Second Edition

Colour Television Servicing

Gordon J King

COLOUR TELEVISION SERVICING

GORDON J. KING

T.Eng.(C.E.I.), R.Tech.Eng., M.I.P.R.E.,
F.I.S.T.C., F.S.C.T.E., M.A.E.S., M.R.T.S.

LONDON

NEWNES–BUTTERWORTHS

THE BUTTERWORTH GROUP

ENGLAND	BUTTERWORTH & CO. (PUBLISHERS) LTD. LONDON: 88 Kingsway, WC2B 6AB
AUSTRALIA	BUTTERWORTHS (PTY) LTD. SYDNEY: 586 Pacific Highway, NSW 2067 MELBOURNE: 343 Little Collins Street, 3000 BRISBANE: 240 Queen Street, 4000
CANADA	BUTTERWORTH & CO. (CANADA) LTD. SCARBOROUGH: 2265 Midland Avenue, Ontario, M1P 4S1
NEW ZEALAND	BUTTERWORTHS OF NEW ZEALAND LTD. WELLINGTON: 26/28 Waring Taylor Street, 1
SOUTH AFRICA	BUTTERWORTH & CO. (SOUTH AFRICA) (PTY) LTD. DURBAN: 152/154 Gale Street

First published in 1971 *by*
Newnes–Butterworths, an imprint
of the Butterworth Group

Second edition, 1975

ISBN 0 408 00137 2

PRINTED AND BOUND IN GREAT BRITAIN BY
COX AND WYMAN LTD., LONDON, FAKENHAM AND READING

COLOUR TELEVISION SERVICING

Books on Radio and Television Servicing
by Gordon J. King

F.M. RADIO SERVICING HANDBOOK

RADIO AND AUDIO SERVICING HANDBOOK

RADIO AND TELEVISION TEST INSTRUMENTS

TELEVISION SERVICING HANDBOOK

THE HI-FI AND TAPE RECORDER HANDBOOK

SERVICING WITH THE OSCILLOSCOPE

RAPID SERVICING OF TRANSISTOR EQUIPMENT

NEWNES' COLOUR TELEVISION
SERVICING MANUALS

THE AUDIO HANDBOOK

Preface

IT HAS BEEN my aim to write a comprehensive book on colour television and on the servicing of PAL receivers in the most down-to-earth manner possible and with the least amount of mathematics. The book has been written to have the maximum appeal to the technician of average qualifications changing from the servicing of monochrome sets to colour, to the student of the NTSC and PAL colour systems (bearing in mind that the latter is essentially a development of the former), to the indentured apprentice technician just commencing a career in television servicing, and to the enthusiastic amateur interested in a general way and desirous of getting the best results from his own set and those of his friends.

Colour television is an involved subject, and to be successful in the servicing of receivers one must first be conversant with the theory, servicing problems and procedures associated with monochrome models. This is because contemporary colour television is a development of monochrome television—that is, the monochrome system with additional features endowing it with colour. Service technicians who are at present familiar with monochrome servicing only will thus have new things to learn and new problems to sort out, but these will be found to dovetail into their existing knowledge, acquired during the years of servicing monochrome sets.

It would have been possible, of course, to have written this book on the basis that monochrome receivers had never existed, but then about half of it would have been concerned with colourless transmission and reception. In other words, a book of that kind would have needed to have been in two parts—monochrome and colour—and since there are many books adequately dealing with the first part, this would have meant repeating much of what has already been written on the subject.

I have concentrated, therefore, on the aspects of colour, bringing in references to the monochrome system only as and when necessary to complete the picture. This also applies to the sections dealing with servicing.

Apprentices and other readers wishing to pursue a study of television receiver servicing from first principles might find my complementary *Television Servicing Handbook* useful. This in its third edition deals with dual-standard sets, transistorised circuits and most of the recent developments in monochrome receivers. It concludes almost exactly where this book starts.

