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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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THE NEW SCHEME FOR THE GRADUATESHIP EXAMINATION

Mention has been made in the last three Annual Reports of Council's proposal to revise the scheme of the Graduateship Examination and to increase the standard of certain subjects. Details of these proposals were also given in last month's *Journal*.

The 23rd edition of the Regulations containing the new syllabus and the scheme of entry has now been published, and the syllabus will come into operation with the November 1956 examination. The main revisions in the examination syllabus come under four headings:—

(*a*) Increase in the standard of physics (forming part 1 of the examination) which will consist of two three-hour papers and include the subjects of Mechanics and Properties of Matter.

(*b*) Inclusion of Fourier analysis and differential equations in part 3—Mathematics.

(*c*) Division of the Advanced Radio and Electronic Engineering syllabus and the addition of a new optional subject, Applied Electronics, which will enable the electronics engineer to show evidence of his specialized knowledge.

(*d*) Division of the examination syllabus into two separate sections, the candidate having to complete the first section before proceeding to the second.

Members will notice that the Council has laid particular emphasis on the study of fundamental subjects, and the extension of the syllabus in Physics and Mathematics will, it is hoped, contribute to securing better results in Section B of the examination.

A three years' full-time course is required in order to cover the entire syllabus although some candidates may be able to write Section A within this time. Candidates will not, however, be permitted to sit Section B until they have passed Section A. In this way it is hoped to improve the standard of attempts in the more advanced subjects.

The Institution has for many years recognized the requirements of the electronics engineer who is primarily concerned with the application of electronics to fields other than communications. The Graduateship Examination has until now always required candidates to sit examinations up to the Advanced Radio Engineering level and requiring a specialist knowledge of communication techniques. This may well have discouraged the prospective engineer in the electronics field. Under the new scheme, such a candidate will have an opportunity to attempt specialist questions in electronic engineering apart from the fundamental questions in the Advanced Radio and Electronic Engineering syllabus. Moreover, in his specialist subject, he may take either Applied Electronics or Electronic Measurements.

Alteration in the scheme of the examination has necessitated revisions to the schedule of qualifications recognized for exemption from the Graduateship Examination. Full information is given in the 23rd edition of the Regulations.

The Council believes that the new examination scheme will provide an established standard of training for radio and electronics engineers in the light of current developments and also provide the academic background and knowledge required of future members of the Institution.

NOTICES

Radio Interference Suppression

The British Standards Institution has recently issued a Code of Practice (C.P. 1006) and a revised Standard on the subject of interference suppression.* This is of particular interest in view of the fact that Statutory Regulations (S.I. 291 and 292) on the control of interference from electric motors came into operation on 1st September 1955.

The Code of Practice is concerned solely with interference from electrical apparatus and installations. It deals with suppression techniques applicable to the long and medium wave bands and to the B.B.C. television band (41 to 68 Mc/s). Although it is expected that these techniques will be suitable for other bands, there is insufficient experience in their practical use to allow firm recommendations.

The standard is a revised edition of B.S. 613: Components and filter units for radio interference suppression (excluding devices for traction, marine, and other special equipment). The main difference between the revised B.S. 613 and the 1940 edition is the introduction of requirements governing complete filter units, the amplification of capacitor requirements and tests and the introduction of clauses dealing with neon-sign suppression inductors.

The general principles underlying the use of such components and which were published as appendices, have now been extended and included in the Code of Practice.

British Association 1955 Meeting

Among the papers read during Section G (Engineering) of the 1955 meeting of the British Association for the Advancement of Science, held at Bristol during September, was one of particular interest to many members of the Institution. Entitled "Linear Acceleration of Charged Particles to High Energy" it was given by Mr. C. W. Miller, M.Sc. (Associate Member), who will be well known for papers in the *Journal* on this subject.

As announced in the Annual Report, Mr. Miller has been awarded a Convention Premium for his paper on "Industrial Radiography and the Linear Accelerator." His British Association paper was published in the issues of *Engineering* dated September 9th and 16th.

* Published by the British Standards Institution, 2 Park Street, London, W.1. C.P. 1006 price 10s. 0d. each. B.S. 613:1955 price 6s. 0d. each.

R.I.C. Annual Dinner

The annual dinner of the Radio Industry Council will be held at the Dorchester Hotel, London, on Wednesday, 23rd November. The Guest of Honour on this occasion will be Sir Walter Monckton, Q.C., M.P., Minister of Labour and National Service.

Higher Technological Education

The Regional Advisory Council for Higher Technological Education in London and Home Counties has recently published the "Bulletin of Special Courses in Higher Technology, 1955-56." This contains details of special part-time courses now being run by 34 Technical Colleges. Nineteen of the courses are in radio or electronic subjects.

In a foreword it was stated that the total enrolment last year was 7,014, of which some 40 per cent. attended courses in physics, radio, electronics, and electrical technology. This is the largest number of students for one group of subjects.

The Council has also published a new edition of "Engineering Education in the Region" which gives details of the engineering courses available. These range from craft courses to external degrees and professional examinations.

Both these publications are available from the Secretary, Regional Advisory Council, Tavistock House South, Tavistock Square, W.C.1. The Bulletin of Special Courses costs 1s. 6d. and Engineering Education in the Region 1s. 0d.

B.B.C. Colour Television Transmissions

The British Broadcasting Corporation has recently commenced a series of experimental colour television transmissions from the Alexandra Palace station. These transmissions will continue for some months and normally take place after the closing of the evening programmes. They consist of still patterns, colour films and simple studio shots designed to provide technical information.

The tests are being carried out in agreement with the Television Advisory Committee, who are to report to the Postmaster-General on the whole field of colour television. One of the most difficult decisions which will have to be made before any regular colour television transmissions take place, is the line system to be used.

ELECTRICAL PULSE COMMUNICATION SYSTEMS

2. Message Encoding and Signal Formation in Pulse Systems *

by

Professor R. Filipowsky, Dr. Ing. (*Member*) †

SUMMARY

Five specifications should be known of an information source: dimensionality; maximum information content and peak rate of information production; average rate of information production; auto-correlation function; and statistical fine structure of the source. Various sources are discussed with reference to the specifications. Message encoding is split into two distinct operations: space matching and entropy matching. The former process has to reduce the dimensionality of the message space to match the three-dimensional signal space, the latter has to remove redundancy. Signal formation involves sampling, quantization and pulse modulation. The typical pulse waveforms are compared and their frequency spectra are listed. Signal encoding is considered as a linear transformation of the signal space into the channel space for the sole purpose of matching it to the requirements of a noisy channel of limited bandwidth.

7. Sources of Information

The first part of this survey was an attempt to demonstrate the wide range of pulse systems and their close affiliation with modern information theory. We may now rely upon the results of this theory when demonstrating how communication systems may be improved in their various sections by making full use of the advantages of pulsive operation.

7.1. *Specifications for Information Sources*

The rough subdivision of a pulse-system are demonstrated in Fig. 3 (Part 1)‡. Fig. 5 displays the various methods in performing the essential functions. Both the figures are headed by the information source. In Part 1 in Section 5.4‡ we find definitions of various classes of sources. Fig. 5 indicates the types of sources most familiar to radio engineers (A 1 to A 5 d in Fig. 5).

A communication system may be designed for one particular source and a given set of restraints only or it may be equally well suitable for different types of sources. In any case we have to explore:

(*a*) The dimensionality of the source (see Section 5.2; in "dead" sources there is no time coordinate),

(*b*) The maximum information content or the peak rate of information production (random source).

(*c*) The average rate of information production (entropy),

(*d*) The auto-correlation function of the source,

(*e*) The statistical fine-structure of the source (short-time entropy, zero level intervals, differential behaviour, etc.).

It is equally important to know the characteristics of the destination. In many communication systems we may suppress information, which should not be evaluated at all by the destination, or for which the destination is rather insensitive (restraint in binaural sensation, flicker limitation, restricted colour vision etc.). The same five characteristics (*a* to *e* above) may be specified for the destination, preferably as specifications of an "equivalent source" which could produce just the maximum of information that the destination can pick-up.

7.2. *Transducers*

All communication systems except some telemetering systems have to pick up information from non-electric physical ranges. Modern electronics has provided us with very sensitive pick-ups (transducers) for conversion of practically every physical magnitude into electric

* Manuscript received 23rd December 1954. (Paper No. 328.)

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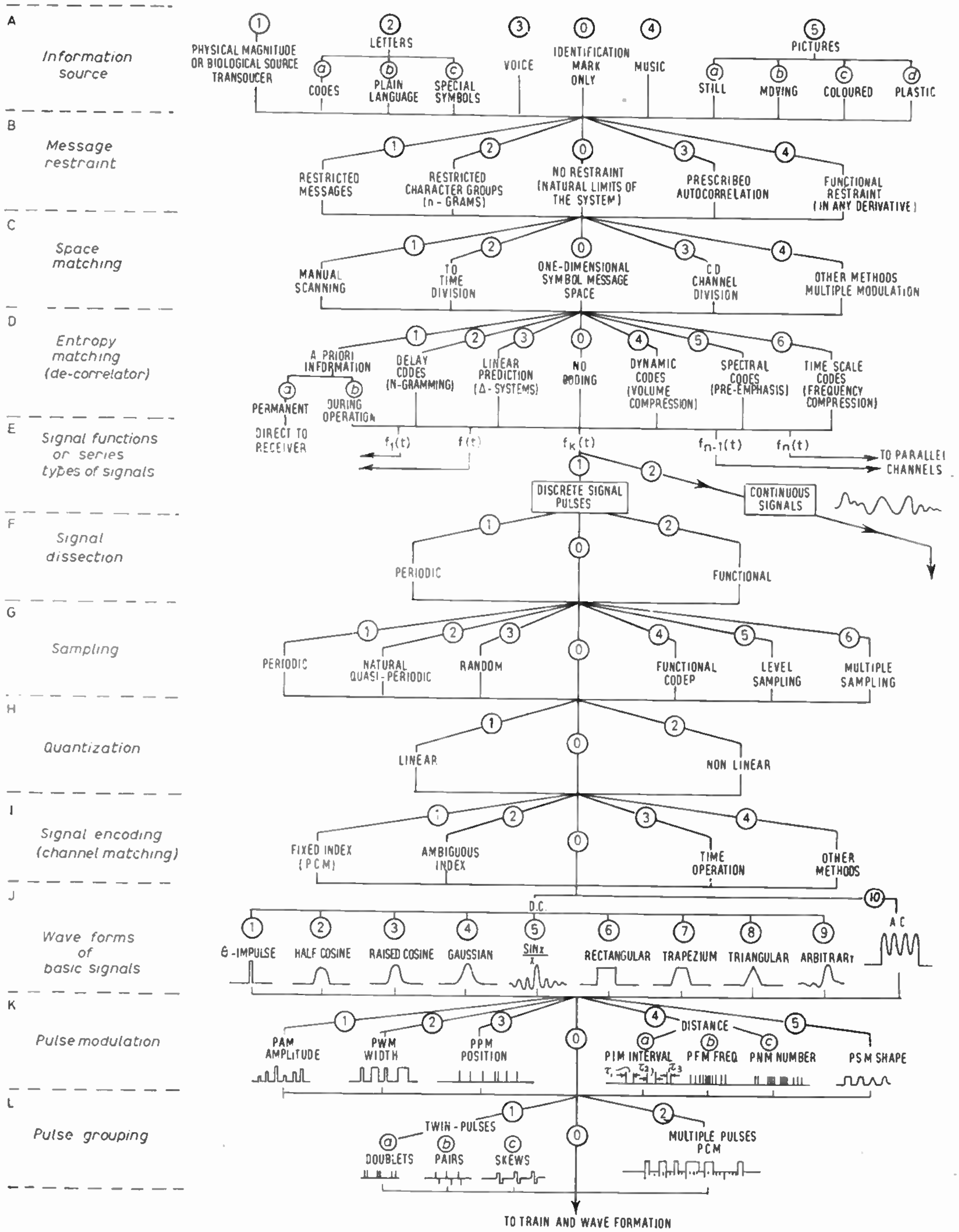
U.D.C. 621.374 : 621.391.

‡ The first part of this paper was published in the *Journal* for September (Vol. 15, No. 9, pp. 451-467). For convenience of cross reference, sections and illustrations are numbered consecutively throughout the paper.

Fig. 5.—Pulse Communication Systems. I—Message and Signal.



signals (microphones, pressure pick-ups, thermocells, photocells etc.). All these devices have their natural limits which should not suppress vital information within the range of the destination, but which may reject information content outside the range of the destination (photocells rejecting infra-red or ultraviolet radiation, microphones rejecting 20 kc/s and higher frequency components etc.).

A further requirement for transducers handling living messages is to secure an adequate rate of information transmission (gaseous photocells, for example, are not adequate for high speed picture transmission but are quite satisfactory for industrial applications). Also the granularity of the symbol space should not be increased by the transducer beyond the threshold of discrimination of the destination, or in some cases beyond the limit set by the channel capacity. Many investigations have concentrated in the past on this "*aperture effect*" of the tranducer. The fundamental approach is the same, whether we consider the beam cross-section of a scanning cathode ray, the inertia of a microphone membrane, the slit width of a sound-on-film recorder, or the diameter of the holes in a Nipkow disk.

The *requirements for the transducer* may be summarized by specifying that it should not restrict the structure of the message space beyond the natural limit set by the thresholds of discrimination of the destination. The constructional problems to achieve this aim are beyond the scope of the present paper.

Whenever transducers are used for "man-communication" (human sensory organ as the destination) we may find the natural limitations from statistical observations of the characteristics of these organs.

Whenever transducers are used in connection with non-biological destinations (recorders, pointer-indicators, servo-mechanisms), we can directly calculate or measure the latter's sensitivity, range and rate of operation. These results will generally allow us to determine the required structure of the message space to be handled by the transducer.

Under A 1 in Fig. 5 we combine all sources other than those for man-communications. Their characteristics have to be separately evaluated for each case. Telemetering pick-ups for example may have 99 per cent redundancy as they may observe a regularly constant magnitude, where any change of the rated value constitutes an emergency. The transmission of the rated value does not give any appreciable information, it is nearly fully predictable. Merely the deviation from the rated value is of interest. If this case arises, it may, of course, be of highest importance to transmit all details of the alterations instantaneously. The system should save all the channel capacity during the normal period and provide full channel capacity during the emergency state. Whether encoding processes can be provided for cases with such extreme redundancy depends on the overall aspects in the case of multi-channel systems and on the maximum tolerable delay in the case of single channel systems. In the first instance we may trade channel capacity between the various subchannels being combined in a multi-channel system.[1]

But this chance may also fail when all the channels are not independent but constitute, for example, a flying test telemetering system, where it is likely that all the magnitudes under observation may simultaneously come into a state of emergency and thus overload the "capacity sharing system".

This example of a telemetering system may demonstrate that it should not always be the aim of the system engineer to remove redundancy completely and match the information source perfectly to the channel.

7.3. *Text Sources (Letters and Symbols)*

Telegraphic messages are surely the oldest form of information presentation in telecommunications, and they provide an excellent example in explaining the various methods of Fig. 5. They are dead sources of generally two dimensions only, one for the character space (the sequence of letters, read in a prescribed manner) and one for the symbol space (C0).* The number and type of symbols is restricted (B1) and is given as *a-priori* information to the destination (D1a).

If the system has to be workable for special telegram codes (A2a) we have to assume equal probability for all symbols (random messages) and no entropy matching can be inserted (D0). The operation from a plain-language source (A2b) offers the possibility of imposing the restriction to use only one particular language

* The letters and numbers refer to Fig. 5.

(see Section 5.3). To take advantage of this restraint involves delay at sending and receiving ends (D2) and the amount to which redundancy can be reduced depends on the maximum permissible delay (practically unlimited in the case of dead messages).

If other symbols than the usual letters and figures have to be used, we classify the source separately under A 2c. In such cases it is profitable to check up each message prior to transmission and to communicate special "*code changing symbols*" to the receiver either ahead of the message or during the message, causing both stations to use temporarily a different code (another message space). Such procedure is very common, even in morse code telegraphy, whenever long parts of messages consist for example of figures only. When changing the code temporarily to one representing figures only, we may use the shortest signal characters in place of the five element characters normally in use for figures. A second code changing symbol will cause the receiver to understand the message characters again as normal letter symbols. In the theory we designate this process as a temporary *a-priori* information during operation (D 1b).

7.4. *Speech (Voice)*

The most usual means of communication between men is speech. Experience with commercial telephony has provided us with a large stock of statistical information on speech transmission. Intelligibility tests have disclosed the necessity to provide at least 3 kc/s bandwidth for a good voice channel, but on the other hand we may calculate that spoken messages, when noted down and communicated by the most efficient system (using word and phrase symbols), would require less than a few cycles bandwith (0·85 c/s is given as a theoretical lower limit by C. E. Shannon[2] and discussed in detail by H. S. Black) (Ref. 3, page 92).

Such large redundancy is not absolutely useless. There is more information in a speech communication than what we could express by the mere text of the speech. The individuality of the speaker, his feelings, temper, mood, etc., may be recognised from spoken words. Removing speech redundancy to the extent suggested by the above limit of a few cycles bandwith would not be much appreciated. But there is a considerable amount of redundancy which may be removed by efficient coding without losing the individual character of spoken messages. Such redundancy results from intervals between words and phrases, and also from the fact that a single telephonic conversation requires usually two channels simultaneously for the two opposite directions (except in radio telephony with voice-operated relay switching). A further large amount of redundancy is due to the structure of phonetic sounds which displays strong periodicity, particularly within vowels. Many investigations concentrated in recent times on the experimental study of speech structure. Their results, evaluated from the point of view of information theory, will be very helpful in increasing the efficiency of voice communication systems.

Trying to find quantitative specifications for speech sources in the sense of Section 2.1 we come first across the problem of *dimensionality*. Truly speaking, we have to consider a four-dimensional character space. But its structure is of high importance only in the time coordinate. The three space coordinates may occasionally be required if we have to discriminate different sound sources in stereophonic transmissions. Remembering however the fundamental principle of limiting the information drawn from the source to the maximum amount which can be picked up by the destination, we may introduce a rather rude space matching system. It will create at the destination an approximate impression where a particular sound source may be placed at the transmitting side.

The *maximum information content* of random sound sources (producing all sorts of noises) may be specified in terms of the ear's capability to accept the information. Most authors agree to figures between 100,000 and 500,000 bits/sec.

The *entropy of speech sources* depends on the amount of restraint which may be imposed on the system. If the text only of a spoken message is to be communicated, we find that not more than 20 letters (of correctly spelled words) can be spoken per second. Selecting them from a 32-symbol alphabet yields an information rate of $20 \log_2 2^5 = 100$ bits/sec. If we apply to this text "delay codes" which restrict the speech further by permitting a particular language only, we may ultimately come to an entropy of less than 20 bits/sec., which corresponds to a bandwidth of 3 c/s as soon as the signal-to-noise ratio is at least 20 db.

If the information should be reproduced by a sort of artificial voice, we may subdivide the speech in "*phonemes*". 40 to 50 such phonemic elements (vowels, consonants, etc.) are sufficient symbols to express any speech in English language. Approximately 100 phonemes will be required to note down any dialect of the world in "phonetic script". The "alphabet" contains in the latter case 100 symbols. Assuming a speaking rate of 10 phonemes per second gives 70 bits/sec., if all phonemes are equiprobable and independent. As speech is an ergodic process we may find its entropy and reduce the 70 bits/sec. at least to the value of 20 bits/sec, the same as for the mere text.

