The Journal of

THE BRITISH INSTITUTION OF RADIO ENGINEERS

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"To promote the advancement of radio, electronics and kindred subjects by the exchange of information in these branches of engineering."

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A RARE OCCASION

The dinner of the Institution held at the Savoy Hotel on May 1st last was the first of such functions to take place in the capital since 1951, when a banquet was given as a prelude to the opening of the Festival Convention. The holding of a formal Institution dinner in London is, therefore, a rare occasion for the Officers, Council and members to entertain eminent scientists and those who support the work of the Institution.

On May 1st a number of guests distinguished in the fields of science, engineering, learning, government and industry were welcomed. Members and guests were received by Admiral of the Fleet the Earl Mountbatten of Burma, Vice Patron of the Institution, and by Mr. G. A. Marriott, President.

Before the speeches commenced, Admiral Mountbatten read a message from Her Majesty The Queen, Patron of the Institution, thanking members for their loyal greetings. Messages of good wishes were also received from representatives of the Institution's members all over the world.

It is felt that all members will be interested to have a record of the speeches made on such a rare occasion.

Sir Cyril Hinshelwood, M.A., D.Sc. (President of the Royal Society) proposed the toast of **"The Institution"**

"You will have noticed how the same set of facts is often used to support diametrically opposite conclusions. My presence here tonight, in my capacity of representing the Royal Society, might be taken as a symbol of how much electronic and radio engineering owe to pure science, or conversely how much pure science has come to depend on electronic engineering. For once both contentions would be true. Radio engineering is like one of those rivers with so many tributaries that the main source is hard to define. Nevertheless I should be inclined to start with Maxwell: in which case radio engineering may be said to spring from what was one of the most abstruse pieces of theoretical physics of its day.

"The tide is now flowing the other way. All of us who have the task of running laboratories know that we cannot get along nowadays without more and more elaborate (and costly) electronic equipment: but we would not for a moment question that value for money is obtained. Things are rendered possible that were once undreampt of and electronics has virtually given us a new sense to add to our other five.

"However, the tide will turn yet again: radio and electronic science will not stand still, and pure science will go on producing surprises, sometimes pleasant ones for you. Look at the revolution that the study of the properties of semi-conducting materials has brought about. This ebb and flow of dependence will go on, and I think the period of the swing will become shorter as time goes on.

"I understand that one of my predecessors at the Royal Society, Sir Robert Robinson, also a chemist, proposed this toast some years ago. Chemistry seems at first sight rather remote from electronic engineering. But it does play a

During the reception the Vice-Patron and the President talk with Captain J. D. M. Robinson, R.N. (Member)

vital part in your science, where the use of appropriate materials may make all the difference between success and failure. Modern chemical techniques offer almost endless variations in alloys, ceramics and plastic materials, of which your Institution takes full cognizance in its Surveys of Materials.

"Chemistry has an even more subtle part than this to play. Think of the possibilities which were opened in the past by the special properties of individual chemical elements, selenium, the alkali metals for photoelectric cells, silicon and germanium for transistors. I do not believe the list is closed. In fact I suspect that practically every chemical element has some uniquely useful property, and such properties are far from having been all discovered.

"There are of course many problems in bridging the gap between science and its applications, and the work of your Institution provides major help in this direction; through your interest in standards of education, through the Conventions you organize, and through your admirable *Journal*.

"Equally important is what you do in a more general way to maintain the standing of the profession. I was interested to read what was said in a recent Presidential Address to the Institution about the importance to electronics engineers of understanding management problems. One of the most vital needs in this country today is to escape from the situation where policy-making circles adopt an attitude of non-involvement about scientific matters, and the scientifically qualified people remain in 'back rooms'. Men of science, technologists, policy-making managers may at a given moment have in some degree to divide their functions, but they should never get far apart. They should never form separate castes, as they have tended to do in the past.

"Your Institution can do—is doing—much to ensure this essential end. You have in your hands one of the most potent techniques of the day. It permeates all science: it uses many other branches of science and it contributes to them all. It provides communications all over the world: it explores the universe. It gives us mathematical brains which surpass our own in speed and efficiency. And yet the material is nothing without the men. So we come back to you yourselves. You have great opportunities, and great responsibilities. The world is full of apprehension today. Literature too often breathes despondency and decay. But science is creative, and full of faith and hope.

"On that note may I ask you all to honour the toast of 'The British Institution of Radio Engineers'."

The response was made by The Institution's Vice-Patron and Past-President
Admiral of the Fleet The Earl Mountbatten of Burma, K.G.

After saying that it gave him great pleasure to be present and to reply to the Toast of the Institution, Lord Mountbatten continued:

"This month we celebrate the thirty-third anniversary of the foundation of the Institution, but we shall always be a very young body compared with the Royal Society, which is now approaching its 300th anniversary. We count it, therefore, a special privilege that the President of the Royal Society, and particularly Sir Cyril Hinshelwood, should have proposed the toast of the British Institution of Radio Engineers.

"We have a direct link with the Royal Society in that just a few weeks ago one of our own members, Professor Mitra, was elected a Fellow. Professor Mitra is actively associated with our Institution in India, and is well-known for his research work into the ionosphere. His election as a Fellow of the Royal Society provides yet another example of the recognition now being given to the importance of research work in radio and associated fields. His election also, of course, gives us all very great pleasure.

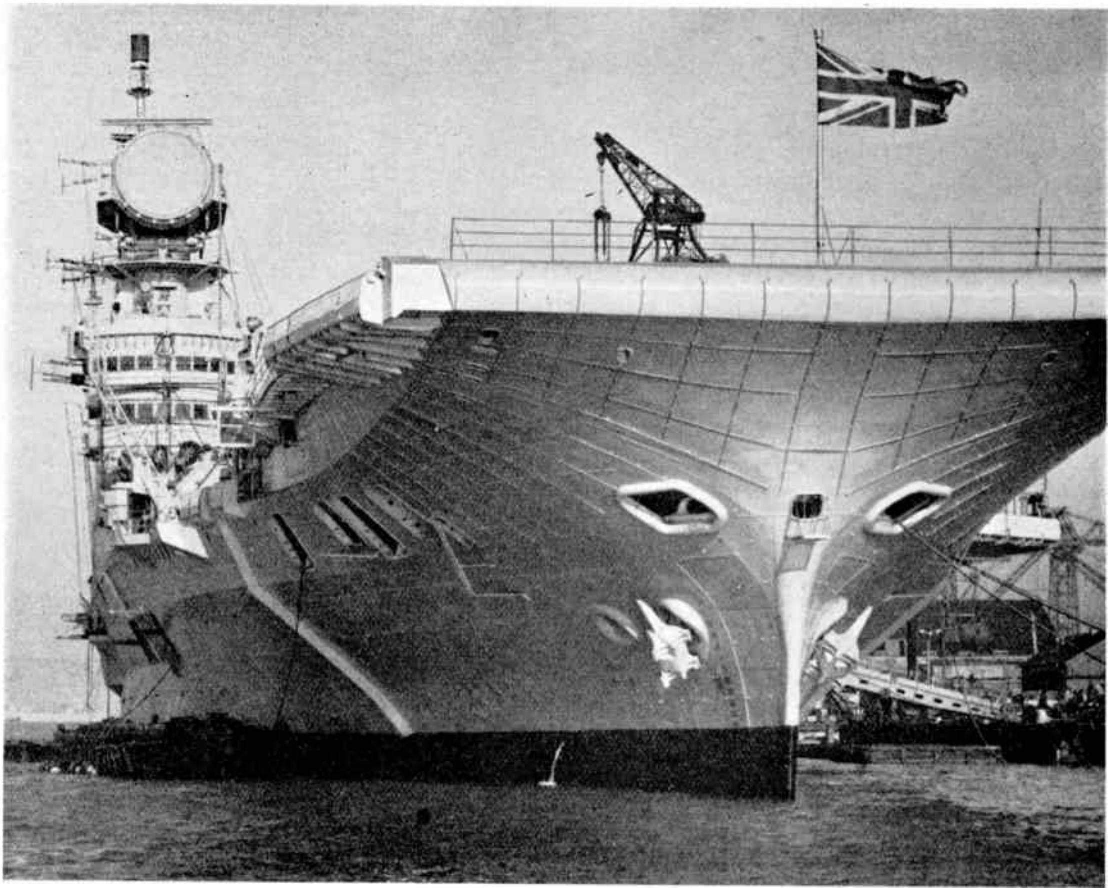
"On behalf of all our members I want to thank Sir Cyril for the most generous way in which he has proposed the toast of our Institution. We should, I think, take particular note of his comments on the inter-dependence of various branches of science. His reference to the usefulness of our reports on the materials used by the radio and electronics engineer will, I know, encourage our various committees to continue their work in this direction. I think Sir Cyril will agree with me that few other branches of applied science have shown so much development and change in so short a time as the one in which our members work.

"When I spoke at the dinner commemorating the Institution's 21st Anniversary in 1946, I gave early information about the new electrical computers, E.N.I.A.C. in the United States and A.C.E. in the United Kingdom, and referred to them as electronic brains. Although the purists criticized this term on the grounds that these machines cannot think, it has nevertheless become the popular description of one of the most striking achievements of the twentieth century. Since then vast strides have been made in many diverse directions but this evening I want to make particular mention of one great Naval achievement.

"Our scientists and designers, supported by the radio industry of this country, have now produced equipment which revolutionizes the operational effectiveness of a modern warship, and which gives to the Captain and his officers powers undreamed of in the past. I am referring to the combination of Type 984 radar and its comprehensive display system which is essentially the eyes, brain and central nervous system of the ships in which it is installed. Integrated with the directing intellect of the human staff, it constitutes a device of almost fabulous performance without which modern warships would be highly vulnerable to long range attack from the air. When compared with our previous radar and with that in service anywhere else in the world, this system can be described in Ford language as a 1958 model as opposed to a Model T.

"It is now installed and in operation in our latest aircraft carrier H.M.S. *Victorious*. The unitiated, looking at this ship or seeing pictures of her, may wonder why she carries an enormous searchlight on the island superstructure. Some might wonder if this contains some new form of black light or possibly even a magic eye. It is indeed a form of magic eye which, in conjunction with its electronic brain between decks, not only gives the Captain phenomenal far sight but also provides him with infinitely greater powers of calculation and judgment than his own eyes and brain could produce unaided.

"The eye part of this system is a revolving stabilized structure which weighs 27 tons and incorporates many new ideas. Like the human eye it uses a radio lens instead of a reflector, and for much the same reason. If a reflector were used the various scanners would obstruct the actual radar beams. Also by using the lens, greater flexibility in aerial design is achieved. The radio lens is made up of hundreds of short



Crown copyright] [Block by courtesy of Marconi's W.T. Co. Ltd.

A view of H.M.S. Victorious *showing the scanner of its Type 984 radar mounted on the "island". Aerials for other radar, communications and direction finding equipment are also shown.*

sections of different length waveguides stacked together like a honeycomb. It has an *F* value of 1, which gives greater collecting power than the best camera lens.

"There is one way, however, in which this eye copies the bat rather than the human being. It sends out its own sort of illumination in the form of a number of narrow pencil beams all sharing the same lens. One of these is fixed in elevation and provides the long range warning while the others make a co-ordinated scan of various sections of the target area as the rotating structure revolves.

"Like the human eye again, this radar antenna unit sends a hotchpotch of impulses to the 'brain', in this case an elaborate electronic computer system in the superstructure of the ship. These impulses, though quite meaningless in themselves, contain all the information on airborne targets which is needed by the operational staff. To enable them to make full use of this information, there is a very complex display system which processes, stores and filters it so that it can be displayed in an easily intelligible up-to-date form. Range, height, bearing, speed and course are all provided and presented for easy use by a novel system of electronic writing. All the numbers and symbols required for identifying targets and for other purposes are written electronically on the display tubes themselves. This is achieved by a suitable combination of different wave-forms to produce Lissajous' characters of the required shape. Even for the most complicated characters not more than four of these waveforms is needed. As if this were not enough, a section of the brain known as the intercept computer works out for the control officer a future presentation of where and when his fighters will intercept or miss their targets if they continue on his present directions. These directions have also been computed for him.

"Even with all this elaborate and effective aid the operational staff of a warship, trying to compete with a mass air attack at modern high speeds and great altitudes, is faced with enormous difficulties. Almost instantaneous decisions have to be made, how best to use all the rapidly changing information.

"This brings me to perhaps the most important and most interesting aspect of these new developments, and that is the integration of man's intellect with his creation. For this system cannot, of course, be used and directed or maintained without the human intellect. By itself it can achieve nothing. Its sole purpose is to provide for the human element much more information than their own eyes and brains can handle unaided, and to help carry out the directions produced by the combination of man and machine.

"If equipment as complex as this radar and display system is to serve its purpose and not become a liability it must be maintained at its designed performance. Moreover this must continue as the equipment becomes older and therefore inherently less reliable. The system is, therefore, fitted with a comprehensive monitoring system. This is extremely important because the mounting cannot be worked on whilst it is in operation and the length of time when the system can be put out of action for maintenance must be kept to the bare minimum. It is, therefore, only by continuous and careful monitoring that the system can be efficiently serviced during the short periods when it can be shut down.

"For the same reason the units and components of the system must possess a very high standard of reliability. When Type 984 Radar was first planned serious doubts were expressed whether the valves and other components would be sufficiently reliable for them all to be kept in working order at once. This equipment uses about 10,000 valves and 100,000 components, to say nothing of a quarter of a million soldered joints, with 275 slip rings to the revolving structure. However, I am glad to say that this and other similar systems are now being operated and maintained at a very good standard of overall reliability, and this must reflect the greatest credit on all in the industry from top management to the worker at the bench.

"There is, of course, a price to pay for all such tremendous achievements and the financial cost is probably the greatest of these. I often wonder if the difference in costs between radio and electronic equipment in ships of the 1938 era and those of the present day is appreciated.

"So staggering are these differences that I will quote a few.

	1938 £	1958 £
Frigate/Destroyer ...	4,000	120-150,000
Cruiser	20,000	½ M.
Aircraft Carrier ...	12,000	Over 1 M.

To this must be added, of course, the huge expenditure on Research and Development.

"The other price is that complicated systems call for a higher degree of skill and personal qualities in our sailors than ever before. The men concerned with equipment of this sort need the ability to think quickly, they need mental endurance and they need sound judgment both in operating the equipment and maintaining it. I am very glad to say that we are getting a sufficiently high standard of recruits coming into the Navy to meet this formidable but fascinating task.

"I would also like to mention one other technique which the Navy is helping to develop—that concerned with the research into semiconductor devices. This is the use of semiconductors for the conversion of heat into electrical energy and vice versa. The principle of these devices has been known for over 100 years and has been used in thermo-couples for temperature measurement and for electric current meters. But it is only the intensive research of the last ten years that has produced substances which give conversion efficiencies big enough to be of practical engineering interest.

"There are, of course, many possible applications of such devices—for instance, the direct use of electrical energy in refrigerators and in the cooling of transistors. But for us in the Navy, the most dazzling possibilities it may offer arise from the opposite effect, the direct conversion of heat into electrical energy without the use of moving machinery—thus saving weight, space and maintenance effort. Materials so far developed cannot be used at very high temperatures, so the sources of heat which immediately spring to mind are diesel exhausts, funnel gases and boiler surfaces. These are all sources of waste heat and their direct conversion into electrical energy even at modest efficiencies, would be obviously particularly rewarding to us. Nuclear reactors so far developed are peculiar among modern primary sources of energy in that they work at similar temperatures to these waste heat sources. They, therefore, offer another most attractive field in the Navy for exploitation if these semiconductor devices can be made to work under the conditions existing inside a reactor.

"New techniques demand more than ever before that engineers as well as scientists have every opportunity to meet and discuss their problems and learn about new ideas. It is one of the principle functions of this Institution to encourage that attitude and in so doing to attract to the profession as many young men as possible trained to progress development from the stage where the older man leaves off. In this task I know we shall be encouraged by the remarks of Sir Cyril Hinshelwood to continue our efforts towards the advancement of radio and electronic science and the dissemination of knowledge of the art.

"I will end by stressing once again the continuing importance of the human element. As a fighting service so highly technical as the modern Navy we are and must be constantly mindful of this element. It is perhaps for this reason that I have found amongst our Electrical and other Engineers a special enthusiasm for character development and improving the officer/man relationship. It was my Fleet Electrical Officer and my Fleet Engineer Officer who were my chief supporters in introducing the Outward Bound Movement or Expedition Training with the Fleet when I was Commander-in-Chief Mediterranean.

"I feel this was because they realized that the higher the stage of development of man's achievements in the material field the greater becomes the importance of the man himself, not only in respect of his skill but equally in respect of his character and spirit. If this were to fail, man's finest creations could well rebound and become his undoing. So let us remember the spiritual as well as the material aspects of technical progress."

The President of the Institution proposed the toast of **"The Guests"**

In the course of his speech, Mr. G. A. Marriott said :

"It is seven years since we had an opportunity to welcome our friends to a function of this character in London. As many of our guests will know, social functions of this sort are usually held during the course of our Conventions, which are arranged at times when we feel there has been sufficient progress in our science to justify all the work involved. I think that our policy has been justified, as evidenced by the success of such Conventions as we held last year in Cambridge, which was attended by delegates from all over the world.

"Let it not be thought, however, that my colleagues and I do not enjoy these functions. We merely feel, as perhaps do some of our guests, that it is not good to get into the rut of holding annual dinners. Too many of them might be compared with the disadvantages of having too many exhibitions. In this latter respect I hold to the view that our industry is concerned with rather too many exhibitions at the present time. That is, however, a subject for another place.

"One disadvantage in not having an Annual Dinner is that it prevents us from meeting our friends so often as we would like. For that reason, I do extend a very hearty welcome to all our guests tonight.

"Arranging technical meetings and publishing a *Journal* are only two aspects of the Institution's work. We are also vitally interested in the educational field, and do our part in stimulating the training of both engineers and technologists. This is a subject of much importance to our country, and we are, therefore, very glad to welcome tonight Sir Harold Emmerson of the Ministry of Labour. We do assure Sir Harold of the Institution's co-operation in the work of his Department so far as it affects the radio and electronic engineer and industry.

"The Institution's educational work would be made very difficult indeed were it not for the help and co-operation given by the Ministry of Education and its various advisory panels. I therefore extend a very warm welcome to Mr. A. A. Part of the Ministry and Dr. W. P. Alexander of the Burnham Committee. Technical Colleges are playing an increasingly important part in the life of our country and I would like to convey our thanks for the way in which they are helping the Institution's work by providing suitable courses of study, and by giving facilities for the holding of our Graduateship Examination.

"For much the same reasons, we are also particularly pleased to welcome Air Vice-Marshal A. C. Kermode, the R.A.F.'s Director of Education. We have always appreciated the good relationship which exists between ourselves and the Armed Forces on the matter of training engineers, whether they are ultimately employed in the Forces, in Industry, or in Government Departments. Indeed, our happy relationship with the Armed Services first became evident around the time of Munich, when the possibilities of radio, and the new field of radar, were first being appreciated.

"A dinner such as this does not provide quite the same opportunity for our members overseas to attend, as do our Conventions. We have had numerous cables of good wishes and we are reminded of our overseas membership by the presence of Sir Ben Barnett, Chairman of the Commonwealth Telecommunications Board, and Dr. V. Armstrong, Chairman of the British Commonwealth Scientific Liaison Office.

"Wherever radio and electronic engineering is practised, one is sure to find some members of the Institution. Quite recently we received a report on what is known as project "White Alice". This, you may recall, is the magnificent achievement of providing a network extending over Alaska. Such a feat would have been quite impossible without the use of radio communication and electronics on a vast scale. It was, of course, an American project, but members of the Institution were engaged in it. I am glad to mention this achievement in welcoming Major C. L. Bachtel of the United States Army. Major Bachtel is a Member of the American Institute of Radio Engineers and has, therefore, been able to convey to the American Institute our greetings, as well as our thanks for the very kind message we have received from the President of that body.

"At one time radio engineers were concerned only with communication. Sir Cyril Hinshelwood and you, my Lord, have indicated tonight other facets of the work of our profession and industry. We always feel, however, that these new applications arose out of our original interest in communication and we in the Institution welcome this opportunity to pay tribute to the pioneer work done by our own British Broadcasting Corporation. We are, therefore, especially pleased to have with us the Chief Engineer of the Corporation, Mr. R. T. B. Wynn, and Dr. K. R. Sturley who is responsible for the B.B.C.'s Engineering Training Department.

"In the new field of atomic energy which Britain has done so much to pioneer, we have very many members. I know that they would want me to welcome on their behalf Major-General S. W. Joslin. The work of General Joslin and his colleagues at Dounreay excites the interest of all engineers, although perhaps none more than Mr. A. J. Sims. We are extremely pleased to welcome Mr. Sims tonight, and we extend to him our congratulations on his new appointment as Director General of Ships. The atomic propulsion of ships is a subject upon which I imagine General Joslin and Mr. Sims will have much in common.

"This is an opportunity for us to say thank you to the President-elect of the Institution of Structural Engineers, Lt.-Col. G. W. Kirkland, for the courtesy extended to us by his Institution for very many years in providing the facilities of their lecture theatre for our members' meetings. In our early days we also received much kindness from the Royal Institute of Chemistry, who live quite near to us. We are therefore particularly pleased to welcome tonight the President, Professor W. Wardlaw.

Few of us envy the task of the British Association for the Advancement of Science in arranging every year their wonderful series of meetings. I personally think that this has done much, not only for British scientists and engineers in diverse fields, but also for the general public in giving them instruction on the importance of scientific training and scientific achievements. We are glad to pay our tribute to the British Association and to welcome Sir George Allen.

"Quite recently we felt that our Institution had reached the stage when it is essential for us to acquire permanent headquarters; we need a building which will give us our lecture theatre and the additional library accommodation that we so badly need.

"Undaunted, therefore, by the credit squeeze, and encouraged by the enthusiasm of our members, we decided to launch a building appeal. Among our guests this evening are several gentlemen in our Industry who have given us considerable encouragement by heading the list of contributors to our Building Appeal with most generous donations. It would not be right for me at this stage to give their names, but it is with considerable pleasure, my Lord, that I am now able to advise you that today our Building Appeal fund has reached £32,000.

"From the way in which this news has been received, I hope that our guests who have opened our Appeal will judge for themselves the way in which we welcome them here this evening. We intend to give full credit for your generosity when we finally launch the appeal later this year. Then, we are sure that you pioneers will be joined by others in enabling us to achieve our object of obtaining £100,000.

"Representatives of our various industrial associations are colleagues of mine on the Radio Industry Council; I will not name them all, but merely say to them that as the professional body of the Industry, we are delighted to have them with us tonight.

"In the background of our country's scientific policy there is a body of gentlemen whose work is, I think, too little known and appreciated. Actually, their work very largely affects our technological development as a country. They are the permanent officials without whom Industry, the Armed Forces, or Government Services could not be adequately maintained. We are glad to have this opportunity of expressing appreciation of their work. I have in mind such men as Sir Charles Snow, who has enormous problems to contend with year in and year out as Scientific Adviser to the Civil Service Commission. The problems of another of our guests, Sir Cyril Musgrave, as Permanent Secretary of the Ministry of Supply, must also be tremendous in trying to maintain strong Services especially in these days of economy.

"Before and during the last war, many of us in the Institution had close association with Sir Frederick Brundrett, and we are particularly pleased to have him with us tonight.

"In the background of the work done by such gentlemen is our Government and Parliament. It is only in recent years that there has been an adequate link between science and Parliament, and in welcoming the Secretary of the Parliamentary and Scientific Committee, Commander C. Powell, I would like, on behalf of the Institution, to extend to him our continued good wishes and support for the work of his Committee.

"We have one guest, however, who has been with us before, but who is extremely typical of those men behind the scenes that I have already described. We have watched his work with considerable interest, and it seems to us that whenever he comes to these occasions he quietly takes notes. The Chief Scientist of the Ministry of Supply is also a man of great responsibility and it gives me particular pleasure to welcome him now, not as Dr. but as Sir Owen Wansbrough-Jones. I take pleasure in extending our good wishes to Sir Owen and I am coupling his name with this toast."

A most humorous response to the toast was made by **Sir Owen Wansbrough-Jones, K.B.E., C.B., Ph.D.** In complimenting the Institution on its progress, Sir Owen said that greater testimony to the interest of the Institution could not have been better provided than the fact that he personally had the same day returned from Paris in order to attend the dinner!

INSTITUTION NOTICES

Obituary

The Council has learned with regret of the deaths of the following members, and has expressed sympathy with the relatives :—

Sir Louis Sterling, D.Lit. (Hon. Member), a Past President of the Institution, died on June 2nd, aged 79 years. An account of his career appears on page 330.

Squadron Leader John Cadogan Hosburn (Associate Member) died on May 12th at Devizes Hospital after a long illness. Squadron Leader Hosburn joined the Royal Air Force in 1925 and served as Wireless Operator. At the beginning of the war he was commissioned in the Technical Branch and held appointments in connection with the setting up of Radio Schools in this country and overseas. In 1947 he was granted the Air Efficiency Award, and in 1949 received a permanent commission as Squadron Leader in the Technical Branch. Four years later, however, he was discharged on medical grounds suffering from the illness which eventually led to his death. Squadron Leader Hosburn, who was 50 years of age, leaves a widow and three children. He was elected an Associate Member of the Institution in 1950.

Birthday Honours List

The Council of the Institution has congratulated the following members whose names appear in the Birthday Honours List :—

Rear-Admiral Kenyon Harry Terrell Peard, C.B.E. (Member) on his promotion to Knight Commander of the Military Division of the Most Excellent Order of the British Empire. (Admiral Peard is Director of the Naval Electrical Department).

Wing Commander John Henry Stevens, B.Sc., R.A.F. (Associate Member) on his appointment as an Officer of the Military Division of the Most Excellent Order of the British Empire. (Wing Commander Stevens is at H.Q., R.A.F. Technical Training Command).

William Thomas Ash (Companion) on his appointment as an Officer of the Civil Division of the Most Excellent Order of the British Empire. (Mr. Ash is Secretary of the Radio and Electronic Component Manufacturers' Federation).

Group Provident Scheme

Considerable interest has been shown in the announcement made in the March *Journal* that the Council is considering starting a Provident Scheme for members which would safeguard them against the expense of private treatment in major illnesses and operations. The Council is therefore arranging to institute the Group Scheme operated by the British United Provident Association, and as already stated, the Association's standard rate of subscription will thereby be reduced by 20 per cent.

