BBC ENGINEERING

Number 103 June 1976

Number 103 June 1976

BBC Engineering

including Engineering Division Monographs

A record of BBC technical experience and developments in radio and television broadcasting

Published approximately four times per year by
BBC Publications,
35 Marylebone High Street,
London W1M 4AA
ISBN 0 563 171898

Edited by
BBC Engineering Information Department,
Broadcasting House,
London W1A 1AA

Printed by
The Yale Press Ltd,
London SE25 5LY.

Price
40p or $1.00 per issue post free
Annual Subscription
£1.50 or $4.00 for 4 issues post free

Contents

The cover photograph shows a transmitter maintenance vehicle on the approach road to a remote relay station. This vehicle carries the equipment described in the second article in this issue.

Editorial

The future of broadcasting

The Japan Broadcasting Corporation (Nippon Hoso Kyokai — NHK) celebrated its fiftieth anniversary of broadcasting in October 1975 and marked the occasion with an International Broadcasting Symposium in Tokyo. The symposium dealt with three subjects: digital television; satellite broadcasting; and outside broadcasting. The highlights of the occasion were two introductory papers which looked to the future of broadcasting: Mr. James Redmond, BBC Director of Engineering, was invited to give one paper and the other was presented on behalf of Japan by Mr. Tatsuji Nomura, who is a member of the NHK Research and Development Committee.

This issue of 'BBC Engineering' contains Redmond's contribution to the occasion and it looks forward to a number of developments in both television and radio. These developments represent a balanced judgement between the resources available to the broadcaster, such as broadcasting frequencies and finance, and the demands of society in the years to come.

The paper by Nomura concentrated on television, and looked far into the future in a most optimistic manner. He looked forward to an increasing population with a continued growth of cities. He saw a decrease in family size and disruption of local communities. His view of the future envisaged increased industrialisation with an increase of well-educated people with leisure time to spare.

To meet these needs he saw community broadcasting (probably associated with interactive communication) restoring a sense of cohesion to society, and a programme of life-long education being introduced with the aid of broadcasting. He looked to an increase in broadcast area coverage and an increase in technical quality to support programmes which "enrich creative volition and increase personal satisfaction".

Not surprisingly, the means to be employed had many points of similarity with those appearing in Redmond's paper. Perhaps the most significant differences were the emphasis Nomura placed on Japanese satellite broadcasting and new services such as the broadcasting of facsimile signals. It is also worth noting that, in spite of severe traffic difficulties in Japanese cities, there were no proposals to use broadcasting to help solve their problem. This is all the more remarkable when one considers the anticipated changes in the character of Japanese society.

It is interesting to note that Japan is just struggling clear of a balance of payments problem, and has approximately one million unemployed and inflation of the order of ten per cent. NHK itself depends on a licence revenue and adjustment of the licence is not without its difficulties because of an impending General Election. In spite of this, the Japanese are very confident of the future, and are making long-term plans to enhance the services offered by broadcasting and hope to bring these services to every citizen of Japan. We should like to take this opportunity of wishing them well in their struggle to achieve this goal.

There is no doubt that society is changing. Pressures on all sides are changing the requirements for broadcasting, and it is not unreasonable to hope that these changing needs will be matched with an adjustment in the amount of money the public is prepared to spend directly on receivers or indirectly in terms of licence revenue. For radio and television to play its full part in the future, every opportunity has to be considered, and there is no virtue in discounting, without careful consideration, future developments whatever the economic circumstances which surround us today. Indeed, it may be said that tomorrow's society will only live up to our expectations if we make full use of all the resources available to us. Broadcasting — that is, the communication of information, education and entertainment — is one of the most important factors which will determine this society.

The Future of Broadcasting*

James Redmond, CEng, FIEE,

Director of Engineering

Summary: In this article, Mr Redmond outlines the influence of important engineering developments on broadcasting history so far (particularly the valve, programme recording, and the transistor), and goes on to examine those likely and needed developments which could be expected to have far-reaching effects in the future.

Two aspects of engineering's influence on broadcasting are considered: the introduction of new equipment, techniques, etc., which can improve the efficiency of production of existing services; and the institution of new services. Digital techniques figure in both categories (e.g. digital recording and CEEFAX), but many other developments which might not be far away and could be of outstanding significance include a sensitive solid-state television camera; further extension of the use of electronic cameras in place of some film applications; and a broadcast information service for motorists.

The transistor has had a major influence on broadcasting by leading to the vast number of medium-wave battery portables and hence the continued (even enhanced) demand for medium-wave transmissions. The large-scale integrated circuit is likely to produce similarly indirect effects. It is already the key to the economic manufacture of CEEFAX receivers and will probably also determine the practicability of other possible services.

*This article is an edited version of Mr Redmond's address to the International Broadcasting Symposium, Tokyo, 28-31 October 1975. It is reproduced by courtesy of Nippon Hoso Kyokai.

1 Introduction

It was with considerable pleasure that I accepted the invitation to go to Tokyo to address the International Broadcasting Symposium on the Future of Broadcasting. I have a very high regard for NHK as a broadcasting organisation because of its cultural and technical achievements, and I feel a strong affinity with it because of its similarity to the BBC. Japan and Britain are in an enviable position in the world of broadcasting inasmuch as each has, in NHK and BBC respectively, a strong and effective public broadcasting service. Many other countries also have public broadcasting services, but in Japan and Britain we have devised a system in which the public service is financed by licence while at the same time it is subjected to competition from other broadcasters who are financed by advertising.

In both countries this mixture seems to work well; the competition ensures the maintenance of quality and efficiency, while the independence which derives from a licence income leaves the public service broadcaster freer from political and commercial interference than seems to be the case with other financing methods. Balance is achieved which permits high-quality broadcasting in the shape of news, current affairs, and cultural programmes but at the same time obliges the public service broadcaster to compete also in popular programming. The product, taking the public service and the commercial output together, is a wide range of high-quality programmes which make both radio and television much used and much valued in our homes.

This mixture of adequately-financed public service and commercial broadcasting is uncommon. There are not many countries where the broadcasters are in a position to exploit their skills in search of excellence, provided only that they pay due regard to economy and efficiency. It is perhaps a sign of a country which has enough confidence in its democratic processes to permit broadcasting to be controversial and free from political control. Where this confidence has been shown the broadcasters over the years have demonstrated that they are worthy of the trust placed in them. I believe it is most important that both Japan and Britain should maintain this position but it is not a simple task in a period of inflation, when the public service broadcaster finds it difficult to secure adequate increases in the licence fee, and the commercial broadcasters find that their operating costs are running ahead of their advertising incomes. The engineer can help here, by using his skills to reduce still further the cost of broadcasting, even though it is already low by comparison with the other available ways of providing information, education and entertainment.

2 The beginning

The present technological standards reached in the fifty years since broadcasting began show the very great pace of development. Let me just remind you of the limitations of the early iconoscope cameras. A major problem with the iconoscope was shading which varied with picture content, and corrections for every shot had to be separately adjusted by an operator. In forty years we have gone from those dull, variable images to the clarity, realism and consistency we insist upon today.

The invention of the thermionic valve made broadcasting possible but valve technology had to progress to higher output powers and higher frequencies before broadcasting could expand into international radio, fm sound and television. Today, with so much broadcasting, making sure that the wavebands we have are exploited to the maximum advantage is one of our major preoccupations; the demand for frequencies far exceeds their availability in all broadcasting bands.

2.1 Recording

Another really significant advance came from the introduction of recording. In the early days of sound broadcasting, every word and every note of music, apart from gramophone records, had to be broadcast 'live'. Once we had developed programme recording systems, we were able to alter methods of production and, of course, we could capture for posterity events that otherwise would have been lost forever.

The Blattnerphone was our first magnetic tape machine but its tape was not the light, easily-cut material we use today. It was thin steel tape and twenty-minute reels weighed about 10 kilograms. Splicing the tape needed solder, not sticky plastic.

The Blattnerphone was before its time and the recording field was led by machines like the MSS disc recorder of 1935. Several types, including a very successful portable machine, dominated recording up to the late forties.

The revolution in our production methods came about because we were able to make programmes at times convenient to the artists, and broadcast them at any time of the day. Recording gave us flexibility in the use of our studios, the ability to broadcast more outside events and to ease problems in the scheduling of resources. All these abilities were first exploited by sound broadcasting; later we introduced, and then steadily improved, our ability to record television.

One of our earliest television recording devices used moving mirrors to provide an image which moved at the same speed as a continuously-moving film. It was a modification of a shutterless film projector and successfully resisted attempts to make it obsolete for many years.

2.2 Transistors

The next turning point in the history of broadcasting came with the invention of the transistor. At the moment when we in Britain expected vhf broadcasting to supersede the use of medium waves, the portable transistor medium-wave receiver changed the listening habits of the public; they were no longer tied to the mains-powered receiver, and the broadcasters had to introduce programmes to suit the greatly increased audiences that so rapidly became addicted to the small battery-powered receiver, which could be carried and used everywhere. We expected medium wave broadcasting to disappear, but instead, it retained and reinforced its great importance. In Britain, and no doubt also in Japan, part of the radio audience uses vhf reception for high fidelity and stereophony, but the majority uses medium-wave portables which make no claim to high fidelity; nevertheless, they give great pleasure to many people and are valued for their convenience.

3 The present

Before I go on to examine in some detail the ways in which engineering can help to ensure that the public broadcasting services continue effectively in a changing economic climate, it is worthwhile to look around and see where we are at present.

3.1 Radio

Today in Japan and Britain we have high-quality radio with a very high proportion of the programmes in stereo, and there are proposals for quadraphonic reproduction which are being investigated by broadcasters in many countries. With the scarcity of frequencies there is no possibility of providing quadraphony on new bands. If it is to be accepted it must be a compatible system in exactly the same way as stereo transmissions have to be compatible with, and share the same frequencies as, mono. In the BBC, we have carried out many tests on methods of quadraphonic reproduction, and we have even invented one or two matrices which, in some respects, are better than others we have heard.

But we are very conscious of the fact that our first duty is to the many millions of people who have equipped themselves with stereo or monophonic radio receivers, and that whatever we might do to please a small band of quadraphony enthusiasts, we must do nothing which would degrade the reception already being enjoyed by the majority of our listeners.

3.2 Television

In both countries we also have very high-quality colour television, and here we see the engineer continuously improving studio techniques and the colorimetry of reproduction processes, and introducing new apparatus for signal origination. We are able to make excellent videotape recordings which allow us to take advantage of programme material and people at times when they are available and to edit programmes after they have been produced.

Perhaps the most valuable technological advances that we have seen recently are in the television receiver. Colour sets have become more reliable and now need less re-adjustment than those which were available when we first opened our colour television services. At one time in Britain the average viewer, on buying a colour television receiver, was apprehensive that he was facing the necessity for several expensive visits each year by a serviceman. The modern set requires very little attention, and the introduction of integrated circuit design is making it even more reliable.

3.3 Digital Technology

In broadcasting equipment the use of digital technology is growing very rapidly, because of the greatly improved reliability and consistency it can provide. It preserves high quality through complex operations and eliminates the re-adjustments associated with analogue equipment.

Our first major operational use of digital techniques in the BBC was in the addition of the television sound signal to the video waveform, so that one circuit could be used to distribute both picture and sound. Television sound, coded into digital pulses by pulse code modulation (pcm) is added into the line synchronisation periods of the video waveform and remains there as far as the input to the transmitter.

At this point it is, of course, necessary to remove the pulses and convert the sound signal back into analogue form before transmission. Compared with sending by conventional analogue circuits, adding the sound to the vision signal effects substantial economies in our networking costs, as well as giving improved sound at remote transmitters.

This process of converting television sound to digital form for distribution with the video waveform is so reliable and has so many advantages that it is now used throughout the Eurovision networks of the European Broadcasting Union. The saving in cost is very great but, even if there were no financial saving at all, the additional quality and the freedom from the danger that the sound and the picture might part company on the way to the transmitters would be sufficient reason for adopting this technique.

The success of our 'Sound-in-Syncs' system has encouraged us to expedite the introduction of pcm for all our audio distribution networks. The BBC has designed and introduced into its radio network a system which carries thirteen separate audio signals in digital form multiplexed on to a standard video distribution circuit. We have now extended

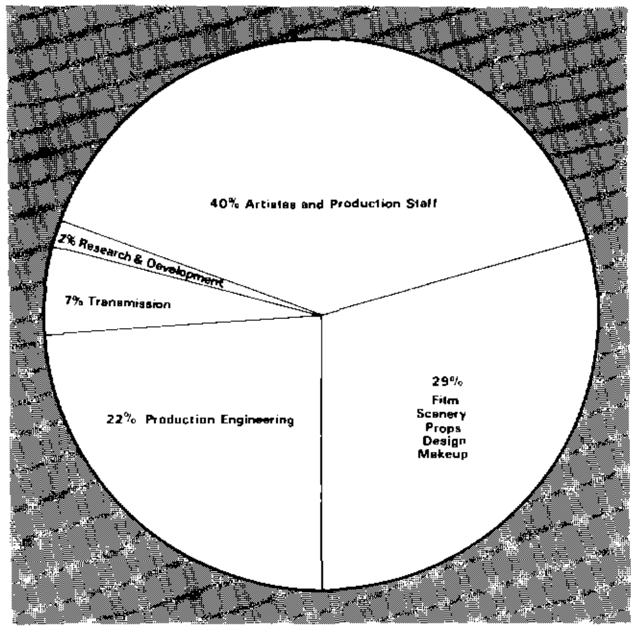


Fig. 1 Breakdown of television production costs

this system to most parts of the United Kingdom; it carries our programmes in stereo over long distances and maintains a quality very noticeably superior to that which can be obtained with analogue distribution.

We have developed these and other techniques to further our continuing objectives of improving quality, reliability and economy.

The BBC, like NHK, is responsible for its own transmissions as well as studios and other origination facilities. We also have our own research and development. It is possible, therefore, to evaluate new techniques of the type I have described and to develop and introduce them quickly when they are seen to be advantageous.

4 The future

Efficiency

In turning now to thoughts on the future, and with public service broadcasting very much in mind, there are still many possibilities yet to be explored of developing new ways of using radio waves to communicate with the eye and the ear. But before discussing some of them, I should like first to return to the continuing preoccupation of the engineer. I am referring to the important need to improve the overall efficiency of our operations wherever and whenever advances in technology make this possible. We are not afraid to introduce complex capital equipment when it offers the opportunity for significant revenue savings. We seek new techniques to permit the whole process of programme making and broadcasting to be speeded up, and carried on even more efficiently than at present.