I considered it desirable to arrange this colour television book in three parts: the first describing how the PAL and the NTSC systems work, in conjunction with the science of colours; the second detailing the circuits employed in the latest hybrid and all-transistor sets; and the third concentrating on fault symptoms and servicing procedures.

Numerous sections are devoted to setting-up adjustments—such as static and dynamic convergence, grey-scale tracking, degaussing and purity—with manufacturers' examples, and there are chapters dealing with colour test intruments, alignment, encoding and decoding, servicing in the field and so forth, including a special chapter giving a kind of bird's eye view of the colour system as a whole, which acts as a guide to subsequent chapters.

Both dual-standard and the more recent 625-line single-standard models are examined, and a specially designed block diagram is used to show the PAL colour signal waveforms at all stages in the system, from the colour camera output to the shadowmask picture tube input. I have also prepared a block diagram to relate fault symptoms to specific areas in the set, as a simple aid to speedy fault diagnosis.

The colour signal oscillograms are real c.r.t. displays photographed in my laboratory, using standard receivers and test equipment, and some of the equipment and off-screen photographs are also of my origin; others were kindly supplied by receiver and equipment manufacturers.

Many of the illustrations and some of the early chapters describing the colour system have been restyled from my series of articles entitled 'ERT Telecolour Course', originally published by *Electrical and Radio Trading*, to which journal I wish to acknowledge my indebtedness; also to Roy Norris, its well known former Technical Editor for his great encouragement and help while writing the series and to Colin Sproxton its subsequent Technical Editor.

I should also like to thank sincerely the manufacturers and distributors of colour receivers and test equipment for answering my letters in great detail and for readily making available to me circuit diagrams and excellent photographs of their equipment, including such firms as the British Radio Corporation Ltd., Bang and Olufsen UK Ltd., Brown Brothers Ltd., Decca Radio and Television Ltd., Mullard Ltd., Philips Electrical Ltd., Pye Ltd., Rank Bush Murphy Ltd., Sony Corporation, Telefunken Ltd., Thorn-A.E.I. Applications Laboratories and all the many other firms without whose assistance this book could never have been written.

My thanks also to Marjorie Campbell for the typescript and Neil Hyslop for the excellent diagrams evolved from my rough sketches.

While the bulk of the information in this second edition remains unchanged, some updating in alignment with current practice has been considered desirable. An extra chapter has also been included to summarise some of the more recent developments in receivers.

A Fault Finding Chart, detailed in colour, based on the Procedure Charts in the *Television Servicing Handbook*, which have proved so popular, is also incorporated in this new edition.

Finally, I would like to take this opportunity to thank the thousands of readers of the first edition, and in particular those who have written to me personally through the publisher with suggestions for the second edition, some of which have been incorporated.

Brixham, Devon Gordon J. King

Contents

CHAPTER 1

Introduction

THE COLOUR TELEVISION SYSTEM adopted by Great Britain and certain parts of Europe is called PAL, which stands for *phase alternation, line*. In the United States of America and some other countries a system known as NTSC has been in operation since 1953. This system was recommended in America by the *National Television Systems Committee*, hence the term NTSC. The PAL system is a further development of the NTSC system by the West German Telefunken Company, under the leadership of a Dr. Walter Bruch. There are other systems, but the NTSC and the PAL development of it are the main ones considered in this book.

The PAL development was considered desirable because, owing to the way in which the colour information is modulated, it is not possible to hold complete control over the colour information in the NTSC system once it leaves the cameras. As a consequence, phase changes of the colour signal can cause colour (hue) changes on the received pictures.

The PAL system effectively neutralises this at the expense of a little extra complexity at the transmitter and receiver, with the result that phase changes on alternate lines of the picture are combined in a manner that cancels out the colour error. The PAL system was chosen after being thoroughly field tested over a period of about three years in the majority of West European countries.

Colour systems can adopt time-sequential or simultaneous methods of colour processing. The sequential method means that the colour information is presented to the picture tube as little 'bits' during specific periods of time which are geared to the field, line or subcarrier frequency. These are called respectively field-sequential, line-sequential and dot-sequential. Colour synchronising is necessary here to ensure that the reproduced 'bits' of colour information occur at the receiver at exactly the same instant as they are produced at the transmitter, from the colour camera.