As an example of the facilities provided by the scheme, a member between the ages of 30 and 49 can join Scale 8 for an annual subscription of £6 12s. and obtain grants of up to £18 18s. a week for in-patient maintenance; £63 in respect of fees for each major operation and, in addition, grants towards other specialist services, in-patient or out-patient, and home nursing. For an additional £3 5s. he can obtain these benefits for his wife as well, while a further £2 4s. secures them for all his children under 18 years of age, irrespective of number : other Scales, providing higher or lower benefits, are also offered.

The Institution's Council strongly recommends the scheme to members, and it is hoped that it will commence at an early date. Further particulars may be obtained from the General Secretary.

Technical Visits

The Institution's Technical Committee has recently sponsored two visits in the London Area for members. On Wednesday, May 21st, a group visited the Radio Research Station, Slough, and had an opportunity of seeing the work of propagation research for which this organization is world famous.

The second visit was on June 4th and provided opportunity for members to see some of the telecommunications and radar facilities both at London Airport itself and at the Southern Air Traffic Control Centre nearby.

The Technical Committee is most grateful to the Director of the Radio Research Station, and the Director of Navigational Services of the Ministry of Transport and Civil Aviation, for granting these facilities.

For further visits, please see *Supplement*.

SIR LOUIS STERLING

THERE are few men who support such Institutions as our own without first having the advantage of actual membership. Sir Louis Sterling was such a man; he had seen the birth of an international radio industry and in the 1930's frequently expressed his views on the need for the Institution to develop its work.

Although not a member of the Institution, his opinions became increasingly sought by those who were, and such consultations soon took the form of his attending meetings of some Committees. It was not surprising, therefore, that in 1939 the Council recommended that Sir Louis Sterling should be elected an Honorary Member of the Institution—the first such election for five years—in recognition of the services he had rendered to industry in general and to the Institution in particular.

Subsequently his services to the Institution was further recognized by his election first as a member of the General Council and then, in 1940, as a Vice-President. He then urged that the Institution should find time, even in war, to play its part in what would be "...continued expansion of the radio and allied industry in the post-war period." In this connection, he again referred to the need for developing an educational system adapted to the real needs of the industry.*

The background to Sir Louis Sterling's interest in the work of the Institution is well known. He was born in America and at an early age became interested in what he called the "phonograph business". He was 24 years of age when he first came to England, and very quickly became associated with the record trade, as it then was, before joining makers of phonograph records. At that time, artistes were reluctant to admit themselves to a medium which, by modern comparisons, was full of distortion! Sir Louis quickly realized the need for improving reproduction and had many interesting anecdotes of how he was able to persuade artistes to commit their talents to records. Many great classical and popular artistes became his personal friends and throughout his life he supported charitable organizations associated with the musical and entertainment professions. Similarly he substantially helped in placing the Institution's Benevolent Fund on a firm basis and he was, in fact, a Trustee of the Fund for very many years.

Whilst these notes are a tribute to Sir Louis Sterling's association with the Institution, personal experience provides the background. It was whilst he was guiding the destinies of the Columbia Graphophone Company that the writer first knew him and experienced his constant drive for improving methods of recording and reproduction, and his belief that the new business of wireless and the record would merge into equipment for which there would be a great popular demand.

This opinion, and a belief in the greater use of communications generally, required research and development work which could only be undertaken by a much larger organization. Sir Louis Sterling brought about the merger of several companies which resulted in the establishment of Electric and Musical Industries Ltd.

Louis Saul Sterling became a naturalized British subject in 1932 and was knighted in 1937. He had a great love for his adopted country, and much appreciated receiving an honorary degree of Doctor of Literature from the University of London.

Sir Louis Sterling did much to establish on a rational basis the administration of the Institution at a time when the whole of its work was done entirely by voluntary effort. He became the seventh President in 1942 and in his Presidential Address expressed the difficulties which must beset new industries and comparatively new Institutions. He urged, however, that the whole profession of Engineering should receive wider recognition which "... implies the need to educate the public *and* employers to appreciate the value of the qualified engineer."†

The Institution's *Sir Louis Sterling Premium* is, by his special request, awarded for the most outstanding paper on television technique published in the *Journal*.

It is with regret that it is necessary to record that Sir Louis Sterling died in St. Mary's Hospital, Paddington, on June 2nd, 1958, only a few days after his 79th birthday.

G. D. C.

* *J.Brit.I.R.E.*, **1**, p. 100, 1940

† *J.Brit.I.R.E.*, **3**, pp. 33-36, Sept.-Nov. 1942.

MASS PRODUCTION TECHNIQUES FOR TELEVISION TUNERS*

by

P. C. Ganderton†

Read before a meeting of the Institution in London on 7th January 1958
In the Chair: Dr. A. D. Booth (Member)

SUMMARY

The design features necessary for easy mass production of turret tuners to cover Bands I, II and III are surveyed. Inter-changeability of coils between different chassis is important. Lead inductance and self-capacitance of components must be kept small and constant. The problems of temperature compensation over the wide frequency ranges are considered. A system of testing which uses a central generator of "wobbulated" signals for the various bands is briefly described and details are given of methods of coil and chassis alignment.

1. Introduction

Since Band III has been in use for transmitting television programmes it has become desirable from the manufacturing, distributing and similar aspects, to produce only receivers capable of being rapidly changed to all available transmissions and, at the same time, covering the possible use of other frequencies. This situation has brought about a trend in Great Britain similar to that already experienced in the U.S.A., where many of the tuner units are designed and produced by highly specialized component manufacturers.

The features at present required from a tuner are: (1) that it should be capable of receiving any frequency in Band I, Band II and Band III; (2) be readily modified to receive frequencies in Bands IV and V; (3) that it should be possible to have non-sequential loading (by a suitable combination of loading, it is possible, in most areas, that the B.B.C., and I.T.A., channels are adjacent on the knob). Of the possible methods of tuning the turret tuner is the one that most satisfactorily meets all these requirements.

By concentration of tuner unit production into specialist factories or departments, designs have been developed which can be manufactured with greater consistency and care. It is then also practicable to use elaborate test equipment especially suited for the most efficient test procedures.

It is not the purpose of this paper to discuss the use or general design features of the turret tuner; these have been adequately dealt with in a previous paper.‡ Consideration will, however, be given to the design features necessary to enable the easy mass production of these tuners. A survey will also be given of the possible means of testing and a description of the method adopted.

2. Tuner Design

The most exacting requirement for the tuner is that all coils should be identical and interchangeable in any chassis. This enables the manufacturer to fit only the operative channels, with the certain knowledge that, at any time, any other channel may be fitted with the minimum of attention by the dealer. The implications of this requirement are that all chassis, even when produced with the maximum possible divergencies, e.g. length of leads, dressing of leads, amount of solder applied, and with maximum tolerances on the valves and components, will still perform on all channels without readjustment of the trimmers. Also, that all coils must be pre-aligned to one

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† Sydney S. Bird & Sons Ltd., Poole, Dorset.
U.D.C. No. 621.397.62

‡ D. J. Fewings and S. L. Fife, "A survey of tuner designs for multi-channel television reception," *J.Brit.I.R.E.*, **15**, pp. 379-404, August 1955.

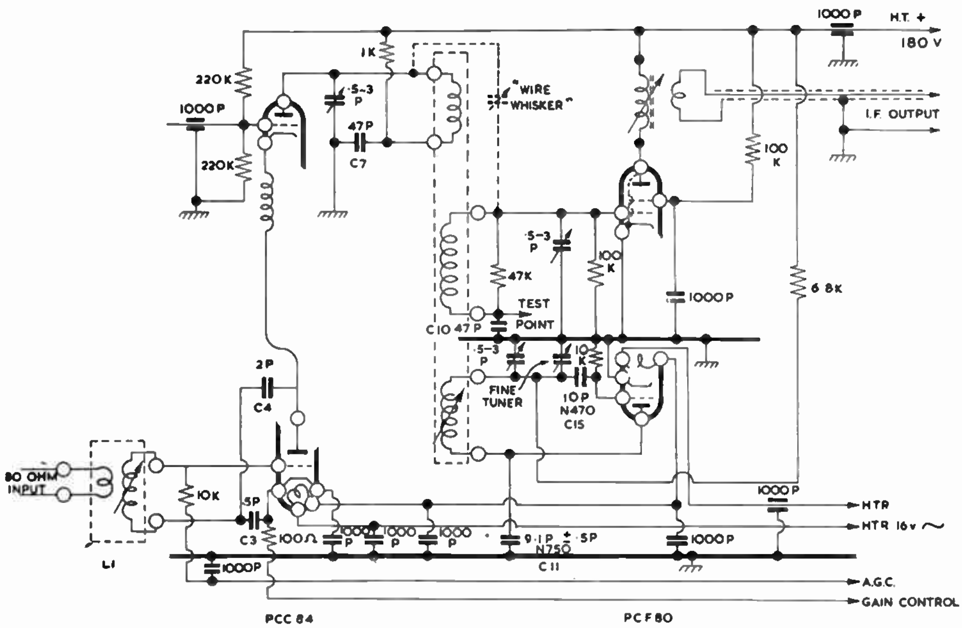

Fig. 1. Circuit diagram of the turret tuner discussed in the paper.

standard which can never be changed once production has commenced. The degree of accuracy to be obtained can be seen by the final tolerances on the tuner response where the whole of the top of the r.f. response curve, from the sound to the vision carrier, must lie within $\pm 0{\cdot}75$ db. To deal more closely with the design features, reference should be made to the circuit diagram in Fig. 1. This circuit is basically quite conventional but the following detailed description will show the points where particular attention is necessary.

In the majority of designs the aerial circuit is aligned by making the bottom capacitor of the neutralizing bridge, C3, variable. If this is used to compensate the variations in grid-to-cathode capacitance of the valve considerable variations will be found in the neutralizing, i.e. should the grid-to-cathode capacitance increase, then to maintain the correct balance, C3 could also be increased, but to obtain correct alignment, it is necessary that C3 should be reduced, thus further upsetting the balance.

Whereas it is very difficult to determine the precise setting for neutralization, this variation does appreciably affect the input impedance of the stage and thus the amount of damping on the aerial transformer (L1) and, in turn, the amount of "fill in" by L1 of the dip in the response curve of the bandpass pair. C3 and C4 have, therefore, been made up of close tolerance capacitors and the adjustments to the aerial stage carried out by the use of slugs in the aerial coil.

One of the greatest problems posed by valve tolerances has proved to be that of variations of heater-to-cathode capacitance. Heater chokes are sometimes used on the cascode amplifier to overcome the detrimental effect of this capacitance on the second section of the cascode stage. However, due to the wide range of frequencies that the tuner has to cover, and the appreciable variations in the heater-to-cathode capacitance, it is difficult to maintain the resonance of heater chokes at a frequency where no detrimental effect will be introduced. Also, due to radio frequency potentials on the cathode of the second triode, these chokes tend to be "hot" and their precise position in the tuner very critical. In the present design these were therefore dispensed with and the heater-by-passed by the shortest possible route.

The major problem in circuit design and layout is in the resonant circuit of the band-pass pair, the only adjustment of which is obtained by the anode and grid trimmers. It is essential, to enable the circuit to track correctly over the range 40–200 Mc/s, that the wiring inductance should remain identical between chassis and that the inductance trimmed by the trimmer capacitor should be as nearly as possible the same as that tuned by the valve interelectrode capacitance. To achieve these ends the following precautions are adopted in the circuit design. The decoupling capacitor, C7 in the circuit diagram, for the anode circuit, and the grid capacitor, C10, are constructed in the manner that eliminates the usual problem of capacitors of having an indeterminate amount of wire between the outside of the insulation and the silvering. This wire, normally being of a relatively small gauge, has an appreciable inductance. The capacitors used, in this application, are based on an axial construction similar to a feed-through capacitor, having a heavy gauge inner connector protruding only at one end and a pre-formed metal tag forced over the silvering on the other end. Using this construction, and mounting the capacitor in such a manner as to avoid bending the centre connector, no appreciable change in inductance can occur due to the variations possible in hand assembly.

The grid circuit of the band-pass pair, having the greatest self capacitance, is most susceptible to small inductance changes; therefore, the lead from the contacts to the valve holder, and to the grid circuit trimmer, are produced in the form of pre-formed metal stampings. The lead to the anode and its trimmer is a little less critical so this is controlled by being extremely short and having double wiring.

If, on the chassis layout, there is any appreciable amount of coupling between the anode and grid circuits, then considerable variations will be experienced in the bandwidth of the band-pass pair due to the normal spread in the valve inter-electrode capacitances. When these capacitance variations are corrected by the appropriate trimmers, having earthing points differing from the earth points of the valve inter-electrode capacitances, there are changes in the r.f. currents flowing through the chassis. To reduce this effect and the actual coupling to a minimum, it is necessary to maintain the earthing of each circuit, as far as is practicably possible, to one point and to have this point as remote as possible from that of the other half of the circuit. Even so, small variations in bandwidth are still experienced. To enable these to be adjusted to an optimum a small amount of adjustable capacitive coupling is used between the band-pass pair. This takes the form of a stout wire "whisker."

The chief requirement of the oscillator section is temperature stability. To ensure that the fine tuner control will not require resetting during a viewing period, and to meet the even more exacting requirement imposed by the use of the tuner for v.h.f. radio, it is necessary that the drift after the initial warm-up period of 3 minutes, should be less than 100 kc/s for a rise of 30°C. It is impractical to conduct a 100 per cent. measurement of drift in production and so it is essential that the layout of the oscillator circuit should be such as to produce repeatable answers with the usual variations in assembly. The major cause of variations in drift from tuner to tuner is the proximity of the oscillator circuit components to the chassis. The stray capacitance from these components to the chassis usually possesses a large positive temperature coefficient and the anode load, being the largest physically and having the greatest temperature rise, becomes the most critical. To this end a type of resistor is used which has an extremely small diameter and, in common with all other oscillator circuit components, it is spaced well away from the chassis.

Although it is possible to arrange the compensating components to correct the circuit drift to very close limits at any given frequency, there is an inherent spread between channel 1 and channel 13 which requires the full limits of ± 100 kc/s to accommodate it. To produce a reasonable safety margin an effort has been made to so design the oscillator coils as to reduce this spread to a minimum. The tendency is for Band I to be under compensated and Band III to be over compensated. Very little can be done to the Band III coils to change their characteristics, but, with the right design, an appreciable reduction can be made in the Band I drift.

A series of oscillator coils were wound having different wire gauges, number of turns and type of insulation. The work was only conducted on close-wound coils as these are more readily produced.

Enamel covered wire, including synthetic enamel and self-soldering enamels, produced coils with the most positive coefficient, presumably due to their higher self-capacitance and the very high positive temperature co-efficients of dielectric constant of most enamels. Nylon-covered wire, which possesses the desirable feature that it may be soldered without stripping, is better than enamel wire, but still not as good as artificial silk. For this reason double rayon was the type eventually chosen. As the gauge is reduced, so the drift lessened but increased again below 30 S.W.G.

Brass, aluminium and iron dust slugs were tried. Very little difference was found between brass and aluminium but a considerable improvement was effected using iron dust. This is again presumably due to the reduced self-capacitance of the smaller coil.

On the coils constructed in this manner the total difference in drift between channels 1 and 13 was approximately 100 kc/s, therefore correction may be arranged such that, on an average chassis, the drift is ± 50 kc/s. This allows a margin of safety to cope with the tolerances in temperature co-efficient, and values of the circuit components. The compensating components used in the chassis are, referring to the circuit diagram C11 (9·1 pF), which is negative 750, and C15 (10 pF) which is negative 470.

3. Tuner Testing

The success of tuner construction depends as much, or more, on the test gear than on any other feature. To design a tuner to perform to close tolerances and then produce it on doubtful test gear is valueless. The tuner specification calls for every response curve to be within 1½ db of flat between sound and vision. The test gear must then have less than ¼ db error to make the specification of value.

The most exacting requirement on the turret tuner is that all coils should be pre-aligned to a given standard, such that they may be plugged into any turret produced, at any time, without further re-alignment, and it is to this end that the system of test is devised.

The test procedures in the works may be broken down to three sections: individual coil alignment, individual chassis alignment, and a final alignment and check on the fully assembled tuner. The gear is designed to be capable of producing at least 15,000 complete tuners per week using non-technical female labour.

3.1. *Coil Alignment*

Band I and Band II coils are wound to close limits on machines which enable the band-pass pair and oscillator coupling to be sufficiently pre-determined as to require no further adjustment. The oscillator coil is aligned by a slug, the band-pass pair requiring pre-alignment by moving turns (the coil former is coated with a rubber adhesive to secure the turns after winding prior to adjustment, the coils being further coated with a lacquer after adjustment).

The Band III coils require both the frequency and coupling of the band-pass pair and the coupling of the oscillator coil to be adjusted, the tuning of the oscillator being by a slug.

Two alternative systems of alignment were considered, firstly by a "Wobbulator" (frequency modulated oscillator), viewing on a visual response the overall curve of the band-pass pair with a meter reading indicating the injected oscillator volts, and secondly, by individual alignment of each coil by *Q*-meter methods. The latter system did not provide for an easy means of adjusting coupling of the band-pass pair nor did it enable a continual check to be maintained on the winding accuracy of the Band I coils.

3.2. *Chassis Alignment*

The chassis require that the trimmers be adjusted on channel 9 to give a correct response against the standard coil. It is also required that the band-pass coupling be adjusted by means of the wire "whisker." Further, as tuners are not necessarily despatched containing all coils, it is essential to check the extremes of each band to ensure that, when future coils are plugged in, they will function according to the specification. Possible means of carrying out this alignment are spot frequencies for setting the trimmers, or a wobbulator signal. Here again the spot frequency system does not really lend itself to the adjusting of the band-pass pair nor can it readily be used for rapidly checking the tuner on channels 1, 6 and 13 for correct tracking.

3.3. *Final Alignment*

After complete assembly of the tuner it is necessary to adjust the oscillator and aerial coil slugs and to check the overall response of each channel. The problems here are then similar to those of the chassis alignment.

4. Alignment System

From these remarks it is obvious that the only satisfactory way of alignment is by use of wobbulated signals. The problem is to offer a presentation of these signals which requires the minimum of thought and adjustment by the operator concerned. To do this in the case of chassis and final alignment, it is necessary to supply the operator with all the required signals, and to present them on one display without switching. Magnetically deflected oscilloscopes with 14-in. screens were adopted having a rectangular time-base and presenting a display as shown in Fig. 2.

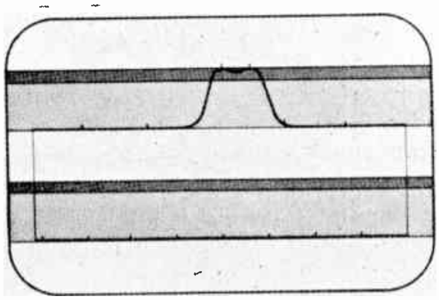

Fig. 2. Typical alignment display showing channel 3.

The Wobbulators are arranged so that Band I sweeps forward during the top portion of the rectangle and Band III sweeps backwards during the bottom portion, i.e. where the spot is returned. Each channel is marked with a vertical pulse at its sound frequency and two i.f. markers (sound and vision) are displayed to enable the oscillator to be aligned and to judge the overall bandwidth of the channel. The vision marker is coded, in amplitude, to identify it. The display shown in Fig. 2 is that seen when the turret is switched to channel 3. All the appropriate r.f. signals are mixed and fed to the tuner. The operator has no switching or adjustments to make to the test gear during the complete alignment. It is only required that she should switch the tuner on test to the appropriate channel when all the displays will be available. On coil alignment the operator's mind becomes somewhat confused if presented with the full display. These units are, therefore, fitted with self-contained ferrite wobbulators displaying, at any time, one channel but continually tunable over the full band, these units having a self-contained crystal marker at the sound frequency, but still obtaining the i.f. marker from the central generating source.

5. The Signal Generating System

As already stated, the majority of signals for use during test are supplied from a central generating system. This contains swept frequencies covering Band I, Band II and Band III for British systems, and F.C.C., C.C.I.R., Australian and Italian frequencies. There is also a square-wave generator supplying switching pulses for blanking the wobbulators to enable them to be mixed (this signal also being fed to the factory to provide the 14-in. display units with time-base switching), and i.f. generators covering the 10 Mc/s, 16 Mc/s, and 38 Mc/s British bands and the C.C.I.R., F.C.C., Australian and Italian standards. Each wobbulator is fed from its own voltage stabilized power supply and all other generators from the main power supply. The unit itself is mounted on a raised platform; filtered air is supplied from underneath this platform to maintain the unit at a stable temperature and to reduce the dust deposit. The signals from the transmitter are fed through an overhead trunking to a mixing panel where any combination of signals may be fed to any test point in the works.

5.1. *The Wobbulator*

Figure 3 shows a block schematic of the wobbulator; from this it can be seen that the oscillator is frequency modulated by a motor driven capacitor rotating at 50 cycles per second. This capacitor is of a dynamically-balanced split-butterfly construction. The inductively-coupled low impedance output from the oscillator is fed through a stand-off attenuator to a splitter box supplying ten main

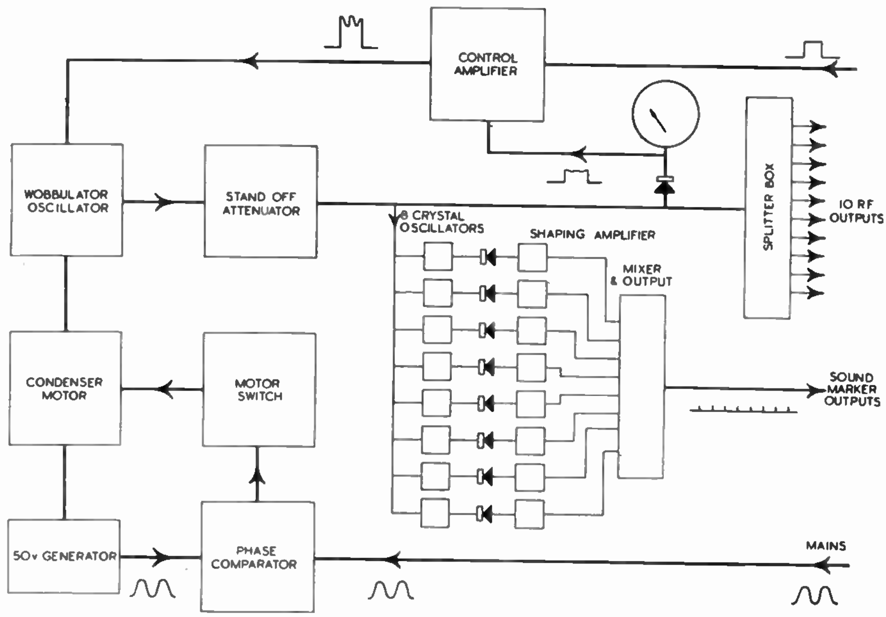

Fig. 3. "Wobbulator" block diagram.

outputs. The signal is also detected at this point to give a carrier level indication. The low-frequency component from this is fed back through a control amplifier to the oscillator valve to correct any level changes during the sweep. By these means the output is maintained level to within 1 db over the complete band and to within less than 0·25 db over any one channel.

To enable the outputs from the wobbulators to be mixed, a square wave is also fed into the controlling amplifier to blank the oscillator during one or other of its sweeps. This signal can be supplied in either phase so that a choice can be made as to which trace the signal will appear on. Fig. 4 is a simplified circuit diagram of the oscillator and its control amplifier. V6 is an Eccles-Jordan trigger circuit triggered by the mixer square wave; the output is switched from either anode to select the required phase and is fed to a control valve (V4). One of the problems introduced by the control amplifier is that it will oppose any attempt to switch off the oscillator. The amplifier is biased to reduce the "off" excursion of the square wave to a reasonable proportion but it was still found necessary to inject an opposing square wave into the amplifier, by supplying the anode of V2 from the h.t. switching valve V5 as well as switching the actual control valve V4 on its screen.

The wobbulator oscillator is of push-pull type and uses a double tetrode type QQV03/10 controlled and switched on the cathodes. The oscillator provides ½ watt output to the external circuits at 200 Mc/s.

The output of the oscillator is also fed to the sound channel crystal oscillators and mixed and detected. The pulse from this output is shaped, mixed with all the other sound markers of that band, amplified, and fed out as a series of consecutive sharp pulses. As the synchronous motor driving the oscillator capacitor can "lock in" to the mains in either phase, a simple 50-c/s generator, consisting of a magnet passing a coil, is attached to the motor spindle and the output of this is compared in phase with the mains. If the generator is running in the wrong sense, the device will switch off the motor for a short period and re-start it again. It will continue to do this until the motor locks itself in to the right phase.

Summarizing then, the transmitter feeds four signals to each bench: the square wave, the

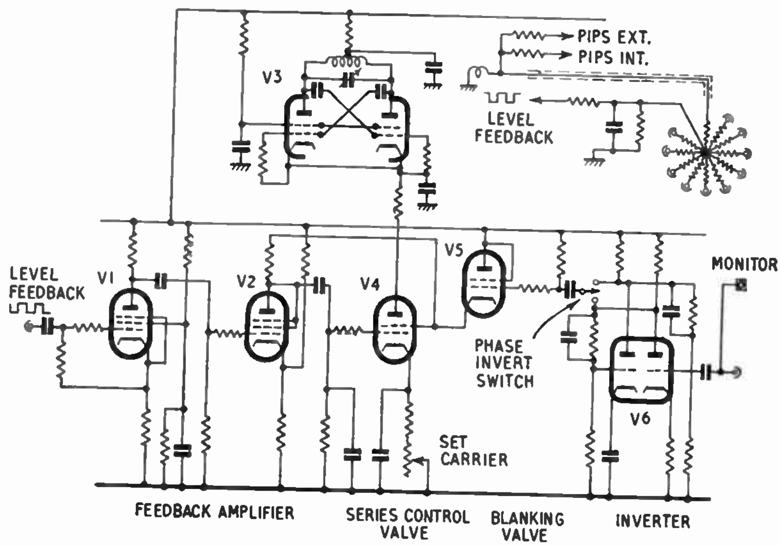

Fig. 4. Circuit diagram of the master wobbulator.

choice of any two wobbulators, of any two sets of sound markers, and of any i.f. markers.