Already the cost of the electronic component of making and transmitting BBC television programmes is less than one-third of the total expenditure (Figure 1). In fact, artists and their scripts require some 40% of the total, and programme services a further 29%. The remaining 31% covers all other engineering expenditure.

The engineer's best chance of effecting further economies is to influence the programme production costs by the elimination of as many constraints as possible.

While many of the costs are basic and inescapable, others are susceptible to reduction by the introduction of new technologies yet to be devised. The engineer can, with advantage, study the problems encountered in servicing and making productions and create facilities which will reduce their costs. Let me mention some of the possibilities.

4.1 Studios

Perhaps the most difficult area in which to achieve further economies is in the major television studio. Already in the BBC we operate these studios 24 hours per day — 12 to 14 hours in programme making and the remainder in setting and lighting. Elaborate dramas and light entertainment shows are recorded at the rate of half an hour of transmission time per studio day.

To achieve a worthwhile improvement we should have to be able to record a 90-minute drama in two days rather than the three now taken. If we are ever to make this possible we shall probably find it necessary to increase still further the complexity of the studio facilities — more cameras, which must also be sensitive in order to ease the lighting problems, and must be small, stable and remotely controllable; improved equipment and controls to reduce the time spent on lighting; more microphones will be needed or, perhaps, radio microphones might be improved sufficiently to enable us to wire each artist for sound and still get good sound perspective; to reduce the cost and complications of elaborate scenery and its handling we might perhaps insert scale models electronically.

4.2 Outside broadcasts

The speed with which a television outside broadcast can be set up is in my opinion an area needing urgent attention. Reduction in the size of crews involved, the amount of transport they need and rigging time could be quite dramatic if we can achieve a really worthwhile breakthrough in camera design. The biggest single step forward would, perhaps, be made if we could get rid of all cables between the camera and the central control. A battery-operated camera with radio connection to the mobile control room would offer great mobility and result in a substantial saving of production time. I do not, however, overlook the problems of radio-linking in confined spaces, and to overcome propagation difficulties will not simply be a matter of technological development. Perhaps a more practical solution would be to use a single, thin and flexible cable as a highway to carry every required signal around the location, a cable so cheap that it could, if necessary, be regarded as disposable.

4.3 Electronic film production

Already we are seeing in the United Kingdom a swing towards electronic methods of production in those areas that have traditionally been associated with film. The time-honoured practice has been to make filmed inserts for studio drama wherever exteriors or difficult locations are involved. The film is prepared in advance and replayed on a telecine which is used as though it were another camera operating in the studio.

We have now developed lightweight mobile television units which, with electronic cameras, can record scenes on location with very little more complication than a film operation. The production rate is substantially greater and the picture quality is a better match for the studio cameras with which the scenes will eventually be inter-cut. It is an important feature of electronic pickup for location shots that the director has an immediate play-back facility and he is not tempted, as he is in filming, to take the same scene several times in the hope that one of the re-takes will contain no errors. With an electronic pickup he can replay a shot immediately, and many re-takes become superfluous. We find that the cost of making productions by electronic means is about two-thirds that of making similar productions on film.

4.4 Television news

News gathering will be increasingly carried out by electronic cameras using highly mobile radio links to bring the signals back to base, thereby avoiding delays in transporting the film or videotape through traffic. Electronically-generated pictures also avoid delay due to film processing, and if the pictures covering an event at a remote pickup point are presented 'live' to an editor, he can save even more time by selecting material for his story as it comes in to the news-gathering centre and is stored on videotape.

Some important new developments of lightweight electronic cameras, radio links and recorders are necessary before electronic news gathering is as simple and reliable as the present filming methods, but the advantages are so great that I am sure these necessary developments will be made. CBS are the pioneers in this field and I am delighted that this has been recognised in the form of an Emmy Award to Mr. J. A. Flaherty earlier this year. We are pleased to be following his excellent initiative.

4.5 Film operations

Even if we had ideal lightweight electronic equipment, needing no extra operators and with no external connections, I doubt whether it would put an immediate end to our film operations. Film equipment is relatively cheap, simple and rugged. It would be naive to assume that sophisticated electronic cameras and recorders will be competitive from these points of view in the foreseeable future. Long-distance expeditions, for nature and similar programmes, where delays are common and risk of damage significant, will, I think, continue to use film for many years to come. We have already introduced various electronic improvements in filming, e.g. electronic synchronisation of camera and sound recorder and automatic iris control. Even so, filming is still a slow and inefficient operation.

The enormous capital investment in a television studio and the fact that at one time everything had to be done 'live' has from the earliest days made it essential for the director to plan studio time in advance and to ensure that everyone involved knows what to do from the word 'go'. Perhaps the productivity of film work might be increased if some of these techniques could be adapted to the requirements of film.

4.6 Editing

It is still possible to claim for film that the ease and accuracy with which programme material can be edited into a polished production is much better than with videotape. Much of this advantage lies in the very low cost of film editing equipment which makes it possible to provide facilities on a generous scale.

For assembling a major television production the high cost of the modern quadruplex videotape machine is just acceptable, and although editing of videotape often has to be carried out under more pressure than the editing of film, it is not an unreasonable process from an operational point of view. We do need, however, cheaper and simpler videotape machines to be used in less important productions where cost is a prime consideration. For example, small television studio centres need several videotape machines to be able to give intimate coverage of local events, but at the same time a restricted operation of this sort cannot afford the high quality and elaborate facilities of networking machines.

4.7 Storage

The broadcasters also need a cheap, simple and durable means of archival storage. It would be interesting to know how many programme years of film and quadruplex videotape are tied up in libraries all over the world. An appropriate system to permit these programmes to be stored in cheaper form is urgently needed.

4.8 Digital coding

I believe that many of the technological improvements we need are likely to be based upon the use of digital coding. As I mentioned earlier the advantages of handling signals in digital form are considerable and the experience we have in the BBC has been most encouraging. The widespread use of a pcm system to distribute programmes in stereo throughout the country and the introduction of sound-in-syncs have brought about very substantial improvements in the quality and efficiency of our transmissions.

Our experience of these digital methods of programme distribution is of great value when considering the use of digital technology in programme making. Digital coding is already well established in the studio; for instance, in standards converters and synchronisers. Whether it can be applied to the television camera is dependent on further development of solid state sensors. The conventional colour camera employing three vacuum tubes is now highly developed and only minor changes in it can be anticipated. Increased use of integrated circuits will bring some reduction of size and weight but this will not be significant in studio productions, though it will improve flexibility in outside broadcasting and news gathering. Major improvements are dependent on successful development of the solid state camera. A worthwhile reduction in camera size can only be achieved with a significant improvement in sensitivity. Our studies suggest that the increase in sensitivity to be expected from solid state sensors and developments in signal processing is equivalent to about two stops; this could be used to bring about a dramatic reduction in lens size and, therefore, in the overall size and weight of the television camera.

A successful solid state camera would also eliminate the registration problem which degrades picture quality in the conventional camera and adds to its operating cost. Solid state sensors have a built-in linear scan and can be expected to maintain registration throughout the life of the camera with the obvious economic benefits.

Digital coding also has great possibilities when used in television recording and the BBC has already demonstrated an experimental recorder using digital techniques. The editing of videotape programmes by analogue transfer from one tape to another introduces degradation which limits the number of times the process may be repeated, but in a digital recording system the final tape can have just the same excellent quality as the first-generation recording, since it is possible to re-generate the digital signals whenever necessary. We have, in fact, demonstrated signals of excellent quality after 2000 re-recordings.

How will this affect television recording techniques? I believe the recording need will be divided into two distinct parts, of which the first is programme compilation. For this purpose the digital machine's ability to make multi-generation recordings without degradation is an obvious advantage, but at this stage its operating costs are too high to compete effectively. The conventional vtr employing frequency modulation has its problems in meeting the necessary quality standards but the digital timing corrector comes to its aid. Our studies in the BBC suggest that the analogue recorder, employing the latest techniques, using 2" magnetic tape travelling at about 7" per second, will remain the norm for some time yet.

The second application for recording will be for simple storage, either between compilation and transmission or, in the case of the more important programmes, for archival purposes. A recorder for this purpose need not have the complexities necessary for programme compilation but it must be possible to make copies with it as required without further losses in quality, on low-cost, long-life material. In the light of our latest work in the BBC, we believe that a digital recorder employing optical recording techniques will meet this need.

5 New services

The last section has been concerned with developments which, when introduced, will improve the efficiency of existing services: many of them are technically possible now. But what new services might we provide in the future without asking for too many more frequencies or rendering millions of existing receivers obsolete? Broadcasting has freed itself from many technical constraints and it can go on to provide more comprehensive services to mankind — and at prices that a high proportion of mankind will be able to afford.

The public cannot demand a new service whose nature is unknown, and yet it is difficult for the broadcaster to invest the money and effort required to make it known before there is a public demand and a guaranteed audience. This chicken-and-egg problem is not new to broadcasting, and the introduction of all new developments has had to overcome this difficulty. Because of the method of financing public service broadcasting, and the breadth of the organization, the BBC — and I suggest the same can be said about NHK — is in a favourable situation to introduce new systems. We are accountable for our expenditure and in many ways we also are subject to competition. However, it does seem that the public service broadcaster can search for excellence and need not fear introducing complexity. Experience has already proved that innovation can be introduced reliably and cheaply; with this in mind what new services are possible?

5.1 Motoring information

In radio broadcasting the BBC is giving the motorist serious consideration. In Britain, as in Japan, there are traffic problems, and the road research laboratories of the United Kingdom believe that a great deal of help can be given to the motorist if he is warned of the hazards and delays in time to change his route. The BBC has for many years included in its radio programmes a proportion of time for announcements of traffic problems and advice to the motorist. Three of our programmes carry such announcements, but a mixture of entertainment and traffic information is not a wholly satisfactory arrangement. Those people who are at home and have no immediate interest in motoring information are inclined to resent the intrusion of traffic announcements into their entertainment. On the other hand, the motorist who is listening out for very useful advice may find that he has to endure an entertainment programme which is not at all to his taste. To give sufficient information to cover all the problems which may be occurring in a densely populated area like South-East England, we would have to devote an unacceptably high proportion of programme time to motoring. There is therefore a very strong case for separating motoring information and entertainment.

The BBC is proposing that a network of about 80 low-power medium-wave stations should be set up to cover the country, and that each station would have an effective service area of about 50 kilometres radius. All the stations would use the same wavelength. To avoid the total chaos which would normally result from 80 stations broadcasting different programme material on the same wavelength, it is arranged that they radiate in turn, through the use of a time-division-multiplex technique.

The country could be divided into five zones, each covered by a total of 16 stations. Only one station in each zone would operate at any moment, so each of the 16 stations in a zone would broadcast in turn for, say, half a minute. In this way the motorist would hear his nearest transmitter come into operation once every eight minutes and would be updated on the state of affairs in the area in which he was travelling at the time. As he moved into the service area of the next station, he would receive its broadcasts instead, since a threshold limiter in his receiver would ensure that only the strongest signal (from the nearest transmitter) was reproduced. A cheap, single-frequency receiver could easily be arranged to mute a conventional car radio, or cassette or cartridge player, which at other times provided the motorist with his own choice of entertainment. This we feel is the great advantage of the system over other proposed motoring services. The motorist is completely free to listen to any radio programme of his choice, or to recordings, or just to talk to his passengers, while at the same time knowing that he will receive the road information he needs at regular intervals.

5.2 CEEFAX

I have not so far mentioned the BBC's new service, CEEFAX, as an extension of television broadcasting; here the signal is wholly in digital form. By modern technological standards, the field blanking interval in television is unnecessarily long — it is literally a waste of time. Television engineers have used some of this spare capacity in different ways; vertical interval test signals, for example, and for internal communications using digitally-coded signals.

About four years ago, BBC engineers began a serious attempt to make more use of this potential communication channel, and our first thought was that coded signals could convey to the receiver messages that could be stored and displayed by a character generator as subtitles for people who were deaf or hard of hearing. However, the number of people in the United Kingdom who are deaf is relatively small; too few to justify a special service and specially manufactured receivers. Nevertheless, they could be included in a wider audience since it was obvious that, given the ability to store a few thousand bits at the receiver, and using two spare lines in each field, we could transmit enough digital information to create a full screen of text within a dozen or so fields.

A CEEFAX 'page', filling the television screen can have up to 24 rows of text, each row containing 40 characters. The resolution of a colour display tube can handle this packing of characters very satisfactorily indeed, and the page can be read easily from a normal television viewing distance (Figure 2). The rather simple alphabet used in English makes this service easier to engineer than it would be for Japanese, but there is no doubt that the world-renowned Japanese ingenuity will be able to overcome the problem (Figure 3).

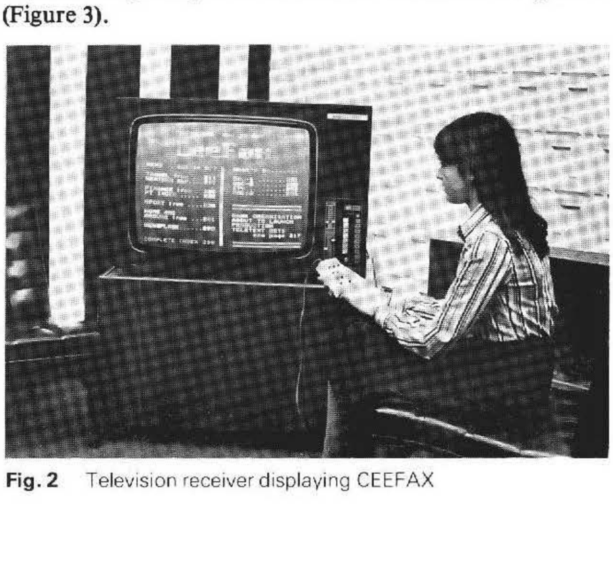


Fig. 2 Television receiver displaying CEEFAX

Fig. 3 Although designed to generate the Roman alphabet, CEEFAX can display other shapes by means of its graphics mode of operation

In the CEEFAX system, we transmit a magazine of 100 pages, taking the pages in sequence and starting a new one immediately upon completion of its predecessor. If each page contained the full 24 rows of text, it would take 24 seconds to transmit the 100 pages before beginning the cycle again, but to make attractive pages with an easy-to-read layout the number of rows of text is usually less than 24, so that the time for a cycle of 100 pages may be only about 15 seconds. The viewer can select on his CEEFAX receiver the page number that he wishes to see and, as soon as that particular page is being transmitted, the solid-state store in the CEEFAX receiver collects the information and causes the character generator to provide the video signal required to display the text. He can at any time switch from the regular programme to CEEFAX and as soon as he has read the pages of interest he has only to press a button to return to the normal television programme. The CEEFAX magazine carries pages of news, weather reports, sports results, financial news, market prices, entertainments, traffic reports and many other subjects.