Even if the individuality of the speaker should be retained, we still may find encoding processes which come close to the entropy under this set of restraints. The entropy has now to take into account the probability that one particular individual is speaking. If all living human beings on the world would be equally probable speakers we require an information content of $\log_2 2 \times 10^9 = 30$ bits to specify one of them. This information could be given as *a-priori* information to the destination whenever a new speaker joins the conversation. Several speakers contributing to a conversation can be discriminated either by their space co-ordinates (stereophonic system) or by special marker signals to be transmitted whenever the speaker changes. The total information rate will be only slightly higher than without the "speaker marking system".

Individuality of speech, of course, means more than to specify the speaker. We have also to transmit the *individual character* of his voice and the instantaneous modulation of the voice with which he may express his personality, his emotional condition etc. Three parameters are listed in speech analysis to express this psychological factors: loudness, pitch and quality of the voice.[4] Many attempts have been made to retain a considerable amount of this "specific" information and still remove the superfluous redundancy. In single channel systems an analysis–synthesis scheme is required as is employed in Dudley's Vocoder,[6] for example. R. M. Fano[7] calculated the entropy for this case as 1,650 bits/sec., which is still less than 1/20 of the entropy for random sounds. In multichannel systems we may again introduce an instantaneous distribution of the channel capacity according to the *ad-hoc* requirements of each of the many channels involved in the system.[1]

The evaluation of the *auto-correlation* of speech waveforms is another important method for finding specifications for the individual voice character which yield less redundancy than the usual energy–frequency–time message space.[8]

The fifth specification of Section 2.1, the fine structure of the source, has also been the subject of many investigations. Most of the results in this direction have been summarized by H. Fletcher.[9] It is interesting to note that even during continuous speech 50 per cent of the total transmission time is wasted as zero level amplitude (out of 128 amplitude steps)—an observation which again stresses the urgent need for more efficient speech communication systems.

7.5. *Music and other Acoustic Messages*

In speech we could theoretically remove redundancy up to the limit given by the text of a speech. Even the "selective" entropy of a few bits/sec. calculated for this case is not the utmost limit. By going to the semantic aspect we may be in a position to express a large portion of longer spoken messages in a more concise manner by converting it to shorter phrases or words.

Nothing of this kind can be done for music or similar acoustic messages. There is most likely no semantic information content at all, but an appreciable amount of ideational (artistic) information content. It is also difficult to calculate the lower limit for its selective entropy as we could do for languages by taking n-gram character groups and making n rather large. Not even "phonemes" may be specified as easily as we could do for voice. Still there is much redundancy in music too and it should be possible to find selective entropy values for particular sets of restraint which may be tolerable in special music transmissions (for example solo concerts, wind instruments only, or string instruments only).

The *dimensionality* for good orchestra reproduction may be more important than for voice transmission. Again it loses importance for solo performances.

The *maximum information* content is determined by the ear and may be slightly higher than for voice due to a well expressed sensitivity for phase differences in musical sounds. It is definitely of the order of 10^6 bits/sec.

The *entropy* is not well known in the case of music, but the *autocorrelation* has been carefully investigated.[10]

The *statistical fine structure* is also absorbing the interest of many investigators from the artist's point of view.

7.6. *Facsimile and other Still Picture Sources*

These are best considered as special cases of television sources with the most important restraint that they are dead sources. Delay codes may be applied to any extent. On the other hand we cannot tolerate as much granularity as in television since a still picture will again re-appear as a dead message (photograph) at the receiving end and may be inspected more critically than any moving picture. Usually it will be further duplicated in newspapers etc., and further information will be lost. Highest resolution, close to the limit of the original, is the paramount requirement for facsimile.

Black and white sources have two-dimensional character space (x and y co-ordinates) and a one-dimensional symbol space (brightness levels). Colour facsimile may be easily derived from colour television, considering the above aspects.

Assuming a picture resolution of 1500 lines in a square area gives $2{\cdot}25 \times 10^6$ square picture elements which constitute the full set of characters of this dead message. It is generally believed that 10 to 15 brightness levels are sufficient for good reproduction. F. Schröter refers to the possibility of using only half the number of brightness levels producing intermediate values by a system of " level shifting " from line to line.[11] But such possibilities already constitute a particular system of encoding, as they are based on a certain redundancy in the message when considering the limitations of the destination (eye). Taking 12 levels (symbols) gives a round figure of $2{\cdot}25 \times 10^6 \times \log_2 12 = 10^7$ bits per picture (message) as maximum information content. The other specifications of this type of information source may be easily derived from television. In particular, the case of simple line drawings seems to offer a promising field for the application of information theory to create picture transmission systems with higher efficiency.[12]

7.7. *Television* (*Moving Picture Sources*)

Television is doubtless the most complex information transmission system—the message space at the source may be seven-dimensional in the extreme case of stereoscopic colour television. But even the standard black and white television offers an enormous maximum amount of information, which is never used. The number of possible messages, when taking one picture interval as the message interval is s^n, where s, the number of symbols, corresponds to the number of grey levels to be distinguished (10 as a minimum) and n to the number of characters (picture-elements) per picture (for good resolution 500,000). The resulting figure $10^{500,000}$ is unimaginably large. This will be evident when considering, that the whole universe, taken as a sphere ranging to the furthest nebulae could never accommodate more than 10^{100} tiny film pictures, when every available space would be closely packed with films of the thinest variety, each containing another of the possible messages which every standard television system can transmit.

E. R. Kretzmer[13] illustrates this giant figure by calculating that the number of film pictures to be passed through a projector when running for 24 hours a day over a full year at standard rate, amounts to slightly less than 10^9 pictures. Thus we would have to wait for $10^{499,991}$ years until the projector had passed all possible pictures without repeating a single one of them. The vast majority of these pictures will, of course, never be seen by a pick-up tube.

On the contrary, in normal television, there is still a much more important restraint than the fact that we are used to composing only pictures which make sense to the human mind, excluding all arbitrary compositions of " snow " pictures. It is a fact that the human mind, as final destination, is not able to perceive an instantaneous total change of the picture. Only small details may be allowed to change every $\frac{1}{25}$th of a second. We know from the cinema that it will take a few seconds to appreciate fully the content of any new scene. Gradual fade-out of one scene and building up of another one is a common means of helping the mind. In good television shows we find that very few details are actually " moving ", and the majority of the picture content is " still " over minutes at least (furniture, background, walls, etc.), The present television system however repeats the whole picture at every picture interval and is prepared to transmit instantaneously any complete change of the scene, thus evidently wasting an enormous amount of channel capacity.

Speaking in terms of information theory the maximum information content is of the order 5×10^7 bits/sec. and the entropy for long intervals must be a small fraction of this figure. The redundancy will be close to 100 per cent. Many investigations of both theoretical and practical nature have been started since 1948 aiming at a better matching of the message space to the signal space. Analysis of the structure of the message space (measurement of auto-correlation,[13] and definition and evaluation of a " picture detail factor ",[14]) has logically to precede the quantitative synthesis of new systems a survey of which has been made by Bell.[15] Imagination however took the lead two decades ago in contemplating some of the most promising systems.[16]

Turning to the five specifications of Section 2.1 we referred to the *dimensionality* of television sources ranging from 4 (monochrome) to 6 (colour) or 7 (stereo-colour). The *maximum information content* is of the order 5×10^7 bits/sec. for monochrome, but will be correspondingly much higher for the more advanced systems. Its exact determination for colour television will require still further physiological investigations, but some results seem to prove that not more than 30 different colours (and shades) would be required for satisfactory reproduction.[17] This would reduce the symbol space for colour television to $30 \times 10 = 300$ quanta, if 10 brightness steps are taken as a lower limit. The maximum information content for colour television may be tentatively taken as $25 \times 5 \times 10^5 \log_2 300$ or approximately $1{\cdot}2 \times 10^8$ bits/sec., expressing the well-known fact that it would require 2 to 3 times the bandwith of monochrome unless special coding operations are inserted.

The remaining three specifications of television as an information source are the subject of intensive investigation : *minimum entropy* (for long messages) cannot be approached in the conventional way successfully applied by Shannon to language sources. The enormous number of possible messages renders the attempt to determine message probabilities fruitless, but monogram probability distribution, i.e. probability distribution of brightness levels has been evaluated by E. R. Kretzmer.[13] He assumes the rather large figure of 64 amplitude steps which gives a maximum monogram entropy of 6 bits/character for equal probability. As a result of elaborate experiments the monogram entropy turns out to be approximately 5 bits/character, indicating a one-bit internal information. Instead of continuing the approach with the evaluation of digram probability, it is more profitable to investigate television pictures from the *auto-correlation* point of view. Linear prediction may be experimentally attempted in the form of " previous value", " slope ", " previous line ", " planar " and " circular " prediction. Results are available for the first two methods.[18] Investigations of the *fine-structure*, particularly along the time-axis may be published in due course, but are not available at present.

8. Message Encoding

Figure 5 gives at level A a representation of all types of information sources and we saw previously that we can specify their characteristics by 5 magnitudes. These specifications vary over rather wide ranges when proceeding from type 1 to type 5d. Level B to level E comprise the processes which we called message encoding.

8.1. *Restraints*

Any type of message will be subject to certain restraints (B) which restrict the maximum information content of the source. The most liberal condition (B0) is the natural limitation, as given either by the source (voice for example), by the destination (ear) or by the channel (hi-fi music over standard radio channel). In other cases specific restraints may be imposed on the system. Telecontrol systems for example will be acting on *restricted messages* only (B 1). If teletype transmissions are rationalised by n-gramming operations, there will be a restriction of messages to a special language if n is very large. For $n = 2$, however, it might be possible to use several closely related languages with nearly equally good efficiency, but there may be a restriction barring certain digrams completely, for example all digrams with q as the first letter except qu (B 2). Similar n-*gram restriction* will be effective with voice transmissions when using the analysis-synthesis principle (8.4). In continuous (non-quantized) transmissions of continuous messages it may be more profitable to express the necessary restraint in terms of *auto-correlation parameters* (B 3).

Finally we have frequently to impose *functional restraint* (B 4) on the tolerable messages. One familiar example is the restriction of the maximum slope of a waveform (first derivative) if the channel bandwidth is given and entropy matching is not provided.

Coding theory is emerging as a highly important branch of information theory[19] and its main concern is the construction of optimum codes or code procedures.[20]

8.2. *Space Matching*

Space matching is only for sources with multi-dimensional character space requirement. We remember that signal characters form only a one-dimensional sequence in the signal space (double modulation of one signal character should be taken as a multi-channel operation) and matching of message space to signal space requires therefore a reduction of dimensionality. The most familiar applications are scanning operations for picture dissection.

We distinguish *manual scanning* (C 1) from all other groups. It is a usual practice in telegram transmissions, where the message is written on a sheet of paper (two dimensional) and read out in the normal reading sequence (line scanning from left to right and top to bottom) by the telegraph operator when encoding it in morse code signals or typing it into the teletype sender. Many secrecy codes however deviate from this procedure and employ any apparently random scanning method, which may even change from message to message. Additional insertion of dummy characters and further encoding by any of the methods listed under level D (Fig. 5) may finally help to render unauthorized de-coding nearly impossible. Authorized de-coders will have got detailed knowledge of the scanning and coding processes by *a-priori* information (D 1) and will find no difficulty in restoring the original message. Such elaborate manual scanning, of course, may be performed by machines, but still should be designated as "manual" scanning (or preliminary scanning) as it is an operation which will be performed on dead messages, prior to their final submission to the actual telecommunication section of the system.

TD (*time division*) *space matching* (C 2) is the normal operation in present day facsimile and television systems. The latter take due advantage of the human eye's limitation in time interval discrimination beyond $\frac{1}{50}$th of a second. Line scanning as introduced by Nipkow and improved by F. Schröter (odd number interlaced scanning, see Table II) is still the basis of all television systems. At least 40 other different scanning systems, ranging from spiral scanning to dot-interlacing[21] and "balayage cavalier"[22] have been suggested in more than five decades of television inventions. Only the recent theory of efficient coding has initiated the search for improved scanning methods as part of a programme for reducing the enormous redundancy of the television message space. It is likely that TD methods will still continue to be of paramount importance, but either linear scanning or line sequential scanning will have to be abandoned giving way to more efficient methods, at least for television network transmissions.

CD (*channel division*) *space matching* (C 3) is usually employed in stereophonic transmissions. In section 1.4 we stressed the rather coarse structure of the message space of sound sources along its three space co-ordinates compared with the highly important fine structure in the time co-ordinate. As the ear is restricted to binaural perception and has no directional scanning capability like the eye, inventors found it sufficient to convey the special information by a two-microphone method which automatically led to a two-channel transmission system. It has been recently extended to a three-channel method in the Cinemascope sound system.[23]

Many other methods (C 4) are conceivable for space matching, but they generally will constitute some mixture of the previous three. An entirely different method seems to be possible, but not very practicable. In stereophonic transmissions one might convey the sound characteristics of the sending room as "*a-priori* information of permanent character" (D 1a) and the instantaneous location of sound sources by "*a-priori* information during operation" (D 1b) to the receiver which may split the incoming signals instantaneously in such a manner that two or more specially separated loudspeakers may imitate stereophonic reproduction. This would be easy if the sources operate frequently in some sort of time division (as in a radio drama). It will be more difficult if the sources operate simultaneously as in an orchestra performance.

An interesting application of space matching may be found in the *Siemens-Hell teletype* system,[24,25] which actually constitutes a mixture between facsimile and teletype. The telegram message is converted into a time sequence by manual scanning, no entropy matching is attempted and the signal encoder produces a binary pulse group with very large redundancy (using 49 bits/character !). On the receiving side the 49 binary digits are re-arranged in a two-dimensional spatial display in a 7×7 element rectangle for each character. For

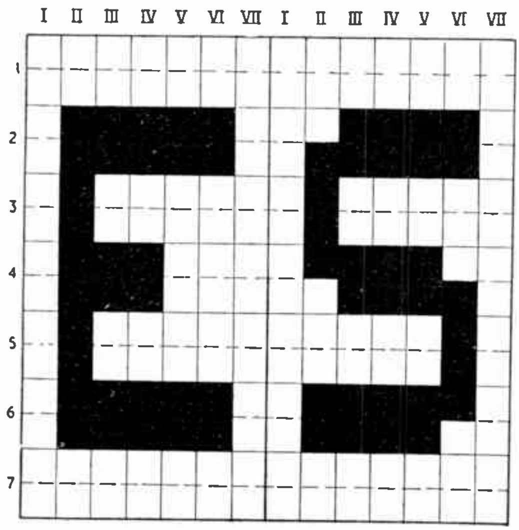


Fig. 6.—Letter reproduction in the Siemens-Hell system

positive bits the corresponding elementary areas will be blackened, and they will stay white for negative bits. The permanent code (D 1a) is framed in such a form that the black elements in each character area produce a facsimile picture of the transmitted symbol (Fig. 6). The mutilation of several bits will still keep the symbol recognizable. In the presence of severe noise and disturbances there may be finally a complete destruction of the symbol, but there will never be an imitation of a wrong symbol. The system is purposely increasing the redundancy in exchange for a very high safety of operation in the presence of severest noise. An automatic error detection and correction by the human mind is secured with practically no additional equipment, merely by the ingenious method of a special letter-display at the receiving side, there being no corresponding scanning process at the sending side. Not even synchronism is required as all characters contain 49 bits, which may be counted. The scanning sequence for the receiver is fixed by the code and given as *a-priori* information. Even admitting that the total system increases channel-bandwidth instead of reducing it, one has to appreciate the large amount of " modern information ideas " involved in an invention of the early thirties.

8.3. *A-Priori Information*

A-Priori information (D 1) is an essential part not only of any entropy matching method but of any communication system provided we define it as the total knowledge of the system available at the receiver prior to the beginning of any new message. It correspondingly involves :

(1) The knowledge of the *system design*, i.e. of the selected principles of operation at all the 24 levels of Fig. 5 and 7.
(2) The knowledge of the exact nature and *specifications of source and destination.*
(3) The knowledge of all *message codes* to be employed throughout the operation (C and D).
(4) The knowledge of all *signal waveform data* and if signal coding is used, the complete *signal code* to be employed.
(5) The knowledge of all *operational data* on the transmitted signal trains and waves (carrier frequency, modulation system, etc.).
(6) The knowledge of the *transmission medium* and its permanent *characteristics.*

Such *a-priori* information may be permanently available at the receiver or may be communicated in convenient intervals by means outside the channel under consideration (D 1a). Highly efficient systems however will have to change some sections of the *a-priori* information at short notice. For example *n*-grammers will change the code in accordance with the language in which a telegram is submitted. Within a message it may be required to cancel temporarily a certain restraint and to switch out the corresponding encoder. Consider a digrammer with " qu " as the only available q-digram and a message in English, where suddenly the word " Qishm " appears (an island south of Persia, actually the only word in the " American

College Dictionary" beginning with q in a digram other than qu). The system would fail to forward the word, unless the digrammer is temporarily switched out and a normal letter code is reinstated. A special code changing signal (N 4) may communicate this action as a "*temporary* a-priori *information*" (D 1b) to the receiver to produce the required action. A different signal has to communicate the reversed process.

All *single symbol* codes (monogram codes), like Morse code, 5-unit, 7-unit- 10-unit- codes may be included in this group. They operate on a one-to-one basis relating one and only one signal to each of the permissible symbols of the message space. There may be a certain amount of entropy matching in cases of unequal symbol-probability, when signal character elements of different area in the *ft*-plane will be available. Morse code is an excellent example, using the shortest signals, for "e" and "t", the most probable symbols in English texts. A comprehensive survey of "telegraph codes" is given by Hayton et al.[25]

It is important to note that these conventional telegraph codes concern us only in connection with *a-priori* information, i.e. with the permanently listed co-ordination of symbols and signals. There is no instantaneous entropy matching involved and all the other operations of conventional telegraph systems are classified under signal formation. The classical Morse code, for example, is a system using multiple pulses of a variable number of pulses per character (L 2), the character elements being classified either as binary p.a.m. pulses (K 1) or as p.w.m. pulses (K 2) of two standard lengths.

The most complicated set of *a-priori* information, or instructions, is required by *privacy systems*. The purpose of message or signal encoding or both is in this case neither entropy matching nor channel matching, but merely the wish to prevent any unauthorized receiver ("enemy") from evaluating the semantic aspect of the information content. Modern communication systems employing entropy matching, and channel matching will automatically offer a certain higher amount of privacy then any continuous wave a.m. radio systems. Nevertheless true privacy systems require additional precautions which consist usually of some dissection of the message- or signal-space (both are frequently identical in conventional systems), either by TD or FD methods, whereby the dissection scheme is changed at short intervals in a predetermined manner. The latter is known only to authorized receivers as *a-priori* information. Inserting a special transformation (a "key") from message to signal space leads to a "*true secrecy system*". The theory of such systems is closely related to the statistical theory of communications and has also been covered by C. Shannon.[26]

Privacy-systems may also be introduced for commercial reasons to prevent non-licenced receivers from participating in a broadcasting, or more likely in a television system. Some vital information, for example the low frequency components, may be sent over a different, individually controllable medium, such as a telephone subscribers line.[27]

8.4. *Delay Codes*

Delay Codes (D 2) or *n*-gramming operations aim at a reduction of redundancy by improving the entropy matching over groups of characters (*n*-grams). Monogram entropy matching has been mentioned above in connection with the conventional Morse code. It will also involve delay if message characters carrying rare symbols (j, y, q) happen to arrive frequently. This delay however is only in dispatching the signals but there is no delay involved in selecting a signal for a given character. Monogram-codes do not require a special *n*-grammer but only a signal selector. Now we consider all codes which require special apparatus for determining the symbol group to be encoded. This starts with digrams. For *n*-grams, there is unavoidable delay for *n*-message character intervals at the sender and a similar unavoidable delay for *n*-signal character intervals at the receiver, if only one channel is used. In addition there will be a varying delay in the dispatch of the signals, which occasionally may outrun the systems ability. All this delay will be tolerable with dead messages, but may become annoying in connection with living messages.