5.2. *The Bench Equipment*

Figure 5 is a final alignment bench equipment. The electrical arrangement of this and the chassis alignment equipment are identical; the mechanical arrangements of the test jig are dissimilar only in that on the chassis alignment position, the jig has mounted on it a turret containing the standard coils, against which the chassis is aligned. The wobbulator signal to the tuner is fed through a 10 db pad to isolate the line from the tuner. This ensures that when the tuner is disconnected no mismatch occurs on the line which could be reflected to other test positions. The output end of the attenuator is a concentric clip, the inside being a pin which will penetrate the inner conductor of the unstripped co-axial lead, and the outside a split clip, which clamps over the co-axial outer screening and makes electrical contact with it. The tuner power supply leads are coupled to the jig by forked clips, the operator being protected by a hinged perspex cover which actuates the h.t. switch. This cover also carries with it a test point which, when the cover is closed, mates with the grid test point on the tuner. This test point consists of a low capacitance cap connected by an r.f. stopper to the test jig. At the grid test point the r.f. response curve of the tuner may be observed, this response curve being detected in the tuner by the mixer valve. The heater supply is at a potential of 50V above earth as an insulation check and a short sounds a buzzer. The h.t. has an overload cut out to avoid damage to the voltage stabilised power supply and the complete gear is fed from constant voltage transformers. The response curve of the tuner cannot be easily observed after passing through

Fig. 5. Final alignment test bench equipment.

an i.f. amplifier because, to ensure that this in no way modifies the r.f. response, it must be at least twice its bandwidth. An i.f. of this bandwidth will then overlap into channel 1 producing, when the tuner is actually aligned flat, a viewed slope rising to the l.f. end where the r.f. and i.f. sidebands overlap. The i.f. output is, however, fed through a narrow bandwidth i.f. amplifier to remove the oscillator volts and is detected to give a reading of overall gain. It is also mixed with the i.f. oscillators and detected to produce two i.f. markers whose position on the trace will vary with the oscillator setting. This enables them to be adjusted. These i.f. markers are in turn mixed with the response curve from the tuner grid and fed to the display units.

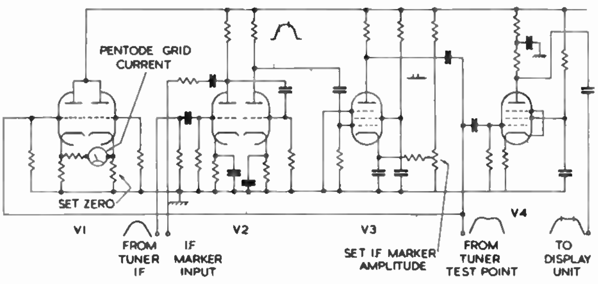

Fig. 6. Final test and chassis test front-end jigs.

Figure 6 shows the circuit diagram of the pre-amplifying and i.f. mixer stage of the alignment jigs. V1 is a conventional valve voltmeter applied to the tuner grid test point to indicate injected oscillator volts. V2, a double triode, is a combined aperiodic i.f. amplifier and mixer; the mixing takes place on the grid of the second triode . The amplifier (V3) has its coupling and decoupling components relatively small in value to reduce the low-frequency component. This eliminates the i.f. response curve and only leaves the two sharp markers. These are then mixed with the r.f. response from the tuner at the grid of the audio pre-amplifier, V4. The i.f. amplifier and detector for measuring conversion gain is not shown in this circuit.

As can be seen in the block diagram (Fig. 7), in the display unit these i.f. marker signals are again mixed with the sound marker pulses, supplied from the crystal generators and the square wave. A combination of these four signals produces the trace seen in Fig. 2. The display units are fitted with coloured graticules, in the form of a band representing the overall response height, with a different coloured strip representing 1·5 db. The only function to be performed by the operator is to connect the

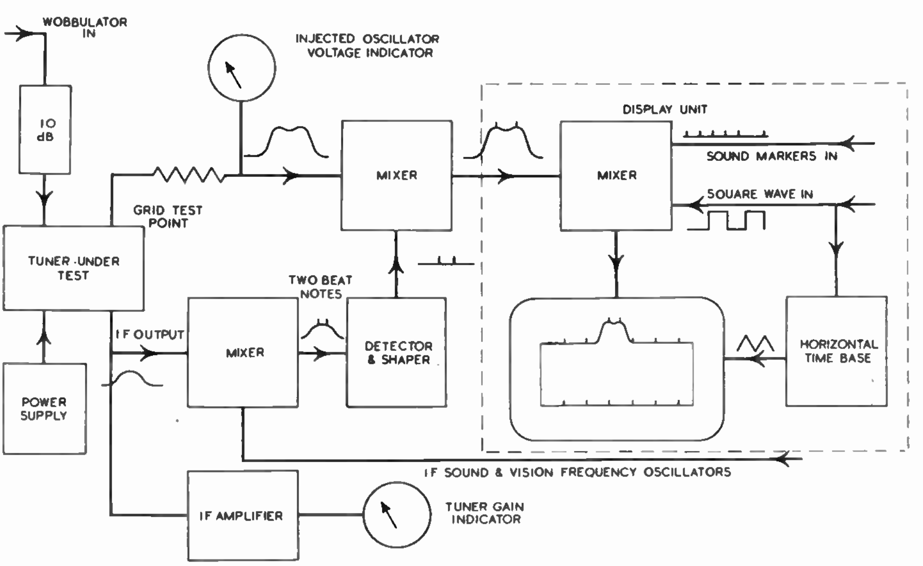

Fig. 7. Test jig block diagram.

tuner, switch to each channel in turn, align the aerial slug for a flat response, align the oscillator slug to make the i.f. sound marker coincide with the r.f. marker, and observe that the response curve between the sound marker and the vision marker, lies within the 1·5 db colour band, and finally, to check the gain and the oscillator volts.

Fig. 8. Coil alignment test equipment.

The coil alignment jigs (Fig. 8) perform a similar function; the actual jig consists of an inverted cut away tuner chassis, mounted in which is a perspex covered turret segment into which the coil to be aligned is inserted and clicked into position. A hole in the cover is provided with bars against which a probe may be purchased to adjust the turns.

Every installation is checked daily by a laboratory engineer. The coil alignment gear is checked hourly by its operator against a standard coil, the standard coil being checked back against master standards at frequent intervals.

6. Quality Control

There are several electrical functions that cannot economically be measured on every tuner produced but it is desirable to keep a check on these and on the general construction of the tuner, its mechanical assembly and even the final packing. To enable these functions to be performed a quality control section takes crates of completed tuners from final packing. These are unpacked and inspected to ensure that they conform to the customer's requirements in every respect. They are then checked for the slope of the response curves, for gain, and for noise factor on each channel fitted. They are also checked for drift on a selected number of channels. All this equipment can be seen batched together in Fig. 9. It consists of an i.f. chassis, an independent wobbulator, a noise generator and a drift measuring gear. Of this equipment the drift gear is worthy of some further explanation: the lower unit consists of an oven in which the tuner under test is inserted, this oven having an adjustable ventilator on the bottom and top and adjustable heating pads to enable any condition of convection currents and rate of rise of temperature to be obtained. A crystal-generated signal is fed into the tuner, the i.f. output being detected by a ratio detector. The i.f. amplifier and ratio detector are contained in a temperature-controlled oven to ensure complete stability. A zero check can be applied to the ratio detector by a further crystal generator. The output of the ratio detector is coupled to a meter reading directly in frequency drift and is also fed to a two pen recorder. The temperature of the tuner is measured at the top of its chassis and is also indicated on a direct reading meter and recorded on one track of the recorder. A third unit, not shown, contains refrigeration equipment to enable both the oven and the tuner to be rapidly cooled.

7. Conclusion

The production of tuners by component manufacturers is rapidly becoming accepted by the receiver industry. The concentration of effort into one component has enabled this to be developed further than is possible by individual manufacturers but there is still room for many improvements. The accent on a

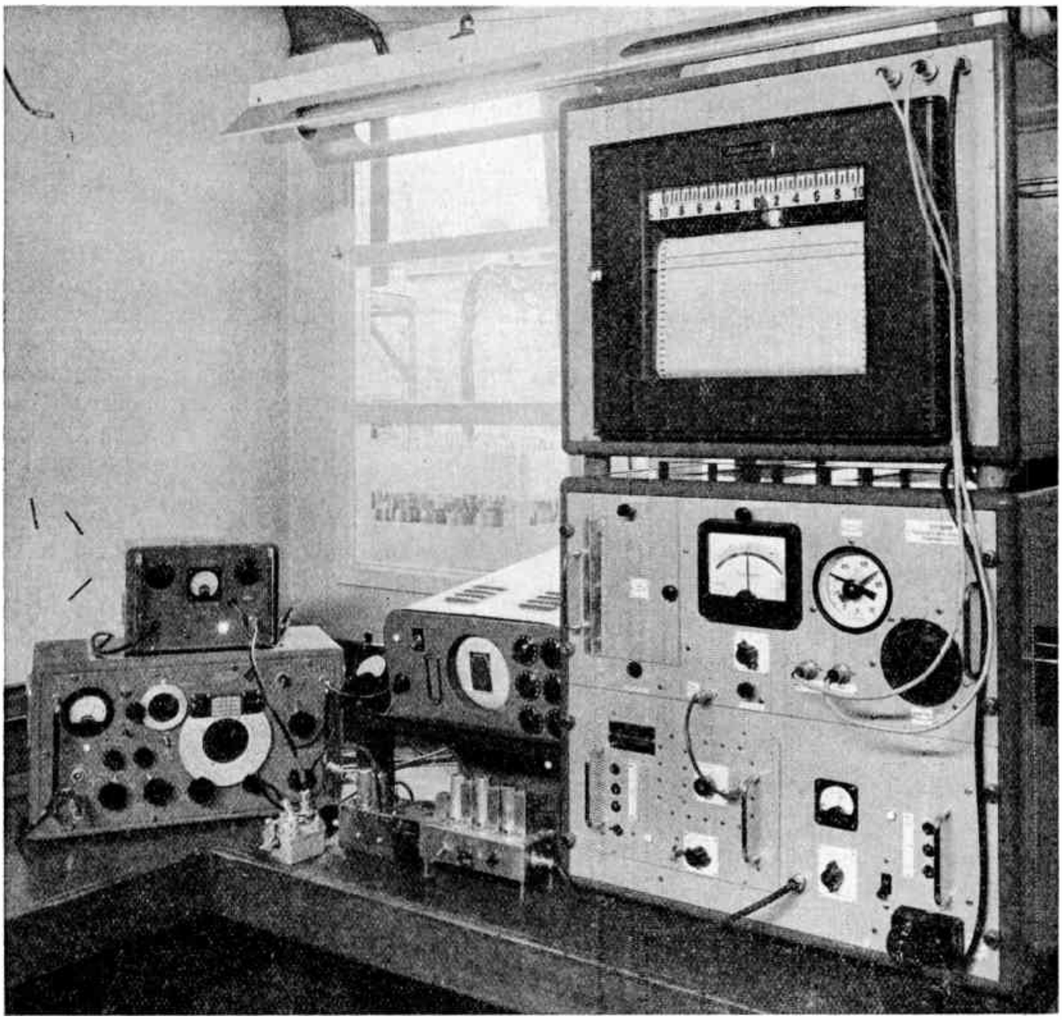

Fig. 9. Group of equipment used in the Quality Control Section.

low-noise aerial stage has been given a further impetus by the introduction of "frame grid" constructed cascode valves. The greater acceptance of f.m. radio on television receivers demands that more work must be done on this facility. With the lower noise figures now obtainable the desirability of raising Band III gain relative to Band I is more pressing. Here the improvement in Band III gain effected by the new cascode valve helps, but more effort must be directed towards the mixer stage. The eventual introduction of 110 deg. deflection tubes will bring about a demand for smaller components to use with them. And finally, the accent on price, with performance, is becoming a greater factor now than has so far been experienced in the relatively short life of the tuner manufacturer.

SOME ASPECTS OF TELEVISION TUNER PRODUCTION*

by

S. H. Perry (Associate Member)

Read before a meeting of the Institution in London on 7th January 1958.
In the Chair: Dr. A. D. Booth (Member).

SUMMARY

The need for accurate assembly to achieve economic mass production of television tuners is discussed in relation to a particular turret tuner. Some manufacturing methods which achieve the required accuracy are indicated. A method of testing to achieve standardized performance is described, together with a reference to the use of statistical method in analysing production variations.

1. Introduction

One type of television channel tuner commonly in use utilizes sets of coils which are pre-trimmed each to its own channel, the coils being located in a rotary turret. The required channel coils are connected into circuit via contacts by rotation of the coil turret. Mass production is only possible if assembly may proceed without the need for selectively assembling components in combinations by trial and error to produce the desired results. In particular, this requires that the channel coils must be made to the correct nominal values and within such limits as are needed to ensure satisfactory operation in all individual tuner units. Further, the tuner unit circuit assembly must be controlled so that the variation in performance of coils when fitted in individual tuner units lies within acceptable tolerances. An additional advantage arising from such a degree of standardization is that it is possible at any time to replace a damaged coil, or to fit coils for a new channel allocation, without needing to adjust the coils especially to suit the characteristics of an individual tuner.

Earlier experience with channel changing in single channel receivers by insertion of plug-in coils has shown that the degree of standardization required would necessitate control of stray parameters, such as self-capacitance of coils, capacitance to chassis of leads, resistors and capacitors, and the self- and mutual inductance of component connections. This is generally a question of correct position and length of all components and connections, and the use of approved types of components.

The trimming procedures adopted for the coils and for the circuit trimmers must correct the residual errors which remain after having given such care to assembly as is reasonably practicable. The trimming must result in satisfactory performance on all channels for which coils are provided, or may be provided at a future time.

It is the purpose of the paper to indicate some of the methods and instruments by which the required degree of interchangeability and standards of performance may be achieved.

2. The Tuner Unit

2.1. *Circuit Description* (Figure 1)

The tuner contains a cascode amplifier utilizing a double triode, followed by a triode-pentode mixer and Colpitts oscillator. The input circuit has two i.f. rejection filters giving an attenuation of 30 db at 34·65 Mc/s and 38·15 Mc/s. The aerial input impedance is designed to give a compromise between reduced noise factor and reflection coefficient, particularly on Band III. Interstage coupling is by an inductively-coupled bandpass circuit, in which the mutual inductance between coils is negative in polarity, to minimize bandwidth variations which may result from variations in capacitance

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† Philips Croydon Works Ltd., Croydon, Surrey.

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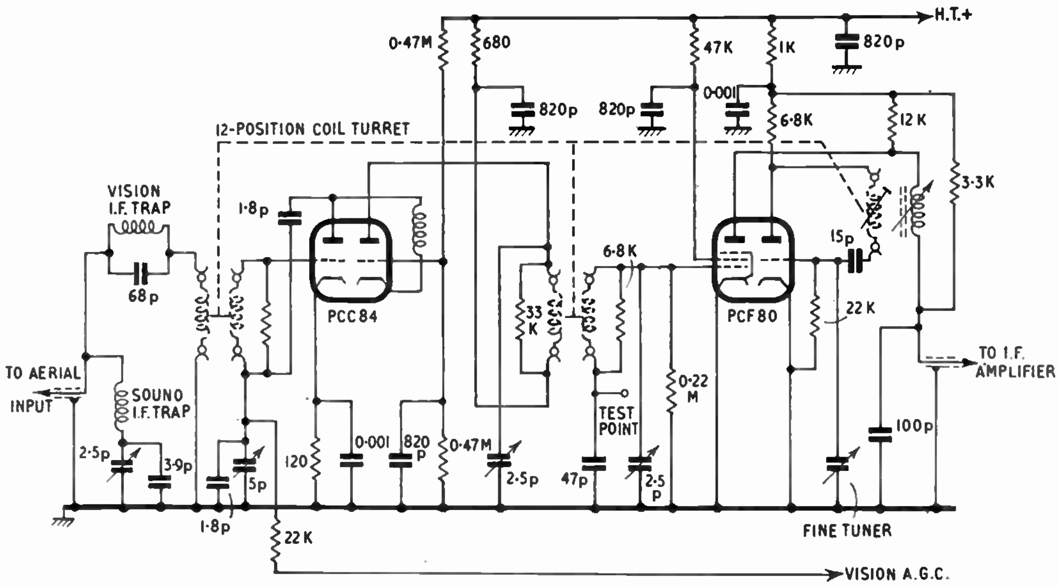

Fig. 1. Tuner unit circuit diagram.

between coils. Oscillator injection is achieved by inductive coupling between the oscillator coil and the mixer grid coil, the oscillator winding and the two interstage coupling windings being wound axially on the same cylindrical former. The i.f. output circuit is a bandpass filter, the primary circuit of which is mounted on the tuner unit, with low impedance capacitive coupling via a screened cable from the tuner to the secondary circuit, mounted for convenience on the i.f. amplifier chassis.

2.2. *Mechanical Assembly* (Figure 2)

The coil formers are glued on contact strips, or "biscuits," and wired to domed-head contact studs. The " biscuits" are clipped into position between end plates carried by the rotor spindle, which may be rotated so that appropriate pairs of coils contact fixed contact strips mounted on the tuner frame. The fixed contacts are wired to the valves and other components as an assembly independent of the rotor and coils. The aerial and cascode amplifier circuits are separated from the mixer-oscillator by a screening bulkhead.

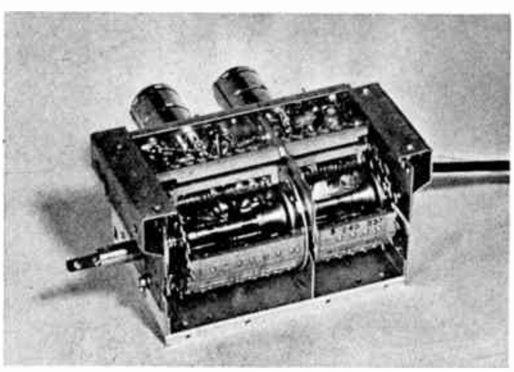

Fig. 2. Assembled tuner with screening covers removed.

3. Coil Manufacture

3.1. *Winding*

3.1.1. Band I coils

To achieve the required inductances, the coils are pitch wound on the formers to the requisite number of turns for each winding. The mutual inductance between coils is critically dependent upon the axial spacing between windings and upon the total length of each winding. The inter-winding spacing is therefore measured in terms of rotations of the lead screw used to control the winding pitch, where the spacing is an integral ratio of the pitch. In other cases, the winding stylus is provided with two guide slots separated by the required spacing. Immediately after winding, the adjacent coil ends are brushed with polystyrene lacquer to secure the end turns.

3.1.2. Band III coils

The coils are wound separately to the correct pitch on mandrels of smaller diameter than the coil formers. With the wire sizes used for Band III coils (21 S.W.G. and 25 S.W.G.), the stiffness is such that the coils, upon removal from the mandrel, spring open to the diameter of the former and may then be slipped tightly upon the former.

3.2. *Preparation of "Biscuit"*

The contact studs are dropped into holes in the moulded alkyd "biscuit" from chutes fed by a vibrating hopper, and solder tags are pressed over the shank of the tags. The tags and studs are soldered together automatically, a machine cutting and feeding lengths of flux-cored solder wire on to each tag, after which the assembly passes through the work coil of an r.f. heater.

3.3. *Assembly of Coil*

The former carrying the wound coils is glued into saddles on the "biscuit," and the ends of the windings are pulled tight to the tags and soldered. In the case of the Band III coils, the spacing between the windings is adjusted with the coil inserted in a machined jig, shown in Fig. 3.

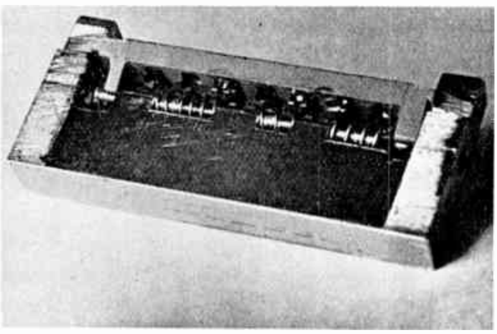

Fig. 3. Band III coil coupling spacing jig.

The windings are slid on the former until the end turns are in contact with the edges of the jig, and are then brushed with polystyrene lacquer.

3.4. *Adjustment of Coil Resonance*

It is not possible to wind the coils exactly within the required inductance tolerance. The coils are therefore adjusted by movement of the end turns remote from the coupling spacings. The testboard used compares the coil on test with a standard coil. For each winding, there is a separate oscillator valve, identical pairs being switched on as needed to compare the test and standard coils. The coils operate with parallel capacitances as near as possible to those in the tuner circuits, in order that self-capacitance variations shall be significant in adjustment of the resonance conditions of the coil. The test and standard oscillators have a nominal frequency difference of 10·7 Mc/s, the actual beat frequency being amplified, detected in a frequency discriminator and indicated on a centre-zero meter. The polarity of error, high or low inductance, is thus indicated on the meter. The permitted error is small, being $\pm 0{\cdot}35$ Mc/s; it is quite practicable to adjust coils to within this tolerance on all channels.

3.5. *Final Coil Test*

Coil assemblies for each channel are paired, aerial coil and r.f./oscillator coil, and inserted into a tuner unit fitted with guides for convenient insertion of the coils. This tuner unit has previously been trimmed and checked to give standard response on all channels. The response curves of the coils are viewed with a wobbulator-oscilloscope, and must lie within $\pm 0{\cdot}75$ db of the standard response between the sound and vision carrier frequency markers. The limit curves are drawn upon transparent interchangeable masks against the face of the oscilloscope tube.

4. Tuner Assembly

4.1. *Chassis and Bulkhead*

Certain components need to be soldered to the chassis and the bulkhead, e.g. valveholder skirts (to avoid crackle) and the feedthrough insulators and capacitors. The heat capacity of the metalwork is such that hand soldering is slow and uncertain in quality. By using r.f. eddy current heating, the surfaces to be soldered may be raised rapidly and accurately to the required soldering temperature. The work coils are designed to obtain heating concentrated into the zones required, the heating current of 20 amps to 30 amps at 540 kc/s being applied for 6 seconds for bulkhead soldering and 20 seconds for chassis soldering.

4.2. *Preforming of Components*

In order to achieve the necessary degree of standardization of tuner wiring, all capacitors, resistors and chokes have their end leads formed to shape and cut to length in such a manner that each component is readily inserted into its correct position. Variations in stray capacitance and lead inductance are thus kept within reasonable limits and short-circuits may be avoided between closely spaced components. In Fig. 4 is shown a group of preformed components, the pin jigs used also being shown.

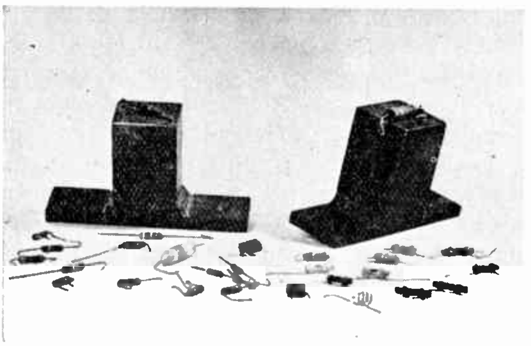

Fig. 4. Preformed components and pin jigs.

4.3. *Wiring*

The wiring is performed in six consecutive operations. The bulkhead is jigged into position to fit accurately between the rotor endplates and soldered to the chassis. The fixed contact strips, carrying loop contact springs, also need to be jigged into position to obtain accuracy of fit to the coil contacts, before being wired to the components. Together with component preforming, consistent wiring within small variations produces the desired degree of standardized performance.

4.4. *Point-to-point Inspection and Insertion of Rotor*

The wired chassis is inspected visually for quality of soldering and correct positioning of components. A resistance test between various points of the circuit is made. A rotor assembly is inserted which has been previously fitted with coils for all necessary channels, omitting channels 3 and 9.

5. Tuner Testing

5.1. *Trimming Method*

Sets of coils for channels 3 and 9 are inserted into the appropriate blank positions by the operator. These coils have been standardized by the controlling laboratory to have each circuit resonant at the correct frequency and to possess nominal mutual coupling, thus giving the optimum response curve and gain in a standard tuner unit. Using these standardized coils, the circuit trimmers are adjusted to give the maximum gain consistent with the broadest and most symmetrical response curve. The r.f. response curve is viewed on a wobbulator-oscilloscope. The curve shape is checked on channel 9 and on channel 3; in both channels the sound carrier and vision carrier must be within 1 db of each other, and the curve between the carrier frequencies must not depart more than 1·5 db from its lowest point.

It is found that a curve check at the centre channel of each Band, namely channels 3 and 9, ensures satisfactory response on any channel. Stray parameter variations which are trimmed out in channel 9 produce, if excessive, curve shape errors in channel 3 in excess of the stated limits. Such errors would usually be due to assembly faults or incorrect components.

After trimming, curve checking and gain testing, the standardized coils are removed. Production coils of channels 3 and 9 are then inserted. The standardized coils are replaced at regular intervals, the moulded strips becoming excessively worn if the coils are used for more than about 500 insertions.

5.2. *Checking Tuner Gain*

The wobbulator-oscilloscope will also display an output response curve at intermediate frequency. A dummy load reproducing the input of the receiver i.f. amplifier is incorporated in the test jig. The input attenuator is set to a determined level, at which level the tuner i.f. output should exceed the nominal amplitude marked on the oscilloscope tube. The oscilloscope amplifier gain control may be calibrated in decibels variation of gain from the standard permissible lower limit of gain. Records may be prepared by the operator showing the gain variations experienced during production, which may be analysed by the statistical methods indicated in section 6.

5.3. *Final Tuner Test*

To ensure correctness of operation of the completed tuner in respect of freedom from microphony and intermittency, and to achieve accurate adjustment of the oscillator frequencies, the tuner is connected to a television receiver supplied with test patterns on all channels. A small signal at intermediate frequency is injected into the sound channel of the receiver, oscillator adjustment producing an audible heterodyne when correctly trimmed. The oscillator frequencies are trimmed by adjusting threaded metal slugs inside the oscillator coil formers.

6. Application of Statistical Method

6.1. *Basic Laws*

It is well known that variations in measured quantities may be expressed with reference to known laws of distribution, for example, the Gaussian (or Normal), Binomial and Poisson distributions. Expressing the tuner gain empirically as

$$\frac{\text{i.f. voltage at i.f. amplifier input}}{\text{aerial voltage}}$$

(both voltages with reference to a 75 Ω measurement source), it is found that the voltage gain in decibels, measured over a large quanity of tuners, conforms with the Gaussian distribution.

6.2. *Assessment of Limits*

Analysis of a sufficient number of measurements, say 100 or more, enables the mean value and the standard deviation to be calculated. The standard deviation is a measure of the range of gains which may be expected to occur quite naturally as a result of chance assembly of components, each within their own permitted tolerances. For production to be economic, the limit for gain should be such that the greater proportion of units subject to these natural differences are accepted as satisfactory, yet rejecting units possessing faults causing low gain. The limit is fixed empirically, and may lie between 2 and 3 standard deviations from the average value. For the tuner described in this paper, the standard deviation is 1·7 db for Band I and 2·1 db for Band III, which means that 95 per cent. of units will lie within ranges of 6·8 db and 8·4 db respectively.