In September 1974 the BBC was authorised by the Government to operate a two-year experimental CEEFAX service. WE have a number of prototype receivers fitted with CEEFAX decoders which basically comprise address-recognition circuits, a solid-state store capable of holding all the bits relevant to one page of text, and a character generator which produces the video signal to display the information. We hope very soon to have the whole of this complicated circuit logic incorporated in a few inexpensive large-scale integrated circuits, perhaps including a micro processor. It is believed that in quantity production, the addition of the CEEFAX facility would not increase the price of a colour receiver by more than 20% and those of us who have experience with a prototype receiver in our homes are very confident that the public will find it a most desirable extra feature.

We believe that CEEFAX is the first general information service to be broadcast in digital form and decoded at the receiver. It was possible to make this choice because CEEFAX is an entirely new system and there is no compatibility problem with existing equipment. The successful introduction of this new service has emphasized the importance of co-operation between broadcasters and the receiver industry. General speaking, complexity in broadcasting apparatus is of secondary importance provided it is reliable and it has the desired effect in reducing production time or producing new facilities. Complication in the receiver, however, is a very different matter, and in devising the CEEFAX system where a 6-megabit per second digital signal has to be decoded in each domestic receiver, we had to be sure that this technical process could be carried out reliably and inexpensively. We knew that in the development of the CEEFAX system the advice and experience of the designers and manufacturers of large-scale integrated circuits would be of vital importance. We were careful, therefore, to publicise our proposed system at an early stage to obtain comments and suggestions from the domestic receiver and component industries and from other broadcasters. As a result, CEEFAX is now an agreed British standard.

A similar problem will probably arise if we should ever use satellites for direct broadcasting to the home. If digital techniques figure in any such proposal, large-scale integrated circuits will be of paramount importance in reducing costs. We have always tried to devise systems which work well with low-cost receivers, and have accepted that, where it is necessary, complications should be at the sending end. With mass-produced integrated circuits, it may be possible to allow for a complicated receiver while still meeting the low-cost requirement.

5.3 Educational broadcasting

Like NHK, the BBC carries a great deal of educational broadcasting. In the United Kingdom the Open University has been the educational success of the last decade. There are proposals to allocate the fourth uhf television network and fourth vhf radio network for educational broadcasting and to include in them an Open University College of continuing education for adults. A combination of radio, television and CEEFAX broadcasting would provide a powerful tool in education.

5.4 Home recording

The vast majority of viewers and listeners accept our normal broadcast programmes when they are transmitted or miss them for all time. Few people take the trouble to record broadcasts in order to enjoy them later, though there could be some growth in the use of home recording with unattended apparatus which may be pre-set to capture programmes of interest. Perhaps a demand will arise for address codes to be transmitted to activate home recorders. It is interesting to note that in the CEEFAX system we have transferred the recording function to the sending end — it is there to be selected by the viewer whenever he wishes.

5.5 Local television

I think the spread of local television is likely to be high on the list of future demands. In the United Kingdom, the BBC at present operates 20 local sound radio broadcasting stations in main centres of the population and we should like to increase this to 60 or 70 such stations. The popularity of local radio in the United Kingdom has become an important factor in any consideration of public service broadcasting.

If we were to introduce local television, as well as local radio, it would need the most careful planning and use of available frequency channels. If local programmes are to reflect the interests and activities of the community, it must be possible to produce programme material at short notice from any point within the area and to do so at low cost. Thus, manpower, mobility and speed of operation, which I have stressed, will be of very great importance. The cost of local television, per viewer, must be made as little as possible without serious effect upon the high standards to which the public service broadcaster operates. We need simple and inexpensive equipment; it must be stable, reliable and effective for its job; it must operate with the minimum of staff. It would be quite impossible for a public service broadcaster to operate many local television stations unless his cost per programme hour can be reduced to a low level.

6 Conclusions

When I look ahead I feel confident that the future of broadcasting is bright. There is so much more that broadcasters can do to ensure that people are informed, educated and entertained. We must continue to adapt to changing conditions and, if necessary, absorb the functions of older methods of communication as they are overtaken by economic events. The number of cinemas continues to fall and the live theatre survives only in the largest cities. Already most people rely on broadcasting for nearly all their entertainment. Newspapers are steadily going out of business in the western world and postal services are being reduced in frequency because of rising costs. Broadcasting will have to be ready in the years ahead to provide some of the services which would otherwise be lost, together with new services, not yet clearly defined as public needs.

It will not be easy to provide these services. Money is scarce and so are frequencies; but both can be found when the need is clear. The public service broadcaster has an important role to play in developing new systems and launching new services, with the commercial broadcaster augmenting and expanding these ideas when they show promise or profitability.

As I said at the beginning, Japan and Britain are fortunate in the combination of effective public service and commercial broadcasting. That, coupled with good engineering, will help us to innovate and lead, as we do now.

A Portable Comprehensive UHF Test Set

G. G. Johnstone, BSc., CEng., MIERE,

Designs Department

Summary: This article describes a portable test set by means of which comprehensive testing of television transmitting and receiving equipment operating in the uhf bands is carried out. It replaces, in one compact unit, a range of separate items of equipment which occupied a much greater volume and provided fewer facilities.

1 Introduction

The equipment described in this article was developed to meet the need to service the range of television transmitters and transposers. Nearly all the BBC's transmitting stations are automatic in operation and unstaffed. They are maintained by mobile teams who require a wide range of test equipment covering video and radio frequencies. There is a clear requirement for the equipment to be versatile and portable.

An earlier design exercise had shown that the requirements for video equipment could be met by re-packaging existing units and this was done. A similar re-packaging of existing radio-frequency equipment was considered but rejected because the units were too bulky to permit a compact result. Also some of the facilities required were not provided by the existing equipment.

A survey of the facilities required showed that there was a need for a modulator to provide test signals on the full range of uhf television channels for testing transposers and receivers. There was also a need for a demodulator covering all channels to enable the radio-frequency output signals of transmitters and transposers to be checked by measurements at baseband. There was a requirement for a spectrum analyser to check the performance of transmitters and transposers, and the absolute level of signals. In addition, there was a need for a sideband analyser to enable the frequency responses of transmitters to be examined.

Finally, there was a need for a frequency sweeper to enable the response of filters, etc., to be examined. It was also desirable that the sweep should be available at vhf to check the performance of equipment and circuits working within this band.

A closer examination of these requirements showed that they could all be provided in one equipment, because a number of the functions are inter-related. For example, a sideband analyser incorporates a spectrum analyser, the radio-frequency input stages of which are similar to those required by the demodulator. Thus not only was it possible to provide the functions detailed above, but also it was practicable to provide a tracking generator to operate with the spectrum analyser. An examination of block-schematic diagrams showed that 72 items would be required to perform separately all the functions listed above. The actual number of items in the equipment is 37 and this shows the scale of economy which can be achieved in a multi-purpose assembly. The final equipment, designated the Comprehensive RF Test Set EP14M/507 is shown in Figure 1. Its overall dimensions are 480 mm x 430 mm x 320 mm and its weight is 30 kg. The outputs are normally displayed on an oscilloscope which is part of the teams' standard equipment.

The operation of the test set is most easily explained if its functions are considered separately.

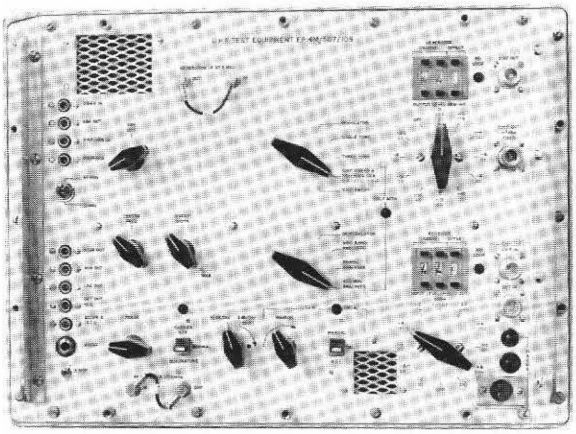


Fig. 1 The new test set

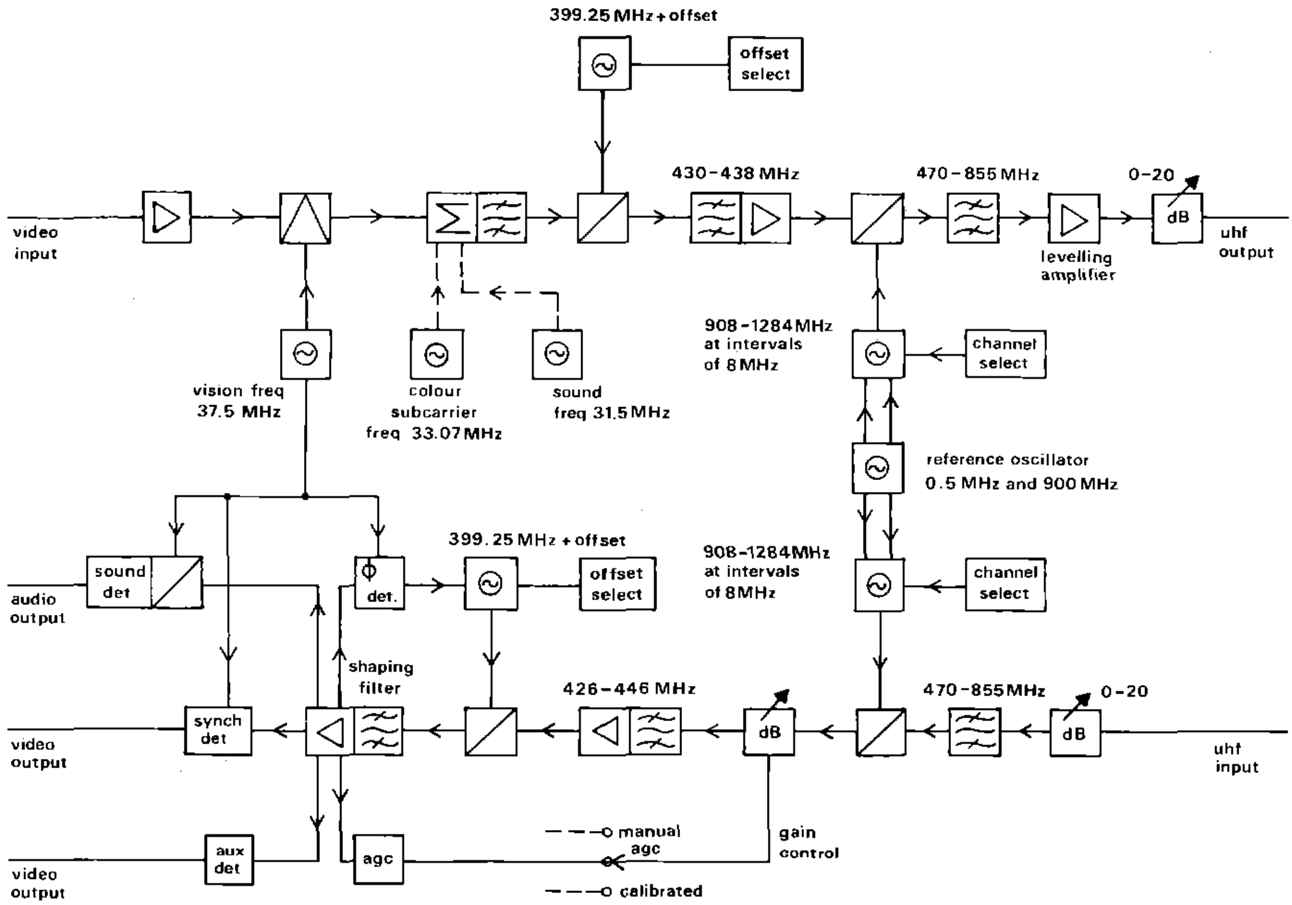


Fig. 2 Block schematic diagram of test set in modulator and demodulator mode of operation

2 Modulator

The block schematic diagram of the modulator is shown in Figure 2. Video modulation is accomplished at an intermediate frequency of 37.5MHz. which was chosen as it was already in use within the BBC as the standard intermediate frequency for re-broadcast receivers. The incoming video signal is amplified and clamped in a conventional circuit arrangement, and modulation is achieved in a double balanced modulator which uses a commonly available integrated circuit. The output signal thus generated is in double-sideband form, and is then mixed with 399.25MHz and translated to 436.75MHz. The 399.25MHz component is derived by multiplication from a basic crystal oscillator operating near 14.8MHz. Using a varactor, its frequency can be shifted by a switched voltage source to provide the necessary range of offset frequencies required on each individual channel. After mixing, the signal is fed to a four-element filter which provides a degree of vestigial sideband shaping. As the output signal is not required to meet the full transmission standard, it was possible to adopt this simplified shaping.

After further amplification, the signal is transposed to its final frequency using a synthesiser working in the range 908 - 1284MHz; the synthesiser frequency can be changed in 8MHz steps. Control of the synthesiser frequency is by means of switches at the front panel, and these switches are arranged to display directly the number of the channel of the final output signal.

The unwanted upper sideband from the final mixer is eliminated by a filter whose passband covers the full range of ultra-high-frequency television channels (21 to 68). This filter has twelve elements and provides adequate rejection of the unwanted output signals from the mixer which, in addition to the upper sideband of the mixing process, includes break-through components of the oscillator and input signals. The output signal is then fed to a levelling amplifier which sets the level of the output signal of the vision carrier to 0dBm, and this is followed by a ten-step 20dB attenuator to provide a range of output signal amplitudes.

In addition to vision signal modulation, provision is also made for additional test signals. An unmodulated sound carrier signal can be added, to provide a composite signal at the output with correct relative levels. Sound modulation facilities are not provided, as these are not often necessary when testing transposer equipment (audio distortion and alteration to frequency response do not usually occur in such equipments). The presence of the basic sound carrier ensures, however, that noise level and cross modulation can be measured. Whilst the incorporation of the sound modulation facility would have been a desirable feature, the urgent overall requirement of minimum size and weight led to its exclusion.

In addition to the facilities described above, the modulator can be set to provide a standard three-tone test signal by generating plain vision and sound carrier components, and adding a signal at the colour sub-carrier frequency (4.43MHz from the vision carrier component). The levels of the vision, sound and colour components can be set to −8, −7 and −17dBm at the output. This test signal enables the linearity of amplifiers and transposers to be measured in those conditions where all three signals are handled in a common system. In such circumstances non-linearity manifests itself most seriously in the generation of a signal at 1.57MHz away from vision carrier, and this component must be kept to a very low level to avoid perceptible picture degradation. Finally, plain carriers can be generated for setting power levels and frequency checking.