Equipment to perform *n*-gramming operations is sketched by B. M. Oliver in his fundamentally important article on "efficient coding".[19]

Operations similar to *n*-gramming may be performed on continuous messages, particularly on speech wave-forms. Speech analysers will select typical message intervals (phonemes) and determine the particular message symbol (phonetic sound, similar to *n*-gram). A selected signal will inform the receiver of the observed facts and a speech synthesiser will try at the other end to produce some standard sound of the type analysed at the sender. The *typo-sonograph* of J. Dreyfus-Graf[28] is a convenient form of electro-optical analyser, whereas the VODER of H. W. Dudley[29] should be considered the first speech-synthesiser, which is merely a companion of the same inventor's VOCODER, the first *analyser–synthesiser speech communication system*.[29]

8.5. *Linear Prediction*

This is a system of entropy matching which is based on the history of a message and is instantaneously acting. It involves only a negligibly small amount of delay which is tolerable for most living messages, such as voice or television. It takes full account of the conditional statistics of the message, i.e. of the dependence of the symbol selected for one character on the appearance of certain symbols with the previous characters, but it does not directly consider the probability distribution of the symbols themselves. Linear prediction is therefore particularly suitable for sources where the mutual dependence of characters is of higher importance than the symbol probability, e.g. in television.

Linear prediction evaluates from the knowledge of the past of a message a prediction for the symbol likely to be carried by the next message character. If this prediction is correct, no signal is transmitted to the receiver. If the prediction is wrong, then only the amount and sign of the deviation from the predicted value is transmitted as " error signal ". The receiver performs the same prediction process, as the past of the message is normally also known at the other end of the channel. Any arriving error signal is immediately used to correct the previous message character and to use this new value for further predictions.

Several predictions are suitable in television and some of them have been experimentally checked on typical television scenes.[18]

(*a*) The next brightness level (symbol) may be the same as the last one available (" previous value prediction ").
(*b*) The slope of the brightness function may continue as the average value of the slope between the last two picture elements (" slope prediction ").
(*c*) The brightness of the next picture element (in the scanning direction) will be the same as that of the nearest picture element of the previous line (" previous line prediction ").
(*d*) The brightness and/or the slope of the next picture element may still be the same as observed at the previous scanning process (" previous picture prediction ").

Combinations of these four fundamental methods or more elaborate predictions are conceivable.

The error signals naturally follow a certain probability distribution as in good predictions zero error should be most probable and large error very improbable. A renewed process of delay encoding could remove the redundancy remaining due to this statistical distribution of the error signal. But even without this additional entropy matching process, there is a considerable advantage in the fact that the error-signal will require a much smaller average transmitter power compared with the power, which the original signal (without prediction) would have required.

" Previous picture prediction " has been for a long time under theoretical investigation as *picture difference method*.[15,16]

A " *delta system* " has been developed for voice communication too.[30] In this case the signal to be transmitted is not the error signal of a prediction process, but a quantized form of a " slope " signal. The effect of the operation is similar to the " previous value prediction ". The particular feature of this system however is not the message encoding process, but the very simple procedure of signal encoding into a series of binary digits. No coding tube or quantizer is required. A good deal of equipment cost may be saved by employing this novel system.

8.6. *Dynamic and Spectral Codes*

These are in operation in connection with continuous messages and continuous signals. The designation " codes " may not be perfectly correct, but it may be helpful to bring closely related procedures together. From the information point of view we may speak of a non-linear transformation of the message space into the signal space.

We speak of " *dynamic codes* " (D 4) if the amplitude co-ordinate is linearly distorted (volume compression) and of "*spectral codes*" (D 5) if the frequency co-ordinate is non-linearly transformed as in pre-emphasis for f.m.

Irreparable volume compression is executed by "*speech clipping*", a process which has proved rather useful under certain circumstances, regardless of its non-reversible non-linear character.[31]

8.7. *Time-scale Codes (Frequency Compression)*

Time-scale codes (D 6) are similar non-linear operations as the dynamic and spectral codes, but affecting the transformation of the time co-ordinate. "*Frequency compression*" is the familiar designation when operated on continuous messages.[32] Present frequency compression systems still have shortcomings which prevent their immediate introduction. It may be assumed that in the near future pulsive sampling technique in connection with variable delay devices may provide means for instantaneous frequency compression without the shortcomings of the present mechano-optical devices. Once such equipment is available, time scale codes will attain much greater importance, as already stressed in connection with Section 8.2 (non-linear scanning methods).

9. Signal Formation

9.1. *Signal Functions*

Message encoding results in one or more time functions (or series) $f_1(t)$, $f_2(t)$ . . . $f_k(t)$ . . . $f_n(t)$ each of which is diverted to a separate transmission channel (Level E in Fig. 5). In most applications there will be only a single time-function $f_k(t)$ and this may be the message function itself (in ordinary audio-broadcasting for example). In some other applications it will differ due to message encoding. We called the set of all possible time functions the "*signal space*". Its structure and its transformation into the "*channel space*" is discussed here.

The signal functions $f_n(t)$ need not be directly available within the equipment. They may be transferred by mechanical means from the source to the signal generator and may cause the correct selection of signals in accordance with a special code (teletype). Usually $f_k(t)$ will be available in electric form and when representing a continuous signal (music for example), it may be kept in this form and transmitted over a conventional continuous channel (E 2). Another way is to convert the signal to a pulsive waveform and perform on it one or more of the following operations (E 1). We are here concerned with this case only.

Pulse systems have the advantage of simple multiplexing in time-division, of the possibility of using an unlimited number of regenerative repeaters within the medium, of good adaptibility whenever channel matching is required, and of higher efficiency and lower susceptibility towards distortion. *Continuous signals* on the other hand can be used without further conversion processes and their technique is fully established. Discrete messages lead towards pulse transmission. Continuous messages may be handled either way.

9.2. *Signal Dissection, Sampling and Quantization*

Pulsive Operation requires in the time co-ordinate at least a subdivision into discrete intervals. We call any dissection of a continuous co-ordinate scale a *quantization process*, when assigning to each "quantum" a discrete number. In particular however we prefer this term in connection with a subdivision of the amplitude scale (H). Such amplitude quantization may or may not be employed, but quantization for the time co-ordinate, we call it usually sampling (G), is unavoidable. Any quantization in the frequency co-ordinate would primarily constitute a FD multichannel system (M 1). Special frequency quantized single channel systems are conceivable but not published up to now.

Signal dissection (F) is a very coarse method of pulsive operation but in certain combinations with other system features it is believed to be a very efficient method of channel matching. V. D. Landon[33] includes in his survey of pulse modulation systems one method designated as p.a.m.-f.m. (slow). It turns out to be the best of all p.m. systems in many respects. Practical difficulties only seem to prevent its general introduction. It starts with a *periodic dissection* of the signal function at a *subaudio repetition frequency* (F 1). Each interval is then linearly compressed in time by a factor n (D 6), thus making the $\frac{n-1}{n}$ th part of the interval free for other channels which are inserted in time division (M 4a, Fig. 7). The whole train finally frequency modulates a sinusoidal carrier (02). The time compression requires instantaneously acting circuits with storage facilities, capable of releasing the compressed signal at the correct instant. Storage tubes or wire recording have been suggested by Landon (1946 or earlier), but the recent progress of dynamic storage devices with compression characteristics may offer much better methods.

Functional signal dissection (F 2) as suggested by the author, is likely to add to the above advantages of p.a.m.–x.x. (slow) the possibility of entropy matching. The idea is to adjust the length of the dissection interval and the compression factor from epoch to epoch in such a manner that the maximum frequency after compression will always be close to the upper frequency limit of the channel. Additional service signals (N, Fig. 6) may be required to indicate to the receiver the instantaneous compression factor of any epoch. Most embodiments of this idea will automatically lead to asynchronous time division (M 4b), in which case channel marking (N 2) becomes unavoidable.

Sampling (G) is the more usual method of quantization in time. Dissection produces epochs of the signal function which contain a considerable fraction of the signal space with a large number of signal characters. Sampling is a true quantization process, with each sample corresponding to one signal character only. Its fundamental importance for pulse communication systems has been stressed in Section 5.6 and is mathematically expressed in *Carson's sampling theorem* (1920) stating that any continuous waveform containing no frequency components equal or higher than f cycles and lasting for T seconds will be completely specified by $2\,fT$ samples taken at regular intervals of $1/2f$ seconds.

Nyquist postulated in 1928[34] the *generalized sampling principle*, that *any* $2\,fT$ discrete values were sufficient to specify the continuous waveform defined above. They need *not* be spaced uniformly and any set of $2\,fT$ independent numbers *associated with* the function may be used to define it completely and uniquely.

H. S. Black (Ref. 3, ch. IV, pp. 37–57) gives a detailed account of all further theorems associated with the sampling process. The freedom in selecting the sampling instants, as expressed in Nyquist's sampling theorem, inspired inventors to use it in the design of novel communication systems.

Level G in Fig. 5 symbolizes such possibilities by 6 subdivisions. We may, of course, by-pass sampling completely (G 0) and still deal with a pulse communication system, whenever there are discrete signals already available at level E (telegraph) or in the case of signal dissection (F).

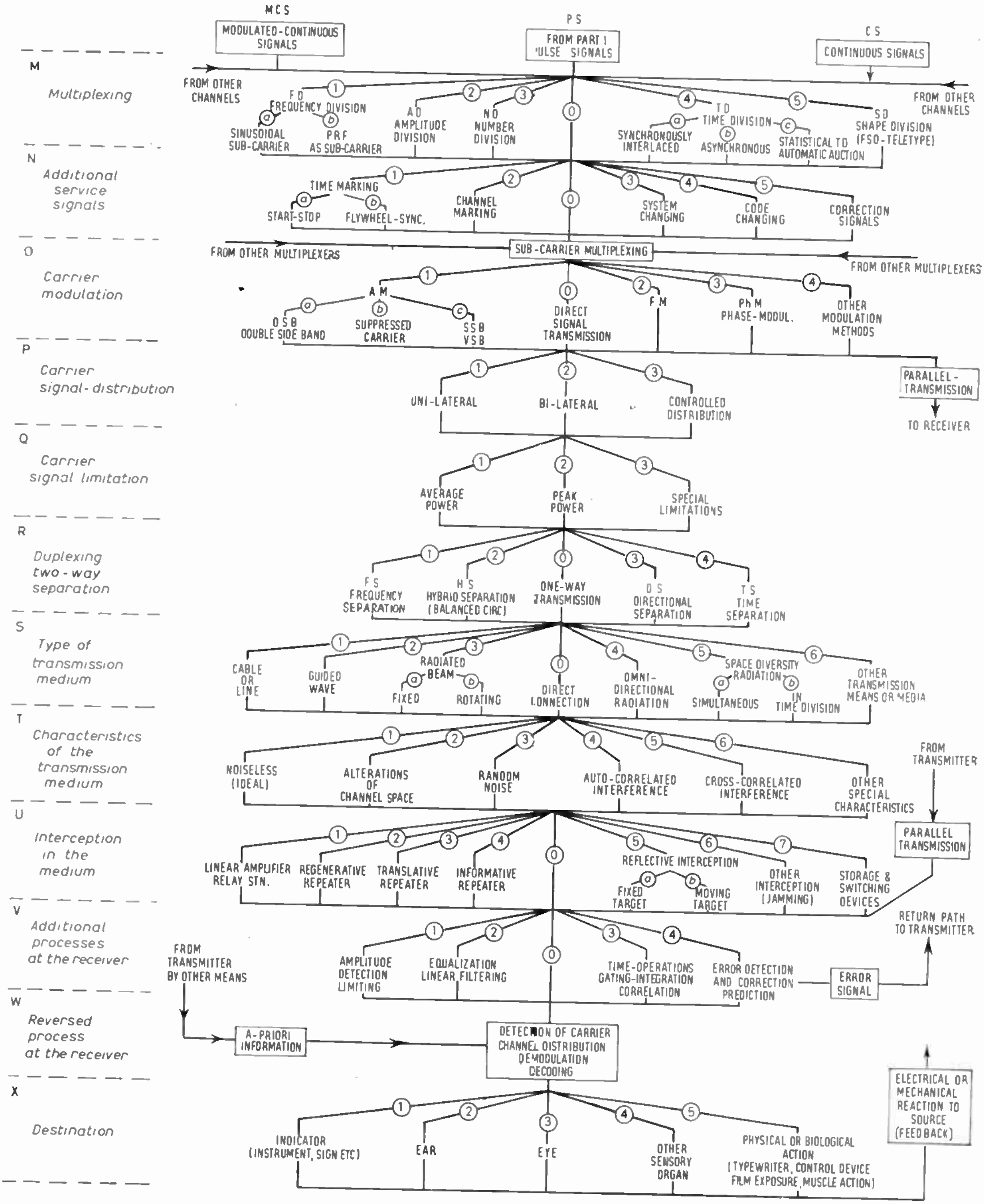
Periodic sampling (G 1) leads to the simplest equipment and is the usual technique applied in most commercial pulse systems. It allows synchronous TD multiplexing, which again is preferred for its simplicity. Over a hundred articles describe these conventional pulse communication systems and the reader is particularly referred to the recent survey by J. E. Flood,[35] containing a bibliography of 93 references.

Natural (quasi-periodic) Sampling (G 2) avoids sampling distortions or correction circuits at the receiver in all cases where the original sampling instant (phase) is changed throughout the further transmission process other than by a mere constant time delay. This happens in all time-modulation systems (K 2, K 3, etc.) and can be avoided by sampling at the instant in which the modulated pulse is finally shifted. H. S. Black (Ref. 3, pp. 282–287) derives the frequency spectrum of time-modulated pulse trains for normal (periodic) sampling as well as for natural sampling.

Random sampling (G 3) has been suggested in connection with certain mobile systems operating in one and the same medium. The varying distances between transmitters and receivers make synchronization difficult. The nature of such systems allows however non-synchronous simultaneous operation as the traffic density is usually rather small. Coincidence of samples at a receiver will lead to a rejection and consequent loss of both the samples. If such incidents occur at random intervals, the disturbances will sound like white noise and become less annoying, than in any periodic case. Random sampling may secure this advantage.[36]

Functional sampling (G 4) is an excellent means of avoiding unnecessary tiny transmission intervals, for example by matching the instantaneous sampling rate to the instantaneous maximum frequency component. The latter expression is illogical, when thinking in terms of Fourier Analysis, as this assumes each component lasting for ever. But recent work[37] has made us think in terms of elementary signals which are practically limited in bandwidth *and* time and it is evident that a highly complex interval of a waveform requires more such

Fig. 7.—Pulse Communication Systems. II—Carrier and Transmission.



elementary signals for its full specification than a rather smooth interval or a constant value would need. Changing the sampling rate in dependence on the " complexity " of the signal is the essential content of a recently proposed pulse communication system, termed CODEP—COmplexity DEpendent Pulse system.[1]

The mere reduction of the average number of samples per time unit with the help of functional sampling does not directly reduce the required channel capacity. Only if the vacated intervals can be used for other purposes we may have a net gain. Merely redistributing the remaining essential samples in a more equal manner over the timescales would just be another form of entropy matching by frequency compression (D 6), only the sequence of the operations would be reversed. A new idea seems to be the attempt to use the vacant signal character intervals for other channels where they might just be required. Thus functional sampling leads to efficient multiplex systems and we shall continue to discuss the corresponding system (CODEP) at the level M of Fig. 7.

Level sampling (G 5) is governed by the wish to reduce the number of symbols per signal character and transmit standard signals only (bits). One idea is to transmit a marking signal at every instant when the signal waveform crosses the borderline between two quantum levels. This will increase the number of bits in instants of highest complexity but it will reduce it far below the figure required for pulse code modulation (I 1) in instants of low complexity.[40] Again the problem arises of how to make use of the vacant character intervals.

Multiple sampling (G 6) is governed by the opposite wish: to increase the number of symbols per character, for example to make full use of a rather noiseless channel, particularly in cases where the signal function is already quantized or may be quantized in a small number of steps (facsimile).[11]

Quantization (H) in its restricted meaning refers to the dissection of the amplitude co-ordinate only. It is an essential part of many signal coding procedures, but it may be avoided also (H0). Ingenious electronic devices have been developed for quantizing continuous signal functions.[41]

Quantization distortion is unavoidable, but can be reduced below any limit by using a large number of quantum steps and by flattening out the reproduced quantized waveform. Any remaining part of it will produce *quantization noise* in the receiver, as the magnitude of the quantization error follows a random distribution. With equal quantizing steps the noise is independent of the signal level. We speak of *uniform (or linear) quantization* (H 1). This has for speech transmission the disadvantage of very noticeable noise at low signal levels against negligible noise at high signal levels. To avoid this we may increase the size of the quanta with the signal voltage and introduce: *tapered or non-linear quantization* (H 2).

9.3. *Signal Encoding*

Signal encoding is essential whenever a further matching process is required between signal space and channel space. (see Section 5.6) One extreme is the reduction of the amplitude scale to two levels only (binary encoding). It has been developed to a high perfection in the well-known pulse code, or pulse count, modulation system (I 1) (p.c.m.).[35d, 42–48] In its present form p.c.m. uses " fixed " indices with uniform quantization. The first bit indicates whether the selected level is in the upper or in the lower half. The second bit again indicates the selection of a level in the upper half or the lower half of that half range selected by the first bit, and so on. Letting a signal function gradually increase from zero to maximum level will produce a sequence of channel characters which keep for the first half of the interval the first element (bit) of each character unchanged. When half the maximum amplitude is reached, this bit will change its state, but again it will remain unchanged for all further channel characters.

C. W. Earp disclosed two short-comings of this system.[50] Firstly there is a danger that a single small disturbance may imitate a wrong bit at the first element and the error produced in the receiver will be much larger than the disturbance. Secondly, when gradually changing the amplitude there is a large amount of transmitted energy concentrated in those signal elements which do not change, and only a fraction of the total energy may generally be used for the indication of the amplitude changes of the signal. A system is conceivable which will allow the change of most of the digits (in continuous encoding, indices) every time when proceeding from level to level. One embodiment of such a system is demonstrated by Earp in connection with a twin-index continuous encoding procedure. It has been tentatively named: "Ambiguous index system" (I 1), to signify the ambiguous tendency of the single character elements.

P.c.m. and similar systems exchange signal-to-noise ratio against bandwidth by splitting one sample (signal character) in two or more signal elements (Fig. 8). The signal space is thus changed to a larger extension in the frequency co-ordinate ($W_0 \rightarrow W_1$) and a lower number of levels in the amplitude co-ordinate ($10 \rightarrow 2$), the total transmission time or the time required for each character (T_0) being unchanged. A similar exchange can also take place between amplitude and time domain, keeping the bandwidth constant. This will be mainly interesting for dead messages of rather limited duration. Again we reduce the height of the signal space but increase its extension in the time co-ordinate (I 3).

Finally it is also possible to increase the extension of the signal space in the amplitude co-ordinate and reduce it in the frequency domain (reduction of bandwidth) or in the time domain (already mentioned as "multiple sampling", G 6). Specification I 4 should include all such possibilities and any combination of the basic methods.

It should be remembered that any such linear space-transformation does not change the entropy of the signal or channel space. It however may help to save average transmitting power in all cases where there is still sufficient redundancy in the signal space (after entropy matching) and where the amplitude levels after the signal encoder can be arranged in decreasing probability with increasing amplitude.