The design specification needs to be written with the knowledge that such statistically normal ranges must be commercially satisfactory. For products of similar design, previously obtained values are reasonable first estimates for the value of standard deviation to be used in assessing new designs.

In Fig. 5 is shown a cumulative frequency graph of measurements upon 100 units, plotted upon linear-probability paper. A Gaussian distribution produces a straight line graph on this paper. It is seen that conformity with the Gaussian law is reasonably confirmed, that the mean value shown at the 50 per cent. ordinate is a gain of 46·2 db and that the gain difference between the 16 per cent. and 84 per cent. ordinates (2 standard deviations) is 3·4 db.

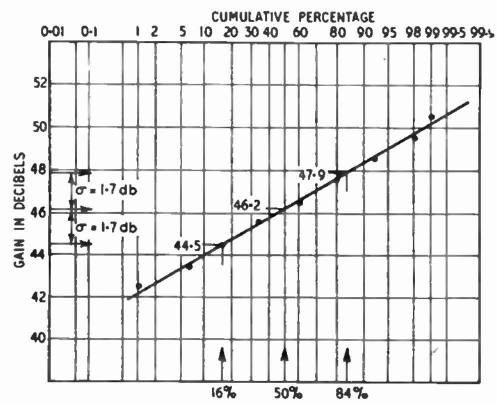

Fig. 5. Gain distribution plotted on linear-probability paper.

7. Conclusion

The methods discussed have been satisfactorily used in the production of over half a million tuner units for incorporation into a manufacturer's television receivers. Special skills are minimized and consistent performance is achieved. The present trend towards greater application of printed circuit techniques may, in the long run, replace some of the methods of standardization, but can be expected to introduce new problems.

8. Acknowledgments

The author thanks the Management of Philips Electrical Limited for permission to present this paper, and Mr. A. I. Godfrey for his assistance with the statistical data and the preparation of slides and diagrams.

A COMPARISON OF TURRET-TYPE AND SWITCH-TYPE TELEVISION TUNERS*

by

V. A. Jones†

The two previous papers have been principally concerned with the manufacture and test methods, etc., used on the assembly of the turret type of input tuner. This type of television tuner is used predominantly in this country and only one or two manufacturers have produced an alternative device. It appears to be in the course of adoption on a similar scale in the rapidly developing manufacture of television receivers in Europe. The reason for this is, without doubt, a combination of features which gives the turret great flexibility combined with a very good electrical and mechanical performance, ease of repair, etc. From the specialist manufacturer's point of view, it has the great merit of ease of variation in details of channel requirement; details of performance of the tuned circuits and similar features may be simply varied to suit particular customer requirements. The flexibility of the turret, particularly if one is concerned at all with export, is of great advantage where there is ease of choice of channel arrangement and the possibility of provision for future station siting. etc. In this country in most areas there is little justification for more than two channels in the near future. Occasionally a situation arises in which equal signals may be received from two B.B.C. or I.T.A. transmitters in fringe conditions. Even if the longer term possibility of additional stations is considered there is little justification for more than four channels.

It may be interesting to comment on another type of tuner which may, in time, find wider application here, namely the incremental switch. The turret tuner was first exploited in the U.S.A. when the need for multi-station and band reception arose and before the Band I and III allocations were finally determined. Its flexibility was of advantage. It is still produced in very substantial quantity in the United States but it is interesting to note that it has gradually been superseded by the incremental switch unit. This perhaps is particularly because of marketing conditions which demand the supply of sets with complete channel complement, due to the large number of stations available with alternative programmes. The turret is relatively expensive where all the channels have to be fitted. The main difference in manufacturing methods in an incremental switch tuner and a turret arise from the need for the test and alignment to be undertaken on the complete assembly. This is because it is not possible to isolate the coil and circuit test. The switch unit normally used for the purpose is specially designed with extra robust contact elements. Construction is that of a normal rotary type wave change switch. However, the coil elements are generally self-supporting units of a few turns of wire supported between the contacts around the periphery of the assembly. The length of connection wire thus forms a large part of the circuit. The circuit adjustment in respect of both resonance and inter-circuit coupling may have to be undertaken step by step from the highest to the lowest frequency. The Band III coils used in some designs are formed of the basic strip metal of the switch elements or may be printed on the switch wafer. The major coil element in each band is generally adjusted by means of a core and the incremental elements separately adjusted by altering spacing after assembly. Little adjustment is possible on Band III particularly where the elements are formed from switch materials but provision is normally made for setting the oscillator frequencies by some capacitive adjustment, such as proximity effects to a screw head.

The final unit is somewhat lower in cost of material content than a turret unit with a full complement of coils and the cross-over in cost is probably at about six to seven channels in the turret. Test adjustment on the complete unit is, in our estimation, somewhat larger than for turret tuners. From the material point of

* Read at an Institution meeting on 7th January 1958; manuscript received 19th May 1958. (Contribution No. 16.)

† The Plessey Company Ltd.

U.D.C. No. 621.397.62

view, the supporting coil formers, mouldings and tag elements of the turret are replaced by the relatively cheap self-supporting coils and assembly of separate components is replaced by a one stage assembly.

The disadvantage of the switch type tuner, even allowing for the extra cost compared with the turret, which has relatively few channels, has been that the electrical performance achieved has not been as high as that for the turret. Each coil assembly in a turret tuner has an optimum for its particular frequency, whereas in the switch tuner, since all channels are in series, there is to some extent a compromise. Normal switch tuners used in the United States have been found to be 4–6 db lower in gain than turret units. Some recent U.S.A. switch designs have achieved performance standards within 2–3 db in gain and 1–2 db in noise factor compared with carefully manufactured turret tuners. Table 1 shows some of the more important characteristics of a recent U.S.A. switch design, compared with a British and a German turret.

The nature of the interdependence of the wiring and the possible variation in the physical lay-out of the components, results in somewhat greater variability in response, performance and other characteristics, than can be maintained in the manufacture of turret units.

Table 1

Comparison of Tuner Characteristics

Parameter	Channel	German (Turret type)	U.S.A. (Switch type)	U.K. (Turret type)
Gain db	1	53	50	53
	5	50	46	48
	9	46	45	46
	13	45	44	45
Noise Factor db	1	8·5	5·0	4·0
	5	9·2	7·0	5·0
	9	6·4	8·0	8·0
	13	7·3	9·0	8·5
I.F. Rejection at at 38·15 Mc/s db	1	21	—	16 or 35 with trap
	2–13	>40	>60	>60
Image Rejection db	1–13	>60	>60	>60
Oscillator Drift kc/s	1–5	60	400	- 100
	6–13	100	350	+ 100
		after 5 min from switch on		
Oscillator Radiation	—	No figures quoted	Within F.C.C. Specification	Within B.R.E.M.A. Specification
Tilt with Bias. db (10 db a.g.c.)	1	10	1	1
	5	4	1	1
	9	2	1·5	1
	13	2	1	1

TURRET TUNER CONSTRUCTION FOR MASS-PRODUCTION*

by

R. W. Ellingham, B.Sc.(Eng.)†

Mr. Ganderton and Mr. Perry have covered very fully the major features of tuner manufacture, including test and alignment, in use in this country and it is proposed to comment only on those features where techniques adopted, and being adopted by my Company, depart from those already outlined.

All coils are wound automatically. Nylon-acetate covered wire is used on Bands I and II. After each winding is completed it is brushed with acetone and dried to hold the turns firmly to one another and the wound former is then assembled by hand to the coil moulding. The wire used is self-stripping so that no cleaning is necessary when making the soldered connections to the contact rivets.

The two coils forming the band-pass are slightly space-wound to overcome to a large extent the variations in coil parameters due to changes in the wire diameter and in the thickness of the wire covering.

By this means, in addition to controlling the outside diameter of the formers to $\pm 0{\cdot}001$ in., the response shape of the band-pass, i.e. channel carriers and the region between, is maintained on channels 1-5 within 3 db of the peak having maximum amplitude. The overall response is kept within the closer limits of 2 db by the core-adjustment of the aerial circuit tuning.

In the cases where the band-pass response is required to be controlled more closely, small adjustments in the inductances of the band-pass coils are necessary. These are made, as is common practice, by slightly opening or closing the end turn or so of the coils at the end remote from the adjacent coil, so as to make the least modification to the coupling between the windings. The limits already quoted can then be reduced to $1\frac{1}{2}$ db and 1 db respectively.

The band III band-pass and oscillator coils are wound in tinned copper wire in the form of self-supporting coils, on a machine which is capable of producing coils to any predetermined pitch and, if necessary, to a varying pitch along the length of the coil. The ends are formed, during winding, in such a way that when the three coils, appropriate to any one particular channel, are assembled on to a former and moulding and soldered to the contact rivets, very little adjustment to the coils is necessary during alignment. The amount of adjustment needed will depend almost entirely on the skill of the assembly operators and careful inspection is carried out to prevent this adjustment from becoming excessive.

To ensure the maximum possible interchangeability of tuner chassis, special wiring techniques are adopted in which sub-sections of the chassis wiring are preformed and assembled in jigs. These sub-assemblies are then wired into the tuner chassis with no further forming or lead length adjustment.

The salient features of the broad-band i.f. amplifier system of testing are as follows:

The mixer anode circuit is sufficiently damped for the tuning of the i.f. output coil to be unimportant. All components with the exception of that at the intermediate frequency are attenuated by passing the output of the tuner through a filter network before it is fed to the broad-band i.f. amplifier.

The error arising from the overlapping of the i.f. amplifier response and the channel 1 r.f. response is corrected by the inclusion of suitable traps in the i.f. amplifier. This results in asymmetry in the viewed response but as this asymmetry lies outside the adjacent channel vision carrier it is considered to be unimportant.

The use of i.f. testing as opposed to r.f. testing makes possible alignment at a signal input level similar to that applied to the tuner under reception conditions.

* Read at an Institution meeting on 7th January 1958; manuscript received 19th May 1958. (Contribution No. 17.)

† The Plessey Company Ltd.

U.D.C. No. 621.397.62

Report of a Discussion Meeting

on

"MASS PRODUCTION OF TELEVISION TUNERS"

Held in London on 7th January 1958. In the Chair: Dr. A. D. Booth.

Nearly 150 members and guests were present at the meeting, which was opened by the presentation of two papers, by P. C. Ganderton and S. H. Perry, and by two short contributions, by V. A. Jones and R. W. Ellingham. These are published on pages 331-348. Informal discussion followed, and these contributions with the replies of the opening speakers are given below.

V. H. Piddington (Associate Member)† I would like to refer to another type of tuner, the permeability tuner, which has been successfully produced in this country for a number of years. For the particular type I have in mind, a complete set of coils (r.f. grid, r.f. anode, mixer grid, and oscillator) for a given band of frequencies is wound on a single former, and tuning to channels within that band is effected by movement of a core assembly inside the coil former. The tuning core may be an assembly of separate iron dust slugs or a combination of iron dust, and brass slugs to provide a greater frequency range. A separate set of coils is provided for each frequency band required to be covered and a switch is employed to effect changeover of coils. The switch may be of the ordinary S.R.B.P. type, either slider or rotary action. The tuning cores must be coupled to a mechanism to provide user operation; this mechanism must also effect changeover of the switch where necessary. Up to the present the control has taken the form of the normal channel "selector knob."

The permeability tuner has a number of advantages, among which are the following:—

(1) It has been found in practice to be cheaper than the turret, for although an operating mechanism is required, the remainder of the tuner tends to be somewhat simpler than the turret.

(2) It is more trouble-free in operation than the switch tuner.

(3) Problems on maintaining stray capacitances and inductances constant are not so pressing, neither does every coil and every tuner need to be standardized. Alignment becomes a matter of adjustment of a unit.

(4) There is no problem of whether to fit coils for all channels, or to fit coils suitable for a particular locality, and then undertake the distribution task of ensuring that each receiver goes to the correct locality. The user has an advantage too, in that he knows that, should he move to a different locality, no further adjustment of his receiver is necessary.

A disadvantage of the permeability tuner is that (in common with the switch tuner), optimum performance must be sacrificed in order to provide adequate performances over the whole band, and variations in coupling between coils with movement of the tuning core cause bandwidths to be somewhat larger than could be wished for on the higher frequency ranges. Another disadvantage is that its flexibility is not so great as that of a turret tuner. For example the provision of tuning facilities for Band II is not so easy, neither is the provision of a straight-through i.f. amplifier for feeding with the output of a v.h.f. tuner.

It must be admitted that, in the past, the performance obtained with a permeability tuner has not compared well with that achieved on turret tuners but with modern designs, performance quite comparable with turrets has been realised. Typical performance figures are:—

	Band I	Band III
Gain (Aerial input to 1st i.f. grid)	50–52 db	48–50 db
Noise figure	6–8 db	8–10 db

Oscillator drift has been a problem, because there are mechanical features additional to those existing in a turret, which have a marked effect on drift. However, giving attention to these features, together with the use of negative temperature co-efficient capacitors, enables the oscillator warm-up drift to be held within ± 100 kc/s from 3 minutes after switch on.

* Discussion Meeting No. 13.
† Bush Radio Ltd.
U.D.C. No. 621.397.62

Incidentally, the existence of a switch enables compensation to be made for the differential in drift between Band I and Band III, by use of different negative temperature co-efficient capacitors for each band.

The existence of a fine tuner has resulted in little interest being taken in long term stability, and no reliable figures are available, but the presence on *all* types of tuners of a fine tuner is sufficient commentary on the expected stability of tuners in general. However, with the current demand for the removal or disguising of the fine tuner more attention is being given to this point.

Even though it has disadvantages, the permeability tuner has been used successfully for a number of years, and its advantages may cause it to be used for a number of years to come; in addition it has avoided a number of problems associated with the production of turret tuners.

V. A. Jones (*in reply*): It is possible that the design to which Mr. Piddington has referred resulted in a particularly successful compromise. We have also made a permeability tuner and various attempts have been made to use this system in the United States but these have not proved very satisfactory for various reasons; turrets and switches are used almost universally there and in Europe. In particular we found it considerably difficult to obtain satisfactory tracking of the various circuits without varying either tuning, noise level or response shape and it would be interesting if Mr. Piddington could gives some figures on these characteristics at different frequencies. We have found that these difficulties, together with lack of versatility, did not commend these designs, in general, to the setmakers buying complete tuners.

R. W. Ellingham (*in reply*): It is agreed that the permeability-type tuner has certain advantages over the turret-type tuner but it is considered that the reduction in performance which inevitably results from an optimization over the whole of a band, as opposed to individual channels, combined with lack of versatility in positioning of channels, of channel frequencies and bandwidths, outweighs these advantages.

The typical performance figures quoted, particularly in respect of gain, are just as attainable with a well designed turret and is is doubtful if they are achieved by the permeability tuner over the whole of each band, if at all.

The need for a high degree of standardization in turret tuner production, whilst presenting its own special problems, results in a more consistent product and it is not considered to be a disadvantage.

P. C. Ganderton (*in reply*): In the early days of Band III reception I think it is true to say that the majority of companies favoured permeability tuners. At first sight they are far cheaper than turret tuners and, in theory, can be made to perform just as well. In production, however, the severe requirements placed on the mechanics necessitate a construction which is so large and so solid as to make it as, or more, expensive a tuner than the turret. This has resulted in all but one of the original tuners being replaced by other forms of tuning.

D. W. Heightman (Member)*: Experience in the large-scale use of turret tuners in two manufacturing organizations over the past four years has shown the long term stability to be good. By comparison with the switch-type tuner, far less trouble has been experienced with high contact resistance. It is probably true to say that the turret designers have given the question of maintaining low contact resistance over longer periods more consideration than designers of early versions of switches used in switch tuners. Silver-plated switch contacts using normal plating thicknesses have been found to be quite inadequate to withstand various forms of atmospheric corrosion.

Whilst the turret tuners I have referred to were fitted with fine tuning controls, it was generally found that these controls were not necessary to correct long term variations in oscillator frequency, but were more generally used in correcting tuning when the receiver was switched from Band I to Band III.

V. A. Jones (*in reply*): With reference to Mr. Heightman's first comment, I can confirm that we have made a series of mechanical tests

* Radio Rentals Ltd.

of the switch contacts and these have shown the resistance to wear of the turret contact to be very good. We have found on our units that no deterioration occurs up to about 30,000 operations. We have made a practice of using a thick silver deposit both on the coil units and the main spring contacts and the spring performance is of importance. The good durability is due, in part, we think, to the form of contact used in turrets. A relatively long spring section is used, compared with the short stiff type of contact used in the normal rotary switches. Pressure changes with movement of the contact during movement of the switch are relatively uniform and the pressure can be lower than with the short spring type.

C. L. Wolsey (Associate Member)*: In answer to the suggestion that an ideal television tuner would have no fine tuner, thus necessitating a.f.c., I would point out that my firm's present range of television receivers have neither fine tuner nor a.f.c. Many thousands have been produced and no frequency drift troubles have arisen.

A cause of oscillator frequency instability which seldom appears to be considered, few facts or figures being ever published concerning its magnitude or cure, is that due to change of humidity of the atmosphere. My own measurements indicate that unless certain precautions are taken the shift of frequency can be quite considerable with changes of humidity met with in ordinary living room conditions. This is more difficult to deal with than shift of frequency with temperature. The capacitor makers have not yet provided us with a range of capacitors having a negative humidity coefficient.

D. W. Heightman : In the television Bands I and III oscillator drift tolerances of the order of 100 kc/s are usual. It is preferable however that, particularly bearing in mind the desirability of good performance of Band II, the drift should be confined to a much lower figure of the order of 25 kc/s. Such a figure of drift would make possible the omission of the fine tuning control so that users would be able to select their programme merely by rotating the channel selector knob. This is the ideal state of affairs. Towards this end, it would be interesting to know if any of the tuner manufacturers have made progress with simple forms of a.f.c.

The Chairman (Dr. A. D. Booth): Thermal stability against drift is also important in the reception of f.m. sound broadcasts. I have personal experience of a set which when new was reasonably free from drift, but which became extremely liable to drift after about six months of use. Has any long term investigation been made to show how these tuning units behave after fairly long use?

S. H. Perry (*in reply*): It is correct to say that the main function of the fine tuner is to apply correction to tuning when switching between channels in Bands I and III. Oscillator frequency drift is not troublesome in television reception.

In relation to the sound i.f. bandwidth, the drift which occurs produces negligible change in sound reception. As oscillator frequency drifts there is a change in effective carrier attenuation to which the vision carrier is subjected in the vision i.f. amplifier. Such a change could produce unacceptable deterioration in picture quality, but the present technique of designing vision i.f. amplifier response to give an optimum compromise between phase linearity and amplitude linearity produces an improved picture quality which is considerably less dependent upon correctness of carrier attenuation.[1] The correct combination in minimized frequency drift and phase-linear i.f. amplifier design could in some cases render the fine tuner unnecessary.

When a type of receiver may be used for the reception of either strong or weak signals, the fine tuner provides the user with another facility. The signal-to-noise ratio of the picture improves as carrier attenuation is reduced by operation of the fine tuner. The optimum settings in each user's locality which has a combination of weak and strong signals may thus be achieved.

Replying to Dr. Booth, the greater part of thermal drift of oscillator frequency is due to changes in capacitance—of valves, capacitors, self-capacitance of coils, stray capacitances to chassis, and of the fine tuning control. The

* Murphy Radio Ltd.

valve capacitance change is important only during the first five minutes of operation. Temperature coefficients of permittivity of various dielectrics used in tuner components vary over a wide range in magnitude and may be either positive or negative. Empirical selection of a suitable negative temperature coefficient capacitor placed in the oscillator circuit can reduce the overall effect of changes in various components, but it remains essential that only approved components may be used; that is to say, that any permitted alternative components must be compatible in regard to temperature coefficient.

Compensated drifts of 20 parts/million/°C on Bands I and III have been acceptable. It is necessary and practicable to keep the drift within 6 parts/million/°C on Band III.

R. W. Ellingham (*in reply*): It is possible, without serious difficulty, to reduce the Band II drift to less than 50 kc/s and this, as far as Band II reception employing an i.f. of 38 Mc/s is concerned, is satisfactory in the majority of cases.

V. A. Jones (*in reply*): A fine tuner is necessary in areas where more than one Band III station is required. This occurs in certain of the relatively large Band III fringe reception areas and where the possibility of adjustment, with variation of reception between channels occurs and the provision of the adjustment is important.

P. C. Ganderton (*in reply*): We have constructed tuners with a.f.c. based on experimental a.f.c. diodes. The results obtained with these were very encouraging in the laboratory but field tests showed an unfortunate snag. When the receivers were used on v.h.f. sound broadcasts in districts where interference is experienced with local mobile transmitters, these being the stronger signal, swung the receiver to their frequency. Thus, instead of an annoying break-through on the desired programme, a complete loss of programme was experienced.

In answer to Dr. Booth I would suggest that it is most likely that a fault has developed on his receiver as I have not heard of this effect occurring purely due to lack of long-term stability. We conduct tests on all materials used in the construction of our tuners, including performance in extremes of humidity and extremes of temperature, and also periodically select units from production which are then retained by the laboratory as reference units. The absence of complaints and the stability of the reference units bears out that there is no long-term increase in cyclic drift. There will, however, be a tendency for a non-cyclic change in frequency which occurs on all receivers probably due to the change in valve slope with age; these changes alter the tuning through the Miller effect.

L. Tye (Associate Member)*: Although it is no doubt convenient for Mr. Ganderton to consider that a television receiver incorporates a built-in delay mechanism of three minutes, I do not think that this is the case. In fact, I am rather surprised that this magic figure of three minutes is so commonly used even by technical people. The warm-up time of the average television receiver is much nearer 1½ minutes and certainly nothing like 3 minutes. The important point is how quickly does the picture appear on the tube so that the effect of the turret drift is visible to the user.

V. A. Jones (*in reply*): Mr. Tye's point is interesting but I think his figure of 1½ minutes is rather short. In my experience most receivers are not very stable for 2 minutes or more and the restriction of the tuner to 2-2½ minutes is not unreasonable. The problem of frequency correction is, of course, largely an economic matter. More complex correction circuits than at present adopted would use extra components and these could readily be fitted but it is doubtful whether the extra cost would be justified until greater uniformity is obtained in the time operation of receivers for other reasons than the tuners. In this connection there is the thermal stability of the i.f. amplifier which is also subject to drift. If this drift is in a direction which offsets that of the tuner, it can make a useful contribution to the stability of the receiver. In some receivers we have investigated, the two effects have added and the result is to increase the total drift by as much as 30 per cent.

* Rediffusion Vision Service Ltd.

V. A. Jones: A factor to which I suggest some attention could usefully be directed is the matching of the tuner to the aerial. The receiver designers with whom we have had contact are concerned about as little as 1–3 db variation in the tuner performance. However we have recently measured the effect of aerial isolation components on matching to the cable, and in some cases have found this introduces a serious mis-match which increases the standing wave ratio by a factor of two.

A further factor which considerably affects the final performance of a receiver is the aerial system itself. Some of the so-called high sensitivity directional aerials can have appreciably reactive components and I wonder to what extent receiver makers, particularly in fringe design receivers, test such characteristics. Any comments on the test and specification details which receiver manufacturers apply to the aerial installation for use with their sets would be of interest. I wonder if these are as stringent as those applied to the tuner?

D. W. Heightman: I consider that Mr. Jones' question is much more a matter for the turret tuner manufacturers, because I think it is true to say that present designs do not represent a resistive 80-ohms termination across the television channel width of 5 Mc/s. Conditions in the aerial input transformer circuit as at present designed make it impossible to obtain accurately the television receiver response curve, even if correctly terminated signal generators or sweep generators are used. According to where the aerial input circuit is tuned, differences in the response curve of the order of 6 db can be obtained. In other words, turret input circuits were not flat over the normal television channel. It is appreciated that to bring about an improved matching arrangement might involve loss in gain and/or signal-to-noise ratio.

Taking the above matching problems into account, together with aerial characteristics which similarly were often very reactive across the television channel, it is little wonder that when connected to an aerial, the television receiver often gives anything but an even frequency response. At the present stage of the art, in fact, this whole matter could be said to be very empirical.

S. H. Perry (*in reply*): In connection with the input impedance of television receivers, of course it must be realized that the input impedance is not constant across the television channel width. Even comparatively simple theoretical studies[2] of single tuned input circuits will show that the impedance is resistive at one frequency only and at all other frequencies is a complex impedance. A more detailed analysis shows that the impedance may be resistive at one, or two frequencies, or even not purely resistive at any frequency at all (in cases of bad design). The magnitude of impedance is to some extent controlled by circuit design, and to some extent dependent on stray parameters. In the case of a double-tuned bandpass input circuit the input impedance is always resistive at one frequency (given good trimming) at the centre of the television channel. It is also resistive at two other frequencies, one at each side of the channel, but of lower magnitude. At all other frequencies the impedance is complex.

In both types of circuit the law of input impedance versus frequency conforms with mathematical equations which may be derived by appropriate analysis. This is a function of tuned circuits and applies to all types of tuning device, whether turret, permeability or switch tuned. It is erroneous to think that a constant input impedance will be obtained across the whole television channel width. The appendages in the aerial feeder connections referred to by Mr. Heightman have, with good design, negligible effect in comparison with the circuit complex input impedance. The appendages are essential to conform with safety requirements.[3]

The aerial characteristics conform with known impedance laws which have been published in many books.[4] The complex impedance presented by the aerial may be obtained from references or measured with a suitable bridge. It is possible to combine the effects of impedance mis-match of both aerial and receiver when connected through a transmission line by the use of the Smith Chart. Such a display indicates the degree of reflection to be expected under a wide range of installation conditions and enables a standard of good practice to be achieved without resort to empiricism.[5]

It is usual practice to arrange that the input impedance at the frequency of resistive impedance is not 80 ohms, but rather that compromise value which gives an improved signal-to-noise ratio[6] without exceeding the permitted magnitude of reflection coefficient indicated by the Smith Chart display. A value of 120 ohms is not unusual. The disadvantages referred to by Mr. Heightman do not exist if there is an understanding of the whole complexity of input circuits and their total requirements, which guides the design and checking of their performance.

P. C. Ganderton (*in reply*): I would like to quote the results of our own work on a tuner having a standing wave ratio over the desired channel, when measured at the aerial coil terminals, of 4·0:1. When fitted with an i.f. trap it has a standing wave ratio of 2·8:1. When fitted with aerial isolating components this falls to from 1·3:1 to 2:1 depending on the dressing of these components. Against this a tuner starting with a standing wave ratio of only 1·6:1 was still around 1·5:1 under the worst conditions. From this it can be seen that whatever results are obtained from the tuner, the deterioration imposed by the rest of the circuit will result in no overall improvement in the picture.