In the USA a field-sequential system was commissioned by the FCC (Federal Communications Commission) in 1950, but was revoked in 1953. It was semi-mechanical, using three colour filters rotating at field frequency in front of the monochrome picture tube and was unsuccessful commercially, if not technically. Colour systems were also tried out using in the UK line-rate and switching periods which were small compared with picture elements (i.e. dot-sequential).

The NTSC system and its PAL development, however, use the simultaneous method, where monochrome and colour picture element information are presented simultaneously to the display tube.

All colour systems must be *compatible*. This means that the transmitted colour-encoded signals must produce monochrome pictures of good quality on ordinary black-and-white sets, adjusted to suit the line standard and programme channel. They must also have *reverse compatibility* to allow colour sets to reproduce in monochrome from a monochrome signal. Both NTSC and PAL have these attributes.

The difference between PAL and NTSC is worth a basic examination. The chief difference is in signal handling at the receiver and transmitter to combat phase errors and hence incorrect colour presentation.

Colour can be fully described by three parameters—hue (i.e. the actual colour), saturation and luminance. The luminance in colour systems is handled in the same way as the monochrome information in black-and-white sets. Hue and saturation are handled by separate colour signals in the system. It is shown in later chapters that the information on hue appears as a phase-modulated component, while that on saturation appears as an amplitude-modulated component. This means that *amplitude* changes of the signals simply affect the saturation of the colour, for instance, causing a red rose to appear either a deeper red (increasing amplitude) or less red, towards pink (decreasing amplitude). Phase change, however, is more of a problem. Much more, in fact, since it can change green grass into red grass!

These components of the colour signal can change in both amplitude and phase anywhere between the television camera and the picture tube due to a diversity of factors at the studio, the transmitter, the receiver and even in space. Amplitude changes can be tolerated, but even the smallest phase change is immediately discerned as a distressing change in colour.

NTSC sets feature a *hue control*, which allows adjustment of the colour phase at the set by the viewer to correct for system phase error. It is the viewer's job, therefore, to adjust hue on a colour test card or for the most natural reproduction of flesh tones—making his own judgement as to what he thinks is the correct reproduction. This can cause problems; but with PAL the colours are always presented correctly once the receiver circuits have been properly adjusted. The only colour control that the PAL user has to bother with is that for setting the saturation. Indeed, with this control turned right down the picture is reproduced in black-and-white, and colour intensity is progressively increased as the control is turned up. This is the *saturation control*.

Some PAL sets do have a further colour control, labelled *tint control*. This can be adjusted on a black-and-white picture to secure the most desirable monochrome colour temperature. We shall see later that white on a colour tube is given by red, green and blue lights superimposed, and the nature of the white is governed by the balance of these three coloured lights. The tint control, therefore, simply allows the red, green and blue lights to be adjusted differentially to give the white most preferred by the viewer. The control can also be used to compensate for unbalance in the tube and video supply circuits.

PAL has developed over several stages. There is, in fact, a simple PAL system (PAL-S). and a de luxe version (PAL-D). These titles refer to the receivers, not to the transmission. That is, PAL-S and PAL-D receivers will work from the common PAL transmission. The PAL transmitter switches the phase of one colour signal over 180 degrees line by line. This will be difficult to appreciate now, but the technique will become apparent.

If there is a wrong hue caused by system phase distortion, the line-to-line phase switching will present the incorrect hue on one line and the complementary hue to this incorrect one on the next line of the particular field. The subjective effect of this is that the viewer sees the error and its complement together, and the impression is then given of the true colour. This is on PAL-S sets.

PAL-D sets go a stage further than this, for the line-by-line opposing errors are fed into an electronic circuit, averaged, and the electrical output presented to the tube in corresponding true colour. Here the eyes are not called upon to assist with the error averaging—it is done electronically. PAL-D sets can cope with errors up to about 70 degrees, while PAL-S sets can cater only for smaller errors.