3 Demodulator

The demodulator block schematic diagram is also shown in Figure 2, and it can be seen that in many ways it is the converse of the modulator system. The incoming uhf signal (bottom right of diagram) is fed via a level-setting attenuator to an input band-defining filter which covers the full range of uhf television channels. The signal is then transferred to the first intermediate frequency of 436.75MHz using a synthesiser identical with that used in the modulator section. The intermediate frequency filter bandwidth differs from that in the modulator in having a wider passband, for reasons which will be apparent in considering operation in the spectrum analyser mode. The signal frequency is then changed again to the second intermediate frequency of 37.5MHz, using a 399.25MHz oscillator similar to that used in the modulator section; the precise frequency can be adjusted in steps in order to cope with the range of offsets in the incoming signal frequency.

The demodulator proper operates at 37.5MHz and is derived from the circuits used in the standard BBC rebroadcast receiver which was designed some years ago. The signal is applied initially to a filter to provide the required sideband shaping and sound carrier suppression, and is then applied to a balanced demodulator. This demodulator is of the synchronous type, and uses the 37.5MHz oscillator available in the modulator as the enhanced carrier source.

For the system to function properly, the incoming signal carrier component must be precisely in phase with this 37.5MHz signal, and this phasing is achieved in a phase-lock-loop circuit. The circuit compares the phase of the 37.5MHz local signal with that of the incoming signal sampled during synchronising pulses; a control voltage is derived, and fed to the 399.25MHz oscillator where it is summed with the offset control voltage.

The demodulated video signal is amplified and fed to the output. Since the front end of the system is inherently broadband, it is possible to calibrate the unit in terms of the radio-frequency input which is necessary to provide a video output signal of 1 volt amplitude.

Two additional facilities are available in this mode of operation. The phase of the 37.5MHz oscillator output applied to the demodulator can be varied over a wide range so that it can be adjusted to be in quadrature with the incoming signal carrier; in this condition the low-frequency components (those where the signal is essentially double-sideband) will give zero output. Any departure from zero output indicates the presence of incidental phase modulation. Furthermore, the vision intermediate-frequency signal can be blanked to give an indication of zero carrier; this enables modulation depth to be measured.

A second vision demodulator is provided; this is of the pseudo-synchronous type. It provides a reasonable quality output even if the synchronous detector is out of lock or set to phase quadrature.

The shaping filter provides an output from the sound signal component of the input signal at 31.5MHz; this signal is mixed with 37.5MHz and the resultant signal at 6MHz is selected, amplified, limited and demodulated to give an audio output signal at standard level. The signal may then be used for making distortion and signal-to-noise ratio measurements.

The complete demodulator can be used in one of three modes; fixed gain (calibrated), manual gain and automatic gain control (agc). In the first mode the demodulator overall gain remains fixed, and as the sensitivity over the uhf band is substantially constant, measurements of absolute level may be made. In the manual gain position the gain can be varied continuously over a small range to enable the operator to interpolate between settings of the input attenuator, which operates in 2dB steps. In the agc position an automatic gain control loop with a range of about 6dB is brought into operation to enable measurements to be made without disturbances from fluctuations of input level.

4 Spectrum analysers

A spectrum analyser is a receiver in which the local oscillator frequency is swept whilst the receiver output is displayed against the sweep voltage, to give a display of signal amplitudes with frequency. As the test set has two intermediate frequency sections, and hence two local oscillators, there is the option of performing spectral analysis in two different ways, and both are provided. If the first oscillator is fixed to receive a given channel then the second oscillator may be swept to give a detailed display of the signal occupying the channel — this is the 'narrow-band' spectrum analyser. If the second oscillator is fixed, then the first oscillator may be swept to display all or any part of the complete Band IV/V spectrum. This is the 'wide-band' spectrum analyser.

In both these modes of operation, the demodulator section at 37.5MHz incorporates a narrow-band detector. This detector is of the logarithmic type, so that the height of a displayed signal is proportional to the logarithm of its amplitude over a range in excess of 60dB. Cursor lines corresponding to 0dBm and −60dBm are also generated, and by selection of the oscilloscope gain, the display can be set to 10dB per division. An additional control on the test set enables any portion of the dynamic range between 0 and −60dB to be displayed at 2dB per division.

4.1 Narrow-band spectrum analyser

A block schematic diagram of the test set in this mode of operation is shown in Figure 3. The circuit arrangement is similar to that of the demodulator except that the 37.5MHz section now incorporates a narrow band detector.

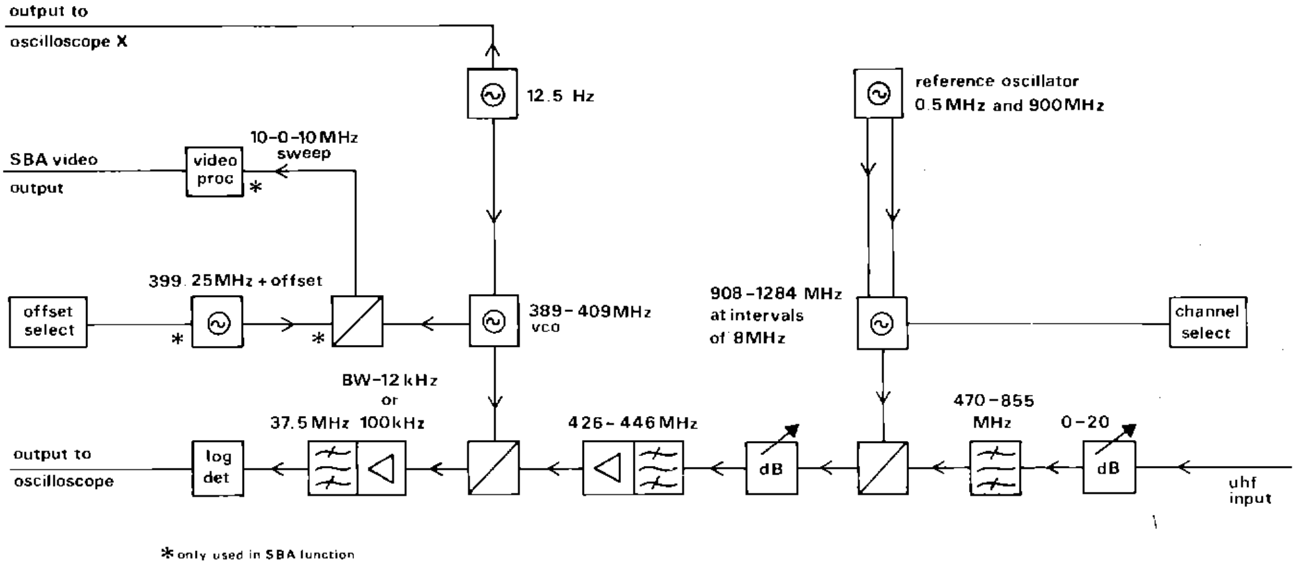


Fig. 3 Block schematic diagram of narrow-band spectrum analyser and sideband analyser

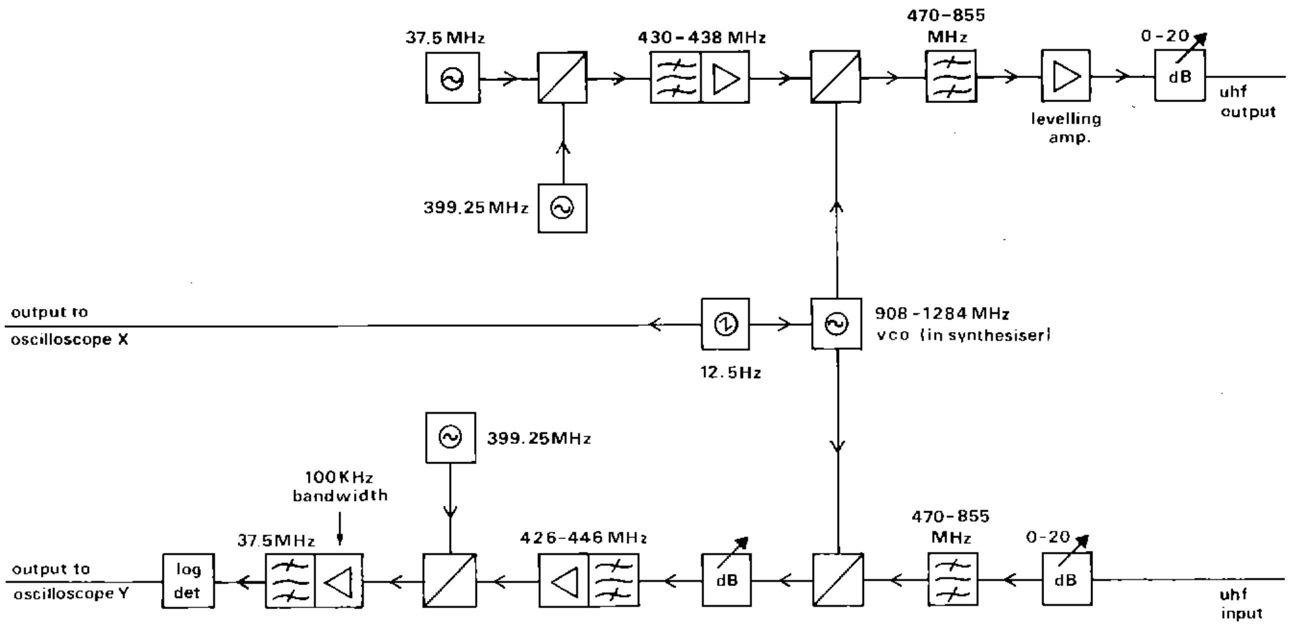


Fig. 4 Block Schematic diagram of wide-band spectrum analyser and tracking generator

The channel under examination is determined by the setting of the input synthesiser. The fixed frequency oscillator at 399.25MHz is replaced by one swept over the range 389 to 409MHz by a 12.5Hz sawtooth waveform — this latter signal provides also the time base of the display unit. The effective receiver bandwidth is 100kHz, and as the receiver sweeps across the band under examination, the components of the input signal spectrum within 10MHz of vision carrier are inspected and displayed. By adjustment of sawtooth amplitude and associated dc component, all or any portion of this band can be examined in detail.

To ensure that the system functions correctly, the bandwidth of the filter immediately prior to the second mixer must be wide enough to pass the band of frequencies within 10MHz of the vision carrier intermediate frequency, and its passband is consequently 426 to 446MHz.

4.2 Wide-band spectrum analyser

The block schematic diagram of the test set in this mode of operation is shown in the lower half of Figure 4. In this instance the 399.25MHz oscillator is fixed in frequency whilst the 12.5Hz sawtooth sweeping voltage is applied to the voltage controlled oscillator (vco) at the heart of the synthesiser. Under these conditions the narrow-band receiver sweeps across all or any part of the Band IV and V spectrum to display the range of signals at the input.

4.3 Sideband analyser

The sideband analyser facility enables the frequency-response of a transmitter to be checked with accuracy. A transmitter normally requires a video input signal complete with synchronising pulses for its correct operation, and hence if a baseband-to-baseband check of frequency response is applied, using a demodulator, it is not possible to state precisely the transmitter response over its total passband. As the shape of the response in the vestigial region is of major importance, an alternative technique must be employed. This technique uses a video signal sweeping over a range of video frequencies which is derived by a 'beat-frequency' arrangement. In this arrangement a fixed-frequency oscillator is mixed with a variable-frequency oscillator operating in the same region; the difference frequency provides the basic baseband video sweep.

If then the variable-frequency oscillator is used in a spectrum analyser examining the transmitter output, the analyser can be made to track one of the sweeping video sidebands, and hence display the overall response of the transmitter.

The overall block schematic diagram of the test set in this mode of operation is shown in Figure 3. The test set demodulator section is operating in the narrow band spectrum analyser mode; the sweeping second oscillator is mixed with the output of the fixed frequency 399.25MHz oscillator, and hence produces a sweeping video signal with a maximum excursion of 10-0-10MHz. This sweeping video signal is then fed to a video processing unit where synchronising and blanking pulses are added to provide a signal in a suitable format for application to a transmitter input.

If the spectrum analyser is set to examine the spectrum of the transmitter output channel, then one sideband corresponding with the video sweep will be held stationary at 37.5MHz. The output display then shows the overall frequency response of the transmitter under test, including the response of the modulator and radio-frequency shaping circuits.

Line synchronising pulses are present in the video sweep and in order to prevent the line-frequency structure from being displayed, the bandwidth of the receiver is narrowed to ±6kHz.

4.4 Tracking generator

When measuring the responses of filters, amplifiers, etc., it is desirable to have a signal generator which tracks the frequency to which the spectrum analyser is set, and this is accomplished in the test set as shown in Figure 3. As explained above, the vco in the demodulator side of the system is swept by a sawtooth generator to display the spectrum of applied signals in the uhf television band. If the generator side of the system is set to produce plain carrier simultaneously using the same vco, as shown, then a tracking generator is achieved. This facility enables measurements of frequency-response to be made over a dynamic range in excess of 60dB.