P. E. Jeppesen*: Mr. V. A. Jones in his appraisal of switched incremental inductance tuners suggests that, in terms of material content, such a tuner is less expensive than a turret tuner and that the debasement of about 2 db in noise factor, found in tuners he has examined, is acceptable when related to the saving in material cost.

In view of the limitation of operating area imposed on a receiver by its tuner noise factor and appreciating that receiver manufacturers are contemplating the use of more expensive cascode valves to improve the signal-to-noise ratio, namely the frame grid double triode (PCC 89)—I would ask if Mr. Jones or the receiver manufacturers can justify a minor saving in the material content of a tuner at the expense of signal-to-noise debasement.

It is interesting to note that comparisons of picture quality under fringe conditions—Poole to the I.T.A. transmitter in Wales—have shown that non-technical observers can distinguish a fall-off of 2 db in signal-to-noise ratio when comparing picture quality in a receiver having a turret fitted with two sets of coils each of similar gain characteristics but one with a noise factor 2 db worse than the other.

V. A. Jones (*in reply*): The question of noise level in a receiver in particular is in part an economic matter. The fringe conditions such as Mr. Jeppesen mentions as occurring in Poole are limited to a small proportion of reception conditions and is, I believe, of the order of 20 per cent. or less of the total possible coverage. Therefore, the question of additional cost and perhaps the use of a more expensive valve to gain 1 or 2 db of noise factor can result in the addition of cost to 80 per cent. of the sets, for the benefit of only 20 per cent. of the users. As many manufacturers now make special fringe models for various reasons other than those associated with the tuner, it would seem that a case exists for special designs of tuner. I would suggest as the increased number of Band III stations comes into service designed to provide coverage up to 94 per cent., the fringe reception will reduce and consequently, the possibility of using a simple lower performance unit for general purposes will follow.

S. N. Doherty†: No mention has been made of production line measurements of local oscillator voltage at the tuner aerial terminals. I have recently examined several makes of commercial television receivers and found all but one exceeded the recommended limit of aerial terminal oscillator voltage on Channel 9 (1mV in 75 ohms).

While the measurement of aerial terminal oscillator voltage is not directly related to the radiated field, it is at least a guide to the expected radiation. It may also be of greater importance in blocks of flats where many receivers are fed from an r.f. distribution system with perhaps 40 db attenuation between aerial sockets. Heterodyne patterning on picture and whistles on the sound channel can occur due to this effect.

* Sydney S. Bird & Sons Ltd.

† Mullard Research Laboratories.

I should, therefore, be interested to know whether such checks are carried out on production line tuners.

S. H. Perry (*in reply*): It is not usual to apply production line checks for aerial terminal oscillator voltage. It is a matter of design whether this feature is within the recommended limit to sufficient extent to allow a latitude for production variations. Unless designed to be correct, the production departments can do little to correct units not conforming with specification. Proper type approval tests prevent the submission for production of unsuitable designs.

R. W. Ellingham (*in reply*): It would not be practicable to make a production line measurement of local oscillator voltage at the tuner aerial terminals and it is considered that careful attention to this parameter, or rather to the more fundamental measurements of radiated field, during the design stage is all that is necessary.

Interference between receivers connected to an aerial distribution system, assuming the generally adopted B.R.E.M.A. intermediate frequencies, will result from the second harmonic of the local oscillator on channels 3, 4 and 5 which fall into channels 7, 9 and 11 respectively. If a reasonable degree of attenuation between receivers is used, the level of this harmonic is such that no heterodyne patterning should be observed.

Interference resulting from the fundamental of the local oscillator on channel 6, which falls into channel 13, is likely to prove much more troublesome when these channels come into use. This is a problem which must be borne in mind when allocation of channels 6 and 13 is contemplated.

F. R. G. Webb*: It has been suggested that increased coverage offered and planned by I.T.A. will reduce the economic value of improving the signal-to-noise ratio of turret tuners, above that offered at the present day. This increased coverage will present another problem in as much as that it will result in a greater number of localities receiving dual coverage. At the moment it is common practice on Band III Channels to make the response symmetrical around the centre of the channel and about 6–7 Mc/s wide. I have experienced extremely bad picture break-up at Potters Bar in Middlesex whilst receiving Channel 9, due to cross-modulation from Channel 8 (Birmingham). I have also observed at Portsmouth a stronger signal from Birmingham than the signal received from London. I submit that this interference will become more common as the I.T.A. service develops, and it will be necessary for the turret tuner manufacturer to consider reducing the bandwidth of the Band III circuits.

V. A. Jones (*in reply*): Mr. Webb's point is very interesting and, of course, considerable study of the total response characteristics may well be necessary but I suggest that considerable advantage could be obtained by the use of directional aerials. We have not received much indication of difficulties of the kind he has mentioned from the usual trade sources.

P. C. Ganderton (*in reply*): The average Band III tuner response curves are about 4 Mc/s wide at the 3 db points. A small amount of adjustable capacitance coupling is used to enable this to be accurately set on all tuners, but as the major adjacent channel rejection is contributed by the i.f., I think it unfair of Mr. Webb to blame his break-up on the tuner. This would only be so if the two signals were sufficiently strong to cause cross-modulation in the tuner and I am sure this cannot be the case.

A. I. Godfrey†: As a statistician, I am less interested in the relative performance of turret, switch and permeability tuners, than in the ease with which consistent runs can be produced. Comparisons of costs based upon design models include labour and material content, but only vague "allowances" for the *hidden* costs, which are the real yardsticks of mass production. Hidden costs are those involved in special work on tuners that, for no apparent reason, do not work as they should. This work

* The Plessey Company Ltd.

† Philips Croydon Works Ltd.

cannot be properly estimated from a few design models.

"Hidden" costs are so-called because they are very difficult to assess, even during production, and I have been unable to obtain any figures within my own company. Nevertheless, I have found that, if my statistical calculations at the beginning of a run show that not more than about 4 per cent. of tuners will be outside limits, the hidden costs will be satisfactorily small. However, I have experience only of turret tuners, and I would value any comparisons of the relative hidden costs of the three types of tuner.

R. W. Ellingham (*in reply*): It is not possible in a meeting of this kind to quote figures giving typical reject rates on tuner production, but it can be said that a reasonably accurate allowance for "hidden costs" can be, and is, made on the basis of past experience when preparing an estimate on a new design.

V. A. Jones (*in reply*): Mr. Godfrey's comments are interesting. We try to prevent such costs being hidden, as a matter of principle. If we have more than a very few per cent. of repairs or other than standard alignment operations in any components, we would consider them unsatisfactory from the production point of view.

P. C. Ganderton (*in reply*): I am unable to quote Mr. Godfrey any figures showing the average price per tuner of any service work needed, but as we are component manufacturers only, this sum cannot be a "hidden cost" as the staff involved work on no other product, i.e. the rest of the television receiver. However, a great deal of attention is given to the control of faults. By the use of quality control and reject control persistent faults are related back to the operator and/or components, and corrected.

P. Scadeng* (Associate Member): The success of the mass production alignment of turret tuners depends upon the technique of aligning all production tuners to a "standard" coil biscuit and likewise aligning all biscuits to a "standard" tuner. This technique ensures that any biscuit will operate with any tuner but only so long as the characteristics of the standards and in particular the self-capacitance of the standard tuners is maintained constant with time. Should the "standards" drift only slightly with time it would mean that production tuners produced at one time would not operate satisfactorily with biscuits produced at another time, and vice versa.

Would the contributors care to indicate whether any special measures have to be adopted to maintain a satisfactory constancy in the characteristics (particularly self-capacitance) of the standards used for production alignment?

P. C. Ganderton (*in reply*): At the start of a production run the line is allowed to produce at least 1,000 tuners before standards are produced. This enables the wirers to settle in their methods. At the end of this 20 tuners are taken at random and their characteristics plotted to find an average. A similar selection of valves are taken from various production batches and evaluated. From the results of this a standard tuner is created. Sub-standards are also produced to have the identical characteristics for day to day use. During the course of production slight changes do occur as indicated by Mr. Scadeng, so periodically new standards are created but only if the coils produced to them will still function within limits on all previous standards. If this is not so the tuner is modified to correct for the change. I can substantiate the results of this system by the fact that, of the many thousands of coils supplied to be plugged into tuners in the field, some of these nearly four years old, we have received no rejects through not tracking.

S. H. Perry (*in reply*): The "standardized" coils used for production testing of tuners are adjusted by the controlling laboratory to be correct for inductance, coupling and capacitance. The response curve and gain of these coils need to be identical with master standards retained by the controlling laboratory. In practice, all the test coils are replaced weekly, each coil being subjected during this time to about 500 insertions into turrets.

The "standardized" tuners used for production testing of coils are likewise checked for performance with suitable master standard

* Regentone Ltd.

coils. In addition, random sample inspections to laboratory standards are in constant process by the controlling laboratory.

V. A. Jones (*in reply*): It is our experience that most variations are due to the inductive components in tuners. The variation in input capacitance of the valves is considerable and it is normally necessary to make provision for capacitive adjustment for this reason. There is also appreciable change in the valves with life. The provision of trimming adjustments in the circuit is therefore to be recommended.

As to the maintaining of standards, we have both reference tuner chassis and coils and use them to cross-check for drifts. In addition provision is made for coil adjustment by means of adjustable cores on the oscillator and aerial circuits in most designs of turret, should valve changes be necessary. Both these and the capacitor adjustments are accessible.

The Chairman (Dr. A. D. Booth) asked whether investigation had been made to find if there existed an optimum coil shape which minimized sensitivity of the unit to variations of the parameters.

S. H. Perry (*in reply*):—Economic factors do not permit the use of complex coil construction in television tuners. The oscillator coils are usually single layer solenoids with the length/diameter ratio lying between 1·6 and 2·6; this indirectly assists in achieving thermal stability, which is best when the axial expansion exceeds the radial expansion by an optimum amount. Mr. Ganderton has indicated in his paper some other coil design factors which influence thermal stability.

A. A. Briers*: In spite of remarks to the contrary, switch type tuners have proved generally more than equal to the turret tuners in general use, and have the big advantage that all channels are covered at all times. Responsibility is taken from dealers for selecting channels as is the case with many turrets. These switch tuners have been manufactured and used for many years and have proved extremely satisfactory; certain export versions have also successfully been made.

* Holloway Engineering Works Ltd.

The basic assembly of the turret tuner differs little from the switch as regards the "chassis" assembly. The major difference is the wafer assembly on the switch tuner. Shortness of wires, selection of components, in some cases special design of components, all apply equally to both tuners.

G. G. Blowers†: As a representative of a capacitor manufacturer I was somewhat surprised to hear Mr. Wolsey's request for capacitors which vary with humidity, as it has been our life's work to try and make capacitors which do not change at all with variations in humidity.

I was interested in the remarks of Mr. Perry concerning r.f. eddy current soldering of capacitors to the tuner chassis, as we always like to hear what our customers do with our components—and are sometimes horrified!—and I wonder whether Mr. Perry would care to give some more details with regard to the power input and times, etc., used.

S. H. Perry (*in reply*): The heating current of 20 amperes at 540 kc/s flows through the single loop work coil for 6 seconds. By the end of this time the bulkhead is hot enough at local spots to melt solder at correct viscosity for good fusion. Four seconds later a cooling draft of air is applied for eight seconds. The degree and time of heating of the ceramic capacitors is less with r.f. eddy current soldering than when a hot iron, which usually comes into direct contact with the ceramic, is used.

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6. L. A. Moxon, "Recent Advances in Radio Receivers." (Cambridge University Press, 1949.) J. Thomson, "Radio Communications at Ultra High Frequency," pp. 89-135. (Methuen and Co. Ltd., London, 1950.)

† Erie Resistor Ltd.

APPLICANTS FOR ELECTION AND TRANSFER

As a result of its May meeting the Membership Committee recommended to the Council the following elections and transfers.

In accordance with a resolution of Council, and in the absence of any objections, the election and transfer of the candidates to the class indicated will be confirmed fourteen days after the date of circulation of this list. Any objections or communications concerning these elections should be addressed to the General Secretary for submission to the Council.

Direct Election to Full Member

BOYER, Frank Albert, B.Sc. *Singapore.*
ROBINSON, Frederick Chetham. *Cheam.*

Transfer from Associate Member to Member

CAUVIN, Gérald André. *Boulogne.*
RIDLEY, Group Captain Leslie Ralph, O.B.E., R.A.F. *London, N.3.*
WILSON, Sidney Thomas. *Romford.*

Direct Election to Associate Member

CHALMERS, David. *Wirral.*
COOPER, Major Anthony Matthew, R.A. *Shoeburyness.*
HARDEN, Lieut. Com. Faulkner, R.N. *Chatham.*
HENMAN, Derek John, B.Sc. *Chelmsford.*
LONG, Arthur. *Pinner.*
SHAW, Derrick, B.Sc. *Rotherham*

Transfer from Associate to Associate Member

GRAHAM, George Albert. *Upminster.*

Transfer from Graduate to Associate Member

CHAUDRI, Enver Hussain. *Ipswich*
DOCKERTY, William Harold. *Farnborough, Hants.*
DUBIEL, Franciszek. *Wolverhampton.*
KELLY, Leslie Charles. *Ruislip.*
LARKIN, Richard Walter Edward. *Staines.*
MATTEI, Rodolfo. *London, N.14.*
MURTHY, Capt. Pillalamarri Venkata Rama, B.Sc., Indian E.M.E. *New Delhi.*
OWEN, Flt. Lt. Clifford Russell William, R.A.F. *Gibraltar.*

PALMER, Donald Ridgeway. *Battle.*
SLATOR, Sidney Lipscombe. *Dublin.*

Direct Election to Companion

WILLSON, Harry Claude. *Wolverhampton.*

Direct Election to Associate

BRIERLEY, Harry Kennedy. *Liverpool.*
BROWN, Clement. *Loughton.*
HUMPHREYS, Humphrey Ioan. *Stevenage.*
MURRAY, Edward Daniel. *Kingsbridge.*
WOODCRAFT, Frank Percy. *London. S.W.1.*

Direct Election to Graduate

CRUMPEN, Mervyn James. *Chelmsford.*
DUCKER, Peter Gerald. *Ville La Salle, Canada.*
KERSEY, Roger Woodford, B.Sc. *Redhill.*
KOCSIS, Ferenc. *Welwyn Garden City.*
WALKER, David John. *London, S.E.15.*
WALLACE, Lieut. Eric William, B.Sc., Ph.D., R.N. *Portsmouth.*
WILKINSON, Alan, B.Sc., Dip.El. *Egham.*

Transfer from Student to Graduate

EXARCHOS, Vladimir. *Athens.*
GURDIAL SINGH, Dhillon. *Kuala Lumpur.*
LAKSHMINARAYANAN, Thirunillai Mahadevan. *Kalpathi-Palghat.*
LEDIJU, Idris Ola. *London, N.16.*
MENKAL, Raymond. *London, E.5.*
NEUMARK, Nathan. *Haifa.*
SAHNI, Pritam Singh, B.Sc. *Coventry.*
TURNER, Dennis John. *London, S.W.19.*
TURNER, Raymond Eric, B.Sc. *Burton-on-Trent.*

STUDENTSHIP REGISTRATIONS

BACON, Philip Morgan.* *Belfast.*
BHATNAGAR, Krishna Prasad. *New Delhi.*
BHATT, M. Sridhar. *Bombay.*
BRITTON, Basil Mervyn. *Wigton.*
BUTCHER, Raymond Alec. *Jersey.*

CHATER, William Charles. *Kampala, Uganda.*
CHEUNG, Leung Fat. *Hong Kong.*
CUMNER, Royston Edward. *Gloucester.*
CURTIS, Horace Brian. *Coventry.*

DUTTA, Subal Chandra. *Bangalore.*

ESTER, Lubbertus. *Eindhoven.*

FIROZGARY, Merwan Khodamorad. *Nasik City.*
FOSTER, David Bernard. *Shelford.*

GARG, Subodh Kumar, B.Sc. *Deoband.*
GHOSH, Amal Kumar, B.Sc. *Bhagalpur.*
GIRDHAR, Bhim Sain, B.A. *Bhiwani.*
GIRIJ KUMAR, T. K. *Secunderabad.*
GREEN, John Owen. *Horseheath.*
GRIERSON, David William. *Colchester.*
GRIGGS, Brian Edward. *Potton.*

JOHNSON, Derek. *Halifax.*

KAUSHAL, Ram Sarap. *Hoshiarpur.*
KHAN, Zakir Ghulam Nasir. *Karachi.*
KRISHNA MURTY, Bulusu Rama. *Visakhapatnam.*

LEUNG, Kam Por. *Hong Kong.*
LEWIS, Vivian. *Treharris.*
LOUCH, Terence George Henry. *Beaconsfield.*

MAHAPATRA, Sasanka Shekhar. *Veraval.*
MANUKULASURIYA, Ranjan. *Dehiwela.*
MILLS, Raymond Hugh. *Stapleford.*
MOHAMMAD SALEEM, CH., M.Sc. *Lahore.*
MOHAN SINGH. *Jullundur City.*
MUTHUKUMARASWAMY, N. *Tanjore.*

NAGARAJA SETTY, C. S. *Srirampet.*
NAIR, N. Janardanan, B.Sc. *Trivandrum.*
NARASIMHA SASTRY, Yellapragada Lakshmi, M.Sc. *Hyderabad.*
NARAYANA RAO N., B.Sc. *Bangalore.*
NARAYANAN, P. P., Bc. *Pazha-Annur.*
NENE, Vasant Ganesh, M.Sc. *Unnas.*

PAI, Krishnananda N., B.Sc. *Bombay.*
PARAMESWARAN NAIR K., B.Sc. *Trivandrum.*
PAUL, William George. *Lowestoft.*

RAMA SESHU, Kasarabada, B.Sc. *Bombay.*
RANGACHARI, Sowmianarayanan, M.A. *Madurai.*
REID, Keith Gordon. *Montreal.*
ROWE, John Maxwell. *Barnstaple.*

SHETTY, Taranath M., B.Sc. *Bombay.*
SIMPSON, Albert John Paddison. *Largs.*
SOAMES, Michael Richard. *March.*
SOOD, Baldev Krishen. *New Delhi.*
SPEDDING, Ronald. *Blackburn.*
SWAMINATHAN, Muthiah. *Dwarka.*

THORPE, Jack Ronald. *Leeds.*

VAN DEN HAAK, Willem. *Leiden, Holland.*
VENKATESH, Sampath, B.Sc., M.S. *Bombay.*

WALKER, John Joseph. *Glasgow.*
WALKER, William. *Brodick, Isle of Arran.*
WALLER, Dennis John. *Basildon.*
WEISSBERG, Ernst Michael. *Ramat Gan, Israel.*
WONG, Woon Man. *Hong Kong.*
WRIGHT, Plt. Off. Robert St. Lawrence, R.A.F. *Waddington.*

* Reinstatement.

HELICAL WAVEGUIDES—CLOSED, OPEN AND COAXIAL*

by

G. M. Clarke, M.A., Ph.D.†

SUMMARY

The application of helical waveguides to electron-beam amplifiers employing slow wave structures is described. The performances of the various possible configurations are discussed.

A recent exhaustive paper by R. A. Waldron[1] on the modes of the closed helical waveguide (Fig. 1 (*a*)) prompts the comments which follow. They are based on work carried out some years ago, in which a very high power slow-wave structure was required for a crossed-field microwave amplifier.[2] Waldron mentions no applications but the slow-wave structure aspect is an obvious one, and for interaction with an electron beam, axial holes or annular apertures are needed which, if suitably disposed to break no wall currents, would leave the propagation undisturbed.

The relevant mode is that which degenerates to the dominant mode in straight waveguide of the same cross-section. The sparsely tabulated solutions of the coaxial cavity mode equation which is shown by Waldron to apply subject to second-order correction terms only, are nevertheless sufficient to deduce the fundamental axial phase velocity characteristic at least qualitatively, if a graphical procedure is adopted. This is shown in Fig. 2.

There are several important features which deserve comment. Firstly, electron beam amplifiers normally operate with a phase change per period about mid-way between zero and π radians phase shift per turn (i.e. $0<\nu<\frac{1}{2}$) where the impedance is not lowered by space harmonic content in the axial wave. It can be seen that this region is inaccessible from a straight guide of the same section, for whatever the radius ratio the region $0<\nu<\frac{1}{2}$ lies beyond its cut-off wavelength $2(b-a)$. This can of course be overcome by using a ridged or tapering feed guide. More serious is the extreme dispersion which exists for normal radius ratios, e.g. for a radius ratio of 5:1 the velocity decreases from infinity at the cut-off to the velocity of light times $D/(b-a)$ at the π-mode in a 3 per cent. frequency band. The less dispersive regions beyond $\nu=\frac{1}{2}$ are barred for amplifier use by the usual difficulty of being unable to avoid oscillation due to synchronism with the higher impedance backward travelling space-harmonic. This is shown in Fig. 3 which

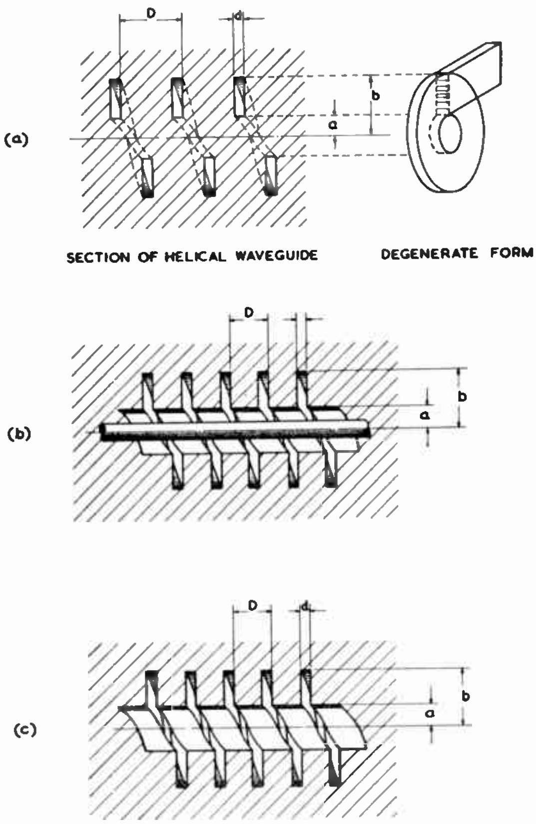

Fig. 1. Three forms of helical waveguide.

* Manuscript received 27th February, 1958. (Contribution No. 18.)

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U.D.C. No. 621.372.822

depicts the phase velocity information of Fig. 2 on the more usual diagram for valve applications.

These dispersive characteristics arrive from the fact that one is "wrapping up" a transmission line which is already highly dispersive in the region where the phase change per unit length is low enough to be usable. The arrangement can be improved by introducing coupling between adjacent turns, e.g. by widening the hole for the beam. This reduces the low frequency cut-off, and if taken to the extreme, the structure becomes a coaxial line with helical grooves in one or both conductors (Fig. 1 (*b*)). Apart from the possibility of transverse modes in the doubly grooved system, it matters little for a qualitative discussion whether one or both conductors are grooved.

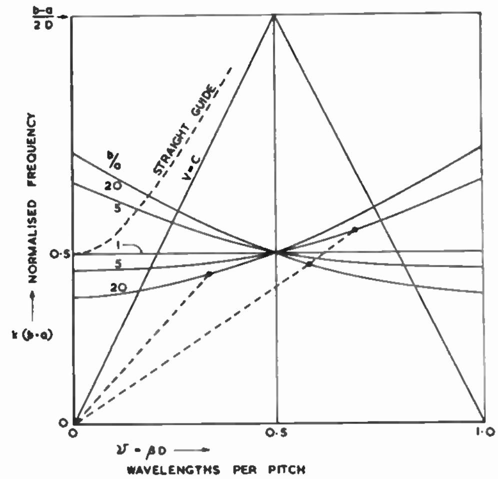

Fig. 3. Frequency-phase change diagram.

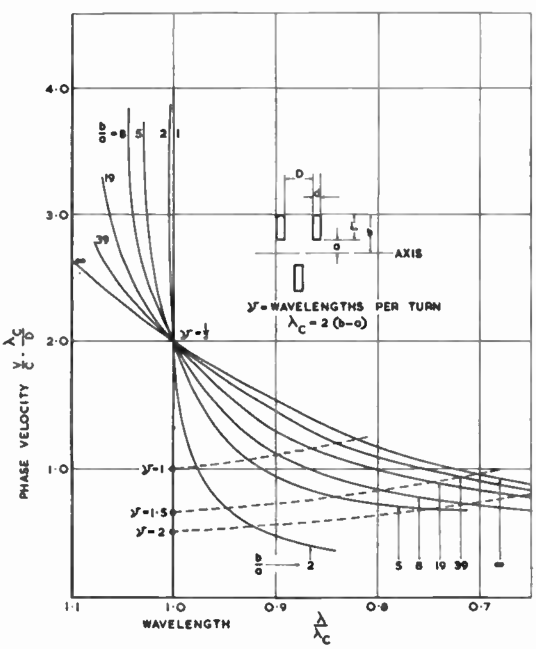

Fig. 2. Phase velocity characteristic.

An approximate treatment of this structure can be made by treating it as a periodically-loaded line and deriving an equivalent circuit for one period. The difference from the well-known disc or slot-loaded line is that the impedance looking into the slots is modified by the circumferential propagation, which takes place in the slots in step with the axial propagation. In the "developed" approximation, a slot load of the form

$$Z_s = jZ_0 \tan(kL)$$

where k is $2\pi/\lambda$ and L is the slot depth, is replaced by

$$Z_s = jZ_0 k \,.\, \frac{\tan(\Gamma L)}{\Gamma}$$

where $\Gamma^2 = k^2 - \beta'^2$

β' is the circumferential phase constant of the wave in the slot and is related to the axial phase constant β by a constant factor depending on the geometry only, for the slot wave is locked to the wave in the line. A difficulty with the "developed" approach is that this factor is not well defined. It is something like the cotangent of the mean slot pitch angle. This factor becomes multiplied by "n" if there are "n" starts to the groove. With this in mind it can be seen that with non-zero "n", the inductive loading of the line increases less rapidly than in the disc loaded ("zero start") case and dispersion is less severe. In fact if the product of "n" and the geometric retardation factor is large enough, the simple analysis predicts that the π-mode cut-off is destroyed, the slot impedance remaining finite with Γ imaginary.

Unfortunately this takes place in the range of parameters where the "developed" model is unlikely to be reliable. To carry out the analysis with cylindrical geometry is a task of some magnitude as elaborate transcendental equations involving Bessel functions arise. However, a field theory method for this circuit[3] supports the view that certainly low dispersion characteristics can be obtained near the π-mode even with a single start helical groove. The simple analysis indicates that the slot fields are no longer sinusoidal but of the exponential decay type, and so the low impedance characteristic of slot-loaded guides may not persist in this case.