9.4. *Pulse Waveforms*

Having prepared the information for transmission by all the previous steps in a communication system, we have now to select the most suitable waveform for the basic signals to be transmitted over the channel. Level J of Fig. 5 displays a large number of basic signals which first of all are divided into *d.c. and a.c. pulses*. The former are generally of non-oscillatory character, except the $\sin x/x$ pulse (J 5), a transitional form to the latter group.

The waveforms J 1 to J 5 involve the most important elementary signals (Section 4.5); they are displayed together with their frequency spectra in Fig. 9.

The *unit impulse* or delta function is a function the value of which is zero, except in an arbitrary small interval around $t = 0$ where it becomes infinite in such a way that:

$$\int_{-a}^{+b} \delta(t)\, dt = 1$$

a and b are finite positive quantities. The delta function is the limiting value of a rectangular pulse, with the pulse width decreasing

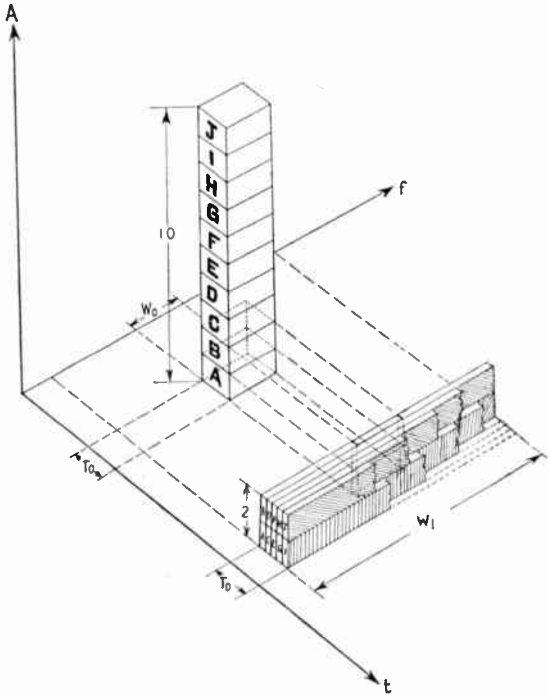


Fig. 8.—Channel matching by signal encoding

to zero, but the area (electric charge or magnetic flux) remaining constant. It is the differential quotient of the unit step function. Its own differential quotient is the unit doublet impulse ($\delta'(t)$). Many other interesting properties can be derived, as for example, in Goldman.[51]

Unit impulses are important tools of theoretical analysis. In practical applications we approach them closely in any switching process covering extremely short intervals compared with the normal time scale of the associated waveforms. Delta functions constitute for example ideal sampling functions.

The frequency spectrum of a unit impulse shows a uniform distribution of the energy over all frequencies from zero to infinity. Its absolute value, the amplitude spectrum, is a constant. This makes it clear that unit impulses never can be useful elementary signals for transmission over the medium.

The *half-cosine waveform* (J 2) is preferred whenever a very short base pulse duration is required with a perfectly clean (zero) condition outside the pulse. Taking this base pulse duration as T_B, we find a half level duration of $\tau = \frac{2}{3}T_B$ The frequency spectrum has its first zero-component at $W = \frac{3}{2\,T_B} = \frac{1}{\tau}$, but considerable energy is still outside this band. To pass this waveform without much distortion through a low-pass filter, will require a much larger bandwidth than $1/\tau$, the bandwidth for the raised cosine (J 3), when referred to the half-level width τ. (At 1·25 W the spectrum has still 6 per cent of its maximum value.)

The *raised cosine waveform* (J 3) is also perfectly zero outside the two instants where it reaches zero level. Taking this base pulse duration as T_B, we find that the pulse width at half the peak value is $\tau = \frac{1}{2}T_B$, i.e. smaller than in the previous case. The frequency spectrum is practically restricted to a bandwidth $W = 1/\tau = 2/T_B$. The energy outside this band is negligible. Passing such a pulse through a low pass-filter with W as cut-off frequency will hardly affect this waveform. It is the best selection, whenever there is a need to transmit a pulse of given duration (at half level) over a small frequency band. Its disadvantage is the large distance between the first zero-points of its waveform. It may not be used if different pulses have closely to follow each other, as crosstalk would inevitably result.

The *cosine-squared* or *sine-squared waveform*[52] is absolutely identical with the raised-cosine waveform as may be seen from the trigonometric relationship :

$$\frac{1}{2}\left(1 + \cos \frac{2\pi}{T_B} \,.\, t\right) \equiv \cos^2\left(\frac{\pi}{T_B} \,.\, t\right)$$

where T_B is the base duration of the pulse. D. Gabor gives the uncertainty product of these signals as 1·14, i.e. only 14 per cent larger than for the Gaussian signal.

The *Gaussian signal* or *error function waveform* (J 4) has already been mentioned as the most ideal elementary signal from an analytical point of view (Section 5.5). It has the smallest uncertainty product and we may now add that it is also the only signal with identical shape for time-function and frequency spectrum. If we compare the Gaussian signal with the raised-cosine waveform by allowing 10 per cent rest-signal at a base-width of T_B (Fig. 9a) we find as half-level pulse width $\tau = 0{\cdot}55\ T_B$, i.e. slightly wider than the pulse-width of the raised cosine signal. The frequency spectrum however is decaying much quicker for the Gaussian pulse (see Fig. 9a).

The *sin x/x pulse* (J 5) (abbreviated si x) is selected whenever the frequency band is prescribed and independent pulses should follow in closest succession. Its frequency spectrum is completely limited to the given range $W = 1/T_B$, but the waveform extends in the time domain far beyond the interval between the first two zero positions. The fact however that zero positions are periodically repeated along the time axis at intervals equal to $T_B/2$ permits the superposition of a sequence of many elementary si x signals with all their zero positions well aligned and with only one of them deviating from zero at any given pulse centre. A practical pulse form has thus been found, which is perfectly restricted to a bandwidth W and still permits 2 WT independent signals to be arranged at any interval T.

The pulse width of a si x pulse at half level is $\tau = 0{\cdot}6\ T_B$, slightly larger than that of the Gaussian signal. The latter however extends in time and frequency domain beyond the limits T_B and W and does not permit independent transmission of closely packed pulses, as there are no zero positions.

The practical difficulties, when trying to transmit independent si x pulses at the Nyquist rate $2W$, are great. In any case we have to sample at the receiver with very small gating pulses exactly at the right instants. No phase distortions are tolerable over the channel and the amplitude modulator has to operate with highest precision. The situation is less critical when quantized n-ary pulses of a low n parameter are used. Particularly binary pulses will operate without much trouble at the Nyquist rate, as any remaining cross-talk will stay far below the threshold.

The *classical rectangular pulse* (J 6) is impractical for transmission over a channel of limited bandwidth. It is the inverse case of the si x pulse as it is perfectly limited in the time domain to the interval T_B. The uncertainty relation requires now an unlimited frequency spectrum, which follows a si x function.

The ideal rectangular pulse, for which, of course, $\tau = T_B$, is only of theoretical interest. Restricting its frequency spectrum to the first group of harmonics $0 < f < 1/T_B$ or $0 < y < 1$, will cause distortions which modify the rectangular form to a clearly peaked shape and which extend the range in the time domain beyond T_B. The band-width at half level will now be $\tau = 0{\cdot}85\ T_B$.

Trapezium (J 7) and *triangular* (J 8) *pulses* are more practical waveforms and they take intermediate positions in respect of their frequency spectrum.

Table 3 opposite gives a comparative list of the time-functions and frequency-spectra for all the pulses mentioned above. They are sketched in Fig. 9.

The equations are normalized by taking the pulse width at the base (T_B) as the unit for the x coordinate. The frequency coordinate is normalized in respect to the reciprocal value of T_B as the unit.

The amplitude scale in both sets of curves is a relative one and only the positive frequency range is considered for the frequency spectrum. The waveforms of (2) to (6) are plotted in Fig. 9.

A.C.-Pulses (J 10) are valuable signals, which have long been used in voice frequency telegraphy and in many other special applications. They allow the independent variation of six different parameters as indicated in Fig. 10. These are the three parameters of the underlying d.c. pulses :

(1) P.R.F. (Pulse repetition frequency), the reciprocal of the period τ.

(2) Pulse width T_0

(3) Pulse amplitude A_0

In addition there are three parameters of the superposed a.c. signal :

(4) The a.c. frequency, being the reciprocal of the a.c. period T_1.

(5) The a.c. amplitude A_1

(6) The a.c. initial phase (φ_0).

9.5. *Pulse Modulation*

The selected elementary signals have now to be modulated in one or more of their independent parameters (Level K in Fig. 5). Analogous to the modulation process for continuous waves, we may distinguish :

(1) *P.A.M.* (*pulse amplitude modulation*) (K 1), offering a rather simple circuit technique, but when directly used over the medium or when

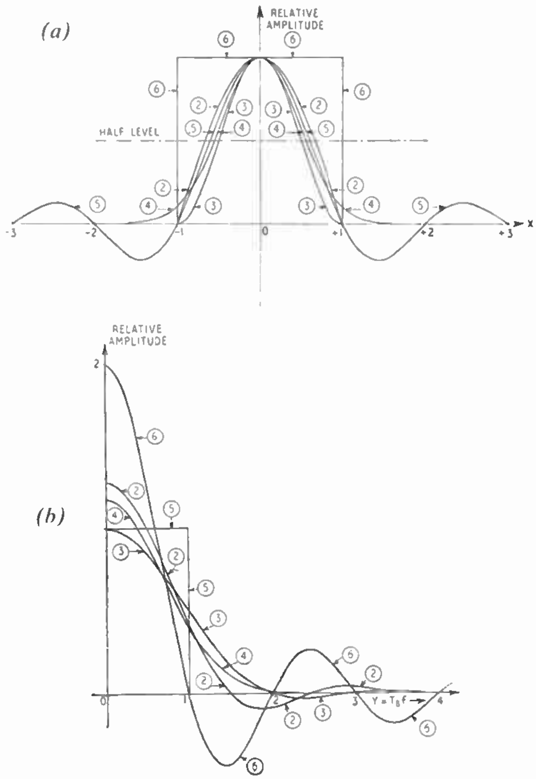


Fig. 9.—Pulse waveforms and their frequency spectrum.

combined with a.m. as carrier modulation, being rather liable to disturbances. It is the first pulse modulation method in the historical sequence (Table I) and it is still in use as an intermediate step in more complicated systems. Full information about this method may be gained from J. E. Flood.[35b]

(2) ***P.W.M.*** (*pulse width modulation* or *pulse length modulation*) (K 2) and *p.p.m.* (*pulse position modulation*) (K 3) have the common feature of modulating the time-coordinate (p.t.m. = pulse time modulation). The first method, changing the width of a quasi-rectangular pulse, is analogous to frequency modulation in the continuous case, as the frequency spectrum

of a pulse is altered when its duration (width) is changed. The second method is analogous to phase-modulation as the position of a narrow pulse is equivalent to the phase of a sine-wave.

P.p.m. may be directly derived from p.w.m. by a differential process. Only the pulse corresponding to the modulated edge of the p.w.m. signal need be transmitted in p.p.m. Merely an occasional time reference signal is required in addition to the position modulated pulses. P.p.m. has the advantage of keeping the transmitted energy low, even during extreme values of the modulating signal, whereas p.w.m. requires the radiation of energy throughout the full width of a pulse. As there are no corresponding disadvantages p.p.m. is preferred.

Time modulation in either form uses binary channel elements, securing similar advantages in respect of signal-to-noise ratio as pulse code modulation. The latter in its present form is closer to a p.a.m. method, but using pulse groups in place of single pulses. P.c.m. requires quantization, whereas the two above methods can use continuous modulating signals. On the other side they are slightly more vulnerable to noise. Due to the finite rise-time of the pulses, noise can affect the accuracy of time specification and can indirectly produce some disturbing modulation. This can be avoided in p.c.m., where only the presence or absence of the pulse within a predetermined time interval expresses the information but not any change of the position of the pulse edges. The circuit technique for p.t.m. systems is summarized by J. E. Flood[35] and many more details will be found in the numerous descriptions of systems already in operation.

(3) Less familiar methods of pulse modulation are listed on the right side of level K in Fig. 5. The distance between two pulses is in three methods the modulated magnitude. Even p.p.m. may be considered as a system modulating the distance between two pulses. This however is not fully correct, as the reference pulse (synchronization pulse) in p.p.m. is only an indispensable requisite as long as there is no absolutely constant frequency source. Actually we give the standard position of the unmodulated pulse as *a-priori* information (about the system) to the receiver and no further indication is theoretically required.

Table 3

Designation	Time function f(x)	Frequency spectrum S(y)
(1) 0-pulse :	0 (0)	$1/\pi$
(2) Half-cosine :	$\cos \pi x$	$\frac{4\cos\pi y}{\pi\, 1-4y^2}$
(3) Raised-cosine :	$\frac{1}{2}(1+\cos 2\pi x)$	$\frac{1}{1-y^2}\cdot\frac{\sin \pi y}{\pi y}$
(4) Gaussian pulse :	$\exp(-9{\cdot}2x^2)$	$1{\cdot}17\exp(-1{\cdot}07y^2)$
(5) si x :	$\frac{\sin 2\pi x}{2\pi x}$	$S(y)=1\ \ldots$ for $0<y<1$ $S(y)=0\ \ldots$ for $y>1$
(6) Rectangular pulse :	$f(x)=1$ for $-0{\cdot}5<x<+0{\cdot}5$ $f(x)=0$ for $\lvert x\rvert>0{\cdot}5$	$2\cdot\frac{\sin \pi y}{\pi y}$
(7) Trapezium pulse :	$f(x)=1$ for $\lvert x\rvert<0{\cdot}25$ $f(x)=0$ for $\lvert x\rvert>0{\cdot}5$ $f(x)=1-4(\lvert x\rvert-0{\cdot}25)$ for $0{\cdot}25\leq\lvert x\rvert\leq 0{\cdot}5$	$\frac{4}{\pi^2y^2}\left(\cos \pi y-\cos\frac{\pi y}{2}\right)$
(8) Triangular pulse :	$f(0)=1$ $f(x)=0$ for $\lvert x\rvert>0{\cdot}5$ $f(x)=1-2\cdot\lvert x\rvert$ for $\lvert x\rvert\leq 0{\cdot}5$	$\frac{2}{\pi^2y^2}(1-\cos \pi y)$

D

This is not so in the true *p.d.m.* (*pulse distance modulation*) systems. There is no *a-priori* information given about the phase of pulses. Whenever a pulse group appears it can be directly demodulated without reference to any standard phase or frequency. The first method is *p.i.m.* (*pulse interval modulation*) (K 4a) where τ_1, τ_2, τ_3 are a sequence of modulated pairs. A particularly useful application of this system can be secured in time-division multiplex operation where the second pulse of one pair can serve as the first pulse of the next pair for another channel. If the shortest intervals correspond to small signal amplitudes and if large amplitudes are rather rare we may save a good amount of channel capacity by such a system, against a multi-channel p.p.m. system. Certain difficulties of channel distribution can be solved by counting devices. Applying a p.i.m. system to a single channel will not secure such a good efficiency as in multichannel systems, but it will also save channel capacity compared with p.p.m., from which system it is clearly distinct. Natural sampling is required and the p.r.f. will depend on the average amplitude level.

Another p.d.m. method is *p.f.m.* (*pulse frequency modulation*) (K 4b) where we modulate the pulse repetition frequency. Applicable only to single channel systems with relatively wide frequency band, we cannot list any particular advantage of this system which was not also shared by other more practical methods too. Only the fact that very simple circuits for modulation and demodulation are available may be held in favour of p.f.m. Its combination with other communication systems may occasionally lead to good results.

P.N.M. (*pulse number modulation*) (K 4c) is closely related to p.f.m.; it has to be listed as a separate method, as it is conceivable that the number of pulses within a group could be modulated without changing their p.r.f. The groups will be of different length in such a system, but this would not be a handicap when the probability for short groups is high.

Finally we meet *p.s.m.* (*pulse shape modulation*) (K 5) comprising a multitude of possible systems, *slope modulation* of triangular pulses being one of them. A.c. pulses, when modulated in one of their three a.c. parameters, may also be classified into this group. Shape modulation offers many possibilities for double-modulation.

Trapezoidal pulses, for example, may be modulated by one sample at the leading edge and by another at the trailing edge. Both the edges may also represent two different indices of a pulse code system or different channels of a multiplex system.

The large number of possible modulation systems has soon inspired investigators to undertake a comparative analysis of their relative merits and demerits.

The investigations by V. D. Landon[33] and by Z. Jelonek[55] seem to be the most complete ones. There is no outright best system, and many specifications have to be considered until a selection of an optimum combination of system sections can be finalized. Source and destination, type and characteristics of the

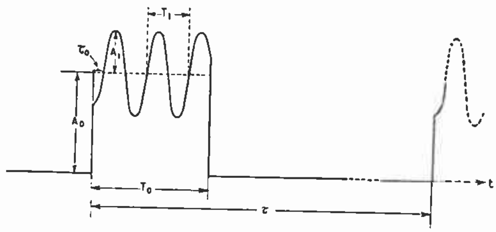


Fig. 10.—The six parameters of an a.c.-pulse.

medium, average or peak power limitation, carrier modulation and multiplexing, all influence the optimum selection of the modulation system. Only after having discussed the further components of a pulse system (Part III of this paper) shall we be in a position to indicate the most favourable combinations.

9.6. *Pulse Grouping*

Pulse grouping (L) is essential in most p.c.m. systems. Each character element (index) requires a separate pulse. Double pulses or twin-pulses (L 1) may be arranged as doublets (L 1a), pairs (L 1b) or skews (L 1c). They may serve in the place of single pulses whenever a special marking of the pulse is required. The distance between the pulses of a pair may serve to identify their origin or at least may aid to discriminate them from noise, pulsive disturbances, or other single pulses. Pairs and skews due to their skew-symmetrical waveform require a smaller frequency band than their unilateral counterpart. They cannot be used for amplitude keying of a transmitter.

Multi-pulse groups are the typical signal carriers of coded signals. Even in systems without distinct signal encoding, we may find that certain coded signals are required if one character is to serve a particular purpose, say to secure perfect synchronization or to change a code simultaneously at transmitter and receiver. Failure of such special signals may cause a long sequence of undetectable errors and it is highly important to secure their perfect selection (or otherwise rejection) even in the presence of severe noise. Using a specified pulse group in place of a single pulse may be helpful in these cases. Such groups can be as complicated as is necessary. They may contain signals of various pulse shapes and may be modulated in different manners. We call them " key-pulses ", " comb-pulses ", " beard-pulses ", " barb-pulses ", etc.

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APPLICANTS FOR MEMBERSHIP

New proposals were considered by the Membership Committee at a meeting held on September 13th, 1955, as follows:—23 proposals for direct election to Graduateship or higher grade of membership, and 65 proposals for transfer to Graduateship or higher grade of membership. In addition, 43 applications for Studentship registration were considered.

The following are the names of those who have been properly proposed and appear qualified. In accordance with a resolution of Council and in the absence of any objections being lodged, these elections will be confirmed 14 days from the date of the circulation of this list. Any objections received will be submitted to the next meeting of the Council with whom the final decision rests.