5 Frequency synthesiser

There are two identical synthesisers, and these share a common reference frequency chain. A block schematic diagram of one of the units is shown in Figure 5. Each synthesiser has a vco capable of covering the range 908 to 1284MHz, and the output of the vco is mixed with a signal at 900MHz derived from a basic reference oscillator at 10MHz. The

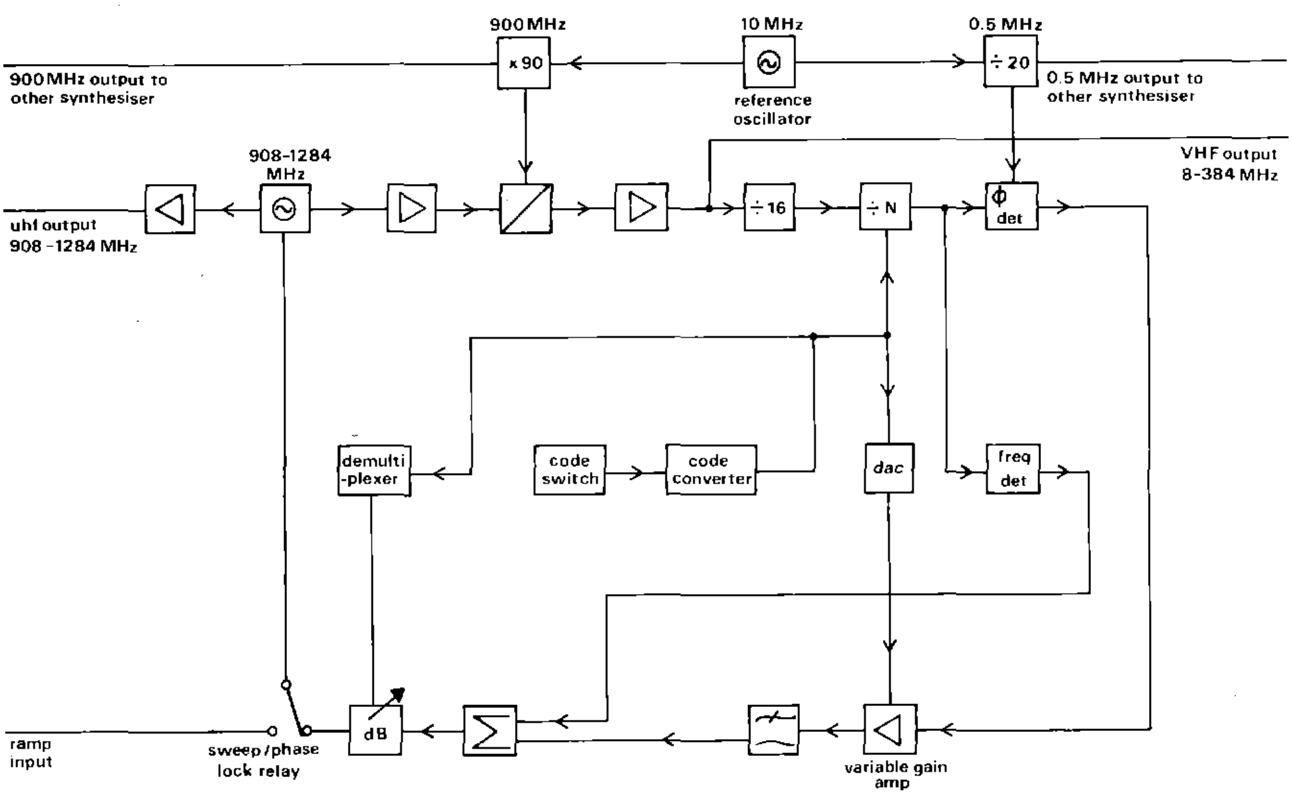


Fig. 5 Block schematic diagram of frequency synthesiser

resultant vhf signal covering the range 8 to 384MHz is fed to a programmable divider chain, and the output signal from the chain is compared with a signal at 0.5MHz derived from the reference oscillator. Two control loops are provided; a coarse frequency control loop which steers the vco to its approximately correct frequency and a phase control loop which steers the vco into phase lock. The vco frequency is determined by the division ratio of the programmable divider, and this in turn is controlled by binary-coded-decimal code switches on the front panel. The switches indicate the number of the uhf channel selected, and a code converter produces a binary output to set the programmable divider to the appropriate division ratio. The sensitivity of the vco varies with frequency, as does the ratio of the programmable divider, and hence steps have to be taken to preserve a reasonably constant loop gain with frequency.

When the synthesiser vco is used in the sweeping mode, the voltage ramp is pre-distorted to produce a relatively linear frequency/time characteristic. When the vco is being swept in frequency, the vhf signal from the mixer is also being swept; this output is separately filtered, amplified and levelled to provide a vhf test signal source covering the range 25 to 250MHz.

6 Measurement accuracy

The generator section of the test set has a levelling amplifier at its output to provide test signals at a known level ±1dB. On the demodulator side, the set has broadband input circuits and in the fixed gain position a level measurement accuracy of ±1dB is provided. The logarithmic detector has a relative accuracy of ±1dB over its working range in addition to the absolute level measurement accuracy. The demodulator video output has linearity errors (line-time and differential gain) of about 1% and a differential phase error of about 1°. Frequency markers are provided on all sweeping facilities using the basic 10MHz oscillator as reference; these markers are presented at a separate output and can be applied to the second trace of a twin channel oscilloscope.

6.1 Operation

The test set provides a generator of uhf television test signals and a corresponding receiver. The functions available are as follows:

Generator:
1. Modulator
2. Single tone
3. Three tone
4. Uhf sweep
5. Vhf sweep

Receiver:
1. Demodulator
2. Sideband analyser
3. Narrow-band spectrum analyser
4. Wide-band spectrum analyser

Not all the functions of generator and receiver are available independently — for instance, the uhf sweep generator function is available only when the wide-band spectrum analyser function is selected.

In operation, comprehensive self-checking is provided since the generator and receiver can be used together. Additionally, 'bridges' can be constructed internally at the intermediate frequency stages as an aid to servicing.

To illustrate the operational facilities available with the test set, the photographs in Figures 6 to 14 are of oscilloscope traces in the indicated modes of operation. Apart from the display oscilloscope, the only other item of test equipment used is a directional coupler employed to display the return loss characteristics of filters.

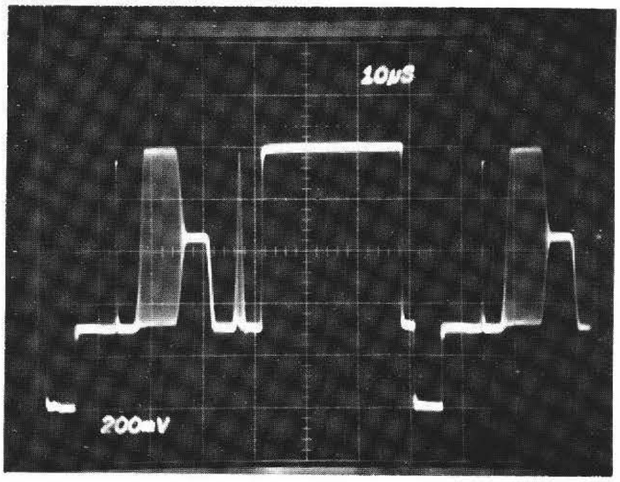


Fig. 6 Video output from test set in back-to-back modulator/demodulator mode

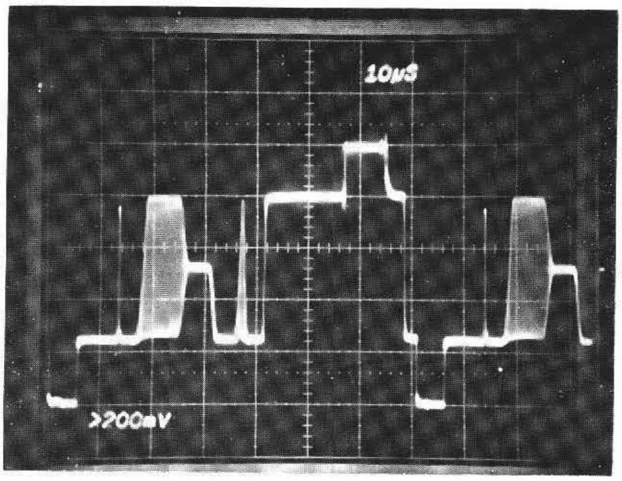


Fig. 7 As Figure 6 but with zero carrier reference

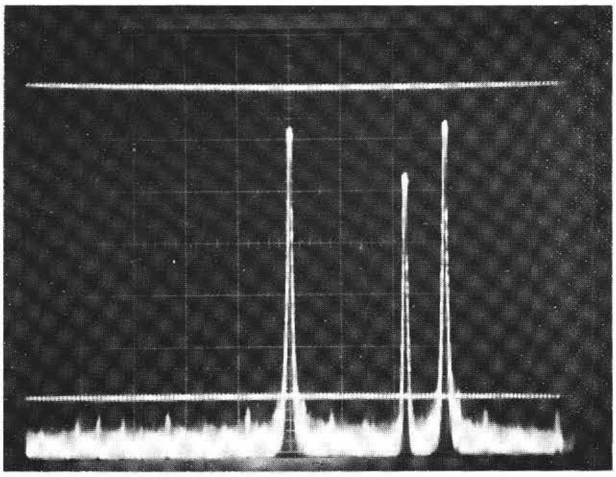


Fig. 8 Narrow-band spectrum analyser display of generated three-tone test signal. Cursor lines show levels of 0dBm and −60dBm

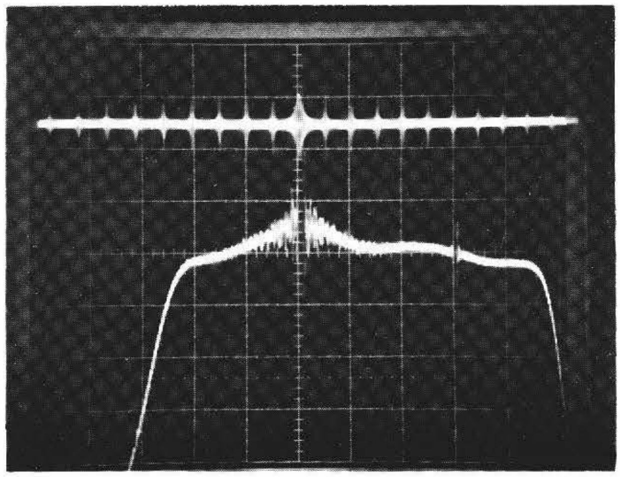


Fig. 11 As Figure 10, but with display set to 2dB per division

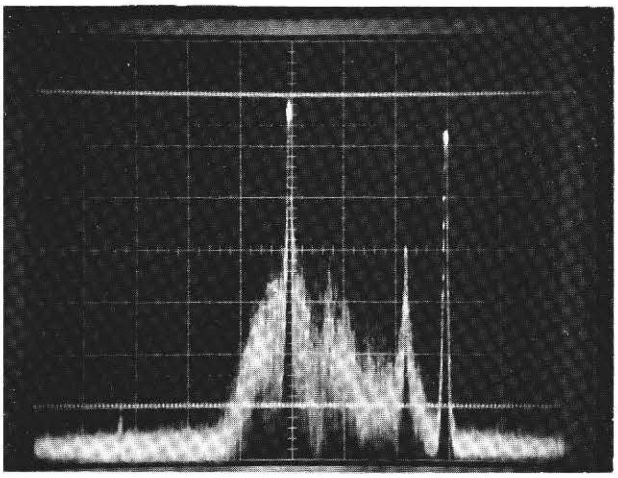


Fig. 9 Narrow-band spectrum analyser display of transmitter output

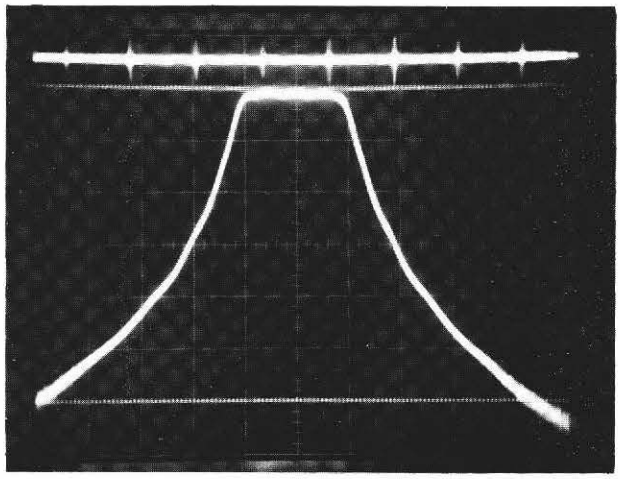


Fig. 12 Wide-band sideband analyser display using tracking generator to exhibit filter response. Markers at 10MHz intervals

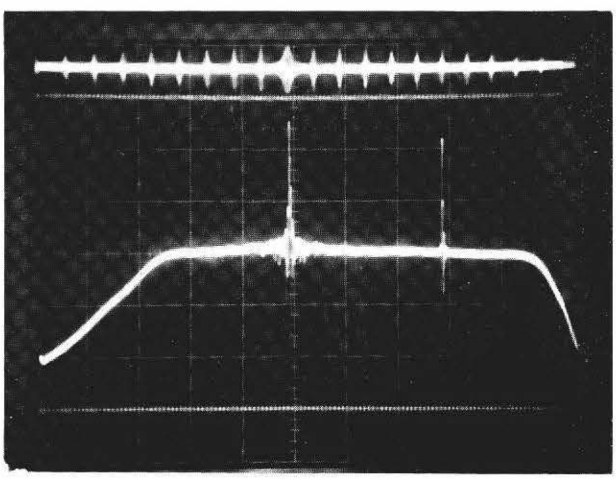


Fig. 10 Sideband analyser display together with 1MHz markers

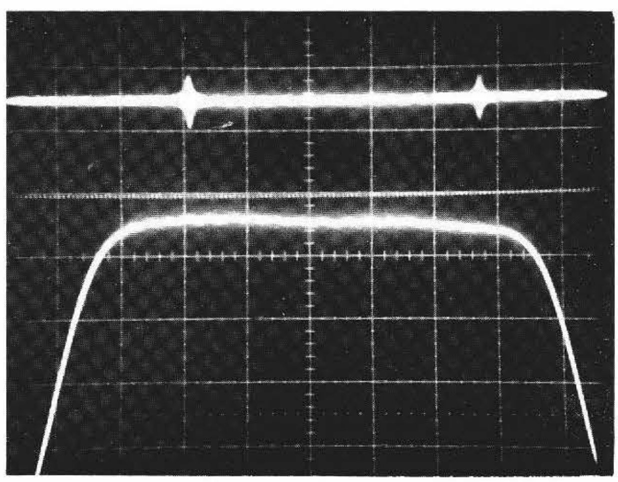


Fig. 13 As Figure 12, but with display at 2dB per division

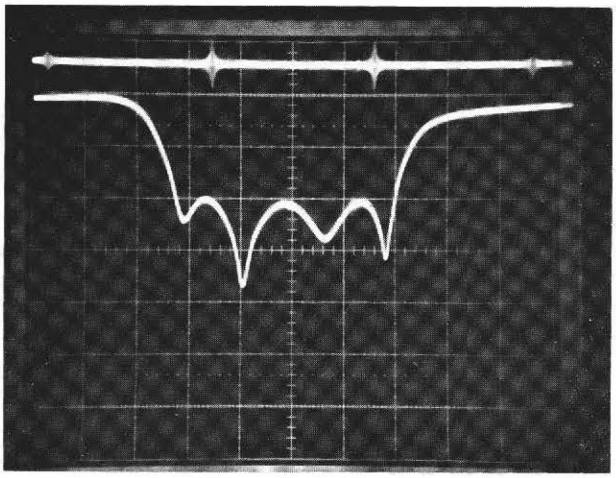


Fig. 14 Return loss of filter using auxiliary directional coupler. Markers at 10MHz intervals

Acknowledgements

The work on the Test Set was carried out by a team of engineers, whose efforts were co-ordinated by C.R. Caine, whilst S.W. Collier, M.T. Ellen and R.G. Seville were responsible for much of the design work.