If the centre conductor is removed then we have an open helical waveguide (Fig. 1 (*c*)) which differs mainly in the introduction of a low frequency cut-off.

The main difficulty with these circuits is getting enough loading to reduce the phase velocity. The helical groove works by preventing the loading from increasing too rapidly and so tends to give the same velocity at high frequencies as low. The low-frequency velocity is independent of the number of starts and depends only on the groove depth and width compared with the dimensions of the interaction space. For instance with grooved coaxial as in Fig. 1 (*b*), to obtain a velocity of $c/5$ it is necessary to make the groove depth some twelve times the radial distance from the centre rod to grooved surface. This leaves little room for a beam at short wavelengths and the high power application is frustrated.

However, bearing in mind that even the zero start system can be made into a useful circuit by intelligent addition of additional coupling between adjacent periods,[4] there could well be possibilities for helically grooved waveguides for slow (but not too slow) waves.

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Comment by R. A. Waldron

I was very interested in Dr. Clarke's paper, although when I wrote my paper on the helical waveguide I had in mind a quite different application. For my purposes, values of angular phase constant (β in my paper, ν in Dr. Clarke's) considerably greater than unity were required, and the curvature of graphs of β against the radius of the inner wall of the guide is sufficiently small for tables of solutions for only integral values of β to be adequate. However, for $\beta<1$, the curvature is much greater, and in order to obtain accurate solutions it is desirable to tabulate solutions for fractional values of β. Since tables of Bessel functions of fractional order are available,† this should not be too difficult.

Dr. Clarke has confined his attention to the case of a helical guide in which the major dimension of the cross-section is perpendicular to the axis, and working in the E_{01} mode. If a helical guide is considered which has the major dimension parallel to the axis, and works in the H_{10} mode, the velocity again exhibits the large dispersion that Dr. Clarke has described.

If I understand Dr. Clarke correctly, he has replaced the helical system by a cylindrical or coaxial waveguide with helical grooves. He is unduly pessimistic in saying that this model is unlikely to be reliable; in fact, the characteristic equation so obtained is identical with that obtained by a treatment of the helical system in helical co-ordinates. This is an example of a general theorem I have proved in a forthcoming paper,‡ relating helical and cylindrical systems.

† Several tables of Bessel functions of order $\pm\frac{1}{2}$, $\pm\frac{1}{3}$, $\pm\frac{1}{4}$, $\pm\frac{2}{3}$, $\pm\frac{3}{4}$, are catalogued by A. Fletcher, J. C. P. Miller, and L. Rosenhead in "An Index of Mathematical Tables," pp. 248-9, 1st Edn. (Scientific Computing Service, London, 1946.)

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THE ROYAL SOCIETY CONVERSAZIONE

Conversaziones have long been a regular feature of the activities of the Royal Society, and provide an excellent opportunity for the exhibition of projects of scientific research interest. A representative of the Institution was invited to attend a preview of the Conversazione held on May 15th. On this occasion, out of a total of 27 exhibits, four were concerned directly with radio, electronics or electron physics.

The Surface Treatment of Semi-conductor Crystals.—An examination has been conducted by Associated Electrical Industries Limited, at their Research Laboratory, on the unwanted impurities in silicon devices, such as transistors and solar batteries. Electron optical examination of pure silicon has revealed the presence on the surface layer of silicon carbide crystallites and etch pits brought about by inadvertent contamination with carbon. It is thought that these effects may be the cause of poorer electrical properties in these devices than those predicted.

The Radio Observations on the Russian Earth Satellites.—The Royal Society has a working party on radio signals from earth satellites, and members of this party combined to exhibit some of the results which have been obtained.

Both satellites went round the earth in about $1\frac{1}{2}$ hours in orbits which were nearly, but not quite, fixed in space relative to the earth, and the earth rotated inside the orbits, so that a given observing point passed nearly beneath twice in 24 hours. The situation was explained by means of a model. In the period that an observing station was beneath the orbit there were three or four "near transits" of the satellite, during which observations could be made on the rapidly changing signals. It was shown how these observations could be used to find out how the angular position of the satellite changed as it passed over. Observations were also made of the frequency of the radio waves and the way in which it was altered by the "Doppler effect" as the satellite approached and receded. From all these data it was possible to calculate the shape and position of the orbit and to find how it changed, partly because of the opposition to its motion by the tenuous upper atmosphere, and partly because of the non-spherical shape of the earth and the consequent abnormalities in its gravitational attraction. The effects of ionospheric propagation were calculated from the accurate measurements taken.

Also included in this exhibit were the results of the tracking of satellites by radar. An interesting feature was the calculation of the speed of rotation, obtained by the change in amplitude of the reflected signal as different surfaces were presented.

Distortion of Frequency-modulated Transmissions by Long-delayed Echoes.—The B.B.C. Research Department exhibited the effect of what is sometimes a serious problem in the reception of v.h.f. f.m. transmissions. This is when the aerial picks up signals which have been reflected from hills or other large objects, and in which the path length is longer by some ten miles. The number of sites affected is small, but in some cases definite audible distortion results. By adjusting the limiter, it was shown that the effect could be greatly minimized, but a directional aerial was often required.

Sceptre.—Associated Electrical Industries Limited, Research Laboratories, also exhibited a model of Sceptre, one-third size, with a museum of original pieces used in its development. This proved to be a popular exhibit, which attracted a great deal of interest. The stand included a working demonstration of the passing of a 10 microsecond pulse into an argon-filled tube. The resultant discharge was viewed through an image converter.

An alternative to electronic control?—An exhibit which would be of interest to electronics engineers concerned with industrial control showed the application of purely pneumatic techniques to the measurement of thickness of soft flexible film. This equipment had been developed by the National Physical Laboratory, and an accuracy of ± 10 micro-inches was claimed; using pneumatic amplifiers it had proved to be capable of controlling a continuous production process.

The 1957 Students' Essay Competition

THE EVOLUTION OF RADIO COMMUNICATION*

by

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(A Registered Student of the Institution)

Foreword.—Although the history of telecommunications spans little over a century, a full account of it would fill a weighty volume. So numerous are the contributors to the science that a short essay could well serve as an index of persons to such a volume. In the essay which follows only a few pioneers have been mentioned in order to give an outline of the evolution of radio communication.

Theoretical beginnings.—The effects of wave propagation were observed, by Adams, as early as 1780, and later (in the eighteen-forties), by Reiss and Henry; however, the possibility of propagation of electromagnetic waves was first suggested, by Faraday, in 1846.

Michael Faraday was tenacious and methodical in his investigations and was interested in a variety of subjects. His research into electricity he compiled in his "Experimental Researches in Electricity", written between 1839 and 1855. After his discovery of magneto-electric induction in 1831 he brooded on magnetic media and lines of force and whether magnetic force required time for its propagation. In his paper of 1946, "Thoughts on Ray Vibration" Faraday suggested that a sudden movement of a magnetic body would propagate a disturbance through the field, the disturbance being transverse to the direction of propagation and the velocity of propagation being related to electrostatic and electromagnetic units of electricity.

Clerk Maxwell, interested in magnetism and electricity since his boyhood, began a study of electricity in 1854 resolving to read no mathematics on the subject until he had first read through Faraday's "Experimental Researches". Maxwell's own skill in mathematics was considerable as he had already proved in other branches of science. He developed a set of equations relating transverse electric and magnetic fields having a velocity of propagation equal to that of light. In 1861, in a letter to Faraday, he claimed to have determined this velocity of propogation: in 1864, in a paper in the Royal Society *Proceedings* for that year, he began to develop his electromagnetic theory of light: in 1873 he published his famous "Treatise on Electricity and Magnetism".

Practical developments.—Maxwell's work led to investigations by others into the means of the production and the detection of electromagnetic waves. In 1879, Hughes claimed to have demonstrated the existence of "aerial electric waves"; he had observed that the opening and closing of a telegraph circuit could produce a sound in a telegraph receiver. Even though he could produce these results over a distance of 500 yards the effect was attributed to induction. Lord Kelvin's study of oscillatory circuits led to the derivation of the now well-known relationship of the constants of such circuits, i.e., for conditions of oscillation $R < L/C$. However, Hertz was the first to demonstrate the production of electromagnetic waves.

The research of Heinrich Hertz into the Faraday-Maxwell theory (as it was then usually called) culminated in his practical demonstration in 1887. This demonstration proved conclusively the existence of electromagnetic waves: Hertz, therefore, verified Faraday's intuitive prediction and Maxwell's mathematical prediction that electromagnetic waves, which differ from light waves only in wave length, could be propagated.

The Hertzian oscillator consisted of two metal plates, from each of which projected a rod terminated in a spherical electrode, the two

* Awarded first prize in the Competition and approved for publication by the Council.

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electrodes forming a spark-gap. The plates were charged by an electric machine until a discharge occurred across the gap. The transmission of electromagnetic waves was indicated by a circular conductor broken by a microscopic spark gap, the indication being a minute spark occurring at the instant of the discharge in the main spark-gap.

Hertz demonstrated that these waves could be reflected and refracted in the manner of light waves. From a consideration of nodal points when the waves were reflected, the length of the waves could be measured; the wavelength of the Hertzian waves was shown to be in the region of 25 to 50 centimetres. It is interesting to note that the use of these wavelengths was considered by subsequent experimenters to be of little practical value, a view held until the nineteen-twenties.

Commercial developments.—In the eighteen-nineties the British Admiralty, foreseeing the possibility of the use of electro-magnetic waves for signalling, offered a prize of £20,000 to anyone producing "a means by which a ship approaching a friendly port by night could signal her presence and her identity without revealing her presence, visibly or audibly, to the enemy".

Among those trying for this prize were Marconi, Muirhead, Lodge and Captain H. B. Jackson. All worked on the same lines, (*a*) producing an oscillator with good radiating powers, (*b*) a method of detecting the oscillations giving more sensitivity than that used by Hertz.

In order to increase the radiating field it was necessary to increase the input power (this was limited to that of the Ruhmkorff coil and the Wimshurst machine) or to increase the size of the radiators. The latter course was taken bearing in mind that this apparatus was intended for installation in a fighting ship. Even so, the size of the radiators were such that the frequency of operation was much lower than that of the Hertzian oscillator.

Various forms of detector were used by early experimenters but the first of practical value was the coherer. Although the effect of cohesion was known as early as 1850 it was not until 1889 (with the coherer due to Lodge) that the effect was applied to the detection of radio signals. Other notable contributors to the development of the coherer were: Branly, Solari, Professor A. Popov, Appleyard and Muirhead. About this time the magnetic detector was developed, workers of note being Rutherford, Professor E. Wilson and Marconi. The uni-directional effect of galena and various metallic sulphides was first demonstrated by F. Braun in 1874 but it was not until 1901 that the Telefunken Company used the principle for rectifying h.f. oscillations. Carborundum was used by Dunwoody in 1906 and zincite by Pickard in his Perikon detector in 1909.

The Admiralty prize was won by Marconi—he beat H. B. Jackson by a matter of weeks. Marconi's work, culminating with his patent of 1896, was to revolutionize the oscillatory circuit. Instead of the large capacitance grids of wire mesh which all earlier workers had used to simulate the Hertzian oscillator plates, Marconi used a more suitable radiator for a ship's installation. His method was to use the earth itself, i.e. the ship and the sea as one plate of the capacitor, the other plate being simply a long vertical wire. Simultaneously, Marconi patented an improved form of coherer and with this combination greatly increased the range of Hertzian telegraphy from yards to miles. Also the approximate formula $\lambda = 4H$ (relating the wavelength to the height of the vertical wire) was established. This formula is introduced here to show the influence of practical considerations on the frequency: bearing in mind that the problem still is with regard to ship/shore communication it can be assumed that the maximum permissible length would be of the order of 60 metres giving a wavelength of 240 metres or a frequency of 1·25 Mc/s.

Early transmitters.—A typical transmitter of this period would use a Ruhmkorff coil taking not more than 100 W from a 12 V battery, the secondary of the coil being connected to a spark-gap. One side of the latter would be earthed, the other side being connected to the vertical aerial wire. For reception the aerial was transferred by a heavily insulated switch to a simple circuit employing a coherer. The coherer was conductive during reception of the signal and was caused to operate a morse inker of the type then used for line communication.

The necessity for earthing the spark-gap first drew attention to the phenomenon of "skin-effect": due to this effect the high frequency currents, in flowing from the spark-gap to the earth, would creep along a tortuous, highly inductive and resistive path. The point is mentioned here because it is an example, possibly the earliest one, of how, in the matter of design, the thought processes of the radio engineer had to follow entirely different lines to those of his low frequency counterpart.

The radiation from these early transmitters took the form of trains of damped oscillations, the train recurrence rate being that of the hammer make-and-break of the induction coil. The damping of the oscillations was very heavy —only 5 to 10 cycles of the radio frequency contributing materially to the radiation. The Q of the early tuned circuits was very low and this meant that the frequency of transmission was spread over a very wide band. Therefore in addition to seeking means of increasing the power, development engineers sought to improve the selectivity. The immediate palliative was the closed tuned circuit with inductive aerial coupling. Another method was quench sparking which caused the whole of the radio frequency energy to be transmitted in the first two or three cycles of each train of oscillations. Progressive attempts to improve selectivity by the development of rudimentary filters in the form of loosely coupled circuits were made.

Continuous waves.—Around about 1912 it became obvious that any considerable extension of communication would be in the generation and detection of continuous waves. This way had been opened by research into pure science without the consideration of future application. Some years previous to this W. Duddell had shown the possibility of producing continuous oscillations of the order of 10 kc/s by shunting the d.c. arc by a suitable acceptor circuit. These oscillations were raised to radio frequency order by Poulsen and Pedersen by burning the arc in a hydrocarbon atmosphere and in a strong polarized magnetic field.

A commercial link on 500 kc/s was actually operated for some years between Cullercoats, Northumberland, and Esjberg, Denmark—however, the principal application of the spark transmitter was on a frequency below 300 kc/s. High power arcs up to 100 kW or more, operating on frequencies down to about 15 kc/s, were extensively used for trans-oceanic communications up to 1940.

Attempts were made (about 1910) to generate the high frequency directly by machinery, sometimes in conjunction with frequency multiplying devices. Notable in this field were Alexanderson, Goldsmith and Joly. These attempts met with partial success, some such generators being in use until quite recently; however these machines made high-speed keying difficult.

The development of the c.w. transmitting method required the development of the c.w. receiver. At first various forms of "interruptors" were used (e.g. the Pedersen Tikker of 1906): all of these were supplanted by the heterodyne method of reception due to R. A. Fessenden. Attempts were made to design suitable heterodyne generators using miniature Poulsen arcs. The c.w. system did not become fully practicable until the introduction of the thermionic valve generator.

Propagation characteristics.—Before proceeding further it is necessary to study the state of the art of this period with reference to range and frequency. Except for minor improvements in apparatus, ship-to-shore communications had become standard on a frequency of 500 kc/s (a frequency which subsequently became used for International Distress) using powers up to 5 kW; at this frequency and power the range would be up to 200 miles (night conditions).

The ever-increasing use of radio for trans-oceanic communication led to the investigation of propagation characteristics, notably by L. W. Austin and the Admiralty Signals Establishment. The outcome of this investigation was the famous Austin-Cohen formula which indicates that the field strength due to the propagated wave decays with range and also with the square-root of the frequency: it would appear from this indication that better ranges can be obtained with low rather than high frequencies. Partly as a result of this deduction and partly because the h.f. generators then available were of greater power and of higher efficiency at low than at high frequencies, the tendency from the earliest days of trans-oceanic communication was to use lower and lower frequencies. For example, Marconi used a wavelength of 1,300 metres for his successful transatlantic transmission of 1901. This point cannot be too strongly emphasized—no worker, amateur or professional, could have discovered the remarkable ranges obtainable on frequencies higher than 3 Mc/s until the development of valves capable of handling a few watts.

Practically all radio communication was achieved by utilizing what is known as the ground wave, although as long ago as 1882 Balfour Stewart, as a result of investigating terrestrial magnetism, had suggested that the earth's atmosphere at a height of about 125 miles should have a conductivity of the same order as that of the earth itself. Kennelly and Heaviside in 1902 pointed out that such a layer would act as a reflector of electromagnetic waves, Kennelly in particular pointing out the reduction of geometrical attenuation which would result.

Direct evidence of conductive layers was first obtained by Breit and Tuve about 1925 and by Appleton and Barnet in 1926. It was then found that there were in fact two such conductive layers, one at a height of 60 to 70 miles (now known as region E) and the second at about 160 miles (now known as region F).

The effect of the earth's magnetic field on free electrons in these regions causes them to exhibit quasi-resonant properties at frequencies in the region of 1·5 Mc/s; as a result, radio waves of frequencies of the order of 1 to 2 Mc/s suffer almost complete absorption and are useless for communication beyond the limits of the ground wave. Radio waves in between 3 Mc/s and 30 Mc/s on reaching these conductive layers are reflected back to earth, reaching the earth at points which may be outside the range of the ground wave: the waves may then be reflected at the earth's surface to be reflected back again at the region of the conductive layers and in this way may reach distances far in excess of those covered by the ground wave.

Radio waves in the band 30 Mc/s to 60 Mc/s can be returned to earth due to scatter, i.e. random re-radiation of the incident wave due to sporadic variation in tropospheric and ionospheric conditions. Communication utilizing the phenomenon of scatter can only be spasmodic: nevertheless, systems have been developed whereby information is transmitted only during optimum transmitting conditions.

Normally, radio waves of frequencies above 30 Mc/s pass through both the E layer and the F layer without reflection. This fact, to digress for a moment into more recent history, was utilized by the Air Ministry on the development of the very-high-frequency radio telephone which played such an important part in the Battle of Britain. Prior to 1939 the r/t equipment of Fighter Command utilized h.f. and it was known that r/t transmissions of quite low power were regularly intercepted in the heart of Germany. The r/t system in the v.h.f. band (between 100 and 150 Mc/s) was engineered completely and put into operation only on the outbreak of the war. It has been stated authoritatively that its contribution to the war effort was equal to that of radar.

Thermionic valves.—The thermionic diode was invented for use as a detector of damped oscillations by Fleming in 1904—it offered little advantage over contemporary detectors.

The introduction of the grid by Lee de Forrest in 1907 may be said to have paved the way for all subsequent communication development. Originally this valve, the triode, was used as a detector of damped waves only; its use as an oscillation generator appears to have been discovered almost simultaneously (about 1912) by Armstrong in America, Round in England and Lieben and Reisz in Germany. This completely solved the problem, previously referred to, of providing a stable low-power heterodyne oscillator. Simultaneously, the triode was also developed as a low-frequency amplifier. Considerable improvement to the triode was made by Round, General Ferrie, and several American workers. Experiments were made with different gas fillings, the air being evacuated and the valve then filled with inert gas; early papers upon the effect of gas inside the valve envelope by Dr. B. Hudson and Professor Ellis Palmer of Bristol University contributed much to the development of the hard valve.

In 1912 Langmuir and Arnold showed that the better the vacuum the more regularly the valve behaves and that by attaining the highest possible vacuum with the available apparatus of that day a valve could be made so that it would possess given characteristics. In 1915 Armstrong published a treatise on the use of hard valves as rectifiers, oscillation generators and amplifiers.

Receiving valves.—The 1914-18 war stimulated the development of thermionic technique. In 1915 Biquet and Peri designed a hard valve which was known as the "French valve"; the British adaptation of this was the "R" valve. Difficulties were encountered in producing a rigid grid mounting and microphony was experienced. The catenary type suspension of the "A" type valve (made by B.T.H.) largely reduced this effect. Further design difficulties lay in the reduction of inter-electrode capacitance and attempts were made to increase the spacing between the valve terminals by distributing these terminals about the valve envelope. Typical valves employing this technique were the French "horned" valve, the Marconi "Q" valve of 1916 and the Marconi V.24 of 1919.

The filaments of the early valve were required to work at very high temperatures, resulting in filament distortion and imposing a heavy drain on the filament supplies. The "dull emitter" was introduced by the Western Electric Company in 1918 and by 1921 dull emitters were being produced in great numbers by the Marconi-Osram Company.

In order to use the triode as an amplifier of high-frequency oscillations neutralization was employed so as to nullify the effects of inter-electrode capacitance; the neutralized triode of the receiver became obsolete with the introduction of the screened-grid valve. Although the screened grid valve had been described as early as 1924 it was not until three years later that this valve was used extensively. The pentode followed in 1928.

About this time the indirectly-heated cathode was introduced; this cathode with its equipotential surface gave the valve characteristic a steeper slope and improved the valve's detection capabilities. Simultaneously, improved electrode construction permitted the use of higher anode voltages. The diode returned to favour as a detector and attempts were made to use the rectified output as a means of automatic control of the gain (i.e. a.v.c.) of the received h.f. signal. These early attempts at a.v.c. were unsatisfactory and it needed the valve with the variable-mu characteristic (introduced in 1931) to produce satisfactory results.

Transmitting valves. — Early transmitting valves differed very little from those used in reception, higher powers, where required, being achieved by using a number of valves in parallel. However the power handling capabilities of individual valves were increased and by 1916 transmitters consisting of one transmitting valve were capable of outputs of 50 W.

To permit valves to be operated at extremely high temperatures the silica envelope was introduced in 1919; the power rating of these valves could be as high as 15 kW. In 1920 the introduction of the copper-to-glass seal (by the Bell Telephone Laboratories) made the anode accessible for water cooling. Within ten years water-cooled valves were being made which were rated at 500 kW.

Ultra-high-frequency valves. — With the development of television and frequency-modulation transmission the need arose for valves suitable for use at very high frequencies. The problem posed in the design of such valves concerned the effects of electron transit time and of stray reactance (due to inter-electrode capacitance and the inductance of connecting leads).

In the acorn valve of the nineteen-thirties connection to the electrodes was made by short leads taken through the glass at convenient points: such a valve can be used on frequencies up to 400 Mc/s. A further reduction in unwanted inductance can be achieved by making the valve part of the tuned circuit. Valves suitable for this purpose were developed during the 1939-45 war, a particular example being the "light-house" valve. The construction of this valve (which gives the valve its name) is such as to permit the valve to be used within a coaxial line.

The lighthouse valve has an upper frequency limit at which the transit time of the electron stream is comparable with the period of oscillation. Reduction of electrode spacing permits this "disc-seal" valve to be used up to about 3,000 Mc/s: above this frequency the conventional valve is abandoned in favour of the valve depending on transit time for its operation.

The effect of placing a diode in a magnetic field was investigated by A. W. Hull in 1921 and a similar arrangement (using a split-anode diode) by Okabe in 1929. However, these early magnetrons, as they were called, were inefficient and unreliable. The development, by Randall and Boot in 1940, of the resonant-cavity magnetron has given us a high-powered reliable oscillator for use in the region of 10,000 Mc/s.

The principle of velocity-modulation and its application to u.h.f. oscillators was described by A. and O. Heil in 1935. This led to the velocity-modulated tubes of Hahn, Metcalf and the Varian brothers, the Varians inventing the "klystron" in 1939.

The early klystrons, using two resonant cavities, could produce power outputs of several hundred watts on wavelengths of 10 centimetres but the tube has been virtually superseded as a high-power transmitter by the more efficient resonant-cavity magnetron.

The reflex klystron, developed by McNally in 1941, provides a useful low-power oscillation generator in the frequency range 3,000 Mc/s to 100,000 Mc/s. The ease of tuning, gained by using only one resonant cavity, makes the reflex klystron suitable as a local oscillator in a superheterodyne receiver.

Amplification at centimetric wavelengths is possible with the klystron (using two or more resonant cavities) and with the "travelling wave" tube. The latter device, invented by Kompfner in 1942, has the advantage of a very large bandwidth; this bandwidth, about 800 Mc/s at an operating frequency of 3,000 Mc/s, is approximately eighty times that of a klystron operating at the same frequency.

Radio telephony.—Although various methods and media were used for the transmission of speech, the modulation of radio waves was not successful until the development of the continuous wave transmitter. Fessenden had achieved a small measure of success in 1900 with a spark transmitter and a high-speed commutator but he was more successful in 1906 when he modulated the output of an inductor type h.f. alternator. Arc transmitters had been modulated as early as 1906 but they tended to become unstable with modulation. A high-powered Alexanderson alternator with a valve modulator was used by the American G.E.C. in 1918 for radio telephony between North America and Europe.

These early radio telephone transmitters could only be modulated in the aerial circuit and a suitable modulation amplifier was not available. For economic reasons, therefore, the range of these transmitters was limited to about 100 miles. With the advent of the valve transmitter "broadcasting" became a practical proposition and by 1923 broadcast stations were operational in Europe and in North and South America.

Commercial radio telephony.—The problems of commercial radio telephony were considerations of giving an economic and reliable long distance link with tolerably faithful speech reproduction. To this end single-sideband transmission was introduced in 1922: a power saving of up to 70 per cent. was then possible, the transmission was less subject to fading, a narrower frequency channel was required and highly selective receivers could be used.

The use of the shorter wavelengths was investigated after most remarkable results were achieved by amateurs. Long distance long-wave (about 25,000 metres) transmission was already in use but the necessary high power and elaborate aerial system made such installations costly. The use of the shorter wavelengths made the erection of highly directional aerial systems relatively simple and lower powered transmitters could be used for the same distance of communication.

The range of transmission was found to be dependent on the wavelength in use and the time of day. For instance, in 1924 it was noticed that the daylight range was increased as the wavelength was reduced to 32 metres; in the following year wavelengths down to as low as 2 metres were investigated. A regular service between England and Canada operating on wavelengths between 16 and 32 metres was opened in 1926 and soon this service was extended to include regular transmission to Australia, India and South Africa.

With the increasing number of transmitting stations some measure of frequency control became essential. Dr. E. H. Eccles, in 1918 had patented a method of tuning-fork control, temperature compensated oscillator circuits were developed and, in 1922, Cady investigated the piezo-electric properties of the quartz crystal. The quartz crystal is now used extensively in frequency control technique.

The superheterodyne.—In 1902 R. A. Fessenden put forward the idea of transmitting two waves of frequency differing from each other by a low frequency. The next step was for the transmission of one wave but for a local generator of h.f. currents to be present in the receiver.

In 1910 it was noticed that the signal strength of a receiver was increased when a nearby transmitter was operated even though the difference between the transmitter and receiver frequencies was above audio. This led to the development of a much more sensitive heterodyne receiver. Arco and Meissner, in 1913, developed the valve oscillation generator. In the same year Round invented the autodyne receiver circuit: one valve was used as a generator of h.f. oscillations, these being superimposed on the incoming r.f. carrier; the resulting beats could be rectified by the same valve or amplified by the valve and rectified by a separate valve.