Direct Election to Member

HIX, Commander Lucien, B.Sc.(Hons.), R.N. *Bath.*

Transfer from Associate Member to Member

CHAKRAVARTI, Lt.-Col. Brahma Mohan, Indian Signals. *Bangalore.*
MARTINDALE, Lt.-Col. James Patrick Alexander, B.A., B.Sc. *St. Albans.*

Direct Election to Associate Member

BORTHWICK, Capt. Roland Heneage, B.Sc.(Eng.), Royal Signals. *B.A.O.R.*
BURNS, Russell Westcott, M.Sc. *Newcastle-upon-Tyne.*
CARTER, Lieut. George Vincent, R.N. *Sheerness.*
FLETCHER, Lieut.-Com. Ronald Percival, R.N. *Southsea.*
FRITH, Com. Leslie Peter, R.N. *Washington.*
PEARTREE, John Allan, B.Sc. *Sidcup.*
ROBINSON, Kenneth Arthur. *Rugeley.*
SHROFF, Lieut. Jeejibhoy Phirozeshah, B.Sc., B.E., Indian Navy. *Fareham.*

Transfer from Associate to Associate Member

ATTEW, James Edward. *Weybridge.*
COTTY, William Feltham. *Windsor.*
HUNT, Frederick Stanley. *Malta, G.C.*
LEWIS, Reginald George. *South Harrow.*

Transfer from Graduate to Associate Member

ANSARI, Mahmood. *Karachi.*
CLARK, Thomas Gordon. *East Molesey.*
GRIFFITHS, Reginald Clive. *Bristol.*
HAMBLETON, James. *Gateshead.*
HARRIS, Peter Michael. *Sidcup.*
HOLSHAUSEN, Desmond James. *Transvaal.*
ROBB, Ronald Laidlaw. *Harrow.*
ROTTENBERG, Ruben Robert. *Kiriat Bialik.*

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BASU, Capt. Aniles, M.Sc., Indian Signals. *Mhow.*
BROWN, Alfred Dixon. *Basingstoke.*
JAYAKARAN, Capt. Israel, Indian Signals. *Mhow.*
OXBOROUGH, Frank William. *Swindon.*
STEWART, Edward Samuel. *Christchurch, New Zealand.*

Direct Election to Associate

KERR, Major Joseph La Motte. *Trinidad.*
MILLER, Ernest George William. *London, S.W.17.*
SIMPSON, Arthur Ian Forbes, M.B.E. *Leamington Spa.**
VALE, Lindsay Harold. *Wells, Somerset.*
VAN DEN HEUVEL, Flt. Lt. Teunis, R.N.Z.A.F. *Wellington, New Zealand.*

Transfer from Student to Associate

ALBURY, Charles Nathaniel. *Nassau, Bahamas.*
HAPPY, Robert Victor. *Auckland.*
HOOPER-SMITH, Laurence Edward. *Jersey.*
HORNER, William Beswick. *London, S.W.13.*
PEGRUME, Peter Hillyard. *Nairobi.*
POOI SAY SOON. *Singapore.*
VOON KIN MIM, Andrew. *Kuala Lumpur.*
WANDEN, William Thomas George. *Chislehurst.*

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BLUSIEWICZ, Stanislaw, B.Sc.(Eng.). *Buenos Aires.*
BYARD-JONES, Michael James, B.Sc.(Eng.). *Cradley.*
HENCE, Flt. Lt. Ronald Harry John, R.A.F. *Birmingham.*
STYLES, Donald. *High Wycombe.*
TREGEAR, Paul. *Weybridge.*

Transfer from Student to Graduate

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BELCHER, John Charles. *Shipley.*
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CHIKERSAL, Chaman Lal, B.A. *Ludhiana.*
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TOWERS, Thomas Dundas, M.A., B.Sc. *Ibadan.*
WOOD, James Gladstone Stewart, B.Sc. *Wellington, New Zealand.*

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BANERJI, Sanat Kumar. *Delhi.*
BARNARD, Clifford Albert. *Haslingfield.*
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GURMEL SINGH. *New Delhi.*
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* Reinstatement.

MATERIALS USED IN RADIO AND ELECTRONIC ENGINEERING

A Survey by the Technical Committee of the Institution

3. Ceramics *

1. Introduction

British Standard Specification B.S.1598 defines Ceramic Materials as "Inorganic materials which are prepared and converted into the final vitreous state by the application of elevated temperatures while substantially retaining their unfired shape."

The importance of ceramics in the field of radio and electronic engineering lies in the fact that they are insulating materials of great thermal and mechanical stability, that in many cases they have highly desirable and often unique electrical properties and that they can be made to have combinations of properties which are of prime significance in many applications. One example of such a combination is low power loss with a pre-determined temperature coefficient of permittivity,† another, a very high value of permittivity with a moderate power loss.

A table follows showing the general classes of ceramic materials which are of principal interest to those concerned with equipment engineering. In the main, the classes are those more likely to be encountered or found of value in connection with general structural applications, but in order to broaden its perspective some classes are included which find their usefulness almost exclusively in the hands of component specialists. The values quoted under each class heading cover not only the nominally pure material but also the variants which are based on that material.

The bibliography accompanying this review is not as a whole restricted to the narrower field of immediate interest to the equipment engineer. In Part I however has been segregated a short list of some of the more general literature which is likely to serve the limited needs of the non-specialist.

2. General Considerations

The properties of ceramics are very sensitive to variations in composition, to impurities which unintentionally may be present and to details of the manufacturing process such as particle size, compacting pressure and firing temperatures. For these reasons the quoted ranges of values of properties are wide; the figures are not to be construed as indicating inherent instability or variability of the properties of any one specific material. The values which are given are based on the published characteristics of materials which are commercially available in this country.

The properties listed in the table are in the main those specified in British Standard B.S. 1598:1949 and cover all characteristics which are likely to concern an equipment designer. Some inherent characteristics of ceramic materials do not require expression in precise terms. They are resistant to deterioration from electric arcs unless the heat generated is so intense that it causes fusion of the material, resistant to hydrolysis and generally resistant to attack by chemicals with the exception of hydrofluoric acid, and they are highly resistant to abrasion.

In selecting a ceramic insulating material it should be borne in mind that generally the lower the power factor, the higher the cost owing to the greater care which is necessary during manufacture in materials control and in shaping. Economy is effected therefore by the choice of the highest power factor which can be tolerated in a particular application.

Another practical point of importance is that it is not always possible to manufacture every class of material in all shapes and sizes, and that in any case close attention to details of configuration and dimensioning at the earliest stage

* Report approved by the General Council for publication on June 24th, 1955. (Report No. 10.) Prepared for the Committee by Mr. F. G. Diver, M.B.E. (Member).

U.D.C. No. 666.3:621.37/9.

† B.S. 1598 designates this property "Temperature coefficient of capacitance" and defines the term in relation to a material. In the interest of uniformity the British Standard term is used throughout the remainder of this review.

of design will ensure not only cheaper articles but increased production by reducing the possibility of waste at both the manufacturing and assembly stages, assembly difficulties and consequent delays. The electrical and mechanical characteristics of a particular piece part will depend on whether it is made by pressing a granulated material or by shaping a plastic material. The equipment designer about to initiate work on any but the obviously simple or well-established forms of ceramic piece parts will do well to recognize that the experience of the specialist ceramic manufacturer will be a valuable aid. Early consultation will materially assist in evolving the most desirable design and facilitating production at minimum cost.

It has been stressed that this review makes no attempt to cover materials which are mainly of interest in the component field but a passing mention of the barium titanate class is thought appropriate. Although the discovery of the remarkable properties of this class occurred only about ten years ago, the literature on the subject is already very considerable. The main lines of the work described in the earlier literature were reviewed and discussed in a paper by Willis Jackson.[7] This paper and others published since reveal the wide range of potential applications of the barium titanate class. Mason and Wick[12] have recently reviewed their properties in relation to their use for capacitors, transducers, dielectric amplifiers and other devices.

3. Summary of Materials

The main table accompanying this review shows eight classes of materials which, with the exception of porcelain, are listed in ascending order of power factor. Porcelain cannot be said to fall into the category of a high frequency insulator but its presence in the table for comparison purposes is justified. A supplementary table is given in order to provide some guidance on the value of power factor which may obtain at frequencies higher than the normal standard test frequency of 1 Mc/s. There follow brief notes on the classes of materials listed and on some other classes which have a more limited or specialized application.

3.1. *Porcelain*

The electrical types of porcelain are made from china clay (aluminium silicate), with quartz as filler and feldspar as flux. The proportions commonly used are two of china clay, one of quartz and one of feldspar. It has a comparatively poor power factor at high frequencies and a rather low volume resistivity at high temperatures. Its comparatively low thermal expansion and high positive change of capacitance with temperature are notable. It is mainly used for insulators at power frequencies. The technique of manufacturing intricate or large shapes in this material is well known. Glazing is advisable where it is necessary to minimise the deposition of dust.

3.2. *Steatite*

Steatite or soapstone in its natural (unfired) state is a coarse, massive or granular variety of talc, greasy to the touch. Chemically it is magnesium silicate. Fired at 800–1000° C it becomes very hard and strong. Materials produced from steatite or having steatite as their principal constituent are the most widely used of the "low loss" ceramics. They combine reasonably low values of power factor, permittivity and temperature coefficient of capacitance with good mechanical strength. The thermal expansion is of the same order as that of a number of metallic alloys thus making them useful for sealing techniques. The resistivity at high temperatures is better than that of porcelain. These properties make the steatite class of ceramic a general purpose high frequency insulator and it is widely used in components such as variable capacitors, coil formers, valve holders and bases and for general structural insulation.

3.3. *Forsterite*

This material chemically is another magnesium silicate but of a different composition from steatite. Its outstanding properties relative to the latter are a very low power factor and a high thermal expansion. It is intended for applications where the lowest possible dielectric loss is important, also where vacuum tight joints have to be made with metal parts, as for example in electronic tubes. Its suitability for the latter application results from the ability to ensure that it has a coefficient of linear expansion which closely matches that of some nickel-iron alloys. It is suitable for high temperature metallizing techniques. The commercial grades have been developed with particular attention to the attainment of high physical and chemical stability and negligible porosity.

3.4. *Cordierite*

This mineral is a magnesium aluminium silicate with the chemical composition $2MgO.2Al_2O_3.5SiO_2$. Although this substance has never been found in any sizeable natural deposit, cordierite crystals can be developed in a ceramic body of the composition talc 39·6%, clay (pure kaolin) 47% and alumina 13·4%. Variants of this composition suitably processed provide a ceramic body consisting in some cases of 60% cordierite crystals.

Such a ceramic has the outstanding property of a very low thermal expansion but its power factor is relatively high being of the same order as that of porcelain. In these respects it will be seen to contrast from forsterite. The low thermal expansion ensures very good resistance to thermal shock; this virtue leads to its usage outside the sphere of high frequency applications —in electrical heater plates, as cores for electrical resistors, for resistance wire supports and other similar purposes in various types of equipment. The mechanical strength of this class of material is not notable but with due attention to shape design in relation to the intended use it is adequate.

In the high frequency field advantage may be taken of its low thermal expansion by use, for example, as formers of coils which are desired to have a minimum change of inductance with temperature. In by no means all such applications could its relatively high power factor be regarded as a disqualifying feature.

3.5. *Rutile*

This mineral is a dioxide of titanium which crystallizes as reddish-brown prismatic crystals in the tetragonal system. It is found in igneous and metamorphic rocks and is a source of titanium. The material has the notable electrical characteristics of a high permittivity and, unlike most other materials, a high negative temperature coefficient of capacitance. These properties are accompanied by a low power factor and good mechanical characteristics.

It is chiefly used as the dielectric of capacitors, an application where high value of permittivity combined with low power factor is an obvious advantage. The high negative temperature coefficient of capacitance of such capacitors becomes a virtue when appropriately utilized to compensate the positive coefficient of other elements in a particular circuit application.

It is of passing interest to note that rutile bodies often show firing shrinkages as high as 25% or even greater.

3.6. *Magnesium Titanate*

A number of special ceramic bodies are made by using 60–90% rutile with one or more of the oxides of magnesium, barium, beryllium, lead and zirconium. Most of these bodies are characterized by the attribute of a very low power factor; magnesium titanate is a typical example. In a specific case the power factor may be lower than that of a rutile body and this feature combined with the low temperature coefficient of capacitance which also characterizes magnesium titanate makes it attractive for high frequency applications.

It is commonly used as the dielectric of capacitors where low loss or high power handling capacity is of prime importance.

3.7. *Barium Titanate*

A reference to this class of ceramic already has been made in this review. An aspect of the versatility of this general class is indicated in the table where it appears under two headings.

One of these shows that a particular variant can be made to have a combination of very low power factor, low temperature coefficient of capacitance and a moderately high permittivity —characteristics which are somewhat similar to those of magnesium titanate and which lead to this variant having a similar field of application.

The second heading exemplifies other variants which have been evolved to provide a remarkably high value of permittivity, thus making possible the construction of relatively high value capacitors in small dimensions while still retaining a tolerable dielectric strength. The power factor of this variant is high but is not a disadvantage in the uses, such as by-pass capacitors, to which this material is put.

The absence in the table of values for some mechanical and thermal properties is a reflection of the fact that in general barium titanate does not claim special attention in the constructional aspects of equipment engineering. Its unique ferroelectric and piezoelectric properties, however, attract a wide interest.

3.8. *Alumina*

This material is the trioxide of aluminium and occurs as the mineral corundum. Ceramics having a high alumina content are notable for their ability to withstand very high temperatures up to about 1750° C; consequently they are commonly used as the electrode supports in electronic valves, as sparking plug cores and in similar applications.

The characteristics of recrystallized or sintered alumina are shown in the table and it will be noted that alumina so processed retains its ability to withstand high temperatures and also has notably high mechanical strength (in the order of twice that of porcelain). The thermal conductivity of sintered alumina is outstanding, being about twenty times that of porcelain and more nearly comparable with that of steel. This class of material has a reasonably low value of power factor at 1 Mc/s and there is evidence to show that it remains in this order at frequencies of about 3000 Mc/s.

3.9. *Pyrophyllite*

This clay mineral is a silicate of aluminium with chemically combined water. It occurs in metamorphic rocks and often resembles talc. Ceramic bodies can be made by firing this material without entailing significant shrinkage such as is encountered in other classes of ceramics. Hyde[8] quotes shrinkage rates of about 3% to 4%. Pyrophyllite bodies in the unfired state are machinable with conventional tools. These two features make it attractive for experimental and prototype use.

The fired bodies have a mechanical strength comparable with that of porcelain. The power factor ($\times 10^4$) of certain mixes based on this material is in the order of 20 and the permittivity about 5.

3.10. *Zircon*

During the past five years much experimental work has been done on ceramic bodies having zirconium silicate as their major constituent. The principal object of this work has been to evolve a low-loss ceramic material which could be fabricated by conventional whiteware forming methods and fired in large commercial tunnel kilns without excessive wastage of the finished product. The firing temperature range of steatite and other types of electrical ceramics is relatively restricted therefore dictating the use of special small kilns and precise control of the firing process. The zircon bodies allow wider firing ranges; consequently they appear to offer an advantage in production costs.

The permittivity of some typical zirconium compounds is 8 to 10 and different variants have power factors ($\times 10^4$) ranging from 2 to 80. The coefficient of linear expansion is in the order of 3·0 to 6·0 and resistance to thermal shock is greater than that of the majority of electrical ceramics. Other mechanical characteristics are comparable with those of steatite.

4. Specifications

(1) "CERAMIC INSULATORS FOR TELECOMMUNICATION PURPOSES"—Prepared by Panel R of the Inter-Service Component Manufacturers' Council,* and issued 1946.

The Specification applies to the following classes of ceramic materials:—

	Approx. Permittivity
General Insulation (usually Porcelain)	5 to 7
H.F. Insulation (usually Steatite) ...	5 to 7
Dielectrics for Capacitors	5 to 300

Dimensional tolerances only are laid down and at first sight this might appear seriously to limit its usefulness to the radio engineer. That this is not a sound conclusion becomes evident when it is appreciated, and it is essential to do so, that ceramic manufacture has distinctive considerations in the purely dimensional aspects. A clear and practical summary of these is contained in the Specification.

Steady progress has been made in the improvement of manufacturing techniques during the time which has elapsed since its preparation but the recommendations contained in Appendix 2 still should receive attention. As the Specification is out of print at present this Appendix is reprinted below. It is entitled "Guidance for Designers":—

"This section has been prepared for the use of engineers and draughtsmen in designing ceramic parts for use in telecommunication equipment. The data included represents that which is considered good design practice, and does not necessarily imply that features contrary to these recommendations cannot be provided by special handling in some form or another. These suggestions will secure not only cheaper articles, but increased production by reducing the possibility of waste, assembly difficulties and

* This body no longer exists as such, its functions now being part of the activities of the Radio and Electronic Component Manufacturers Federation, 22 Surrey Street, Strand, London, W.C.2, to whom enquiries regarding the Specification should be addressed.

TABLE 1—Classes of Materials

PROPERTY	Barium Titanate Low power factor	Magnesium Titanate	Forsterite (2 MgO.SiO$_2$)	Rutile (Titanium Dioxide TiO$_2$)	Steatite (Magnesium Silicate 3MgO.4SiO$_2$)	Alumina Recrystallized or Sintered	Cordierite (Magnesium Aluminium Silicate)	Barium Titanate High Permittivity	Porcelain Low & High Voltage
Power-factor at 1 Mc/s (tan $\delta \times 10^4$) ...	1—5	1—10	1·5—3	2—7	5—35	6—10	50—100	50—300	50—100
Permittivity	20—50	10—20	6·2—6·4	60—100	6—6·9	9—10	4·5—5·5	1500—5000	5—7
Temperature Coefficient of Capacitance at 1 Mc/s (parts in 10^6 per °C)	−100—0	−100—+120	—	−700—−830	100—280	120—140	—	-10^4—$+10^4$ (Non-linear)	400—550
Low Frequency Electric Strength (kV r.m.s. per mm.) *(See Note 1)*	—	5—15	9—10	3·5—8·5	10—25	10—20	3—8	3—8	2—20
Surface Resistivity (MΩ) ...	—	10^8—10^{10}	—	10^8—10^9	10^5—10^7	—	—	—	10^7—10^9
Volume Resistivity (MΩ/cm) **20° C**	10^6—10^7	10^8—10^{12}	10^7—10^9	10^8—10^{12}	10^7—10^{11}	10^7—10^{10}	10^9—10^{11}	10^7—10^9	10^8—10^{10}
300° C	—	10^3—10^4	—	10^2—10^3	30—10^4	10^4—10^8	10—10^3	10^{-1}—1	5—10^2
600° C	—	1—10	—	10^{-2}—2	0·1—10^2	10^4	10^{-1}—1	10^{-5}—10^{-2}	10^{-2}—1
Cross Breaking Strength (10^3 kg/cm^2)	1·0—1·4	1·0—1·6	1·26—1·4	1·3—2·2	0·7—1·75	2·0—3·0	0·12—0·5	0·5—1	0·3—1·5
Compressive Strength (10^3 kg/cm^2)	—	8—9	5·5—6·5	8—9·5	3·5—12·5	16—30	1·5—3	5—9	1·5—9
Tensile Strength (10^3 kg/cm^2)	—	0·4—0·6	0·65—0·75	0·5—0·6	0·21—0·56	1·2—2·6	0·1—0·25	—	0·1—0·5
Impact Strength (Charpy Test) (cm/kg) ...	—	1—2	3·5—4·5	2—3	0·3—5·0	2·5—3·5	0·2—2·5	—	0·5—1·5
Coeff. of Linear Expansion (parts in 10^6 per °C) ...	—	6—10	8·5—12·5	6—9·6	7—9·5	6—9	1—2	9—13	3—6
Safe temperature (°C) ... *(See Note 2)*	—	800—1000	1000	1000—1100	1000—1100	1250—1950	1200—1250	—	900—1000
Porosity (% Increase in weight)	—	0	0—0·1	0	0—0·1	0	0—10	0—1	0—2
Specific gravity	—	3·1—3·7	2·8—3·0	3·9—4·2	2·6—2·9	3·7—3·9	2—2·4	5·3—5·8	2·3—2·5

TABLE 2—Some British Proprietary Materials.

