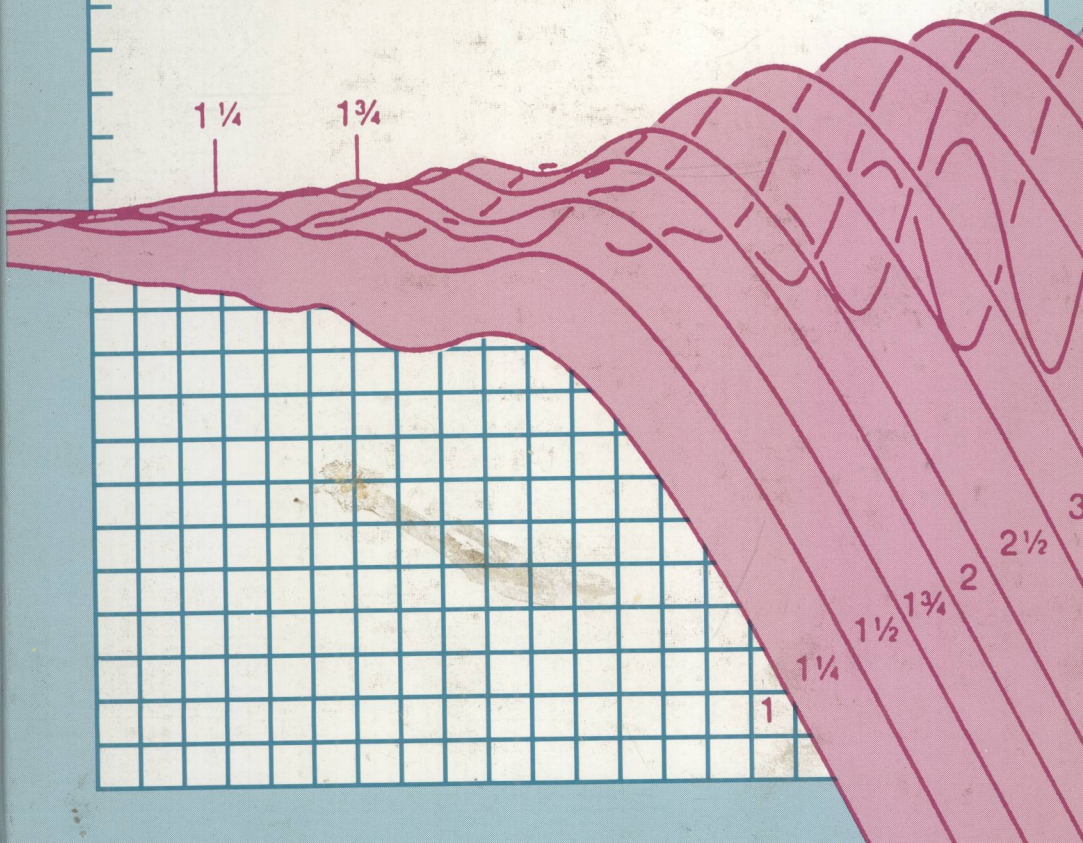

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PREFACE

This book resulted from investigations that started several years ago. At that time I had been working with FM radio systems for a couple of years. I was frustrated by the lack of detailed information regarding FM transmission. Several books discussed FM radios, but few were specific concerning performance factors and limitations.

Over the last decade, digital transmission has become a dominant means of microwave transmission. One naturally asks the question as to how this affects microwave transmission. The main information required is full coverage of modulation theory, performance requirements and standards, and effects of propagation. Baseband and modulated digital signal transmission is adequately treated by existing texts, notably the following:

> Franks, L. E., *Data Communication: Fundamentals of Baseband Transmission*, Stroudsburg: Dowden, Hutchinson, and Ross (Halsted Press), 1974.
>
> Korn, I., *Digital Communications*, New York: Van Nostrand Reinhold, 1985.

Performance requirements and standards for microwave radio are still in development by the various administrations and international bodies. Effects of propagation are not well understood, at least from the path engineering of performance versus path characteristics point of view. Path engineering is still performed the same way as in frequency modulation systems but with a dispersive fade margin factor added to the calculation. Otherwise, path engineering and propagation considerations remain unchanged. Frequency modulation remains an important means of communication in many areas and full coverage is still lacking.

This book is intended to bridge the gap between theory and practice. If a topic is developed in other sources, only the result is given. If new results are given or old results are extended, theoretical development is detailed. Emphasis is placed on illustrating formal results through graphs and tables. In many cases abbreviated numerical approximations are developed.

Chapter 1 includes the use of logarithms, logarithmic measures of power, and noise weighting. Chapter 2 introduces frequency and

phase modulation, two popular forms of angle modulation. Also introduced are forms of external interference and baseband signal related distortions. Chapter 3 surveys thermal and oscillator phase noise. Single and multiple receiver results are given for a wide range of carrier-to-noise ratios. General results are developed that are then extended to specific telephony, video, and program channel transmission cases. Chapter 4 examines factors to be considered in the choice of a frequency plan. Next, direct and image frequency external interference noise is presented. General results are given for primary (overlapping spectrum sidebands), secondary (direct adjacent channel interference), and tertiary interference noise. Noise due to waveguide nonlinearity intermodulation and spectrum truncation is also presented. During the development, spectral densities for carriers FM or PM modulated by band limited white noise are given. Chapter 5 predicts harmonic and intermodulation distortion due to mild transmission nonlinearity described by a polynomial output function. Chapter 6 develops harmonic and intermodulation noise for FM and PM signals subjected to a single small echo. Various numerical results are provided. Effects due to large and multiple echoes are then presented. The chapter closes with practical measurement limitations. Echoes can occur in transmission systems in many ways. The most common cases are multiple signal reflections in the transmission line and multipath propagation between antennas. For long echoes, the echo distortion reduces to cochannel interference addressed in chapter 4. For short echoes, the distortion reduces to differential gain and phase slope or bow addressed in chapter 5.

Chapter 7 develops the relationship between low-order polynomial transmission medium linear distortion and differential gain (linearity) and differential phase (delay) distortion. Measurement error due to large frequency test tones is then addressed. Correction factors for high-frequency test tone error are developed. The chapter ends with a discussion of the frequency range over which the distortion polynomial must be accurate. Chapter 8 presents differential gain (insignificant) and differential phase (distortion) for circular, elliptical, and rectangular waveguides. Effects due to coaxial cable are then summarized. Chapter 9 presents antenna radiation patterns and related effects. Transmission loss is then developed. Far field results are presented. Near field correction factors for various antenna configurations are added. Various causes of received signal variation are described.

Chapter 10 examines international and North American analog hypothetical reference circuits and real noise objectives. Examples are included. Chapter 11 presents various examples. Chapter 12 presents various topics indirectly related to system performance prediction.

Special thanks to my wife, Anne, for her support. This book could not have been done without her help and patience. I also appreciate the patience of our children, Amy and Mark, who put up with me when I sat for hours at the kitchen table poring over piles of strange looking papers.

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LIST OF ILLUSTRATIONS