During the years of the first world war reception of waves in the range 500 to 3,000 kc/s were investigated (names of note being Round, Latour, Armstrong and Schottky). Difficulties were encountered in the design of the h.f. amplifier; valve inter-electrode capacitance caused instability and stray capacitance by-passed the h.f. signal; a.f. amplification was limited due to inherent valve noise; and the use of square-law detectors meant very poor response to weak signals. Round's low-capacitance valve and his highly resistive h.f. transformer only partly solved the problem.

Levy, in 1917, developed an idea to reduce interference due to unwanted transmissions and from atmospherics: the idea was to change the frequency of the wanted signal to one at which the signal could be separated from the interference. He did so by a heterodyne which produced ultra-audio beats; the beats were rectified, amplified, combined with the output of a second heterodyne to reduce the beat to the audio range and then rectified by a second detector. The amplifying stages were almost all at medium or low frequencies and instability was only encountered in the signal frequency stages. The additional amplification provided greater sensitivity and the associated tuned circuits provided greater selectivity than had previously been possible. Levy had, in fact, produced a circuit involving the superheterodyne principle.

Schottky and Armstrong (in 1918) each developed receivers using the superheterodyne principle. Armstrong also envisaged the use of multiple conversion in which the first supersonic beat could be converted to lower ones; at each frequency conversion stage a heterodyne and a rectifier would be used. This idea of Armstrong's was the forerunner of the "double-superheterodyne".

Signals transmitted by amateurs in the U.S.A. were received in Scotland using a receiver employing the superheterodyne principle; this was in 1921 but it was not until twelve years later that the superheterodyne receiver really became popular in Great Britain. Fundamentally the objection to the early "superhet" was the cost and the drain on the power supplies. It also had to compete with the neutralized triode and, later, the screened-grid valve. Other disadvantages of the early superhet were poor quality of reproduction and the various forms of whistles and interference not usually found in the "straight" receiver. The introduction of the dull emitter valve reduced the drain on the filament power supply, multiple valves reduced the cost, band-pass circuits reduced interference and improved quality, the diode rectifier reduced distortion and automatic volume control reduced the undesirable effects of fading. Domestic broadcast receivers of the superhet type are now made with only three valves—albeit two of the valves being of the multiple type; these receivers have a high order of selectivity and quality of response. On the other hand a commercial receiver using the double superheterodyne principle may employ as many as twenty-five valves; however, such a receiver, though expensive, can be relied upon to give a constant and interference-free output for signals varying from the very weak to the very strong.

Recent innovations in the design of domestic broadcast receivers have been due to the development of transistors and printed circuits.

Frequency modulation. — The use of frequency modulation (f.m.) as a method of radio communication was considered as long ago as 1914: however, due to the great improvements made in valve technique at that time, many of the problems of amplitude modulation (a.m.) were solved and there seemed little need for f.m. In 1922 J. R. Carson showed mathematically that an infinite bandwidth was required for an f.m. transmission: later, Armstrong showed that the significant bandwidth could be a small percentage of the carrier frequency. In an attempt to reduce the effects of noise, Armstrong began experimenting with f.m. in 1925. Bearing in mind Carson's conclusions, small frequency deviations were first used in order to restrict the bandwidth. These first attempts produced no noticeable improvement in noise reduction: however, Armstrong showed that with wider deviation and bandwidth an improved signal-to-noise ratio could be achieved. In 1937, he constructed a high-powered f.m. transmitter which demonstrated the practicability of these techniques.

For some time f.m. has been used by the Army for short distance communication using carrier frequencies as low as 5 Mc/s; however, for broadcasting the bandwidth required restricts the carrier to very high frequencies.

Although f.m. has certain advantages over a.m. some engineers maintain that, in the balance, its disadvantages make it inferior to a.m. This controversy led the B.B.C. to test both systems extensively before opening up the v.h.f. broadcast band: finally, f.m. was recommended. With the first ten stations the B.B.C. provides 83 per cent. of the population of Great Britain and Northern Ireland with a reliable high-quality broadcasting system of three programmes.

Video communication technique.—The communication of information in video form was envisaged as far back as 1881 with Bidwell's demonstration of picture telegraphy, the forerunner of the present day facsimile and television. With facsimile it is now possible to transmit over great distances news photographs of intelligible definition. Television experimental transmissions of low definition (30 lines in each picture with 12½ pictures per second) were broadcast regularly by B.B.C. in conjunction with the Baird Television Company between 1929 and 1935. The higher definition system (405 lines per picture and 25 pictures per second) due to Blumlein and others was adopted in 1937. Since then the quality of transmission and of reception has gradually improved and the number of transmitters increased so that television is now within the reach of almost all in the British Isles. Future developments envisaged are colour television and the construction of a transatlantic link.

Although radar is, strictly, not a means of communication its development led to the discovery of techniques which extended the frequency range of radio communication. The art is now so developed that frequency modulation and pulse-width modulation of centimetric transmitters is now possible. An example of equipment using this technique is the renowned No. 10 Set which provides a mobile 8-channel radio-telephone link of great secrecy (a very narrow beam being used) over a range of up to 50 miles; it operates on a wavelength of about 7 cm. and employs pulse-width modulation.

Future developments.—What of the future? Can there be a limit to the utilization of electromagnetic phenomena in the field of communication? To mention but one possibility: world television coverage could be achieved by utilizing microwave-link technique, improved cable links and (who knows) equipment borne by earth satellites; this service could be a major contribution to a better understanding between nations.

Which ever way lies the trend of future development it can be certain that engineers and physicists will emulate the pioneers of a century ago. That is, with imagination and perseverance they will seek among the discoveries of the past, improving on the old and devising the new, according to the needs of mankind or the individual's love of pure research.

APPARATUS FOR THE MEASUREMENT OF THE VELOCITIES OF SONIC PULSES IN FLAWED MATERIALS*

by

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SUMMARY

An equipment is described for the measurement of elastic pulse velocities in materials which present a high attenuation to the elastic waves. A variable nickel delay line is used for the measurement of the pulse transit times. By way of illustration of the use of the apparatus, some measurements on coal, a highly cracked and porous solid, are described.

1. Introduction

Elastic pulse techniques have been used repeatedly during the last decade for the examination of the physical properties of materials[1-5]. By applying a voltage pulse to an electro-mechanical transducer coupled to the material under examination, an elastic pulse can be propagated in the specimen. After travelling across the specimen, the pulse is detected by a second transducer and is displayed on the screen of an oscilloscope. The transit time, which is usually measured by an electronic timing device, gives a measure of the elastic wave velocity v in the specimen. For a homogeneous material this is related to the appropriate elastic modulus k by the equation

$$v^2\rho = k \qquad \text{.........(1)}$$

where ρ is the density.

If the acoustic attenuation of the material under examination is sufficiently low, as is the case for single crystals and many metals, pulses of megacycle frequencies may be employed. Since in this example the start of the displayed pulse is sharply defined, very high accuracies of measurement may be obtained[1].

If, however, measurements are made on lossy materials (e.g., coal which is permeated with cracks and other inhomogeneities ranging in size from the sub-microscopic to the macroscopic), high frequency pulses cannot be transmitted any appreciable distance, and measurements often have to be carried out using pulses of kilocycle frequencies. If accurate measurements are to be made with such materials, great care has to be taken in locating the exact position on the oscillograph trace which corresponds to the beginning of the received pulse. Moreover for such materials, many measurements of different samples are required for representative evaluation, so that there is need for a rapid, although accurate, method of timing. The present account describes an elastic pulse equipment which incorporates a simple acoustic timing device, and which was constructed specifically for measurements on flawed materials.

2. Description of the Pulse Equipment

2.1. *The Electro-mechanical Transducers*

Many types of electro-mechanical transducers are available and have been described[6]. Two types of transducer were used in the present equipment. Where comparatively high frequencies could be employed, a matched pair of pre-polarized barium titanate discs, each having a fundamental resonance frequency of 90 kc/s (when placed in the mounting assembly), was employed; the mounting assembly is shown in Fig. 1.

For very lossy specimens, lower frequencies had to be used. Low frequencies can be obtained by the use of a sandwich transducer, consisting of alternate layers of piezo-electric material and steel. In the present work, the matched pair of transducers available (resonance frequency 15 kc/s) were of an early design and employed quartz as the piezo-electric material (see Fig. 2); in fact, because

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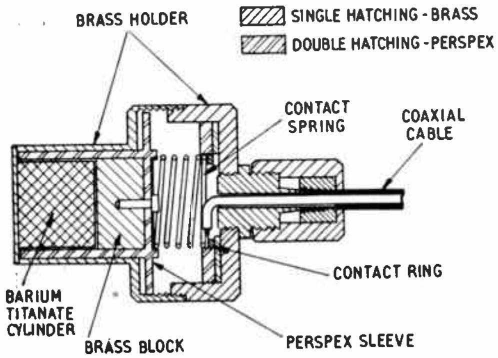


Fig. 1. Holder for 90 kc/s barium titanate cylinder.

of its higher electromechanical coupling factor and lower cost, barium titanate is to be preferred.

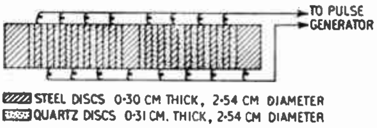


Fig. 2. 15 kc/s sandwich transducer.

2.2. *Arrangement of the Apparatus*

Figure 3 shows a simplified block diagram of the apparatus. The pulse generator applies a large voltage impulse to the transmitting transducer; this causes the transducer to ring at its own natural resonance frequency, launching an elastic pulse of the form shown in Fig. 4 into the specimen. After travelling across the specimen the elastic pulse is detected by the receiving transducer, and is then amplified before being displayed on the screen of the oscilloscope. So that a persistent trace should be obtained, the action is repeated many times a second, the rate of excitation of the pulse generator being determined by the pulse repetition frequency generator.

In order to time the passage of elastic pulses across the specimen, a variable acoustic delay line was employed. An elastic pulse was propagated along the delay line simultaneously with the propagation of the pulse across the specimen, detected by a transducer, and displayed on the second beam of the oscilloscope. The length of the delay line was adjusted until the two displayed pulses, i.e., that from the specimen and that from the delay line, were aligned. Since the velocity of elastic waves in the delay line was known, the transit time across the specimen could be calculated from a measurement of the length of the delay line.

2.3. *Variable Acoustic Delay Lines*

Several types of variable liquid delay lines have been described[7]. The transmitting transducer is immersed in a tube of the liquid, and the pulse is received by a second transducer also immersed in the liquid at the other end of the tube. In order to vary the delay time, the receiving transducer is adjusted in position along the length of the tube. Mercury, or a mixture of alcohol and water, which have low temperature coefficients of velocity, are most frequently used.

It was considered, however, that considerable practical advantages such as greater robustness and ease of handling could be obtained by

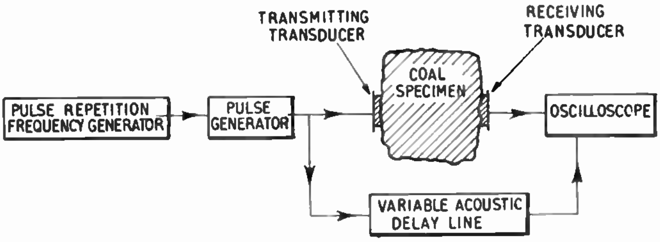


Fig. 3. Simplified block diagram of apparatus.

using a solid rather than a liquid delay line. Initially a steel bar of one inch square cross-section was tried, pulses being introduced by a barium titanate disc coupled to the end of the bar. The pulse was received by a second barium titanate transducer coupled with a thin film of oil to one side of the bar, and the position of this transducer could be varied along the length of the bar. It was found, however, that the transit time for the received

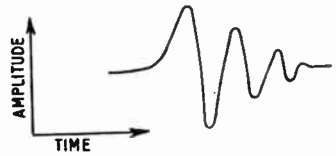


Fig. 4. Waveform of transmitted pulse.

pulse varied considerably with the state of contact between the bar and the receiving transducer, and this made consistent readings difficult. To overcome this difficulty, a magnetically polarized nickel rod was employed; pulses were introduced by a barium titanate disc (resonance frequency 200 kc/s) coupled to one end of the rod and were detected magnetostrictively by a small movable coil placed concentrically about the rod. With this system, sharp received pulses could be obtained.

2.4. *General Description of the Apparatus*

A complete block diagram of the apparatus is shown in Fig. 5. The pulse repetition frequency generator (block 1) is a simple variable square-wave oscillator, the frequency of which determines the time interval between successive pulses. The time interval must be long enough to enable an elastic pulse in the specimen to die away before the next is propagated, but provided this condition is satisfied, the time interval should be as short as possible in order to give a bright trace on the oscilloscope.

The square wave output of the pulse repetition frequency generator is differentiated by a resistor and capacitor combination (block 2) to give positive and negative voltage impulses; the negative peaks are removed by the limiting amplifier (block 2), and the amplified positive peaks are used to trigger the pulse generator (block 3). Before excitation the barium titanate transducers (A), which are connected in parallel, are charged to a high voltage. The pulse generator, which is similar to that used by Jones and Gatfield[4], consists simply of a thyratron connected across opposite faces of the transducers. When the positive voltage peak from block 2 is impressed upon the grid of the thyratron, the latter conducts, discharging the transducers which are thereby shock-excited into mechanical vibration. Thus elastic pulses are transmitted simultaneously into the specimen and the nickel rod. These pulses are detected by the barium titanate transducer B and receiving coil C respectively. After amplification (blocks 4 and 5) the received pulses are fed to separate beams of the oscilloscope and displayed.

Coil C is adjusted in position until the images of the two received pulses displayed on the oscilloscope screen are aligned with respect to each other. This can be done accurately if the lengths of the images along the time axis are as large as practicable, which requires a fairly fast time-base sweep, usually about 150 micro-

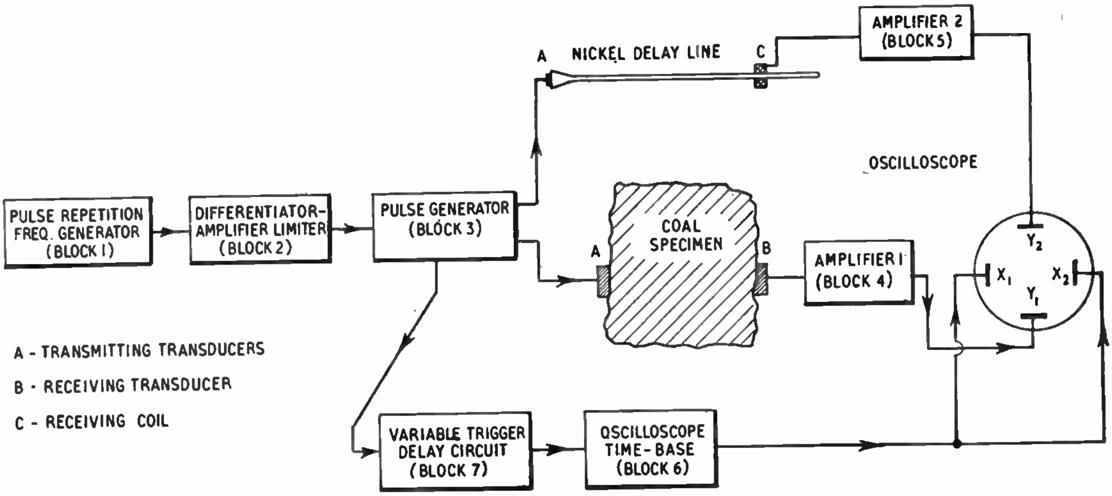
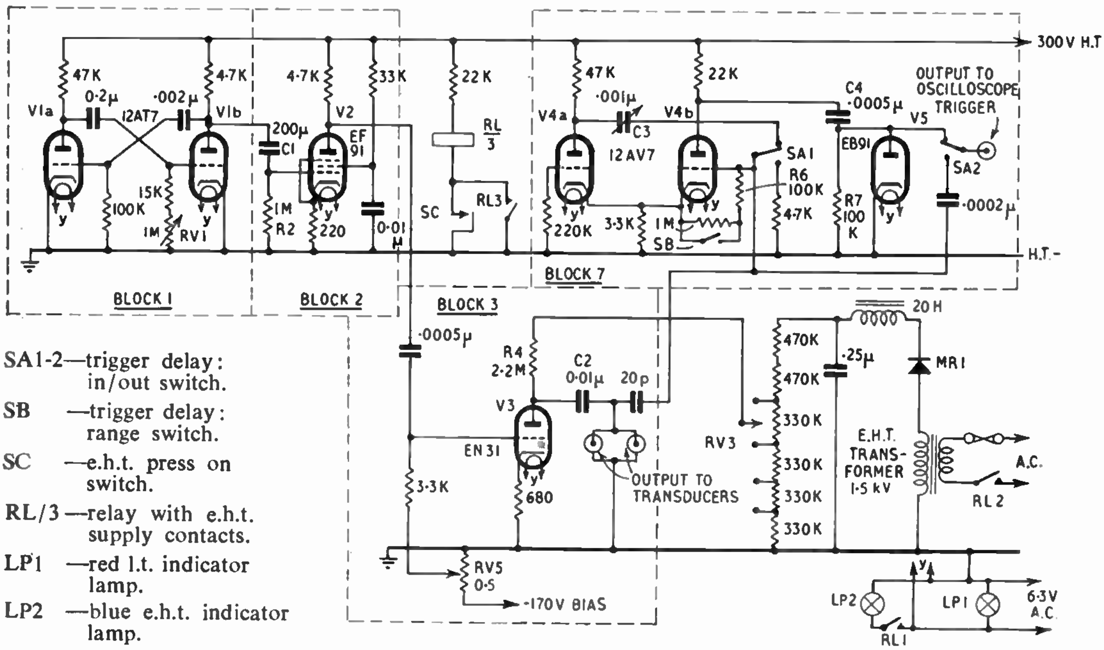


Fig. 5. Block diagram of apparatus.



SA1-2—trigger delay: in/out switch.
SB —trigger delay: range switch.
SC —e.h.t. press on switch.
RL/3—relay with e.h.t. supply contacts.
LP1 —red l.t. indicator lamp.
LP2 —blue e.h.t. indicator lamp.

Fig. 6. Circuit diagram of pulse equipment.

seconds for a 10 cm trace. In order to obtain a stationary display, the time-base has to be synchronized with the pulse repetition frequency. This is achieved by triggering the time-base (block 6) with the output of the pulse generator. However, to centralize the image of the received pulse on the screen, it is necessary to delay the triggering of the time-base by an amount only slightly less than the transit time of the specimen. This is accomplished by introducing a variable electronic delay unit (block 7) between the pulse generator and the time-base.

2.5. *Detailed Description of the Apparatus*

The detailed circuits of the pulse repetition frequency generator, differentiator-amplifier, pulse generator, variable electronic delay, and the high voltage power supply for the pulse generator are shown in Fig. 6. The power for all units, except the pulse generator, was supplied by a Solartron Regulated Power Unit.

2.5.1. The p.r.f. generator (block 1)

This is a conventional multivibrator, generating a square wave at a frequency determined by the setting of the variable grid resistor RV1. A frequency range from 20 c/s to 1,000 c/s was available, but for most purposes a frequency of 25 c/s was found to be the most convenient.

2.5.2. The differentiator-amplifier (block 2)

The square wave pulse (Fig. 7 (*a*)) from the pulse repetition frequency generator is differentiated by the combination of capacitor C1 and resistor R2 to give the wave form shown in Fig. 7 (*b*) The bias of valve V2 is so adjusted that only the negative peaks are amplified and these are inverted by the amplifier. The output waveform of the amplifier is shown in Fig. 7 (*c*).

2.5.3. The pulse generator (block 3) and high voltage power supply

The high voltage power supply employs simple half-wave rectification of the transformed mains voltage; outputs of 280, 550, 860 and 1080 volts may be obtained by adjusting the tapping of the potentiometer RV3. The relay RL/3 is incorporated in order to prevent the high voltage being applied to the pulse generator before the valve heaters have reached operational temperature. The two barium titanate transducers, which are connected in parallel, are charged through the resistor R4. When a positive pulse from the differentiator-amplifier arrives at the grid of the thyratron V3, the latter conducts, discharging the transducers which are thereby shock excited into mechanical vibration. The time-constant of R4 in series with the total capacitance due to the combination of the transducers and capacitor C2 is small enough to enable the transducers to be charged in between the arrival of successive voltage pulses at the grid of V3.

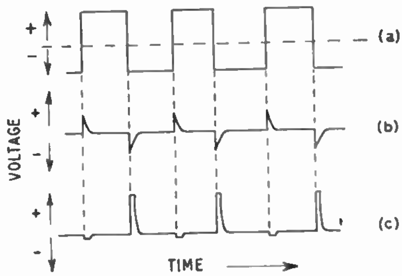


Fig. 7. Differentiation of waveform from square wave generator.

A standing bias for the grid of the thyratron is obtained from the standard power supply unit, and can be adjusted for optimum operation by varying the potentiometer RV5.

2.5.4. Variable electronic delay (block 7)

A complete analysis of this circuit, which is known as a "one shot multivibrator", is given by L. F. Curtis[8]. When a negative impulse (Fig. 8 (*a*)) from the output of the pulse generator is fed to the grid of valve V4B, a square wave is generated by the multivibrator action of the circuit (Fig. 8 (*b*)). The duration of this square waveform depends upon the time constant of the capacitor C3 in series with the resistor R6. The square wave is then differentiated by the combination of capacitor C4 and resistor R7 (Fig. 8 (c)) and the leading impulse is removed by the diode V5 (Fig. 8 (*d*)). The trailing impulse, which is used to trigger the time-base, is therefore delayed with respect to the impulse from the pulse generator by an amount depending upon the time-constant of the combination C3 and R6. In the circuit used, two values for R6 of 1·1 megohms and 100 kilohms could be switched into position and C3 was a variable capacitor of maximum value 0·001 microfarad; thus a range of delay times from 5 to 1600 microseconds was available.

2.5.5. Amplifiers (blocks 4 and 5)

In order to obtain a short rise-time for the received pulse from the specimen, a wide bandwidth about the resonance frequency of the transducers is required. A conventional wide-band amplifier was employed for the pulse received from the specimen (see block 4, Fig. 5); this amplifier had a gain of 1,500 times and a flat response from 200 c/s to 200 kc/s. The amplifier incorporated in the oscilloscope (a Cossor type 1052) was found to be quite adequate for the pulse received from the delay line (see block 5, Fig. 5) as in this case (see section 3.2) the second peak of the pulse received from the delay line, instead of its leading edge, was used for alignment and a very broad bandwidth was not required.

3. The Nickel Delay Line

3.1. *Description*

The advantages of using a magnetostrictive rod as a variable delay line for measuring the transit times across the specimens have already been given. Nickel is a particularly suitable material since it is highly magnetostrictive and has been shown[9] to have a temperature coefficient of velocity of only $-1{\cdot}20 \times 10^{-4}\,^{\circ}C^{-1}$. Initially, several nickel rods of various diameters, ranging from ½ inch to 1/16 inch, were tried; each rod was polarized by placing in a solenoid having a field of about 200 oersteds. It was found that for the larger

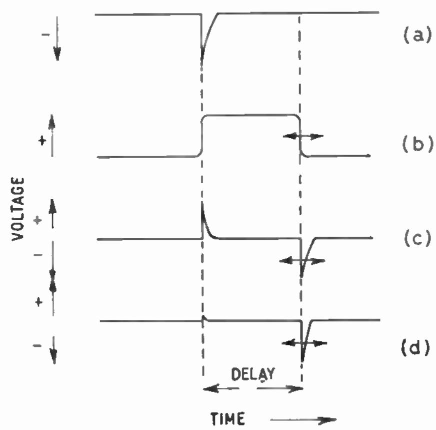


Fig. 8. Waveforms produced by variable trigger delay circuit.

diameters the received pulse was considerably dispersed, but as from purely practical considerations a fairly rigid rod was required, a 3/16-inch diameter rod was found to be a suitable compromise.

A barium titanate disc of resonant frequency 200 kc/s and diameter of 0·54 inch, was used as the transducer. To obtain a good transference of acoustic energy from the transducer,

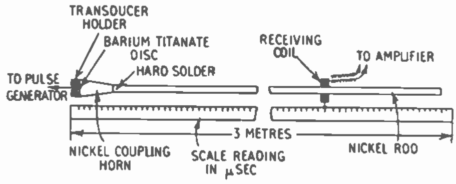


Fig. 9. Diagram of delay line.

it was necessary to couple the latter to the nickel rod via a nickel exponential horn, tapering from 0·54 inch diameter to 3/16 inch diameter and soldered to the nickel rod (see Fig. 9). The nickel rod was 3 metres in length, equivalent to a delay time of 600 microsec, and was rigidly clamped at its ends; a fixed scale was mounted alongside. The adjustable receiving coil, of value 1 mH, was mounted concentrically about the rod and carried a small pointer over the scale. In order that a sharp representation of the acoustic pulse travelling along the rod should be received, the width of the coil should be small compared with the wavelength; a coil of width 2·5 mm was found to be suitable. The internal diameter of the coil was ¼ inch, only slightly larger than the diameter of the rod, so that there was good inductive coupling between the coil and the rod.

3.2. *Calibration*

It can be seen from Fig. 10 that the second peak of the pulse received from the delay line is more sharply defined than its leading edge. It was decided, therefore, to use the second peak as the reference point for alignment with the leading edge of the pulse received from the specimen.

For the first part of the calibration, it was necessary to measure the delay time per unit length of the nickel rod. The output of a standard 100·18 kc/s quartz crystal oscillator was synchronized to the pulse repetition frequency by impressing a voltage from the differentiator amplifier (block 2, Fig. 5) on to the suppressor grid of the crystal oscillator valve. The received pulse from the delay line and the output of the crystal oscillator were displayed on the oscilloscope screen. By adjusting the coil, the second peak of the received pulse was aligned with a peak of the oscillator signal and a reading of the scale made. The coil was then moved until a fresh alignment was made with a further peak of the oscillator signal ten cycles later than the original peak; another scale reading was then made. This procedure was repeated along the whole length of the delay line; the results obtained are shown in Table 1.