A Crystal-controlled Monitoring Receiver for Medium and Low Frequencies

P. A. Tingey

Designs Department

Summary: With the introduction of BBC Local Radio in the medium-frequency band and the progressive de-staffing of network radio transmitting stations, the requirement for off-air monitoring has greatly increased. In 1974, therefore, design work was started on a compact modern receiver which would be usable in a variety of applications and would be easy to manufacture at reasonable cost.

The resultant receiver, known in the BBC as the RC3/10, is described in this article. It uses the Synchrodyne technique which has extended the range of applications.

1 Introduction

Recently introduced into BBC service, the crystal-controlled receiver and its ancillary, pre-tuned aerial unit (Figure 1) provide high-quality reception of amplitude-modulated broadcast signals in the low and medium frequency bands. The receiver is intended for checking the audio quality and power level of a remote transmitter and for relaying information about the status of that transmitter to a control room, but other applications are being exploited.

The circuit techniques used in the receiver have made it practicable to provide an output of reconstituted carrier which is phase-locked to the one being received. This output can be used for locking secondary signal sources to master transmissions — a facility which is particularly useful as the number of low-power transmitters operating on a common frequency or closely-spaced ones grows. Another application is in providing a reference from a standard-frequency transmission such as the Droitwich 200kHz service, to lock a colour subcarrier generator at television outside broadcast sites.

The receiver utilises a circuit technique which was devised in the 1930s as the Homodyne and which was developed by D.G. Tucker[1] in 1947 as the Synchrodyne. With the advent of integrated circuits the application of the Synchrodyne principle has become practicable.

In conventional receivers, tuned-radio-frequency or superheterodyne, the frequency-selection process is carried out in tuning circuits prior to the detector. The Synchrodyne differs in that the passband-defining circuitry is after the detector. This, of course, requires a detector which does not crossmodulate adjacent-channel signals onto the wanted signal carrier. (Adjacent channels occur at 9kHz intervals above and below the wanted carrier frequency.) A locally-generated signal, locked to the incoming carrier, is used as the reference signal for a synchronous demodulator. Linearity is good and crossmodulation is minimised. The circuit is completed by an audio filter with a level response up to 5kHz and rapid attenuation thereafter.

2 Design considerations

The number of tuned radio-frequency circuits in the receiver was reduced to a minimum by using the superheterodyne technique with crystal oscillators for local and synchronous reference oscillators. To keep the size of the receiver down, a crystal filter was chosen with a centre frequency of 10.7MHz and passband of ±6kHz to determine the IF response, allowing an audio bandwidth of 5kHz with a 1kHz tolerance for trimming the two oscillators. The reference oscillator runs at 10.7MHz and the local oscillator at signal frequency plus 10.7MHz. At these frequencies the oscillators, crystal filter and decoupling components are all quite small, and the result is a compact, well-screened, stable receiver. Other advantages of the apparently strange intermediate-frequency are the superior image-channel rejection, the lack of breakthrough of 10.7MHz signals into the signal-frequency amplifier and the improbability of a local oscillator signal passing through the signal-frequency stage to the aerial.

The crystal filter, with a cut-off slope of 10dB/kHz, would not eliminate the adjacent-channel signals (at ±9kHz) so synchronous demodulation was used to allow attenuation of the adjacent channel in the subsequent audio filters. A commercially-produced integrated circuit comprising limiter, demodulator and amplifier, intended for use at vhf in radio and television receivers, has been used in the RC3/10 as a demodulator (for amplitude-modulated signals), and reference oscillator phase-locking circuit. Most of the filtering is achieved in the audio section of the receiver so that an overall cut-off rate of 50dB/kHz is achieved, this providing a minimum of 30dB and a maximum of 90dB rejection of adjacent, out-of-channel signals. Assuming no cross-modulation in the stages preceding the demodulator, out-of-channel signals are almost entirely eliminated.

3 Reconstituted carrier signal

By mixing the outputs of the local and synchronised internal oscillators in the second mixer, an output is produced which is their difference frequency. This automatically has the same frequency as the wanted carrier signal and is phase-locked to it. The difference frequency is readily selected by a two-section, low-pass filter because the highest wanted signal frequency is 1.6MHz and the unwanted crystal oscillator frequencies are at 10.7MHz or above.

Removal of the amplitude-modulation component permits further automatic processing without the phase or amplitude disturbance associated with the modulation. The frequency of the received carrier can also be checked accurately.

4 Programme failure monitor

BBC television sound and vhf radio transmissions usually have a low-level 23kHz pilot-tone so that automatic monitoring equipment can detect the presence of modulation. This is not possible with lf or mf transmissions because of the limited audio bandwidth, so a Programme Failure Monitor Unit, connected to the audio output of the receiver, is used as a modulation monitor. However, when the transmitter goes off the air, the receiver automatic gain control increases the sensitivity, and noise or unwanted transmissions would be present at the audio output, holding the monitor on. To prevent this, the receiver incorporates a muting circuit whose threshold level can be set by a front panel control.

5 Circuit description

5.1 Signal circuits

The block diagram (Figure 2) shows a conventional

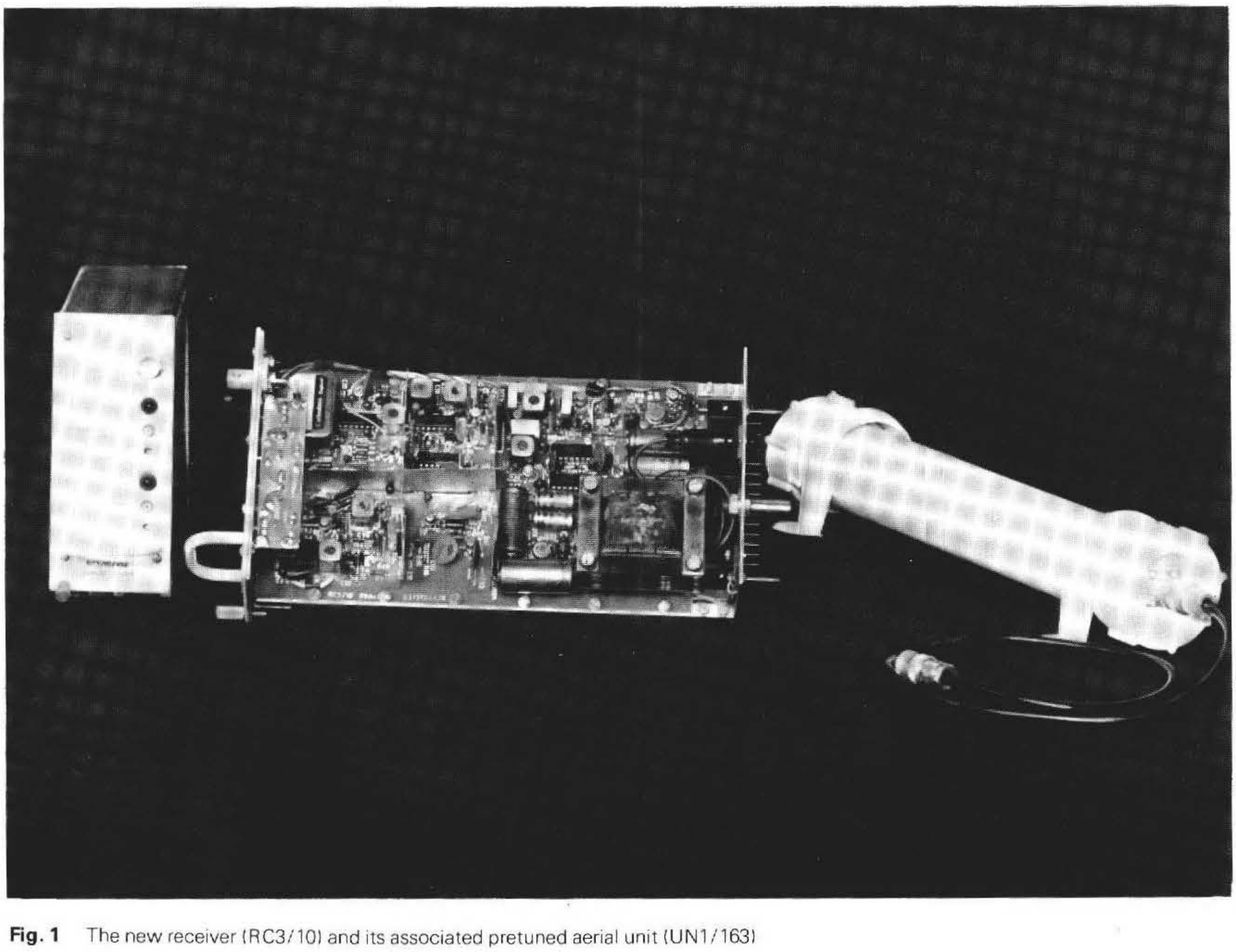


Fig. 1 The new receiver (RC3/10) and its associated pretuned aerial unit (UN1/163)

superheterodyne receiver to which have been added the synchrodyne features and operational facilities. The required signal is selected by a bandpass circuit of medium 'Q' so that adjacent channels are only slightly attenuated. The radio-frequency amplifier is a dual-gate, field-effect transistor with the signal applied to gate 1. The second gate has delayed automatic gain control and at input levels exceeding 1mV gain reduction is achieved by reverse bias. This maintains a reasonable signal-to-noise ratio at the following mixer stage without overloading or cross-modulation. The signal is transformer-coupled to the transistor mixer which is also driven from the crystal-controlled local oscillator at a frequency 10.7MHz higher than the signal frequency. Thus the intermediate-frequency signal at 10.7MHz is derived and passed to the crystal filter where the signal bandwidth is restricted to ±6kHz with rapid attenuation at 10 dB/kHz on each side and an insertion loss of 4 dB.

5.2 Automatic gain control

After the crystal filter, the signal is amplified in an integrated circuit which also contains the automatic gain control processing. This integrated circuit is one which was designed specifically for use in television receivers, but has also proved satisfactory in this role. The output of the synchronous demodulator goes more positive with increasing input level and signals derived from this in the agc-processing integrated circuit are used to control the gain of the intermediate-frequency and radio-frequency stages. Control is maintained over an aerial input range from 4μV to 400 mV with negligible change of audio output level.

The audio output frequency range from the demodulator is restricted to 5kHz by further audio filtering before the signal passes via the muting circuit to the output power amplifiers which provide push-pull output by using the common-mode, phase-splitting input drive configuration.

5.3 Carrier drop and carrier fail detectors

One output from the agc-processing integrated circuit is a voltage proportional to the agc action, which is in turn proportional to the applied signal. This voltage is applied to a dual voltage comparator, one half of which functions as a 'Carrier Drop' detector with the threshold level determined by a front panel control. Normal reception is indicated by the illumination of the 'Carrier Drop' front panel lamp. The other half of the comparator functions as a 'Carrier Fail' detector which controls the audio muting and the 'Carrier Fail' front panel lamp. Both detectors operate transistors as switches across pairs of contacts on the rear connector. For normal operation the transistors are in conduction, each capable of taking 200 milliamps, and in the 'Fail' condition they are capable of withstanding 50 volts.

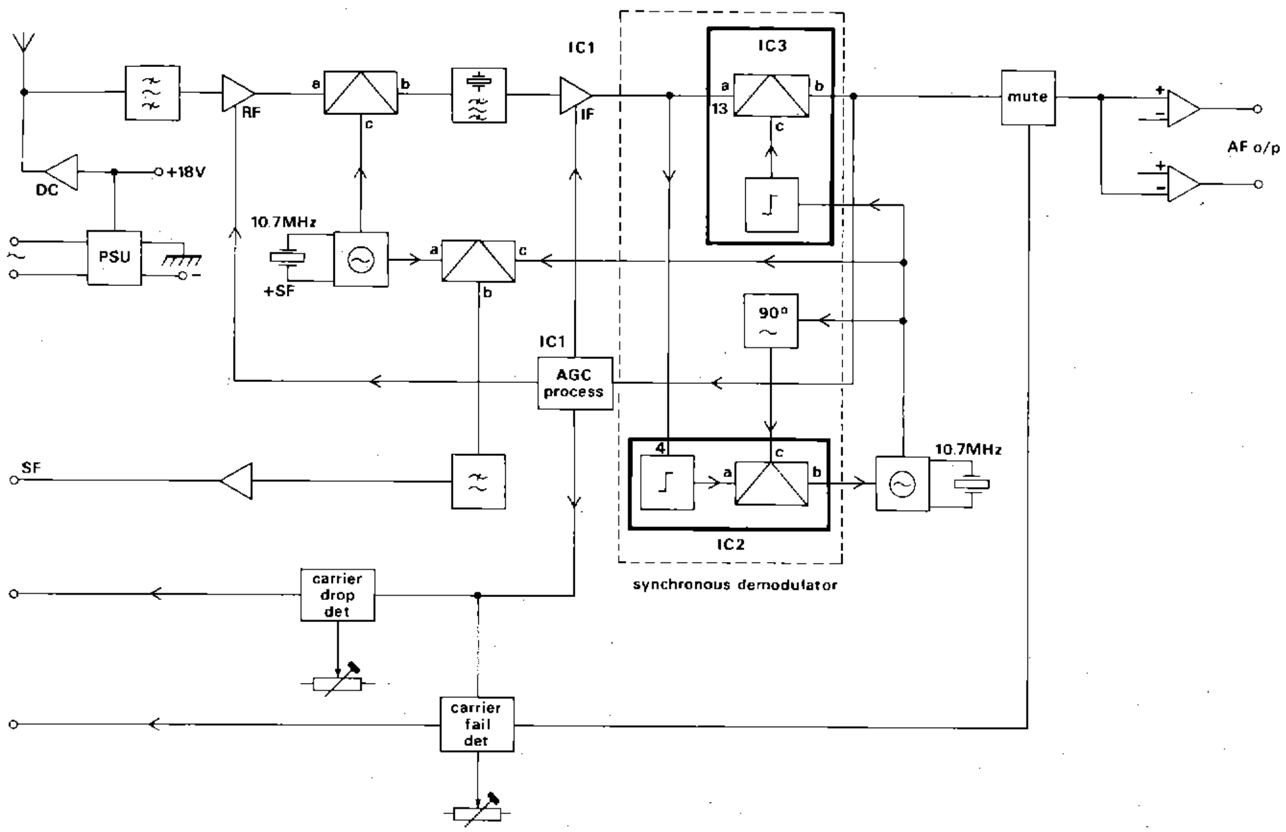


Fig. 2 Block schematic diagram of complete receiver.