MANUFACTURERS	**Barium Titanate** Low power factor	**Magnesium Titanate**	**Forsterite** ($2\ MgO.SiO_2$)	**Rutile** (Titanium Dioxide TiO_2)	**Steatite** (Magnesium Silicate $3MgO.4SiO_2$)	**Alumina** Recrystd. or Sintered	**Cordierite** (Magnesium Aluminium Silicate)	**Barium Titanate** High Permittivity	**Porcelain** Low & High Voltage
Geo. Bray & Co. Ltd.				'Perilain C'	G, GP, J, JP, 'Ellain'				45
Bullers Ltd.		'Templex'—T1, T5, T50		'Permalex'—P3, P40, P41	'Frequelex'—F2, F4		'Cordalex'	'Ultra-Permalex'	Porcelain
A. G. Hackney & Co. Ltd.			Forsterite No. 352		No. T222 No. 907		HR 129 HR 133		Porcelain
K.L.G. Sparking Plugs Ltd.						'Hylumina'			
Lodge Plugs Ltd.						'Sintox'			
James Macintyre & Co. Ltd.					LL 3				Porcelain
Morgan Crucible Co. Ltd.						'Triangle' Recrystd. Alumina'			
Steatite & Porcelain Products Ltd.		'Tempradex'	'Frequentite S'	'Faradex D'	Steatite 'Frequentite'			'Faradex H'	Porcelain
Taylor Tunnicliff (Refractories) Ltd.		HF 115		HF 102	HF 20		252	HF 1500	Porcelain
The Thermal Syndicate Ltd.						'Thermal Recrystd. Alumina'			
United Insulator Co. Ltd.	'Tempa T'—M98	'Tempa S'—L75		'Conda C'—M241, M243, M303	S2, 'Calit' S 8 C				P 7

General.—The values given in Table 1 are obtained from the published characteristics of commercially available grades of materials, the trade descriptions of some of these being given in Table 2. The values are expressed in ranges which cover the variants of the class; the precise characteristics of a particular material should not be deduced from the figures.

Apart from the exceptions noted in the Table or below, the values quoted are obtained under test conditions which are identical with or equivalent to those specified in British Standard B.S. 1598 : 1949.

Note 1.—The values given are not reliable for precise evaluation of this property because they are obtained under test conditions which vary one from another and from those specified in B.S. 1598 : 1949. For such values to be strictly comparable it is particularly essential that the test conditions are identical.[15]

Note 2.—The Safe Temperatures quoted here are approximations for initial guidance only. The values of other properties are not necessarily maintained at these elevated temperatures. B.S. 1598 : 1949 specifies test conditions for the determination of maximum thermal shock, a property which is not synonymous with safe temperature. The latter is not necessarily determined under abruptly changing temperature conditions.

TABLE 3

Order of Variation of Power Factor with Frequency of Typical Materials compared with Fused Quartz

Unit: tan $\delta \times 10^4$

Frequency	Magnesium Titanate	Forsterite	Rutile	Steatite	Fused Quartz
1 Mc/s	1	2	3	9	2
100 Mc/s	1	2-3	3	9	2
10,000 Mc/s	20	2-3	40	15-20	~ 2

delay. In order to ensure the most desirable design and to facilitate production at minimum cost, it is strongly recommended that designers consult the ceramic manufacturer in the initial stages concerning specific design details applicable to the part under consideration.

Tolerances.—Every effort should be made to adopt the normal tolerances detailed in the specification. Where closer tolerances are needed, these should be specified only for those dimensions where they are essential. The ceramic manufacturer is in a much better position to interpret the purchaser's requirements and to provide him with trouble-free assembly, if he has full information regarding the size and character of the parts to be used in conjunction with the ceramic. In addition to drawings of such associated parts, a sample assembly is a great help, and should be sent to the ceramic manufacturer whenever possible. Frequently, as a result of an examination of the assembly, the ceramic manufacturer is able to suggest detail design alterations of the ceramic parts which will improve production and assembly.

Hole Centres.—The distance between holes may change due to variations in shrinkage. This can generally be accommodated by elongating one or both holes by an amount equal to the total tolerance on the hole centres. If selective assembly is to be avoided, additional elongations may have to be provided to accommodate the variations in the stud or screw spacing of the part to which the ceramic is assembled. If pin gauges are used for checking the hole centres, the design of gauges should be such as to meet the assembly requirements, but such pin gauges should also take into consideration the tolerance on the hole centres as well as the tolerance on the diameter of the holes.

Extruded Shapes.—The section of extruded rods should be as symmetrical as possible.

Tubular shapes which are produced by extrusion should have a wall thickness as uniform as possible. All outside shapes should be made as symmetrical as possible, and the inside preferably cylindrical and concentric with the outside.

It is desirable to maintain a reasonable wall thickness whenever possible, and under no condition should walls be excessively thin. If the outside diameter exceeds ten times the wall thickness wider tolerances will be required.

All holes perpendicular to the axis of extrusion are by the nature of the process somewhat oval. This fact should be taken into consideration by the designer.

Die Pressed Parts.—In this process the powder can be used with different degrees of moisture content. The plasticity of the material increases with the moisture content. In consequence a broad division can be made as follows:—

Wet pressing, in which the powder has a moisture content generally in excess of 10%. The material flows in the dies under relatively low pressure. This enables articles to be pressed to an even density without undue complication of the dies.

(*a*) More complicated articles can be pressed by this method than by dry pressing.

(*b*) Automatic pressing is not generally applied.

(*c*) The die costs are generally lower than with dry press tools.

Dry pressing, in which the powder contains generally less than 10% of moisture. The material does not flow as freely as that used in the wet press method, hence higher pressures and more complicated dies are necessary to give articles of even density which will not warp excessively in the firing process.

(*a*) This method is particularly suitable for articles of simple shape. Articles with many non-planar surfaces with at the same time varying thicknesses cause such complexity of the dies that they become non-economic and wet pressing has to be employed.

(*b*) Automatic pressing is often possible.

(*c*) The die costs are relatively high and therefore the process is only economical where large quantities are involved.

Generalizations other than those herein as to which designs are and are not suitable for dry pressing are not available at the present time, and consultation with individual manufacturers is recommended.

It is recommended that die pressed parts be so designed as to maintain as nearly as possible a uniform thickness over the full area of the piece.

The minimum thickness of simple flat shapes, discs, plates, and the like, should be computed as follows:—

Where the ratio of the maximum superficial dimension to the largest dimension at right angles to it is less than 5,

minimum thickness in inches ... $\frac{1}{10}\sqrt{A}$

Where the same ratio is 5 or greater,

minimum thickness in inches ... $\frac{1}{8}\sqrt{A}$

In both cases A is the outline area in square inches.

Exceedingly small holes and blind holes should be avoided where possible. For economical production holes should not be less than 0·060 in. diameter.

Reasonable tapers and radii (draft and fillets) should be specified for all depressions or bosses.

Thin walls (less than 0·040 in.) should be avoided where possible.

Where parts are to be mounted on some flat surface they should be so designed that they can be ground flat after firing to prevent breakage during the mounting operation. The area to be ground should be reduced as much as possible, for example, by providing small bosses round the fixing holes. The height specified for these bosses should take into consideration the camber tolerance. Their diameter should be about twice that of the hole which they surround with a minimum of 0·080 in., plus the diameter of the hole.

To minimize warping, grooves or channels which run right across a part should be kept as shallow as possible, and should preferably be not deeper than one third the thickness of the piece. Whenever possible, a recess which does not run right across the part should be substituted for a channel.

Coil former threads.—It is most economical for the thread to be continuous for the entire length of the former. Any portion which must be left unthreaded should preferably not be of greater diameter than the diameter at the bottom of the thread unless the wall thereby becomes too thin.

A slight radius must be provided at the bottom of "V" threads.

"V" thread should, when convenient, approximate to Whitworth shapes.

For the purpose of this specification the thickness of a threaded former shall be considered to be that between the root of the thread and the bore.

A pitch finer than 32 t.p.i. introduces manufacturing difficulties.

Fastening of ceramic parts to associated fittings.—Tapped holes in ceramic parts and external screw threads for assembly purposes should be avoided.

In securing ceramic parts to those in other materials, consideration must be given to the great differences in the coefficient of expansion which may exist between the two materials.

Mounting at the minimum number of points is desirable, preferably not more than three.

Radial serrations around holes where eyelets and rivets are to be used, help in eliminating any tendency of the metal parts to turn, reduce breakage during assembly and serve to take up variations in the thickness of the ceramic. Spinning is less likely to damage the ceramic than riveting."

(2) "CERAMIC MATERIALS FOR TELECOMMUNICATION AND ALLIED PURPOSES." B.S. 1598: 1949—A British Standard Specification.*

This Specification covers vitreous ceramic materials, moulded, cast, or extruded, to be used for telecommunication and allied purposes. It provides a classification of these materials based on their electrical characteristics; the classification is subdivided into materials for insulators and materials used as dielectrics for capacitors. The standard specifies limits and methods of test for electrical, mechanical, thermal and other general properties of these materials.

The scope of this Specification is considerably wider than that of (1) above but it makes no

* B.S. 1598: 1949 and B.S. 1540: 1949 are obtainable from British Standards Institution, British Standards House, 2 Park Street, London, W.C.1, price 4s. and 5s. respectively.

attempt to deal with dimensional tolerances which are the almost exclusive concern of the latter. For this reason it is strongly recommended that equipment designers should take full account of both specifications.

(3) "MOULDED ELECTRICAL INSULATING MATERIALS FOR USE AT RADIO FREQUENCIES": B.S. 1540:1949—A British Standard Specification.*

A reference to this Specification is made here since ceramics are included in its scope. However in practice it can be accepted that it is superseded by (2) above so far as ceramics are concerned.

(4) "CHOICE OF MATERIALS FOR RADIO AND OTHER ELECTRONIC EQUIPMENT AND FOR COMPONENTS THEREIN." Specification No. RIC/1000/A, Issue No. 1 dated July 1949, published by the Radio Industry Council, 59, Russell Square, London, W.C.1.

Section 5 of this Specification covers inorganic Insulating Materials and includes Ceramics under this heading. The subject is dealt with in a briefly descriptive manner; no standards or limits are specified. The Specification is undergoing revision at the present time and Issue 2 is expected to be available for distribution during 1956.

5. Acknowledgments

Thanks are due to various manufacturers for assistance given in the compilation of this review.

6. Bibliography.

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3. "Low-loss ceramics," R. Russell and L. J. Berberich, *Electronics*, **17**, p. 136, May 1944.
   Zircon porcelains widely used as insulation where ability to withstand heat-shock is important, such as in spark-plugs, have been developed for high-frequency use. Properties of such porcelains and of steatites, ultra-steatites, high-tension porcelain and transparent fused quartz are given. Test methods are described.
4. "Porcelain and other Ceramic Insulating Materials," E. Rosenthal. (Chapman & Hall Ltd., London, 1944.)
5. "Steatite for high-frequency insulation," J. M. Gleason, *J.Brit.I.R.E.*, **6**, p. 20, January 1946.
   The composition, production and physical and electrical properties of steatite and other ceramic insulators are discussed. The dielectric power factor and its dependence on frequency and temperature, and the variation of dielectric strength with thickness of specimen and temperature are also discussed. Methods of testing and typical results are quoted. Advice is given on the design of die-pressed ceramic parts in general.
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E

City & Guilds of London Institute Annual Report for 1954

In the recently published annual report covering the period 1st October, 1953, to the 30th September, 1954, the Department of Technology of the City and Guilds of London Institute records a year of development in all its activities.* The number of candidates entering for City and Guilds Examinations has continued to show an increase rising from 82,298 in 1953 to 89,211 in 1954. This maintained growth provides evidence of the interest of the individual to secure qualifications as well as the improved training facilities available.

The number of candidates alone does not fully show how the work of the department has developed; a further indication of this development is obtained from the number of question papers which are offered annually. The report includes a diagram illustrating the growth of the number of question papers set annually since 1879; just under 900 papers were offered in 1954, which is an increase of approximately 100 over 1953.

Examination Results.—Examination results in 1954 show that the average pass percentage in all subjects was 59·6 per cent., the number graded as first class being 15·8 per cent. In the Telecommunications Engineering subjects there were 32,481 candidates, which is some five times larger than any other subject for which the Department sets examinations. Here the pass percentage was larger than average, being 62 per cent. of the candidates; the vast majority are home candidates whose pass percentage was 63 per cent. whereas in the case of candidates overseas it was 51 per cent.

As is to be expected the bulk of the entries in the Telecommunications Engineering subjects were for the lower grades of Telecommunications (Principles) Radio and Mathematics, and this is emphasized by the very small number of Full Technological Certificates awarded in this subject—67. The Full Technological Certificate is awarded for successes in 13 individual examinations.

Revision of Syllabuses.—The Advisory Committee on Telecommunications is at present undertaking a revision of the curriculum of syllabuses of Telecommunications Engineering subjects in the light of recent developments. The Committee also has under consideration the possibility of arranging a first year course in Telecommunications Engineering which could also serve as a first year course for National Certificates in Electronic Engineering. Similarly there has been a revision of the syllabuses of Radio and Television Servicing Certificate Examinations to include v.h.f.f.m. and multi-band television transmissions. This revision has been undertaken in conjunction with the Radio Trades Examination Board.

Insignia Awards.—The Report reviews the first nine months of the operation of the administration of the Insignia Award in Technology (C.G.I.A.). The Award was first established in November 1952 (see the *Journal* for that month) but, because it is based on the submission of a thesis which obviously takes some time to prepare, its operation has only been effective since January 1954.

Up to the 30th September, 1954, 18 candidates had been recommended for the Award and it had been conferred upon 10. Since that date the number of Awards made has reached over 30. Applications have been distributed among the five industrial groups, chemical, constructional, electrical, mechanical and textile, with predominance in the constructional and electrical industries. In the Telecommunications section, apart from the foundation awards, three have been granted, of which two were to Associate Members of the Institution, Mr. A. H. Watkins and Mr. W. F. Cotty. Congratulations have been extended to both these members on behalf of the Council.

Examination Prizes.—The Department of Technology has also published a prize list for 1954 and the following members are to be congratulated on their recent awards:—

Telecommunications (Principles)—3
2nd Prize: B. W. Sheffield (Student)

Telecommunications (Principles)—4
1st Prize: J. T. Floyd (Graduate)

Radio—2
2nd Prize: Rex Rivers-Young (Student)

Radio—3
Joint 1st Prize: D. L. Dix (Graduate)
J. E. H. Thompson (Graduate)

* Report 1953-4, Department of Technology of the City and Guilds London Institute, 31 Brechin Place, London, S.W.7, price 2s. each.

THE USE OF RADIO-TELEPHONY FOR THE CONTROL OF WORKS TRANSPORT *

by

E. N. Farrar † and M. T. O'Dwyer ‡

SUMMARY

The reasons for the economic attractiveness of radio control over very short distances are discussed. The paper then describes a number of different types of industrial vehicles which have been fitted with radio and gives details of their functions. The reactions of drivers to the installation of radio are discussed and a typical control system is described with reference also to its application to private cars in works service, and to the savings that can be effected. Typical installations are dealt with and details given of the construction, special installation problems and performance of the transmitters and receivers used in the main station and in the mobiles.

1. Introduction

The use of radio for the control of works transport is comparatively new, the first scheme having been installed in this country as recently as September 1951. As people are apt to think that, because America is ahead of England in the industrial use of radio, this scheme must have been copied from a similar installation in the States, we would like to make it clear that this is not the case. The organisation who installed it did so because they considered that radio was the only means whereby they could control their transport economically. In fact, the idea seemed so natural to them that they were surprised to find that nobody else had done it before.

2. Reasons for the Use of Radio in Factories

Whilst radio is now accepted as the normal means for controlling fire engines, police cars, ambulances, and taxis—vehicles which range over fairly large areas—many find difficulty in appreciating its value for the control of vehicles which never travel more than 250 yards from their control point. The authors have therefore devoted some time to analysing the success of radio in this field and they have come to the conclusion that it is due to the following facts :

(1) Works vehicles are comparatively slow and it would be uneconomic for them to return to their control point for fresh orders on the completion of each job.

(2) Time is vital in industry, and radio increases appreciably the speed with which jobs can be placed, and completed.

(3) The average factory is an extreme example of a " built-up area " and this, combined with the fact that works vehicles can go inside the buildings, makes it much more easy for them to be " lost " than vehicles travelling along roads.

These points are developed in the following section which gives particulars of a number of vehicles which have actually been fitted with radio and describes their functions.

3. Typical Radio-equipped Vehicles and their Functions

Electrically-driven Platform Trucks (Fig. 1) are used for general transport within a factory and by reducing empty-running to a minimum, radio ensures that the maximum value is derived from each nightly battery-charge. It might even, in the case of battery-electric vehicles operated in an extensive works, eliminate the need for a second battery, costing a matter of some £120.

In addition, as is the case with all the vehicles to be described, radio enables orders to be passed to the truck drivers as soon as they are received by the Controller, avoiding the necessity for protracted searches, or for passing messages by telephone. Incidentally, before they installed radio, the firm in question employed a chargehand, full time, to pass messages to truck drivers. The chargehand is now more profitably employed.

In use in the same works as the electric trucks just described, and, for that matter, in several other works, are a number of Fork Lift

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† Davey, Paxman and Co. Ltd., Colchester, Essex.

‡ Pye Telecommunications Ltd., Newmarket Road, Cambridge.

U.D.C., No. 621.396.931 : 656

Trucks, equipped with radio. These serve to call attention to the fact that when two or more similar vehicles are equipped with radio, the Transport Controller can find out, before placing each job, which of his drivers is in the best position to deal with it. For instance, the Controller receives a message to the effect that a Fork Lift Truck is required urgently to unload a lorry. He calls up each of the drivers in turn and, quite apart from finding out which truck is nearest to the lorry, he learns which has the longest job in hand. He is then in a position to decide whether to break off the driver with the longest job, or to wait whilst the one with the shorter job completes what he is doing.

Fig. 1.—Transmitter-receiver installed on an electric truck.

Whilst the same remarks apply to a pair of mobile cranes, used in a works manufacturing diesel engines, here the value lies more in the fact that, as the cranes have a maximum road speed of something like 3 miles per hour, it is uneconomical for the drivers to travel in them, even to the nearest telephone, for further orders on the completion of each task. (Fig. 2.)

Radio has been found particularly valuable on Mechanical Horses and other types of Tractor, which handle similar trailers. On learning that a load has to be transferred from one shop to another by one of these vehicles, the Controller instructs the driver to find an empty trailer and place it in the shop where the load is. This done, the tractor driver can go and do something else, secure in the knowledge that, when the trailer has been loaded, he will be called back to take it out of the shop. Without radio he would have had to stand by whilst the loading was proceeding.

Further advantages are exemplified by a 5-ton lorry which operates a sort of carrier service between two works belonging to the same company in one town. At first, it was thought that radio would not be justified on this vehicle, but the driver was so persistent in his requests for a set that one was subsequently purchased and it soon proved its value. Instead of reporting to the Transport Office after he has disposed of the load which he has brought from the other works, the driver now establishes contact by radio as soon as he arrives on the premises and, with the aid of the Controller, maps out a route which will enable him to load and unload at the same time. Other advantages are that the Controller is able to find out at any time how much space is left on the lorry, and therefore decide whether a certain item can be included in the load then being made up. Also, the driver can arrange for fork lift trucks—similarly radio equipped—to meet him at appropriate points on his journey to assist him to load or unload—the majority of the parts to be transported being loaded in advance on pallets, so that, with the aid of the fork lift, loading and unloading become very quick jobs.

