RADIO, TV & AUDIO TECHNICAL REFERENCE BOOK

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With specialist contributors

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PREFACE

The Radio and Television Engineers' Reference Book was first published in 1954 and subsequently brought up to date in a number of new editions. Since the fourth edition was published in 1963 there have been sweeping developments in radio, audio, and television. For example the valve has been supplanted in all low-power applications by the transistor or the integrated circuit: valves are now used only in the high-power stages of transmitters. Nearly all the television programmes in this country are now transmitted in colour and half the television receivers in use are colour types. In radio there has been a great increase in stereo transmissions and experiments in quadraphony have begun. There has been an explosive increase in the use of mobile radio in the v.h.f. and u.h.f. bands. This growth has been matched by a great increase in the use of tape recorders for music in cars, shops, restaurants, and the home.

In most modern electronic equipments the transistors or i.c.s are mounted on printed wiring boards. This method of manufacture gives better reliability than was achievable from earlier equipment using valves. Faults are rarer and when they occur they call for different servicing and repairing methods than for older equipments. The introduction of solid-state devices and modern manufacturing methods has thus changed servicing techniques.

To reflect the changes in hardware and maintenance practices it was decided to publish this new reference book and to direct it not so much to the needs of the engineer or designer but to the technician who has to operate and maintain electronic equipment. This book should therefore be suitable for the technical assistant, the technical operator, the service man, and the amateur radio or audio enthusiast. The title of the book indicates the intended scope and readership.

The aim of the book is to give an essentially practical account of modern developments in radio, audio, and television. Mathematical presentation has been kept to a minimum and the graphical symbols used in the diagrams conform to the recommendations of BS 3939.

The book is the work of 31 contributors, each expert in his subject. Their qualifications and present positions are given in the List of Contributors.

S.W.A.

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1 FUNDAMENTALS OF SOUND TRANSMISSION

FUNDAMENTALS OF SOUND TRANSMISSION 1

1 FUNDAMENTALS OF SOUND TRANSMISSION

MODULATION

Introduction

The first requirement in broadcasting is to generate, amplify, and radiate a *carrier wave* in order to form a link between the transmitter and receiver. In essence a carrier is an electromagnetic wave of constant frequency and amplitude and the transmitting station may be thought of as a powerful lighthouse sending out invisible electromagnetic waves in all, or specific, directions. But just as a steadily shining light tells us nothing other than it is there or not there, so the carrier wave of a radio transmitter indicates only its presence. To provide *information* this steady carrier must be modified or varied in some way. If, for example, it is switched on and off, or its frequency shifted between two fixed limits in accordance with morse or teleprinter codes, then we can convey messages by radio-telegraphy or pictures by radio-facsimile. Or we may use slightly more complex techniques whereby the carrier is varied in accordance with sounds or picture information. All the various techniques for conveying information by means of a carrier wave (or in some applications where the carrier is *suppressed* prior to transmission) are known collectively as *modulation.*

In radio broadcasting we are concerned primarily with *amplitude modulation* and *frequency modulation* and it is on these systems of modulation that we shall concentrate in this section.

The carrier is important not only in providing what is essentially a time reference to the receiver to facilitate the *demodulation* process by which the information is recovered from the radio signals, but also in providing a means of distinguishing by its *frequency* or *wavelength* between different transmissions which may be radiated at the same time using the process of adjusting or *tuning* the receiver to the specified frequency of transmission.

Carrier waves can be generated and radiated over the entire radio spectrum (although as the frequency is increased this becomes increasingly difficult); however the *propagation characteristics* differ significantly and as the frequency approaches that of visible electromagnetic waves (light waves) the range increasingly approaches that of 'line-of-sight' transmission. Since there are today innumerable applications of radio and radio navigation other than broadcasting, only certain portions of the frequency spectrum are allotted internationally to broadcasting, and these are subject to periodic revision by the International Telecommunications Union, an agency of the United Nations. The bands of frequencies currently allocated to sound and television broadcasting are listed at the end of this section.

BASIC MODULATION SYSTEMS

As just explained *modulation* is the variation of an electrical current by information; a carbon-granule microphone *amplitude modulates* a steady direct current to provide the telephone. Radio transmission similarly requires the modulation of a constant-amplitude carrier wave. Where the information (a.f.) signal is mixed with the carrier r.f. wave to produce further signals (*sidebands*) of a strength or amplitude governed by the volume or amplitude of the sound and whose frequency differs from that of the carrier wave by the pitch or frequency of the audio note, the radio wave is said to be *amplitude modulated* (a.m.).

In such a system the total power (envelope power) radiated at any instant of time is made up of the carrier power with the addition or subtraction of the power contained in the sidebands. The average power radiated increases during loud passages of speech or music. For convenience an a.m. wave is often represented diagrammatically as a carrier wave modulated in strength by the a.f. signal impressed upon it. It is however important to appreciate that in reality the a.m. signal consists of a steady carrier wave at the frequency of transmission accompanied by sideband signals of varying frequency and strength, each audio note producing two sideband signals equally spaced on either side of the carrier frequency.

This form of modulation was used exclusively for all broadcast transmissions from 1920 to 1939 and remains at present the standard form of regular broadcast transmission on l.f., m.f., and h.f.

Instead of making the total transmitted power change with the amplitude of the audio signal and the sideband frequency vary with the frequency of the a.f. signal, it is possible to interchange these two characteristics. If this is done, the transmitter frequency varies with the strength of the audio signal, while the rate at which it varies about the mean carrier frequency is governed by the frequency of the a.f. signal. Such a process is termed *frequency modulation.*

As for a.m. this process results in a steady carrier wave accompanied by sidebands but because the total envelope power remains constant, there is a continuously varying and complex relationship between the power of the carrier wave and the total sideband energy; the number of significant sidebands is mathematically determined by Bessel functions and theoretically the bandwidth of an f.m. signal is infinite. There are certain relationships at which the power contained in the carrier wave is reduced to zero.

The principles of f.m. have been understood from the earliest days of broadcasting but for many years it was believed that the system would inherently distort the audio signal with few compensating advantages. However the work of E. H. Armstrong, which culminated with the opening of W2XMN in New York in 1939, showed the fallacy of these arguments when the deviation or modulation index of the signal is increased beyond unity, and today v.h.f./f.m. broadcasting is accepted as providing much greater protection against the effects of static and electrical interference, with dynamic and frequency ranges that are impracticable with lower-frequency a.m. transmissions.

AMPLITUDE MODULATION

To the listener the *loudness* of the audio information contained in an a.m. transmission depends upon how much energy is contained in the sidebands, and this in turn may be represented by the peak and troughs of the envelope power. For example in *Figure 1.1*, the amplitude of the unmodulated carrier is represented by A, and the peak variation in carrier amplitude due to modulation by a. The ratio of a/A is termed the *modulation depth* and is usually expressed as a percentage, with 100 per cent being the highest possible undistorted modulation.

A carrier is 50 per cent modulated if the positive peak voltage rises to a value 50 per cent greater than its unmodulated value.

The maximum value of 100 per cent occurs when a equals A and the envelope swings between zero and $2A$. If any attempt were made, in normal circumstances, to further increase modulation depth the negative trough would drop to zero and remain at zero for a finite period of time. The resultant envelope shape would no longer follow faithfully the audio waveform, implying distortion. Furthermore, since the total energy during this time is zero it implies the absence of the carrier wave, which is then said to be