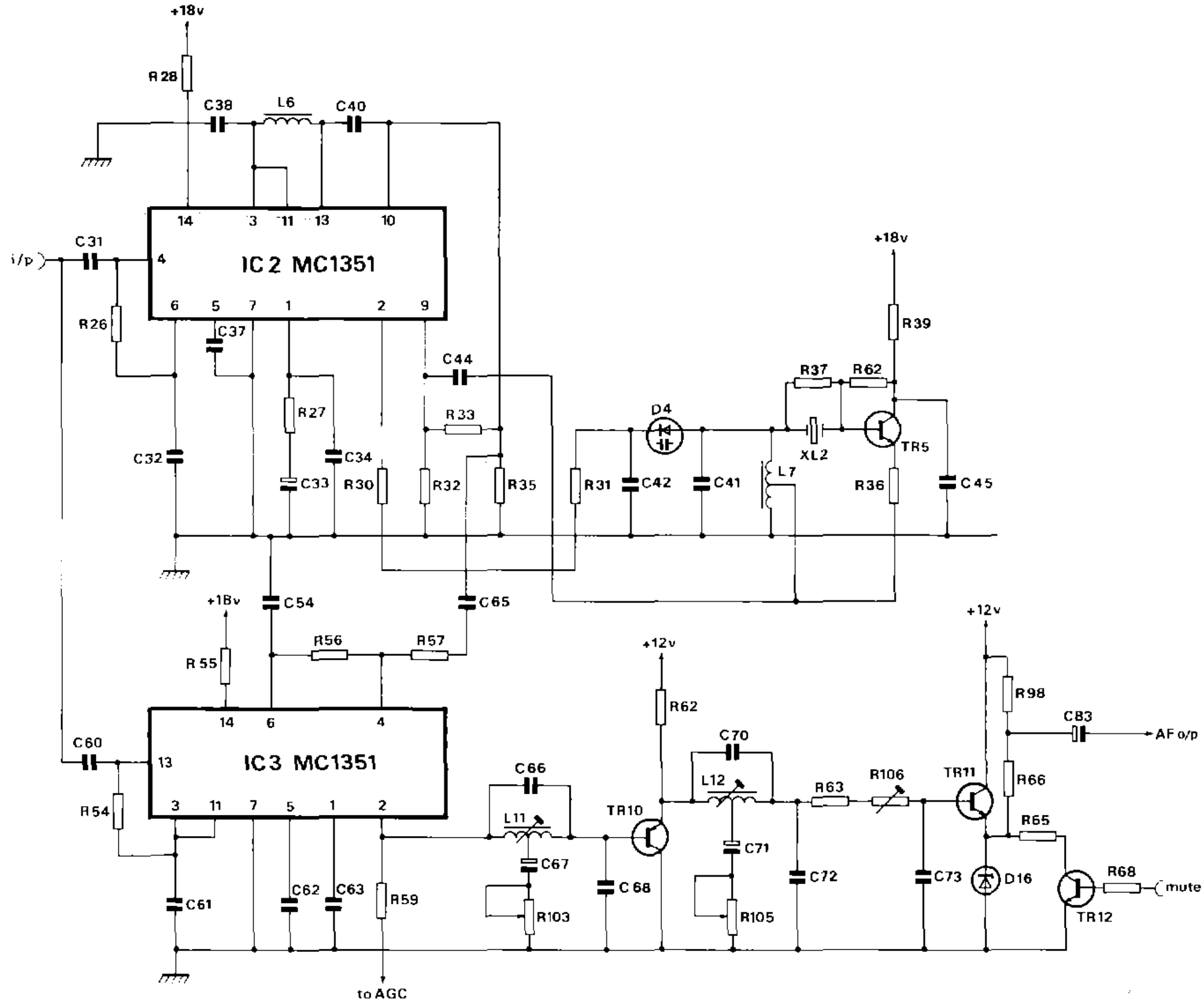


Fig. 3 Circuit diagram of synchronous demodulator and associated stages.

5.4 Synchronous demodulator

The circuit diagram is shown in Figure 3. It consists of two identical integrated circuits and a crystal oscillator which together function as the synchronous demodulator. Fifty millivolts of intermediate-frequency signal (10.7MHz) is applied to the limiter input of IC2 and limiting action is maintained down to an input level of 100 μV, representing 54 dB compression of the signal at peak modulation. Within the integrated circuit, the limited signal becomes the reference signal for the demodulator. In this screened compartment of the receiver is the 10.7MHz crystal-controlled oscillator, the output of which passes to the buffer amplifier at IC2. One output of the amplifier passes through a 90° phase-shift network (C40 and L6) and is then applied via pin 13 to the demodulator which functions as the frequency and phase detector. The phase detector output (at pin 1) has alternating and direct components, the latter of which is proportional to the phase difference between the reference signal and the crystal-controlled oscillator. This signal is processed by a filter with a cut-off rate of 6dB/octave and a noise bandwidth of 150 Hz, then via pin 2 of IC2 to the variable-capacitance diode, D4, which controls (to a limited extent, approximately $\pm$1kHz) the crystal oscillator frequency. This completes the automatic phase-controlled loop necessary to lock the crystal oscillator to the intermediate-frequency signal irrespective of any amplitude modulation.

A second output from the buffer amplifier in IC2 is passed to IC3 (pin 4) where the limiting amplifier changes the sinewave input to a square wave as the new reference signal. The intermediate-frequency signal enters the demodulator at pin 13 of IC3 where it is synchronously demodulated and the resulting audio and the dc level proportional to the carrier level are available at pin 2 of IC3.

Further band-shaping is provided by the 'bridged T' rejector filters L11 and C66 resonating at 6kHz, and L12 and C70 resonating at 6.7kHz which restrict the response to 5kHz with negligible after-response.

5.5 Audio frequency muting

The normal operating condition is for transistor TR12 (see Figure 3) to be in conduction and this in turn maintains conduction in TR11 through which the audio signal passes. With operation of the Carrier Fail detector, TR12 is switched off and TR11 is reverse-biased by the resistors R66 and R98, so impeding the passage of the audio signal. Further attenuation of the audio signal is provided by the zener diode D16 going into conduction.

5.6 Power supply

The receiver contains a mains power supply which provides a regulated 18-volt positive output and a negative bias voltage for the agc-processing circuit and the radio-frequency stage field-effect transistor.

A constant current of approximately 10 mA is available at the aerial socket to power the aerial unit.

6 Unit construction

The receiver is constructed on a single printed-circuit board mounted on a chassis with front and rear panel, the printed-circuit board being screened and protected by a metal base cover and wrap-round lid. The complete unit is 223 mm deep, 127 mm high and 54 mm wide. All connections except for the aerial are made by a 15-way inline connector at the rear of the unit. The front panel has the BNC aerial socket and two pre-set controls (Carrier Drop and Carrier Fail) with their respective lamps. The high-frequency circuits on the printed board are in four separate screened compartments to prevent crosstalk.

7 Aerial unit

For some time now long and medium-wave receivers have used internal ferrite receiving aerials, but for remote receiving aerials it has been common practice to use various wired aerial arrays coupled to a cable to feed the receiver.

The UN1/163 pre-tuned directive aerial, developed for use with the receiver, has a bundle of six ferrite rods around which is a tuned inductor of multi-strand wire on a low-loss former, of suitable dimensions for optimum pick-up at the required frequency. A low 'Q' circuit is coupled into this circuit in order to widen the passband to ±5kHz, so maintaining the required passband. A loop coupling on the main inductor passes the received signal to a transistor voltage amplifier which is followed by a complementary Darlington output stage. The output signal (at 50 ohms impedance) passes to the BNC connector on the front panel. The overall gain of the unit is adjusted so that the level of the output signal (when terminated in a 50-ohm load) approximately equals the field strength of the received signal.

The receiving aerial was based on a design originally developed by engineers at the BBC Washford transmitting station during 1966/68.

8 Diplexer FL1/44

The diplexer allows low, medium and high frequency signals to be combined onto, or separated from, a common cable with negligible insertion loss. It enables the receiver and its associated aerial unit to be economically installed at sites where there are already coaxial cables carrying vhf signals. The diplexer consists of a simple capacitor/inductor band-splitting network suitable for 50-ohm termination. The dB crossover point occurs at approximately 11MHz and the cut-off rate is 6 dB/octave.

By combining the output of the Aerial Unit with that from an omnidirectional aerial (a vertical wire, for example), a cardioid radiation pattern is obtained. Careful phasing and level control at the combining point can produce a front-to-back ratio of at least 40 dB.

References

1. 'The Synchrodyne'. D.G. Tucker. "Electronic Engineering", 19th March 1947.

UHF Television: Requirements for Long-Term and Short-Period Carrier Drive Frequency Stability

R. V. Harvey, BSc., MIEE,

Research Department

Summary: The frequency stability required for the carrier drives of a group of co-channel television transmitters is examined theoretically. An upper limit is suggested for the permissible levels of long-term frequency drift and of frequency modulation uncorrelated with the video waveform. This takes into account both protection against co-channel interference and impairment of the received picture in the absence of interference. Also considered are the requirements of the inter-carrier sound signals where the sound and vision carrier drives are separate.

The results are given for both nominal and precision offset working.

1 Introduction

System I television transmissions in the UK have carrier frequencies which are maintained within ±500 Hz of either the nominal carrier frequency or one offset by ±⅔ line frequency (approx. ±26·0 kHz). For this nominal stability, the CCIR[1] recommends a protection ratio against tropospheric co-channel interference at ⅔ line offset of 30dB and indicates that this may be reduced to 22 dB if each transmitter has a 'precision-offset' stability of ±1 Hz. Brown[2,3] has suggested, however, that the protection ratio for precision-offset working should be 24 dB, even when the carrier-frequency stability is ±1 Hz. From the work of Hopf,[4] the frequency stability should be ±1·25 Hz in order to ensure that the protection ratio does not rise by more than 1 dB above the precision-best value.

These protection ratios apply to carrier frequencies which are within tolerance on the assumption that the frequencies are constant during an assessment. However, a specification has not yet been agreed which describes precisely how the frequency may be permitted to fluctuate on a short-term basis, that is to say what degree of frequency modulation or phase flutter can be allowed, bearing in mind that these may affect not only the visibility of interference but also reception in the absence of interference, and that some domestic receivers may use quasi-synchronous demodulators.

This article is concerned only with phase modulation produced in the carrier drive unit (e.g. a frequency-synthesiser) before picture-modulation is applied, not with picture-correlated phase perturbations which may occur in signal amplifiers and modulators.

2 Requirements for short-period stability

It is possible for short-period fluctuations in carrier frequency, which may be caused within the vision-carrier drive unit, to be intolerably large without the frequency averaged over a short time being outside the presently specified tolerance. A specification covering short-period fluctuations is therefore desirable:-

(i) to cover existing practice with nominal (±500 Hz) stability
(ii) to cover requirements with precision stability (±1·25 Hz)
(iii) to protect inter-carrier sound reception from impairment by audio-frequency fluctuations in the case of separate vision-carrier and sound-carrier drives.

Figure 1 gives suggested curves for the maximum permissible peak deviation of the transmitter frequency as a function of modulation frequency for the latter three conditions. These curves will be discussed in detail with regard to picture and sound quality respectively.

2.1 Picture protection

Figure 1 curve (a) refers to the precision stability condition; the values which it indicates for the maximum allowable frequency deviation are supported partly by observations and partly by theory, as given in the following paragraphs.

Considering first the condition of co-channel interference from another transmission having a relative frequency offset of (n±⅔) line frequency where n is a small integer, there is an interference pattern containing about 100 horizontal light and dark bars which are easily visible when they are nearly stationary. If the transmissions each have precision stability and if the offset frequency is arranged to be exactly an odd multiple of half the field frequency ('precision best'),

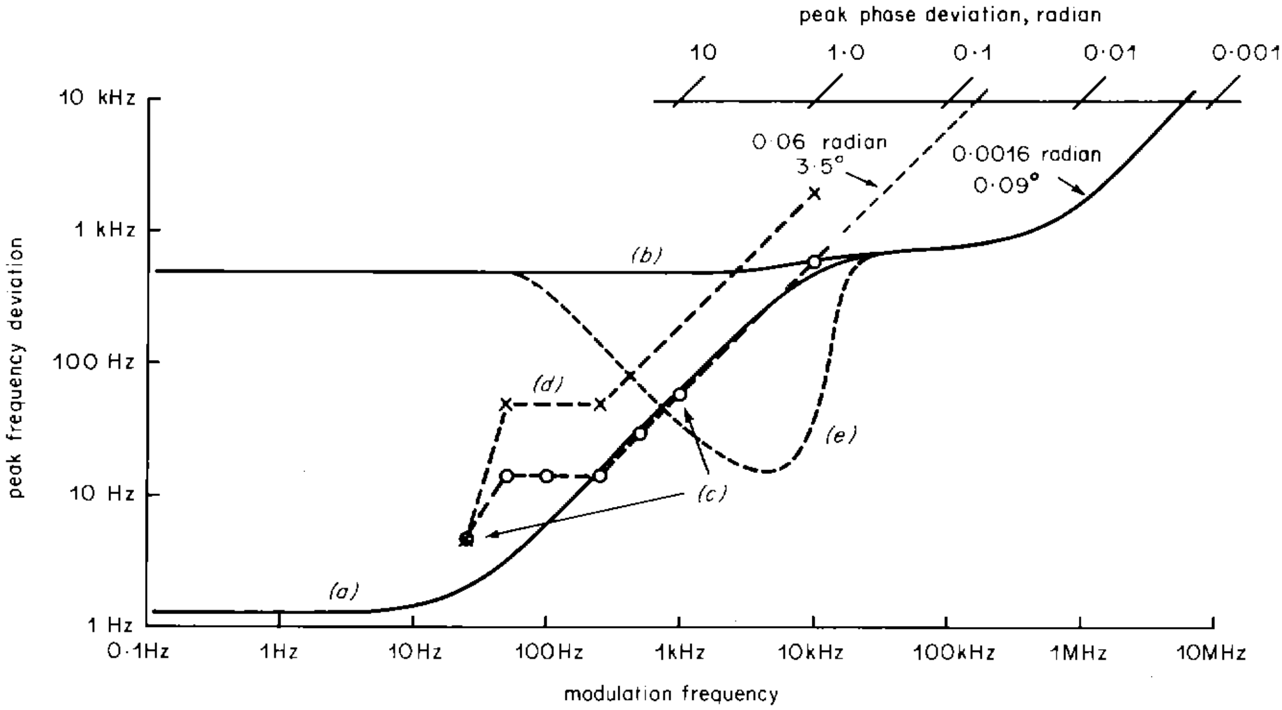


Fig. 1 Suggested limits for frequency modulation of carrier drive for System I transmissions using nominal and precision offsets

(a) precision stability ±1·25 Hz

(b) nominal stability ± 500 Hz

(c) precision stability (Reference 5)

(d) precision stability (Reference 6)

(e) additional limitation for separate sound and vision drives

then the bar pattern alternates in phase on succeeding interlaced fields and is least visible, requiring a protection ratio some 8 to 14 dB less than that of the stationary pattern.[1] The required ratio will increase by no more than 1 dB if the offset frequency remains within ±2·5 Hz of the optimum condition. For this to apply, each transmission must have the stability of ±1·25 Hz as mentioned in Section 1. This determines the tolerance at the low-frequency end of curve (a) in Figure 1. A frequency deviation of ± 1·25 Hz would be expected to be the allowable maximum at modulation frequencies of up to about 10 Hz.