Other firms have fitted radio to 10-cwt. vans which collect supplies and deliver spare parts in the vicinity of their works. The radio equipment enables the drivers to be directed from one supplier to another, reducing mileage and saving time.

Radio has not only proved useful on road vehicles. A large chemical factory in the north of England has equipped some 20 locomotives with sets, and has simplified control and speeded up the operation of the works to a remarkable degree as a result. Radio-equipped locomotives (Fig. 3) are also in use in a soap factory and in a heavy engineering works. This latter concern has also fitted a rail-mounted mobile crane with radio.

4. The Control of Radio-equipped Vehicles

It should be borne in mind that it is desirable to reduce the number of points from which vehicles can be controlled to a minimum—the ideal arrangement being that vehicles are controlled from one point only, or at any rate, that vehicles of one type are controlled from one point only. This suggests that in works where vehicles are allotted to departments to do with as they please, radio offers no advantage. Such however, is not necessarily the case, for the authors hold the view that in many works where this practice exists, better service could be obtained with fewer vehicles if all the transport services were pooled, and control rested in one person with a radio set. However, it is impossible to be dogmatic on this point; it depends on so many factors, such as the extent to which the vehicles are used, the area over which they operate, and the degree to which they are specially adapted to a certain department's needs

Fig. 2.—Transmitter-receiver installed in roof of cab of a 6-ton mobile crane.

Therefore for the purposes of this paper, the authors propose to take the case of a works in which the majority of the vehicles are pooled and are radio-equipped, whilst those vehicles which are not radio-equipped are allotted to departments and placed under the exclusive control of the departmental heads. In this works there is an extensive system of internal telephones and most of the requests for transport reach the Controller by this means. However, some come in the form of verbal messages. On the receipt of a request for transport, the Controller enters particulars of it on a printed form bearing the number of the vehicle best suited for carrying the load in question and, if that vehicle is free at the moment, passes the message to the driver immediately. If it is not free he passes the message as soon as the driver reports that he has completed the job on which he was engaged at the time. As has already been indicated, the Controller can also use his radio to find out how jobs are proceeding, and its use is by no means unknown as a means of finding vehicles or people which are not radio-equipped. Should a request for transport be made direct to a driver, he consults the Controller on the subject before complying. This prevents "queue jumping" and ensures that jobs are carried out in order of priority.

5. Driver Reactions

The reactions of drivers to the installation of radio in their vehicles depend to a considerable extent on the district in which the equipment is being installed. In the Eastern Counties, from which the authors hail, there has never been any difficulty whatever in persuading drivers to use radio. In fact, as already indicated, they themselves ask for it in some cases. However, perhaps the most significant indication of the drivers' attitude to radio is provided by the fuss which they make if their sets go off the air: they complain that they have lost touch with the Controller and that they are exhausting themselves running to and from telephones to obtain orders !

The main reason that the drivers like radio is undoubtedly that it enables them to refer their troubles to the Controller for solution. For instance, before the days of radio, if a driver required the assistance of the overhead travelling crane installed in the shop to which he was delivering, for unloading, he had to await the convenience of the shop foreman before he could obtain its use. An example is on record of a driver who waited four and a half hours to be unloaded and then, when dinner time came, walked back to the Canteen and to report to the Transport Controller. When radio is installed, the drivers soon find that, by advising the Transport Controller that they are held up, they can be sure that within a short time the Transport Supervisor will be on the telephone to the head of the department concerned, and that the crane will be made available to them. In one works, even this is now unnecessary, the foremen having become so concerned at the prospect of their lack of co-operation being broadcast, as the drivers allow them to think, that they send a crane immediately a driver of a radio-controlled vehicle asks for it. Again, a vehicle may be unable to reach the shop to which it has to deliver a load because of an obstruction in another part of the works. The driver advises the Controller who, apart from doing what he can to ensure the removal of the obstruction, informs the Superintendent or Foreman who is waiting for the load, so that he does not castigate the driver when he eventually arrives.

The drivers of mobile cranes appreciate their radio sets for another reason. They are often called upon to load goods for despatch just prior to finishing work and, before they had radio, it not infrequently occurred that, before the message had reached them, they had tucked their cumbersome vehicles into the garage for the night. Nowadays, they know, as soon as their chief does, if they are likely to be required for a last minute " lift " and there is much less risk that they will be called out once they have garaged their cranes.

Drivers also appreciate their radio sets as a means of obtaining assistance in the case of a breakdown on the road. Radio is particularly valuable in the case of a vehicle carrying a load which might attract the attention of pilferers if left alone whilst the driver went in search of a telephone to report that he was in trouble.

6. Radio on Private Cars

Most firms who use radio on their transport vehicles also have one or two private cars equipped for the transport of visitors, and it is usual for one of these cars to be included in the convoy which is now necessary for the collection of the weekly wages from the Bank. The value of radio in reducing mileage by enabling cars to be diverted from one job to another when they are already on the road can be assumed from what has previously been said about vans and lorries. However, less obvious, is the value of radio as a means of saving the time of senior executives. One company with which the authors are acquainted, and which welcomes a large number of visitors to its works in its search for markets, has gained many advantages by using radio-equipped cars to convey visitors between the railway station and the works. On leaving the station, which is some three miles from the works, the driver calls the Gatekeeper and gives the names of his visitors and the people they have come to see. The Gatekeeper then telephones each host in turn to give him the opportunity to make himself ready to receive his visitors, and to find out if it is his wish that the visitors should be brought straight to his office by the car driver, or whether they should be requested to spend a short while in the waiting room while, for instance, he is completing his business with somebody else. By the time the car reaches the Gate, all is prepared ; the Gatekeeper knows who should remain in the car, and who be asked to alight till the hosts are ready to give their guests a proper welcome. In pre-radio days, every visitor had to spend some time in the waiting room whilst the Gatekeeper telephoned to the various hosts to find out whether they were ready, and he then conducted them into the offices on foot.

A driver waiting at the station for visitors can also use his radio to advise the host that the train is late, and that he has time say, to dictate another letter or two before the guest arrives. In the case of a senior executive who is going to devote the rest of his day to looking after his visitor, the time thus saved may be almost priceless.

Radio can also prove useful for passing messages to and from passengers in the cars. For instance, a member of the staff who is held up on his way to keep an appointment can use the radio to ask his office to notify the people who are expecting him that he will be late.

Again, the Managing Director of a company owning radio-equipped cars has been known to dictate his letters to his secretary by radio whilst being driven direct from his house to a meeting in a neighbouring town. Provision can, of course, be made for feeding such dictation straight into a magnetic recording machine.

7. " Walkie-Talkie " Sets

What have come to be known as " walkie-talkie " radio sets are also beginning to be used in industry. In the transport field they can prove useful as a means of maintaining contact with gangers in charge of loading or unloading vehicles and with foremen charged with the responsibility of controlling the movement to and from the loading and unloading bays of visiting vehicles which cannot, in the nature of things, be fitted with radio themselves.

Maintenance foremen have also been equipped with sets so that they can be directed from one job to another more quickly, and the authors know of two large concerns—one a brewery, and one an engineering works, in which walkie-talkie sets are provided for the works police to permit them to be contacted immediately when they are on patrol if their help is required in another part of the works, and to enable them to call for assistance should they meet with an accident or encounter an intruder.

Another use for such sets is found in directing the drivers of cranes and excavators working in the holds of ships or in deep holes in the ground. In these circumstances, a man equipped with a portable radio telephone is much more efficient, and economical, than a pair of men passing hand signals from the bottom of the hole to the surface, and thence to the driver.

8. Savings

Whilst the authors have been unable to find any user prepared to provide figures for publication which show the savings which have been effected by the use of works radio, all agree that substantial savings have been achieved, both directly or indirectly.

The direct savings come under the following headings:

(1) *Savings in capital invested in vehicles.*—Whilst under almost any conditions, if ten similar vehicles were in use in a works before radio was installed, one can be eliminated by the introduction of radio, a much lower figure applies in some works. In others, the purchase of an additional vehicle to be used for only part of the time has been made unnecessary because the fitting of radio has resulted in the more efficient use of existing vehicles.

(2) *Reduction in fuel costs.*—Fuel is saved every time that radio eliminates an unnecessary journey and, in the control of works transport, it does this continuously, as it disposes of the need for vehicles to return to base for fresh orders.

(3) *Savings in upkeep costs.*—The cost of maintaining vehicles is reduced in very much the same proportion that the cost of providing them with fuel is reduced.

(4) *Savings in labour costs.*—For every vehicle which radio makes unnecessary, the wages of the driver, amounting to some £400 per annum, are saved.

(5) *Savings in supervisory costs.*—An example has already been given of a chargehand being transferred to other work when radio was introduced. Such an event may be a rarity but it is by no means unique. In most works radio has reduced the work of those responsible for transport control.

The indirect savings are less easy to assess, being generally related to the increased speed with which movements can be completed when the necessary instructions are issued to vehicle and crane drivers by radio. Since all time spent in transit is, in effect, wasted time, the more it can be reduced, the cheaper becomes production.

9. Radio Equipment

The equipment used in a number of the installations discussed consists of a main station with a transmitter power of about 10 watts, and mobile transceivers having transmitter powers of about 2 watts. The frequencies used are usually in the 156—184 Mc/s band. Vertical half-wave dipole aerials are employed with the main station equipment, and quarter-wave whips with the mobiles.

9.1. *Main Station*

The principal operational features of the main station equipment are as follows.

The receiver is a double-conversion crystal controlled superheterodyne having a sensitivity of 50 mW output for 1 μV r.f. input modulated 30 per cent. The a.g.c. characteristic is such that the output variation does not exceed $\pm$ 2 db for a change of input of from 5 μV to 10 mV. The a.f. response is substantially flat from 250 c/s to 3000 c/s, and an output of 2 watts is available to the built-in loudspeaker. An output of up to 45 mW is also available at the 600-ohms line terminals. An effective noise-limiter is incorporated which suppresses impulsive interference of the type caused by vehicle ignition systems and a noise-compensated muting circuit disconnects the speaker in the absence of a signal.

The transmitter is crystal controlled and gives an unmodulated r.f. output of 10-12 watts. A double-tetrode push-pull r.f. amplifier in the output stage is anode and screen modulated by two a.f. tetrodes in push-pull. The voltage amplification of the modulator is sufficient to provide 100 per cent modulation when a pedestal-mounted moving-coil microphone is used. A panel mounted meter can be switched to monitor the various transmitter circuits for tuning and also indicates modulation depth. A simple key switch is used for transmit/receive in the usual simplex schemes.

Both transmitter and receiver are assembled in a metal cabinet and the weight of the complete station is 90 lb. Mains consumption is about 80 watts in the "Stand-by" condition and 180 watts on "Transmit". Materials are chosen and components rated to ensure that the equipment is suitable for use in any part of the world.

Remote control facilities are provided so that the station can be fully controlled over a single pair of lines at distances up to about 20 miles. Extension control is more usually employed in factories, and the operator may be up to 200 ft. from the equipment.

9.2. *Mobile Equipments*

A self-contained transceiver is fitted to the vehicles; the overall size is 9 in. wide × 14 in. deep × 5½ in. high, and the total weight is only 17 lb. An r.f. output of 1-2½ watts is obtained whilst retaining a very low power consumption from the vehicle battery. A "press-to-talk" switch on the telephone-type handset operates the transmit/receive relay in the transceiver.

The performance of the mobile receiver is similar to that of the fixed station receiver; however, a mute circuit is not normally provided, and the a.f. output is reduced to 1 watt.

In the transmitter a double-triode r.f. amplifier in the output stage is anode modulated by an a.f. tetrode which also serves as the receiver output valve. No voltage amplification is required in the modulator, as a double-button carbon microphone is used in the handset to drive the modulator valve directly. The only controls are an ON/OFF switch and volume control on the front panel, and the transmit/receive switch on the handset.

The transceiver can be supplied to operate from 6 or 12V vehicle batteries, with either positive or negative pole earthed. On a 12-V supply the current consumption is 3½ A on "standby" and 4 A on "Transmit".

A separate test meter can be plugged into the set for circuit alignment. This meter is mounted in a metal box with a selector switch and an 8-way cable terminated in a plug.

Because the required ranges are restricted in the present application, the aerials used with the mobile sets are mounted wherever convenient, frequently on the roof of the driver's cab, or in the case of the smaller vehicles, directly above the set. They are invariably ground-plane quarter-wave whips, and a length of 39-ohms coaxial cable connects them to the set.

10. Signal Strength and Coverage

With the equipment described, in no case has the coverage been inadequate, even when the mobile transceivers have been located inside steel buildings. Indeed, the absence of "blind-spots" has been notable.

The ranges at which communication is required in the present application of mobile v.h.f. radio are, of course, short when compared with the average in other more conventional schemes such as police, ambulance and fire brigades. Nevertheless, screening is frequently severe, and the "solid" coverage obtained is no doubt contributed to by multiple reflections in an area of generally high field-strength.

The signal-strength from a 10-watt transmitter to a mobile receiver at 3 miles, for example, is of the order of 50 μV and the receivers used in the equipment described can give a signal-to-noise ratio of about 10 db for 1 μV input.

11. Electrical Interference

No additional precautions are taken to avoid the effects of electrical interference in factory areas; the noise-limiter normally fitted to the receivers appears adequate under all conditions of operation.

12. Installation

As will be seen in the illustrations the mobile equipments are not usually given additional mechanical protection; the mounting position is chosen, as far as possible, to give accesss for servicing, and at the same time to be out of the way of the driver of the vehicle.

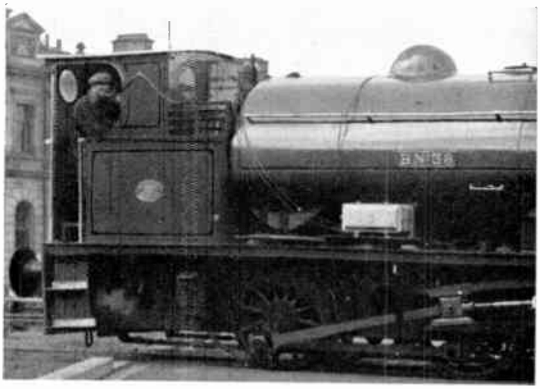
Despite the fact that many vehicles fitted with radio-telephones are equipped with solid tyres and have virtually no springing (for example mobile cranes), the fault incidence shows no increase above average. The same has proved true in the case of fork-lift and platform trucks, frequently used to tow loose-coupled bogies.

Only in the case of radio-telephones fitted to steam or diesel locomotives has it been necessary to provide special protection and mountings. This has taken the form of a water-tight cast-alloy container, which is fitted externally on the locomotive. (Fig. 3.) Protection from dust, water and even heat has been obtained in this manner; it is not unusual for some of these locomotives to remain for several minutes immediately opposite the out-flow from a blast furnace. No ventilation whatever is provided ; the surface area of the case is sufficient to dissipate the heat by radiation alone. To overcome the stresses imposed by shunting, special shock-absorbing suspension units were devised.

13. Maintenance

Experience has shown that the reliability of the radio equipment is not impaired when fitted to vehicles of the types discussed, despite the frequently arduous conditions of use and unfavourable atmospheres. No significant increase in the fault-rate or fault-nature can be detected when records are compared with those applying to radio-telephones in more favourable environments.

In earlier installations it had been found that, in common with other radio telephones operating in a high ambient noise level, loudspeaker failures were higher than normal. This was due to the fact that they were always operated at or near the maximum a.f. output of the set ; a modification to the voice-coil connectors eliminated the trouble.



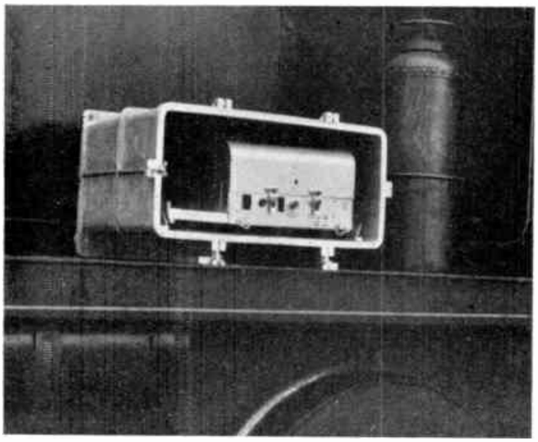


Fig. 3.—(top) Radio telephone installation on a steam locomotive for coverage trials at an Iron Works. In later permanent installations all control leads to the equipment were routed through conduit. In some cases Pyrotenax cable was used for the aerial feeder, as for example, when the installation was made on a steam locomotive, and damage to polythene-insulated cable by heat could be anticipated. The lower photograph shows a light alloy protective casing for transmitter-receiver on diesel locomotive.

14. Conclusions

The authors are convinced that there is scope for enormous expansion in the use of radio for the control of industrial transport. So far, it has made comparatively slow progress, many firms wishing to observe the results achieved by others before embarking on the comparatively modest expense of an installation themselves. However, the authors have no doubt that radio can be used with advantage by a very large number of industrial concerns in this country and that, provided sufficient frequencies are made available for development, it will soon be regarded as the natural way of controlling works vehicles—just as it is now regarded as essential for ambulances, fire-fighting vehicles, and police cars. Certainly, those firms who are already using it would find it extremely difficult, now, to do without it.

15. Acknowledgments

The authors wish to thank the Directors of their respective companies for permission to publish this paper and also to thank the many transport managers who provided information about their operations.

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DISCUSSION ON

"The Use of Correlation Techniques in the Study of Servomechanisms"

Professor D. G. Tucker (*Member*)†: The authors have adopted a usage which I have encountered before but have always viewed with dismay—namely, the incorrect use of the word "coherence". The authors say (in Section 2): "Cross-correlation is a measure of the coherence between two random functions", and for the case where the two functions are independently generated, they say: "the functions are said to be incoherent". This usage is quite inconsistent with the ordinary dictionary definition of the words; the Concise Oxford Dictionary‡ defines "coherent" as "not rambling or inconsequent", which seems to rule out immediately any application to random functions. Moreover, no comparison of two functions is inferred in the dictionary definitions.

I feel strongly that there is no justification at all for the use of ordinary words, even in a technical context, with connotations right outside the ordinary ones given in good dictionaries. The opposite process, that of narrowing their meaning for technical and scientific purposes, is far more justifiable. In technical contexts I prefer to use "coherent" to mean "of constant and specified form", so that a sine-wave, or pulses of continuous periodic carrier (not necessarily sinusoidal), are coherent signals; noise is always incoherent. I accept, however, that a good case can be made out for calling any signal "coherent" if it conveys wholly relevant information.

The literature includes many references to the terms "coherent detection" and "incoherent detection". This rather extended usage of the idea of coherence can possibly be justified on the lines that (*a*) "coherent detection" uses a coherent tone to control the rectifier; (*b*) the ordinary detector allows the received signal itself to control the rectifier, so that if this signal has noise or interference mixed with it, and is in consequence a partially incoherent signal, then the detection process is incoherent. But I do not like this argument.

This matter is not in general a trivial one, as unintelligibility of papers and reports can easily arise from it. But as far as the present paper is concerned, it fortunately in no way diminishes the great interest and usefulness of a very lucid contribution, since the authors do not actually repeat the use of the words "coherence" and "incoherent" after they have been first introduced.