PAL-S sets have a shortcoming, however, for when the error exceeds a few degrees the eyes see the two lines of opposing colours separately. This is aggravated by the interlaced scanning, since this puts together two lines in colour error and two lines in colour error correction successively over the whole picture. The viewer then becomes aware of horizontal lines or bars of colour across the picture, which in colour television are referred to as 'Hanover blinds' (see Chapter 5).

PAL-D sets use an electrical delay line which effectively stores the colour information of one line for its duration (about 64 μs) and then delivers it during the next line of signal along with the colour information of that line, but in opposite colour phase error. The error is thus cancelled out electronically, and the Hanover blind effect is avoided.

A by-product of phase error compensated by PAL-D is a change in colour signal *amplitude*, but the phase error in PAL-D sets needs to be substantial before saturation changes become apparent; but this is all that can happen, and it is far less disturbing than changes in hue.

The process of adding colour signal to the monochrome signal at the transmitter is called *encoding*, and extracting the colour signal from the monochrome signal at the receiver is called *decoding*. A receiver's decoding system must, of course, match the nature of encoding. Many encoding/decoding systems have been evolved over the years and patented, including the French SECAM, the Soviet NIIR, the German FAM and others. The components of the signals derived from the primary colours of the SECAM system are transmitted sequentially, as already explained.

PAL sets feature many of the familiar 625-line standard black-and-white circuits, including the intercarrier sound channel, the i.f. strip, u.h.f. tuner and so forth. Indeed, a colour set can be considered as a monochrome set of 625-line or dual-standard—with refinements to the tuned circuits, power supplies and timebases—plus two main colour sections. These are the electronics to process the colour information (decoder and colour channels), and the colour display (shadowmask tube) with its controlling and correcting circuits.

The monochrome parts of the set produce the *luminance* signal, which is the same as the signal delivered by black-and-white sets, while the colour electronics deliver red, green and blue primary colour signals required by the colour tube. The elementary arrangement is shown in Fig. 1.1. The composite signal carries all the information necessary for a black-and-white picture plus the colour

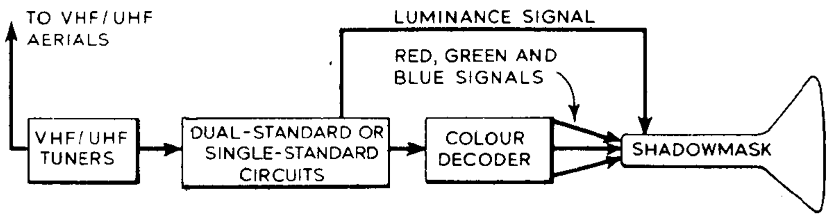

FIG. 1.1. *Elementary diagram of a colour receiver, showing the basic additions a monochrome set needs for colour.*

information which is used only by colour sets. Thus, monochrome sets working from a colour transmission by-pass the colour information.

At the transmitter, the signals from the colour camera are first processed into *colour-difference signals*, which are then specially modulated, giving chrominance signal, and sandwiched into the luminance signal. To facilitate extraction of the colour signals at the receiver, bursts of colour subcarrier are developed on the 'back porch' periods of the line sync pulses, as shown in Fig. 1.2. These are called *colour bursts*, and their purpose is to help recreate a subcarrier at the

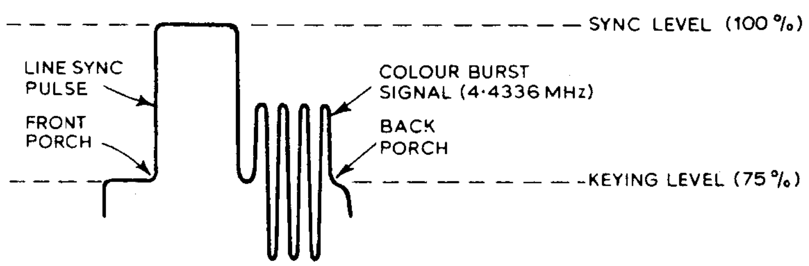

FIG. 1.2. *Colour bursts contain 10 cycles of subcarrier signal on the back porches to the line sync pulses. These signals lock the locally generated subcarrier signal at the receiver to the phase (and hence frequency) of the subcarrier upon which the chrominance information is modulated at the transmitter, but not transmitted.*

receiver which is identical to that at the transmitter on which the colour signals were originally modulated, but which was not transmitted. The bursts also identify the phase alternations of the PAL lines.