To assist in determining the permissible levels of frequency or phase modulation at frequencies between 25 Hz and 10 kHz, some experimental evidence is available from work done in France.[5,6] Reference 5 describes tests carried out to assess the peak frequency deviation of the interfering carrier that gave a perceptible increase in the required protection ratio in a precision (n ±⅓) line-offset situation with a wanted-to-interfering-carrier ratio of 22 dB. The results obtained are shown in curve (c) of Figure 1. Reference 6 describes other tests made with similar conditions and yielding somewhat different results, shown in Figure 1 as curve (d).

The permissible levels of phase modulation shown in these two curves differ by some 10 dB over most of their frequency range. The central portion of the suggested limit curve has been drawn to coincide with curve (c) for reasons which are discussed in Appendix 1.

Although the above-mentioned theoretical support for the middle section of curve (a) of Figure 1 is restricted to the precision (n ±⅓) line-offset situation, no more stringent requirements are expected of precision zero-offset working.

For a nominal tolerance of ±500 Hz, no relaxation is shown in Figure 1(b) for phase deviation at modulation frequencies of up to 10 kHz although, in general, a phase perturbation would tend to reduce the pattern visibility and allow a relaxation for the same protection ratio. It has in fact been suggested[7] that the protection ratio for nominal offsets could be reduced by introducing a particular form of phase jitter in the drive unit.

A theoretical consideration of the effects of frequency modulation of the wanted signal at modulation frequencies higher than 10 kHz suggests that this should be limited to a peak deviation of 0·8 kHz in order to prevent the amplitude modulation, which is caused by the asymmetry of the receiver v.s.b. characteristic, from impairing the picture (see Appendix 2). Above about 1 MHz the asymmetry is complete and the peak phase deviation should then be limited to about 0·0016 radian, as shown in Figure 1, curve (a). With this limitation, the picture impairment caused by phase flutter a frequencies above 10 kHz will be no greater than grade 1½.

The characteristics of synchronous detector receivers[8] may cause errors in the demodulated video signal level if the signal is phase-modulated at a frequency higher than about 0·5 MHz. However, the restriction to 0·0016 radian peak phase modulation will be more than adequate to prevent any significant impairment from this cause.

The foregoing derivation of curves (a) and (b) is believed to be valid for a phase perturbation at a single frequency but no attempt has been made to assess the effects of two or more simultaneous perturbations. For example, if the offset frequency is at the limit of the long-term average tolerance, then the permissible additional deviation of the offset frequency will be smaller than that shown in Figure 1.

2.2 Sound protection

The protection ratios required for co-channel television transmissions at the frequency offsets normally adopted give adequate protection for the sound signals as well as the picture signals so that the question of additional safeguards for the sound signal in the presence of interference does not arise. However, phase disturbances in the drive unit may affect the sound signal in the absence of co-channel interference.

If the carrier frequency drives for the vision and sound transmitters are separate (either partly or entirely), then any independent phase disturbance in either drive will appear as a phase disturbance in the 6MHz inter-carrier beat signal which is frequency-demodulated in the sound-channel circuits of domestic receivers. As an example of the audible impairment, the threshold of perceptibility for a 7kHz continuous tone is about 75dB below peak programme level. The system peak deviation is ±50kHz and, taking into account the aural weighting curve (CCIR Rec. 468) and the attenuation caused by the standard 50 μs de-emphasis circuit in the sound channel, the permissible peak frequency deviation is shown by the broken curve in Figure 1(e). If precision offset is employed, the permissible deviation is given by Figure 1(a) or Figure 1(e), whichever has the lower ordinate.

3 Conclusions

For the two cases of long-term frequency stability of transmitters commonly referred to as 'nominal offset' and 'precision offset' conditions, the requirements for short-period stability have been estimated, based partly on available experimental data and partly on calculation.

References

1. CCIR XIIIth Plenary Assembly, Geneva 1974. Report 306-2.
2. Brown, A. 1967. Television co-channel interference: PAL transmissions. BBC Research Department Report No. 1967/62.
3. Brown, A. 1968. Television co-channel interference: protection ratio for five-thirds line frequency precision offset of carriers with moving pictures. BBC Research Department Report No. 1968/21.
4. Hopf, H. 1958. Experiments on the operation of television transmitters with precision offset carrier frequencies, Rundfunktechnische Mitteilungen, 1958, **2**, 6. pp. 256-276.
5. CCIR Doc. 11/94 (France) Period 1970-1973.
6. Keller, A. 1972. Synthétiseur d'emetteur: modulation de fréquence de la porteuse image admissible dans le ca du décalage de précision. Etude 17903/A/72, ORTF, January 1972.
7. Page, H. 1970. Minimising co-channel interference in television reception. Electronics Letters. 1970, **6**, 15.
8. Harvey, R.V. 1970. UHF Television: impairments to domestic reception with envelope and synchronous detectors caused by carrier phase perturbations in relay transmitters. BBC Research Department Report No. 1974/6.

Appendix 1

Calculation of tolerance for fluctuations at frequencies between 25Hz and 10kHz

In a precision-offset interference situation, visible effects are reduced because the striped patterns are interlaced on alternate fields. If, now, either of the two vision carriers involved are phase-modulated at a modulation frequency exactly equal to the field frequency (25Hz) or to an odd harmonic of the field frequency, alternate fields will contain, over part of the picture, interference patterns which are displaced in opposite directions and so a stationary pattern will reappear. This stationary pattern is easily visible at a low level and if we make some assumptions about the way in which the protection ratio required for the precision-best pattern is increased by the presence of the stationary pattern, then we can calculate the phase deviation which will give rise to a 1dB increase in the protection ratio. The increase in the protection ratio can be described by the expression $p^a + q^a = r^a$, where p and q are the protection ratios in voltage terms required for the two interference patterns separately (i.e. the precision-best pattern and the stationary pattern), r is the protection ratio required for the combination of the two and a is an exponent representing the law of addition, such that $a = 1$ for linear addition and 2 for square-law addition.

From the foregoing, we can calculate the values of a that correspond to the two different levels of permissible phase modulation, 0·06 radian and 0·2 radian, given in curves (c) and (d). In making this calculation, we must bear in mind that the amplitude of the stationary pattern must be between 8 and 14dB (say 11dB) below that of the precision-best pattern which requires the same protection ratio and that it will be proportional to the sine of the phase displacement when the latter is small. Thus, the permissible values of phase deviation given by curves (c) and (d) of 0·06 radian and 0·2 radian respectively, yield stationary pattern amplitudes that are 24·6dB and 14dB below that for the 'precision worst' condition and hence protection ratios that are 13·6dB and 3dB respectively below that for precision best.

Normalising to $p = 1$, the values of a that correspond to the conditions for curves (c) and (d) are given by the following:—

for curve (c), $1 + 0{\cdot}21^a = 1{\cdot}12^a$ or $a = 1{\cdot}2$

and for curve (d), $1 + 0{\cdot}71^a = 1{\cdot}12^a$ or $a = 2{\cdot}8$

For the summation of two different interference patterns of this type which are related coherently, the value of $a = 1{\cdot}2$, i.e. a very nearly linear addition, is thought to be much more likely than $a = 2{\cdot}8$. Hence the central portion of the suggested limit curve has been drawn to coincide with curve (c).

Appendix 2

Calculation of tolerance for fluctuations at 10 kHz and above

The calculation of the permissible frequency modulation or phase modulation of the carrier drive at modulation frequencies of 10 kHz and higher is based on a consideration of the asymmetry of the f.m. sidebands after passing through the vestigial sideband response of a television receiver. This asymmetry causes amplitude modulation of the carrier. The picture impairment produced by this amplitude modulation may be equated with the impairment caused by an interfering signal at a frequency which differs from the vision carrier frequency by the frequency of the unwanted phase or frequency modulation.

In order to equate these two impairments, an allowance must be made for the fact that the amplitude of the video-frequency component caused by the unwanted modulation process is proportional to the vision carrier amplitude whereas that caused by an added c.w. interference is independent of the vision carrier amplitude. It is assumed, taking into account both the magnitude of the unwanted modulation component and its visibility against the background, that it will have the greatest effect on the picture signal in dark grey areas of the picture where the vision carrier amplitude is about 70% of the peak sync level. The permissible modulation depth is therefore about 1·4 times (3 dB higher than) the ratio of permissible interference level to the peak sync carrier level. The permissible c.w. interference level is assumed, for this purpose to be 15 dB lower than the CCIR levels[1] acceptable for 1 to 10% of the time for planning purposes. The limiting modulation depth may therefore be taken at 12 dB below the CCIR levels, leading to a ratio of −62 dB, ignoring the relaxations below 100 kHz and above 1 MHz which are allowed by the CCIR protection ratio curve.

Consider the vestigial-sideband filter response of an ideal television receiver, which rises linearly from zero at $f_0 - f'$ through 0·5 at f_0 to 1·0 at $f_0 + f'$, where f_0 is the vision carrier frequency. Let the vision carrier have unit amplitude and be sinusoidally phase-modulated at a frequency f with a peak phase deviation of $\Delta\phi$ radian (<< 1) corresponding to a peak frequency deviation of $\Delta f = f\Delta\phi$.

The asymmetrical response of the filter to the carrier sidebands at $f_0 - f$ and $f_0 + f$ can be regarded as converting them into a pair of quadrature sidebands with identical amplitudes plus an additional signal at the upper sideband frequency $f_0 + f$ with an amplitude, after filtering of

$$\tfrac{1}{2}\Delta\phi\frac{f}{f'},\ 0 < f < f'$$

Since the attenuation of the filter at frequency $f_0 + f$ is

$$2f'/(f' + f),\ 0 < f < f',$$

the amplitude of an interfering signal which, when added to the carrier before the v.s.b. filter, produces the same effect as the phase modulation, will be

$$f\Delta\phi/(f' + f) = \Delta f/(f' + f),\ 0 < f < f'$$

When $f \geqslant f'$ the lower sideband will be zero and the equivalent interfering signal level becomes $\tfrac{1}{2}\Delta\phi$. With the ideal v.s.b. receiver response for television System I, $f' = 1{\cdot}25$ MHz; however, there is evidence that in in the majority of UK receivers the vestigial flank is somewhat steeper than the ideal. For the purposes of this report, it has been assumed that $f' = 1$MHz. Thus, at modulation frequencies of 1MHz and higher, we may equate this level with the level of −62dB as explained earlier in this Appendix, leading to a constant phase modulation limit of

$$\Delta\phi = 0{\cdot}0016 \text{ radian} \qquad f \geqslant 1\text{MHz}.$$

When $f << f'$, the equivalent interfering signal level becomes approximately $\Delta f/f'$ so that, taking a typical value of f' of 1MHz, we equate this level with the level of −62dB as explained earlier, leading to a frequency deviation limit of

$$\Delta f = 800 \text{ Hz} \qquad f << 1\text{MHz}$$

As f approaches 1MHz, Δf becomes proportional to f, as shown above and in Figure 1.

Robert ('Bob') Harvey joined the BBC Research Department in 1950. Working at first in Radio Group, he was concerned with the effects of multipath propagation on the reception of f.m. broadcast transmissions. In 1967, he joined the team developing the Field-Store Standards Converter and engineered some novel techniques for equalising quartz delay lines.

Returning to Radio Group in 1970, he led a team developing an experimental digital modulation system for television distribution by satellite. At present he is collaborating with the European Broadcasting Union in planning the efficient use of the 12GHz frequency band for direct television broadcasting by satellite to 100 countries in Europe and Africa, in preparation for the World Conference in January 1977.

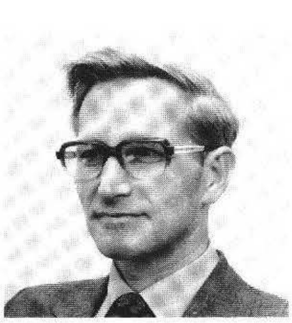
G. G. ('Johnny') Johnstone is a graduate of King's College, London, and has been with the BBC since 1948. His first post was in Radio Outside Broadcasts, after which he joined the Engineering Training Department as a technical author. He became well-known because of his writing partnership with S. W. Amos which resulted in numerous articles in the technical press on frequency modulation and allied subjects.

He transferred to the Designs Department in 1960 where his early work concerned vhf television translators and the BBC's standard fm modulator. He did pioneering work on automatic monitoring techniques and became Head of Automatic Control Section. Since 1971 Johnny Johnstone has been Head of RF Section where his responsibilities have included the development of radio link equipment and television transposers.

James Redmond has been Director of Engineering of the BBC since 1968. He was educated at Falkirk Technical School and Caledonian Wireless College, Edinburgh. After a year as a Marine Radio Officer, he joined the BBC in 1937. He was a sound engineer in Edinburgh during 1973/38, later moving to London where he was a vision mixer in the television service in 1938/39.

During the war Mr. Redmond returned to the Merchant Navy and served in various ships until he rejoined the BBC in 1945. He was a planning and installation engineer until 1954, and then became Assistant Superintendant Engineer Television (Film), a post which he held until 1960 when he was promoted to Superintendant Engineer Television Recording. He became Superintendant Engineer Television Regions and Outside Broadcasts in 1962, Senior Superintendant Engineer Television in 1963, and in 1967 was appointed Assistant Director of Engineering.

Mr. Redmond is a Fellow of the Institution of Electrical Engineers, a Member of the Institution of Electrical and Electronics Technician Engineers, a Fellow of the Society of Electronic and Radio Technicians and a Fellow of the British Institute of Management. On 1st October 1973 he was appointed as Vice-President of the IEE for a three-year term of service.



Peter Tingey qualified as an Artificer Telecommunications in the Royal Electrical and Mechanical Engineers and was later employed in industry as a colour television engineer. In 1963 he joined the Designs Department of the BBC where he was involved in the investigation of colour television systems and the design of associated equipment. His recent work has included the development of a variety of uhf, vhf, mf and lf receivers and he has adapted domestic colour television receivers for monitoring purposes.