The mean length of delay line corresponding to 10 cycles of the crystal oscillator is 49·90 cm; since the frequency of the crystal oscillator is 100·18 kc/s, the delay per cm is therefore 2·00 microsec/cm. The consistency of the intervals at different positions of the rod

(*a*)

(*b*)

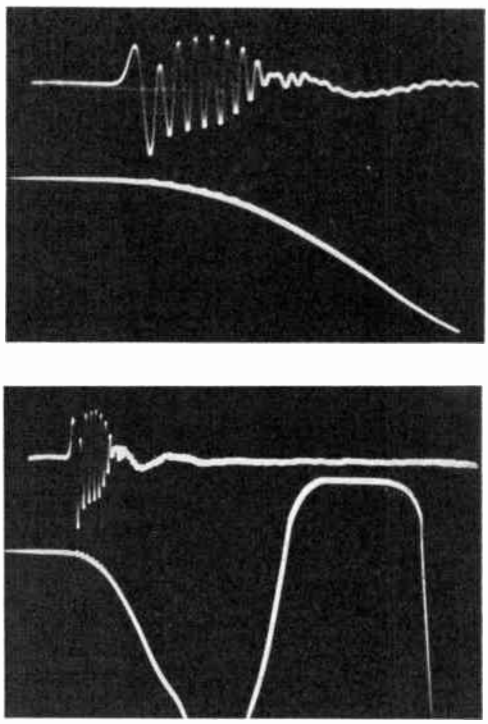


Fig. 10. Signal received from nickel delay line (top trace) and coal specimen (bottom trace).
(*a*) Time-base sweep 0·02 cm/μsec.
(*b*) Time-base sweep 0·067 cm/μsec.

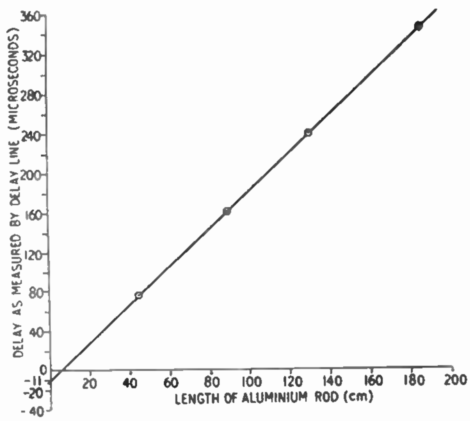


Fig. 11. Transit times for aluminium specimens of different lengths.

indicates that the effect of dispersion is not important.

In order to complete the calibration, some measurements of the transit times were made for a set of ¼ inch diameter aluminium and nickel rods using both the 15 kc/s and the 90 kc/s transducer pairs.

If the specimen lengths are plotted as abscissae, and the corresponding delay times as ordinates, a straight line should result, the inverse slope of which is equal to v, the velocity of elastic waves in the specimens. The plot for the first set of results is shown in Fig. 11. If $\bar{y}$ and $\bar{x}$ are the mean ordinate and abscissa respectively, and we define

$$\bar{y} = \frac{\bar{x}}{v} + D \qquad \text{.........(2)}$$

then, by the method of least squares,

$$v = \frac{\Sigma(x_i - \bar{x})^2}{\Sigma(x_i - \bar{x})(y_i - \bar{y})} \qquad \text{.........(3)}$$

Values for v and D are given in Table 2.

The values of the velocity of sound in aluminium show reasonable agreement with the value quoted by Child[10] of 0·51 cm/microsec. To obtain a more precise check, the shortest nickel specimen was set into resonant vibration magnetostrictively using a technique which has been described elsewhere[11,12]; the fundamental resonance frequency (f) was found to be 8·027 kc/s, and the sound velocity is therefore calculated ($c = 2fx$) as 0·495 cm/microsec which shows good agreement with the measurements made by the pulse technique.

The negative values obtained for the intercept D indicated that the scale was not correctly aligned with the delay line. The values of D also depend on the time taken for the pulse generated by the quartz or barium titanate element to reach the free surface of the transducer assembly: since this time is different for each transducer pair, a different value for D is obtained. By adjusting the position of the pointer carried by the coil of the nickel delay line, D was corrected to zero for the 90 kc/s transducers, since these were the ones most usually used. A final correction of − 8·6 microsec (1·2–9·8 microsec) had therefore to be applied to any subsequent delay times measured with the 15 kc/s transducer pair.

The calibration made in this way took into account the variation of elastic wave velocity across the exponential horn element of the delay line.

Occasional checks that have subsequently been made over a period of 12 months on specimens of aluminium have shown no substantial variation in the measured velocity. Evidently the change in the elastic wave velocity along the delay line due to changes in the magnetic state of the nickel is negligible.

Table 1

Position of Receiving Coil on Scale Corresponding to 10 Cycle Intervals of the Quartz Oscillator

Reading of Delay Line Scale (cm)	21·87	71·77	121·60	171·50	221·40	271·37
Length of Delay Line Corresponding to 10 Cycle Intervals (cm)	49·90	49·83	49·90	49·90	49·97	

4. Some Measurements on Coal Specimens

The Mining Research Establishment is concerned with improving and developing techniques for the winning of coal from the seam. As an aid to the understanding of the coal winning processes, basic investigations into the mechanical properties and physical structure of coal have been undertaken. The crack structure in coal exerts a dominating influence on mechanical properties, and the apparatus described provides a convenient means of investigating both the elastic properties and the crack structure; although all the investigations have not yet been reported, some of the measurements are given here to illustrate the use of the apparatus.

For specimens of a low carbon content bituminous coal (Barnsley Top Hards), the elastic wave velocities were measured in three directions, i.e., perpendicular to the bedding plane (or stratification plane), parallel to the bedding plane and parallel to the major cleat plane, and parallel to the bedding plane and perpendicular to the major cleat plane. (The cleats are a well defined system of macroscopic cracks oriented in planes perpendicular to the bedding plane). In order to obtain a seating for the transducers, flat surfaces 1½ in. in diameter were ground on the specimens using a high speed steel slot drill. The transducers were coupled to the coal by means of a thin film of a mixture of glycerine and kaolin clay, and were held in position by light springs mounted on a pair of wooden calipers (see Fig. 12). The coal specimens were mounted on sorbo rubber to reduce the effects of external vibration.

Errors of measurement of the transit time can arise because of the difficulty of locating the exact position of the trace corresponding to the beginning of the received pulse. Fig. 10 (*a*) and 10 (*b*) show a pulse received after travelling across a Barnsley Hards specimen of path length 10·8 cm, using the 90 kc/s transducers. To obtain an accurate measurement, the trace was adjusted until its horizontal portion coincided with a horizontal index line on the oscilloscope screen (see Fig. 13); the position where the trace started to deviate from the horizontal indicated the beginning of the pulse. The pulse from the delay line was then adjusted until its second peak coincided with this

Table 2

Measurements of Transit Times for Aluminium and Nickel Rods

Transducer	Specimen	Specimen Length x_i cm	Delay time measured with the delay line y_i μsec	Elastic wave velocity in the specimen v cm/μsec	D μsec
90 kc/s	Aluminium	44·56	75·7		
		89·56	161·3		
		130·24	239·0		
		184·90	346·4	0·518	−10·9
	Nickel	30·86	52·2		
		62·42	113·9		
		89·12	166·8	0·508	−8·6
					−9·8 (Mean)
15 kc/s	Aluminium	44·56	84·6		
		89·56	171·6		
		130·24	294·4		
		184·90	354·4	0·521	−0·9
	Nickel	30·86	60·4		
		62·42	123·4		
		89·12	176·8	0·500	−1·4
					−1·2 (Mean)

Table 3

Measurements of the Elastic Pulse Velocities in Barnsley Hards Coal

Specimen	Parallel to the Bedding Plane and Parallel to the Major Cleat Plane			Parallel to the Bedding Plane and Perpendicular to the Major Cleat Plane			Perpendicular to the Bedding Plane		
	Path Length cm	Transit Time μsec	Elastic Wave Velocity km/sec	Path Length cm	Transit Time μsec	Elastic Wave Velocity km/sec	Path Length cm	Transit Time μsec	Elastic Wave Velocity km/sec
1	22·0	107	2·06	—	—	—	—	—	—
2	18·7	91	2·05	—	—	—	—	—	—
3	23·1	108	2·14	—	—	—	26·5	176	1·51
4	32·2	155½	2·07	—	—	—	24·2	142	1·70
5	23·7	110½	2·14	—	—	—	21·5	133½	1·61
6	19·9	112½	1·77	24·2	122½	1·98	25·7	157	1·64
7	—	—	—	26·0	146	1·78	27·6	142½	1·94
8	31·1	167	1·86	41·9	226	1·85	23·5	167	1·41
9	23·2	119	1·95	—	—	—	15·4	90	1·71
10	23·6	111	2·13	24·9	111	2·24	16·6	88½	1·88
11	—	—	—	20·3	101	2·01	—	—	—
12	—	—	—	27·9	132	2·11	—	—	—
Mean			2·02			2·00			1·68
Standard Error of the Mean			0·04			0·07			0·07

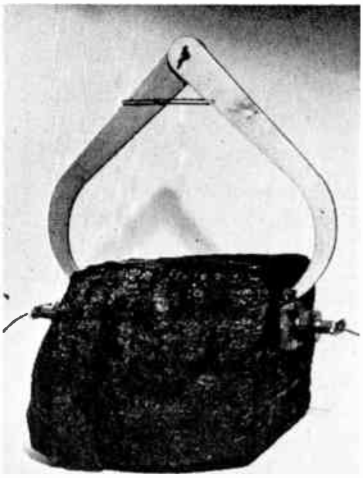


Fig. 12. Mounting of transducers on coal specimen.

position. The results of measurements on 12 different run-of-mine blocks of Barnsley Hard coal are shown in Table 3.

Individual measurements were repeatable to within about ½ microsec. The between sample scatter is due to the effect of cracks and inhomogeneities on the elastic wave velocities.

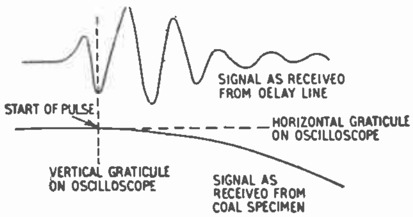


Fig. 13. Alignment of pulses from specimen and delay line.

It can be seen that there is no significant difference in the elastic wave velocity for the two different directions parallel to the bedding plane, but the wave velocity perpendicular to the bedding plane is significantly lower than that parallel to the bedding plane, i.e., the coal exhibits a transversely isotropic symmetry. It is probable that this is due to the oriented micro-crack distribution rather than to an anisotropic elastic behaviour of the basic coal material. Further experiments, in which the elastic wave velocities will be measured for coal samples subjected to high external stresses, are planned; and anistopy due to oriented micro-cracks should be modified as the cracks are closed under stress.

5. Acknowledgments

The authors are grateful to Mr. R. Jones of the Road Research Laboratory and Mr. J. A. Sage of the Royal Aircraft Establishment, Farnborough, for helpful discussions at the commencement of this work. This paper forms part of the programme of research of the Mining Research Establishment and is published by permission of Dr. W. Idris Jones, Director-General of Research in the Scientific Department of the National Coal Board. The views expressed are those of the authors, and not necessarily those of the Board.

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"Problems in Long-Term Component Reliability" *

In the May issue of the *Journal* a summary under the above title was published which was reprinted from the Interim Report of the International Symposium on Electronic Components held in Malvern last year. The author of the paper, Dr. K. E. Latimer† has pointed out, to use his own words, that this "... was a summary of a summary reported under somewhat difficult and hurried conditions," and that consequently it contained a number of factual errors. Dr. Latimer has submitted the following contribution which clarifies some of the main points, and in addition he puts forward an interesting problem which is not included in the full published version of his paper. Copies of the paper may be obtained from the author. It is also included in the full *Proceedings* of the Symposium which is now available on application to Mr. G. W. A. Dummer, M.B.E., Superintendent of Technical Services, Royal Radar Establishment, Great Malvern, Worcs.

When a conventional submarine cable is laid in deep water, it rotates on its way to the ocean bed. It also rotates, mostly in the same direction, when it is picked up. The total number of turns is large, about 2,000 on laying and more than this on pick up. The speed of rotation is 60 to 150 rev./min. The centrifugal forces are not large, only about one or two *g*, but the structure of the repeater is subjected to repeated bending stresses due to its own weight and the fact that it rotates.

The word "creep" in the summary suggests stress relief and slow deformation under load. I did not use this word to describe deterioration.

I mentioned metallic tin whiskers on tin-plated surfaces and one solitary instance of non-metallic whiskers on a soldered joint, shown in the accompanying photograph. The latter phenomenon could not be reproduced. The white growth is definitely not a mould; it is inorganic in nature. The underlying white mass contains mostly some tin compound, but there was not enough material to obtain a good analysis although the attempt was made. The joints were made with good quality resin cored solder in the ordinary way. If I am not very specific about the nature of the sleeving and the ingredients of the protective lacquer it is merely because I would then probably gives clues to the names of the makers, a worry which has been in my mind throughout the preparation of this paper. In fact we made many tests on the sleeving, lacquer and all other associated objects but without any indication of trouble whatever. The whisker growth took place in the drawer of a clean desk in a room with comparatively low humidity, so that it is not explained by climate.

The list of slow deterioration effects is documented in the main paper. With regard to the effect of helium on valve filaments, the point was that tungsten helide is one of the few genuine compounds of helium (it is reported to be a black powder). If helium leaks into a valve through the glass, there is a chance that it is cleaned up by the filament but one would then wonder whether helium embrittled the filament. Helium has a low breakdown voltage, another reason for not using it for filling repeater casings.

Of course a short list like this cannot possibly discuss whether a given phenomenon is a well-known effect or a mere possibility. In the submerged repeater field one tends to play safe if there is the slightest risk.

Incidentally, I did not suggest that inaccessibility had any effect upon physical processes, although like most engineers, I suspect that there is a law of natural cussedness.

Fig. 1. An enlarged (about eight times) and un-retouched photograph of the non-metallic growth on a soldered joint. The lead-out wire is from a transformer bobbin and is terminated on a seal. The wire is covered with good quality sleeving.

* Received 10th June, 1958 (Contribution No. 18)
† Submarine Cables Ltd., London, S.E.10.
U.D.C. No. 621.396.69: 621.315.28

RECENT TECHNICAL FILMS

A further list of films of interest to the radio and electronics engineers. Previous lists have been published in the October 1956 and November 1957 issues of the *Journal*.

NUCLEONIC MEASUREMENTS

Producer and Distributor: Baldwin Instrument Co. Ltd., Brookland Works, Dartford, Kent. (1958). 15 minutes.

Deals with the use of radio-active isotopes in the measurement of thickness of various strip and sheet materials.

THE PHOENIX TOWER

Producer and Distributor: British Insulated Calenders Construction Co. Ltd. B.I.C.C. Group Film Library, 21 Bloomsbury Street, London, W.C.1. (1958). Colour, 41 minutes.

Describes the construction of the 708 ft. tower at the B.B.C.'s Crystal Palace Television Station.

LEO—THE AUTOMATIC OFFICE

Producer and Distributor: Leo Computers Ltd., Elms House, Brook Green, London, W.6. (1957). 15 minutes.

The construction, use and programming of the Leo Computer.

THE DOUNREAY SPHERE

Producer: U.K. Atomic Energy Authority. (1957). *Distributor:* Ace Distributors Ltd., 14 Broadwick Street, Wardour Street, London, W.1. 35 minutes.

A technical film on the construction of the sphere of the experimental breeder reactor.

CRITICALITY

Producer and Distributor: As above. (1957). 25 minutes.

Defines criticality in radio-active materials and explains the conditions under which it occurs and the safety factors which should be observed.

MIRROR IN THE SKY

Producer and Distributor: Mullard Ltd., Film Section, Mullard House, Torrington Place, London, W.C.1. (1957). 15 minutes.

Deals with the discovery of the Heaviside and Appleton layers and the development of pulse techniques for investigation.

MODERN MAGNETIC MATERIALS

Producer and Distributor: As above. (1958). 16 minutes.

Shows production of hard and soft magnetic materials and discusses research into application.

THE TRANSISTOR—ITS PRINCIPLES AND EQUIVALENT CIRCUIT

Producer and Distributor: Mullard Ltd., Publicity Division, Mullard House, Torrington Place, London, W.C.1. (1958). Colour, 15 minutes.

A fairly detailed exposition on the physics of the different types of transistor and their equivalent circuits is given, the emphasis being on the junction transistor.

THE JUNCTION TRANSISTOR IN RADIO RECEIVERS

Producer and Distributor: As above. (1958).
Part 1—Design of an I.F. Amplifier. 15 minutes.
Part 2—The Complete Receiver. 10 minutes.

This film, which is in two parts, follows on from "The Transistor" and deals with the special circuitry required.

THE MANUFACTURE OF JUNCTION TRANSISTORS

Producer and Distributor: As above. (1958). 10 minutes.

Shows the preparation of the germanium crystal, the cutting of "p" type wafers, alloying with indium pellets and the assembly and testing of the complete transistors.

THE PRINCIPLES OF THE TRANSISTOR

Producers: Mullard Educational Service and E.F.V.A. (1958). *Distributor for educational establishments:* Educational Foundation for Visual Aids, 33 Queen Anne Street, London, W.1. *Distributor for other organizations:* Mullard Educational Service, Mullard House, Torrington Square, London, W.C.1. 20 minutes.

Intended mainly as an aid to teaching, it shows the development of the use of crystals and the working principles of the germanium diode and the transistor.

SEMI-CONDUCTOR DEVICES

Producers and Distributors: As above. (1958). Filmstrip, 35 mm. Colour, 31 frames.

Gives a non-mathematical treatment of the physical aspects of electron and hole conduction; simple descriptions of crystal diodes and transistors; and also deals with manufacture, characteristics and applications of transistors.

All the films listed are 16 mm., black and white, with sound, unless otherwise stated. Application should be made to the distributors concerned for further information and loans.

. . . Radio Engineering Overseas

A selection of abstracts from European and Commonwealth journals received in the Library of the Institution. Members may borrow these journals under the usual conditions; requests for loans should give full bibliographical details, i.e., title, author, journal, and date of the paper required. All papers are in the language of the country of origin of the journal unless otherwise stated. The Institution regrets that translations cannot be supplied.

538.63:681.14

The use of Hall-current generators in analogue multipliers. J. OXENIUS. *Nachrichtentechnische Zeitschrift*, **11**, pp. 263-268, May 1958.

The possible use of Hall-current generators in electronic analogue multipliers is discussed. A test model of an analogue multiplier with a Hall-current generator is described in detail. The static errors of the equipment are 1% max., the dynamic errors have an effect only above 1 kc/s. The rise time to 99% of the peak value of a step function is 25 microsec.

621.315.618

The electrical breakdown of small gaps in vacuum. A. S. DENHOLM. *Canadian Journal of Physics*, **36**, pp. 476-493. 1958.

An investigation of the electrical breakdown in vacuum of small gaps subject to contamination by diffusion pump oil showed that the most consistent results were obtained when electrodes were conditioned by a hydrogen discharge. Even with this method of conditioning a few preliminary sparks were usually required before the breakdown voltage reached a plateau level, so that the vacuum discharge itself could affect the final values obtained. The circuit parameters which controlled the discharge current were found to influence the magnitude and consistency of the breakdown voltage appreciably. Direct, alternating, and impulse voltage tests showed that the time for which voltage was applied to the vacuum gap influenced the breakdown voltage, and curves are presented which give the insulation strength of the gap. Two possible explanations of the time dependence of the breakdown voltage are given.

621.318.1:549.731:621.3.029.6

Microwave ferrites. B. JOSEPHSON and P. E. LJUNG. *Ericsson Technics*, **14**, pp. 39-70. 1958. (In English).

The physical phenomena forming the basis of the applications of ferrites at microwavelengths are briefly discussed. Following a description of experimental procedures and methods of preparation, a graphical representation of the influence of composition on the electrical properties is given for materials to be used within the 3, 6 and 10 cm wavebands. The optimum compositions of ferrites for these wavelengths and their principal properties are presented. In conjunction with the research on materials, a number of components have been developed using these ferrites.

621.365.92:021.373.4.072.86

Experimental electronic generator for dielectric heating, with automatic load matching. C. VAZACA. *Automatica si Electronica (Bucharest)*, **2**, pp. 16-22, January 1958.

An experimental electronic generator is described for dielectric heating with 1.25 kW and 30 Mc/s. For maintaining optimum operating conditions an automatic load matching device is used, which controls the capacitor of the oscillator circuit by means of a servomechanism. The d.c. component of the anode current is held constant during the heating of the dielectric material.

621.372.41:538.221

Ferrites for magneto-strictive filters. S. SCHWEIZERHOF. *Nachrichtentechnische Zeitschrift*, **11**, pp. 179-185, April 1958.

The paper is a report on the development and the practical application of ferrite oscillators for filter circuits in carrier-frequency engineering. The requirements for the characteristic values of the core material are outlined. Commercial ferrites do not meet these specifications and for this reason new ferrites with an improved temperature stability and higher Q-values have been developed. In order to obtain the correct coupling factor and to avoid spurious modes annular compression oscillators with residual polarization are used. Two examples of practical applications of such oscillators in filters are shown.

621.372.8

The uniform rectangular waveguide with damping foil. H. BUSECK and G. KLAGES. *Archiv der Elektrischen Übertragung*, **12**. pp. 163-168, April 1958.

The influence of an axial damping foil on the transmission properties of rectangular waveguide is theoretically analysed under the assumption that the foil is metallically connected to the walls of the latter. A detailed discussion is also given of the field distribution and the planar waves that establish the wave field in the quasi-optical treatment. Measurements on foil dampers of the kind customary in the laboratory show considerable deviations from the calculated values, in particular for the phase constant; these are attributed to the absence of contact between the resistive layer and the metallic waveguide.

621.373.432:621.387.23

Studies on thyratron pulse generator. S. C. MUKHERJEE. *Journal of Technology (Bengal)*, **2**, pp. 105-116, December 1957.

Generation of fast pulses by using a triggered thyratron is studied and the nature of the output fully discussed. Amplitude, shape and delay in firing is explained as due to the various effects of tube construction, different parameters of the circuit, and the repetition frequency of the triggering pulse. Suggestions are made to remedy the timing instability of the delay under actual operating conditions.

621.375.132.3

A double cathode-follower. A. SEGAL. *Automatica si Electronica (Bucharest)*, **6**, pp. 263-267, November-December 1957.

The shortcomings of the cathode-follower when used in impulse operation are briefly pointed out. The circuit of a double cathode-follower is then analysed. The general formulae are derived for the amplification and the output admittance in linear operation, applying classical negative feedback amplifier theory. The characteristics of the double cathode-follower in non-linear operation are then analysed, and the performance of this circuit is stressed. A series of experimental data is given to confirm the theoretical investigation.

621.382.3

Experimental and theoretical investigation of the equivalent circuits of new h.f. transistors with special reference to drift transistors. W. GUGGENBUHL and W. WUNDERLIN. *Archiv der Elektrischen Übertragung*, **12**, pp. 193-202, May 1958.

Starting from a simplified model, the transport factor of the base of a drift transistor is derived and compared with experimental results. The high frequency behaviour of a transistor with uniform base layer resistivity is discussed for high level injection. The prevalence of an electric field in the base may be shown experimentally. Measurements of the collector capacitance and the short-circuit input-impedance of the common emitter circuit are shown and discussed. Methods for evaluating the transit time through the base layer are given.

621.385.832:681.142

Analogue multiplier and function generator with cathode ray tube. A. K. CHOUDHURY and B. R. NAG. *Indian Journal of Physics*, **3**, pp. 141-148, March 1958.

A multiplier and a function generator using a cathode ray tube with a capacitive pickup device are described. The device simplifies the construction of the multiplier and function generator without impairing the speed of response or the accuracy of the instrument.

621.39.001

Phenomenological model of stochastic signals in measurement techniques. H. R. LOOS. *Slaboproudy Obzor (Prague)*, **19**, pp. 143-150, March 1958.

The output quantities of pickups for radiation meters, vacuum tube noise, photocell noise, atmospheric disturbances, etc. constitute stochastic processes with various physical origins and having continuous frequency spectra. The work describes a mathematical model, the so-called phenomenological model which permits a uniform processing of these phenomena which are important for measuring techniques. Formulae are given for determining physically important magnitudes such as mean and effective values, dispersion, correlation functions and power spectra.

621.391

Automatic detection of signs. K. STEINBUCH. *Nachrichtentechnische Zeitschrift*, **11**, pp. 210-219, 237-244, April and May 1958.

The paper relates to the possibilities of detecting printed, typewritten or handwritten signs with the aid of automatic devices. The main process of detection is a comparison (comparison in the most general sense) between the available sign and a choice of given signs. The detection should not be affected by deficiencies of shape. The paper describes known methods, two new methods, and gives a systematic categorization.

621.395.623.7

Advances in the design of loudspeakers. F. K. SCHRODER. *Nachrichtentechnische Zeitschrift*, **11**, pp. 169-172, April 1958.

With the aid of test examples it is shown how moving coil loudspeakers can be improved by bead impregnation, dip treatment or coating of the diaphragm as well as by an installation of short-circuit rings of copper in the magnet gap. The relationship between electro-acoustic properties and mechanical loading shows the importance of defining suitable load test methods. At present, the introduction of these improvements would lead to an undesirable increase in production costs. A standardization of loudspeakers and magnet systems could lead to a rationalization in production and could make possible the simultaneous introduction of improvements.

621.395.623.7

The operation of corona loudspeakers. G. BOLLE. *Nachrichtentechnische Zeitschrift*, **11**, pp. 172-178, April 1958.

On the basis of an explanation for the physics of generating sound pressure waves and a proof by formulae, the point discharge used in corona loudspeakers and possible interferences are discussed. The noise interference can be kept low when the radius of curvature on the point is small enough and when the field strength at the point is large enough. A test arrangement is described which produces a sound pressure of 85 db (variations smaller than + 3 db) over a frequency band from 1 kc/s to 20 kc/s. The causes for non-linear distortions are outlined. The sound pressure for the described arrangement is calculated by means of the derived formulae. Disadvantages and advantages of corona loudspeakers in comparison with other types of loudspeakers are discussed.

621.397.62:621.314

A line transformer with a screened h.t. winding. H. REKER. *Nachrichtentechnische Zeitschrift*, **11**, pp. 147-153, March 1958.

Parasitic oscillations may occur in the h.t.-winding of line transformers for television receivers because of the relatively large stray inductance of this winding. These oscillations are superimposed on the ordinary line scan and can be very troublesome for this reason. The present paper relates to the investigation of the natural causes for the generation of such parasitic oscillations and gives an equation for the data, which permits the design of a transformer having no interfering oscillations. Recommendations are given for the most efficient realization of the derived design conditions.

621.397.7

Standards conversion with vidicon tube. W. DILLENBURGER. *Archiv der Elektrischen Übertragung*, **12**, pp. 209-224, May 1958.

The suitability of the vidicon tube for converting the standards of television picture signals is taken up for investigation. The picture tube whose screen display is scanned must meet particular demands; the paper reviews the possibility of their fulfilment. Results with respect to definition, gamma, and signal-to-noise ratio are discussed.