The colour-difference signals represent the difference between red primary and luminance signals and blue primary and luminance signals. The green colour-difference signal is not transmitted, but is recreated at the receiver. These techniques help towards bandwidth saving and ensures that when there is no colour in a televised scene there is no colour signal.

The shadowmask colour tube is normally used with current television receivers and monitors. In this tube, for any particular spot or element of picture, there are three minute dots of screen phosphor which glow red, green and blue when bombarded by electrons. There are three electron beams, and each one is focused upon its own corresponding colour dot. The phosphor dots are not coloured, just the light they emit when bombarded. At viewing distances the eye is aware of only a single spot consisting of a mix of the three colours.

The mix is changed by *relative* changes in the strength of the three beams, and for white light the light outputs of the three colours have to be balanced. The intensity of white light is thus varied by the three beams changing strength equally and in the proportions required for white light. This gives all the shades of grey, from peak white down to black (beam cut-off).

Although the shadowmask tube looks almost the same as its monochrome counterpart from the outside, the inside is much more complicated, as shown in Fig. 1.3. Figure 1.4 shows the outside appearance. Colour tubes are much

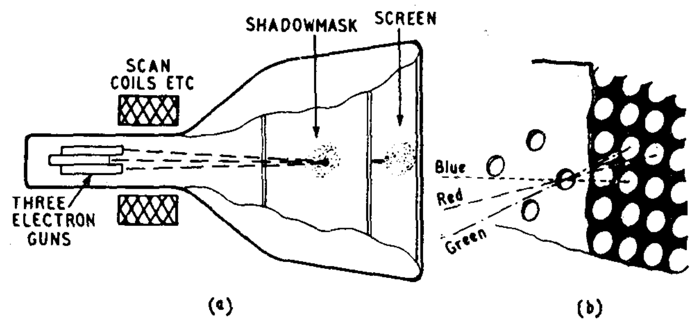

FIG. 1.3. *The basic features of the shadowmask picture tube, (a) in section and (b) part of the shadowmask.*

more expensive than similar size monochrome tubes. Fortunately colour tubes appear to be longer-lasting than monochrome ones, and in the USA some tubes are still giving good pictures after 13 years' use.

Colour tubes need a greater e.h.t. potential than monochrome ones, with a final anode voltage often of the order of 25 kV. This means that soft x-rays are produced by the resulting high velocity electrons, and precautions are taken in tube manufacture to prevent them from harming the viewer. X-rays can also occur inside the set from the e.h.t. rectifier and regulator valves, but internal screening and the use of semiconductor devices reduce troubles of this kind. It is most important, therefore, that all screens and shields are correctly replaced after servicing operations. Sets using semiconductors throughout are less prone to internal x-rays, because these devices do not generate them in the same way as valves.

The three beams of the shadowmask tube have to register accurately with their colour dots to ensure the right colour mix. This is also necessary to obtain good-black-and-white reproduction on a colour tube. Colour fringing effects are soon apparent if the registration is wrong. Registration is achieved by beam convergence correction of two kinds—*static convergence* and *dynamic convergence*. The first uses fixed magnets on the tube neck which line up the three beams in the middle of the screen. Dynamic correction is achieved by passing corrective currents through windings on the neck-mounted convergence unit. These currents are obtained from the line and field timebases, and they preserve the registration when the three beams are deflected away from the centre of the screen.

It will be appreciated that the colour tube is sensitive to magnetic fields, and stray fields near the neck or flare will impair the beam convergence. Stray fields

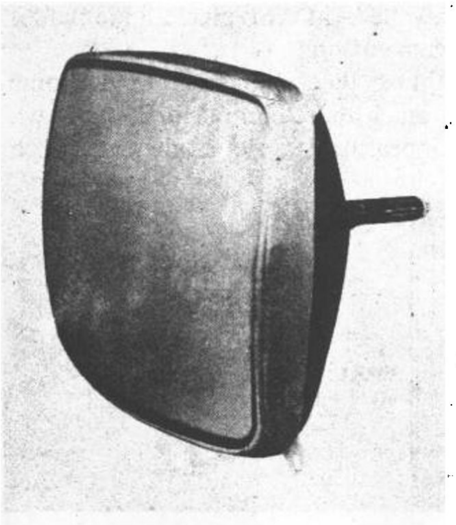

FIG. 1.4. *External appearance of shadow-mask picture tube (courtesy, Mullard Ltd.).*

can result from the magnetisation of steel parts within the set and shadowmask tube, and it is essential that all such fields are neutralised before the tube is adjusted for *purity* (see below).

This is achieved by a process of degaussing (meaning demagnetising) based on 'influencing' the set, tube and metal parts with the field from a large coil of wire connected across the a.c. mains supply. All sets now have a degaussing coil built into them, which comes into operation each time the set is switched on. This is called *auto-degaussing*.

While convergence control affects the three beams separately, another neck-mounted magnet, called the *purity magnet*, affects the three beams together. This ensures that the three beams approach the shadowmask at the correct angles so that they pass through the right holes to strike their appropriate colour phosphors in the centre. If this does not happen (tube not pure), the beams may strike the edges of the phosphors and cause wrong colour dots nearby also to emit light. This is corrected by the purity magnet.

In Great Britain colour sets are made both as single 625-line standard and dual-standard models. Only the u.h.f. channels, however, carry the colour signals of the BBC and ITV. The plan is for all 405-line standard programmes to be duplicated on the u.h.f. channels and then at some time in the future for the main v.h.f. transmissions on 405 lines to cease. By then the majority of viewers will be in range of a u.h.f. regional group (carrying four u.h.f. channels), and the old v.h.f. channels may then be re-engineered to take 625-line standard programmes, on monochrome and colour, to cater for those areas which are badly shielded from the u.h.f. signals. It will take at least a decade to put all this fully into operation.

In the meantime, dual-standard colour (and monochrome) sets will be continued, but with more sets being made for the 625-line standard only, for those areas in which all programmes can be received on the u.h.f. channels.

It is important that colour sets are fed with an adequate aerial signal, for a weak signal can produce an abundance of coloured grain (noise). U.H.F. signals are more difficult to receive adequately than v.h.f. and, since colour is in the u.h.f. channels (to start with, anyway), this is another good reason why special care must be taken over the aerial installation feeding a colour set.

Colour sets will work from communal aerials and relay systems, but poor results can be expected on those systems in which phase and amplitude distortion (and non-linearity) are present. These systems work by distributing over the cable u.h.f. signals at natural frequencies or at v.h.f. (or lower frequencies)—the latter using a u.h.f.-v.h.f. converter at the aerial end. These, however, do call for alterations in the colour set so that it will work on the 625-line standard when the channel selector is adjusted to a v.h.f. channel.

CHAPTER 2

The Science of Colours

THE SOURCE OF the Earth's light and heat is the sun, which emits a wide range of radiation, from ultra-violet through the visible light spectrum into the infra-red and heat radiation wavelengths. This radiation is in the form of electromagnetic waves and comprises a very small part of the overall electromagnetic waveband, which includes the waves we use for radio and television transmissions and other more dangerous waves such as x-rays, and gamma-rays which are caused by the release of nuclear energy. The only difference between radio and light waves, and heat and other waves from the Sun, is that of wavelength.

LIGHT WAVES

Light and heat waves are close together in the scale of radiations but substantially removed from the wavelength of radio waves. Radio waves usually have their wavelength measured in metres (m), while light and heat waves are so short that they are best measured in micrometres (μm), millimicrometres (mμm)* or Ångström units (Å). A micrometre is a millionth of a metre (10^{-6} m) or a thousandth of a millimetre (10^{-3} mm). A millimicrometre is thus a thousandth of a micrometre (10^{-9} m or 10^{-6} mm). Colour television sometimes makes reference to the Ångström unit which is 10^{-10}m or a tenth of a mμm. The reason for using these units is that they enable light wavelengths to be considered in whole numbers. Each wavelength has a corresponding frequency, given by dividing its value in metres into the velocity of light, which is 300×10^{6} m/s. A wave 1 mμm in length, for instance, has a frequency of 10^{16} Hz. Since light wavelengths are in hundreds of millimicrometres, however, the frequencies fall in the 10^{14} Hz range.

Figure 2.1 shows the overall electromagnetic wave spectrum with the visible sunlight band ranging from red to violet in hue and from 700 to 400 mμm in wavelength. The frequency range, which is not often used to describe colours, ranges from about $3{\cdot}8 \times 10^{14}$ to $7{\cdot}9 \times 10^{14}$ Hz, the violet end having the highest frequency and the shortest wavelength.

Although sunlight consists of this spectrum of colours or hues, the eye registers them collectively as white light. It is possible, however, to 'tune' the eye, so to speak, through the light spectrum by using a special optical instrument

* Often expressed mμ. The nanometre (10^{-9} m) is also gaining popularity.

or, more easily, to select certain wavelengths passing to the eye by attenuating the unwanted ones. A piece of red glass plate, for instance, is a red-pass filter when placed in front of the eye, since it lets through only waves of the red wavelength from the sun or other light source while greatly attenuating the remaining waves.

White light is usually defined as that given by the noon sun on a clear day. This light, as we have seen, is a band of radiations and is called pure. It ceases

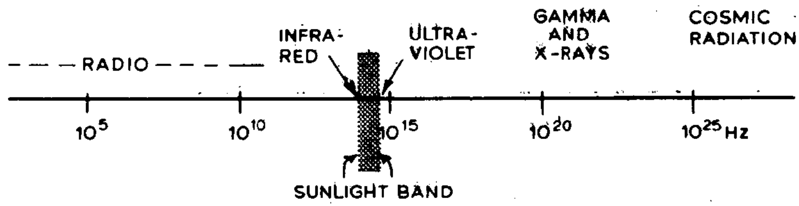

FIG. 2.1. *The electromagnetic wave spectrum.*

to be pure when some component radiations are missing or attenuated. Morning and late afternoon sunlight is not pure in this context—nor is the light on a dull day. This is why colour photographs fail to reproduce colours correctly when taken during these times without a special lens filter.

Artificial light is not pure, but approaches purity when it is emitted from arc sources. A great deal of work has been undertaken by lighting engineers and others in this connection, but pure light is not necessarily what the public wants from lamps or from television screens for that matter.

COLOUR SPECTRUM

One way of analysing light is to pass it through a prism or train of prisms. The emerging light is then dispersed in colour bands to form a spectrum display. This is caused by a process known as refraction. As light passes from air to glass, and vice versa, its direction of travel is bent, due to the different refractive indices of air and glass. The higher the frequency, the greater the degree of bending. Figure. 2.2 (left-hand side) shows how white light passed through a prism is dispersed into spectrum hues. By passing the spectrum colours through a second prism, or through a lens, reciprocal refraction occurs and the original white light re-appears as shown by the right-hand side of Fig. 2.2. Naturally, if one or two of the colours are removed or altered in energy before recombination, the original nature of white light will not be obtained.

However, it is this phenomenon that makes colour television possible, and if just three colours—or even two in some cases—remain the eye is deceived into seeing white. Indeed, we can get not only white but a great range of hues by varying the proportions of the mix of lights. With two colours only, the range of colours obtainable is limited.

Let us suppose that three projectors are set up in such a way that three overlapping pools of light are thrown upon a white screen, and that each projector