J. W. R. Griffiths†: The authors appear to have made a careless slip in Section 2, in the paragraph following eqn. (3). The autocorrelation function is surely asymptotic to the *square of the mean* of the time function, not to the *mean square*.

Professor V. C. Rideout (*in reply*): As pointed out by Dr. Tucker, it appears that the use of the words "coherence" and "incoherence" will lead to the need for new definitions, and to a certain amount of confusion. In our paper we used the word "coherence" in Sect. 2 only to help explain the nature of cross-correlation. Perhaps the choice of the word "similarity" would be preferred.

In reply to Mr. J. W. R. Griffiths and to a private letter from Dr. D. A. Bell, the words "mean square" in Sect. 2 should be changed to read "square of the mean".

* T. M. Burford, V. C. Rideout and D. S. Sather, *J.Brit.I.R.E.*, 15, p. 249, May 1955.

† Received by the Institution 6th June, 1955.

‡ Full definitions in "The Concise Oxford Dictionary": "*Cohere*, Stick together, remain united (of parts or whole); be consistent, well knit (of arguments, style, etc.). *Coherent*, Cohering; consistent, easily followed, not rambling or inconsequent (of argument, narration, etc.)."

# of current interest . . . .

Long Distance Television Reception

Reports have recently been given of the successful reception of French Television programmes at Southend-on-Sea, Essex. This is a distance of about 120 miles from the transmitter at Lille and reception was of the 819 lines high-definition programme on 185·25 Mc/s vision and 174·10 Mc/s sound. (Channels 7 and 6 respectively).

It has apparently been found that certain receivers designed for the British standard of 405 lines will synchronize successfully at 819 lines but that others synchronize at half speed and therefore produce two pictures.

Since transmissions are horizontally polarized it seems probable that there should not be excessive interference with British Band III transmissions. These are vertically polarized and, in the case of the London transmitter, the allocated frequencies are in Channel 9.

Conference on Human Problems in Industry

As a result of the recommendations of industrialists and trade unionists to His Royal Highness the Duke of Edinburgh, a Study Conference is to be held at Oxford in July 1956 under the title of "His Royal Highness the Duke of Edinburgh's Study Conference on the Human Problems of Industrial Communities within the Commonwealth and Empire."

This will be attended by 280 delegates of which 90 will be from the United Kingdom, approximately 135 from other countries of the Commonwealth and 55 from the Colonial territories. The membership will be composed of men and women, broadly between the ages of 25 to 45, engaged in the managerial, technical and operative roles of industry. They should hold, or in the foreseeable future will hold, positions of responsibility, and have a proven interest in the life of their community.

The Conference is to conduct a practical study of the human aspects of industrialization and, in particular, those factors which make for satisfaction, efficiency and understanding, both inside industrial organizations and in the relations between industry and the community. It is a big advantage of the Conference that it gives a unique opportunity to explore a common problem against the background of widely differing experience.

His Royal Highness the Duke of Edinburgh will open the Conference in the Sheldonian Theatre on Monday, 9th July, 1956, and it will close on Friday, 27th July. Apart from lectures by eminent Commonwealth administrators there will be study groups and study tours of nine days' duration during the 19 days of the Conference.

All proposals for membership of the Conference will be made through an industrial undertaking, trade union, nationalized enterprise, or other appropriate body. The Conference Council will be responsible for the final selection of members and the issue of invitations.

All enquiries concerning the method of selection for invitation should be addressed to the Administrative Headquarters of the Conference, 48, Bryanston Square, London, W.1.

Mobile Radio Development

Among recommendations of the Mobile Radio Committee (a report was given on page 328 of the June issue of the *Journal*), was the proposal that the width of frequency channels allocated to users of v.h.f. mobile radio services should be reduced from the present figure of 100 kc/s to 50 kc/s as soon as practicable.

Considerable interest therefore has been aroused by the demonstration in London recently of equipment developed by Pye Telecommunications Ltd., suitable for these wave lengths, in which channel spacings of 25 kc/s are possible. This has been achieved by the use of oven-controlled crystal oscillators in the fixed transmitter, and a double superheterodyne circuit with both local oscillators crystal controlled for the receiver. The mobile equipment is virtually the same size as the comparable equipment designed for the existing frequency requirements.

New President for the A.I.R.M.A.

Mr. R. K. Phatak (Associate Member) has recently been elected President of the All India Radio Manufacturers' Association for the current year. He has also been nominated by the Government of India to the Development Council dealing with the manufacture of storage batteries, dry batteries, radio receivers and parts. This Council recommends targets for production and coordinates production progress and revises the progress of the industry.

THE RADIO TRADES EXAMINATION BOARD

FOUNDED 1942

The Board comprises representatives from:—

THE RADIO INDUSTRY COUNCIL
THE RADIO AND TELEVISION RETAILERS' ASSOCIATION
THE BRITISH INSTITUTION OF RADIO ENGINEERS
THE SCOTTISH RADIO RETAILERS' ASSOCIATION

RADIO SERVICING CERTIFICATE EXAMINATION—1955

Of the 527 candidates who sat the examination which took place in May of this year, 213 candidates satisfied the examiners in both the written and practical parts; 167 candidates passed the written examination but were referred in the Practical Test, and 50 candidates completed the examination, having previously been referred in the Practical Test in the 1954 examination.

The following candidates satisfied the examiners in the entire examination :

ADAM, Brian Fergus. *Dundee.*
AITKEN, Thomas. *Barrhead.*
ALLEN, Arthur. *Leeds.*
ANDERSON, Bertram. *Glasgow.*
ANDERSON, Sydney Robert. *Bath.*
ANDREW, Robin. *Grimsby.*
APPLEBY, Brian Lawrence. *Wolverhampton.*
ARMES, Cyril Francis. *Westcliff-on-Sea.*
ARMSTRONG, William. *Ayr.*
ARROWSMITH, John James. *Preston.*
AUDUS, Brian Arthur James. *Blackpool.*

BAILEY, Lawrence. *Doncaster.*
BALLEY, Edgar Arthur. *Stanmore.*
BANCKS, William George. *Altrincham.*
BARKER, John. *St. Helens.*
BARR, George Salmond. *Stirling.*
BEADLE, John Henry. *Welling.*
BENNETT, Albert. *Stoke-on-Trent.*
BLACKLER, Philip Charles. *Cornwood.*
BOARDMAN, Richard. *Preston.*
BRAITHWAITE, Clive. *Hull.*
BRITTON, John David. *Derby.*
BROOKER, David Allen. *London, N.10.*
BROOKER, Fredric David. *Liverpool.*
BROOKES, Albert E. *Walkden.*
BROUGHTON, Neville Alan. *Leicester.*
BRUCE, Ronald McLellan. *Newark.*
BUCHAN, Peter Bernard. *Hereford.*
BUCKMAN, Douglas George. *Chatham.*
BULL, Cyril Edward. *Ruislip.*
BURNSIDE, John Norman. *Paisley.*

CAMPBELL, Glenroy. *Paisley.*
CANTRELL, John Raymond. *Birmingham.*
CARRUTHERS, Rutherford. *Pitlochry.*
CHALK, Edward Cyril. *Driffield.*
CHAMBERS, Albert. *Blackpool.*
CLARK, Archibald. *Glasgow.*
CLIFFORD, Bernard. *Timperley.*
COLLINS, Richard William. *Truro.*
COLTMAN, Reginald Lawrence. *Leicester.*
CONNOR, John. *Motherwell.*
COOK, Peter Robert. *Dartford.*
COOKE, Samuel John. *Durham.*
COUPAR, William Moir. *Blairgowrie.*
COX, Ronald. *Sheffield.*
CRAIG, Stuart. *Coatbridge.*
CRANE, Peter. *Leicester.*
CUMMINGS, Michael. *Bradford.*

DALE, Joshua Peter. *Stoke-on-Trent.*
DARLEY, Cyril. *Lea, Lincs.*
DAVENPORT, Bernard. *Stockport.*
DAVIES, Brian John. *Bristol.*
DAVIES, David Harris. *Colwyn Bay.*
DAVIS, Alan. *Nottingham.*
DENNIS, Peter Edward. *London, N.W.9.*
DERBYSHIRE, Ronald. *Bolton.*
DIONYSIOU, Angelos. *London, N.7.*
DIX, Grahame Henry. *Bristol.*
DONALDSON, John. *Beckenham.*
DRAY, Derek Malcolm. *Pevensey Bay.*
DUTTON, John Barry. *Loughborough.*

EDWARDS, Roy. *Wolverhampton.*
ELLIS, Charles Frederick. *Ruislip.*
ELLIS, John Hilton. *Newcastle-upon-Tyne.*
ELLIS, Richard John. *Edgware.*
EVANS, Ian Stewart. *Heswall.*

FEWTRELL, Brian John. *Sutton Coldfield.*
FIDDIAN, David Garth. *St. Budeaux.*
FIELD, Ronald. *Dewsbury.*
FINLEY, Eric Campbell. *Scarborough.*
FLETCHER, Raymond. *Burnley.*
FOSBERRY, Robert. *Chichester.*
FRANCE, Henry Thomas. *Liverpool.*
FROST, Alfred. *Newport, Mon.*

GARDINER, Harry. *Cupar.*
GARDNER, Alexander. *Clarkston.*
GAYNOR, Alan Roger. *Liverpool.*
GEMMELL, William. *Alva.*
GIBBONS, Donald Elvin. *Thornton Heath.*
GIBBONS, Thomas. *Sunderland.*
GOODSON, Brian. *Doncaster.*
GRAHAM, Hugh. *Glasgow.*
GREEN, Brian Edward. *Oldbury.*
GRYNBLATT, Siegmund. *London, E.5.*
GUNN, John Ronald. *Wallsend.*

HACKNEY, Terence John. *Irchester.*
HALL, Arthur. *Long Eaton.*
HALL, Gordon Cameron. *Grimsby.*
HARRIS, Kenneth Richmond. *Bolton.*
HARRISON, David. *Blaby.*
HARRISON, Peter Gerard. *Wallasey.*
HAWS, David Charles. *London, N.19.*
HENDERSON, William Johnson. *Wallsend.*
HEVICON, Douglas. *Manchester.*
HEWETT, Angus John William. *London, W.5.*
HEYWOOD, Alan William. *Bolton.*
HILL, Brian. *Sheffield.*
HODGKINSON, Alec John. *Congleton.*
HOLDEN, Christopher James. *Swinton.*
HOOD, Joseph Acland. *Bedford.*
HOPKINS, Frederick Stephan. *Portsmouth.*
HOPKINSON, Frank Keith. *Birkenhead.*
HORTON, David Lawrance. *Croydon.*
HORTON, Dennis Victor. *Birmingham.*
HOWE, Michael. *Bristol.*
HUDSON, Robert. *Egham.*
HUGHES, Gordon. *Torquay.*
HUGHES-KEAST, Alan George. *Torquay.*
HUXFORD, Richard William. *Grimsby.*

IRWIN, Michael Jerome. *Nottingham.*

JOHNSON, George Herbert. *Hull.*
JOHNSON, Gordon. *Stockport.*

KANWAR, Gian Singh. *London, N.8.*
KEATINGS, George. *Glasgow.*
KELLY, Donald. *Bury, Lancs.*

LAYZELL, Peter Robin. *Southend.*
LINSEY, David John. *London, N.20.*
LISTER, Arthur George. *Grimsby.*
LYNCH, John Rees. *Stoke, Plymouth.*

McCARTNEY, William. *Paisley.*
McDONALD, Robert. *Paisley.*
McELVENNEY, Joseph Anthony. *Sheffield.*
McEVOY, Norman R. *Stoke-on-Trent.*
McKENZIE, James Angus. *Dundee.*
McLAUGHLIN, Alexander Wallace. *Hamilton.*
MARS, Roy Ernest. *Torquay.*
MASON, Francis Noel. *Huyton.*
MELLOR, William Kenneth. *Oldham.*
MILLER, Alfred Henry. *Stafford.*
MILLER, Leslie David. *Dover.*
MITCHELL, Charles Ronald. *Gillingham.*

MOORE, Kenneth Langstaff. *Timperley.*
MOUNTAIN, Bernard Charles. *Hull.*
MUNRO, Joseph Ian Stuart. *South Shields.*
MYERS, Jack. *Leeds.*

NELSON, John Campbell. *Belfast.*
NESBITT, Michael. *Bradford.*
NEVITT, John. *West Kirby.*
NEWELL, Derek William. *Doncaster.*
NEWEY, Denis George. *Stourbridge.*

O'CALLAGHAN, Thomas Neil. *Dublin.*
OGLE, David Geoffrey. *Leeds.*
OGSTON, Ian Murray. *Dundee.*
OWEN, Hugh. *Birkenhead.*
OWINGS, Albert. *Liverpool.*

PARTRIDGE, John Richard. *Northampton.*
PENROSE, Grahame. *Leicester.*
PHILLIPS, Ernest M. *Shiremoor.*
PITCHER, Richard Dennis. *Leicester.*
PLUCKROSE, David. *Dorking.*
PORTEOUS, Kenneth Gordon. *Manchester.*
PRATT, Reginald James. *Bexhill-on-Sea.*
PULVER, Maurice Gerald. *Luton.*

QUINN, John Robert. *Doncaster.*

REED, Graham George. *Cambridge.*
RENSHAW, Mathias. *Birkenhead.*
RIGBY, Gerald. *Preston.*
ROBINSON, Edward. *Gainsborough.*
RONSON, Robert. *Bolton.*
RUSSELL, Arthur. *Ellesmere Port.*
RUSSELL, Brian. *Blackpool.*

SARGEANT, Malcolm John. *Northwich.*
SEABOURNE, David Ernest. *Halesowen.*
SEDGELEY, Thomas Howard. *Blaby.*
SHEPHERD, Henry Thomas. *London, S.E.22.*
SHIRLEY, Donald. *Stafford.*
SHOOBRIDGE, Stanley Westcombe. *Easingwold.*
SHUFFLEBOTHAM, Alan. *Salford.*
SIMMONDS, Patrick. *Westgate.*
SINGLETON, Allan. *Ilminster.*
SMITH, Derek Richard. *Nottingham.*
SMITH, Muir. *Glasgow.*
SNOWDEN, John. *Manchester.*
SOLE, John Albert. *Hull.*
SQUIBB, Derek. *Southampton.*
STANTON, Geoffrey Millett. *Cheadle Hulme.*
STARBUCK, Maxwell Howard. *Nottingham.*
STEPHENSON, Brian Stanley. *Hyde.*
STICKLER, Rex. *Rhondda.*
STONE, William Hayes. *Brighton.*
STONES, Michael. *Grimsby.*
STURMAN, Alan. *Kingsley.*
SUMMERS, Barrington Frederick. *Cambridge.*
SWEENEY, Michael. *London, N.W.1.*
SWEENEY, William. *Port Glasgow.*
SYKES, Alan Walter. *Morley.*

THORNTON, Donald Arthur. *Pudsey.*
TILLEY, David Albert. *Leicester.*
TUCKER, Anthony Hal. *Leicester.*
TUDOR, Terry. *Sale.*
TURNER, John Sefton. *Birmingham.*
TURNER, Michael Leonard. *Wembley.*

VINCETT, Percy Albert. *Barking.*

Waldie, Alexander J. *Newcastle-upon-Tyne.*
Walker, Charles William. *Anlaby.*
Ward, Robert. *Manchester.*
Watmough, Kenneth. *Aberdeen.*
Whale, Desmond Victor. *Colerne.*
Whittington, Patrick James. *London, W.10.*
Wilkin, Derek Reginald. *Cambridge.*

Williams, Harry. *Stoke-on-Trent.*
Wilson, Alan. *Stoke-on-Trent.*
Wilson, Eric. *Leeds.*
Wilson, Neil Black. *Clydebank.*
Windsor, Douglas Charles. *London, W.5.*
Winn, Arthur. *Bury, Lancs.*
Winnett, John Terance. *Camberley.*

Wood, Brian. *Accrington.*
Wood, Colin Michael. *Heanor.*
Wormald, George Kendall. *Benrhydding.*
Wright, Peter Martin. *Rainham.*
Wright, Ronald Herbert. *Hull.*

Yeats, Thomas James. *Liverpool.*

The following candidates passed the written papers but were referred in the Practical Test:

Allenby, Norman Appleyard. *Cleckheaton.*
Archbold, Ernest. *Newcastle-upon-Tyne.*

Bagnall, Denis. *Southampton.*
Barton, Anthony John. *Teversham.*
Barton, John Stephen. *Cambridge.*
Bates, Alan. *Brighouse.*
Bennett, James Thomas. *South Shields.*
Beresford, David Robert. *Rainford.*
Black, Andrew Millar. *Dundee.*
Black, Leonard. *Manchester.*
Blackburn, Dennis Barrington. *Leeds.*
Blackmore, Roy Dennis. *Torquay.*
Bolesworth, James. *Glasgow.*
Bradley, Eric. *Awsworth.*
Broster, John. *Wirral, Ches.*
Brown, Kenneth. *Leeds.*
Brown, Richard John. *Worthing.*
Burditt, John Terence. *Ibstock.*
Burns, Robert. *Helensburgh.*

Cassel, Walter. *Glasgow.*
Charles, Geoffrey Frank. *Brighton.*
Chinn, Milton Desmondu. *London, N.1.*
Clark, Harry Colin John. *Haverhill.*
Coates, Alfred William. *London, N.7.*
Coles, William Thomas. *Plymouth.*
Collar, Albert Ernest. *London, S.E.25.*
Cox, Victor Michael. *Leeds.*
Crowe, Walter Norris. *Mirfield.*

Dale, Peter Ringolds. *Salford.*
Davies, Anthony William. *Birmingham.*
De Ros, Dudley. *Sidcup.*
Donegan, Albert Ernest. *Lisburn.*
Dutton, Joseph Donald. *Northwich.*
Dyer, Gerald. *Sherwood.*

Easton, Gavin Livingstone. *Shotts.*
Edge, James Joseph. *Liverpool.*
Edwards, Wilfred Eric. *Cannock.*
Elliott, Lawrence. *Mirfield.*
Evans, Alfred. *Liverpool.*

Farrelly, Eugene A. *Glasgow.*
Finnis, Gordon Edwin. *Deal.*
Firstbrook, Walter. *Chadderton.*
Foot, William Roger. *Ilford.*

Galloway, Richard Wilson. *South Shields.*
Gamble, John Wynn. *Cambridge.*
Gay, William Conn. *Glasgow.*
George, Lloyd W. *London, S.W.1.*
Gillman, Robert Arthur. *Bromsgrove.*
Glenn, Jack Bajen. *Gainsborough.*
Goodison, Brian Anthony. *St. Helens.*
Gordon, Joseph. *London, W.9.*
Greaves, Joseph Raymond. *Burton-on-Trent.*
Griffin, Roy. *Sandiacre.*
Griffiths, Frederick John. *Neath.*
Griffiths, Ronald Edward. *Southsea.*
Grimwood, Donald Bernard. *Cambridge.*

Halls, Raymond Geoffrey. *Birmingham.*
Hamer, Francis. *Liverpool.*
Hardwick, John Buxton. *Burton-on-Trent.*
Harper, William. *Smethwick.*
Harrison, Leonard George. *Rochdale.*
Harvey, Roy. *Bexleyheath.*
Higginson, John Ernest. *Alderley Edge.*
Higgison, Robert. *Glasgow.*
Hill, Alexander. *Kilmaurs.*
Hockley, Ernest. *Wakefield.*
Homan, John Albert. *Higham Ferrers.*
Hough, Charles William. *Birkenhead.*
Hughes, John Chassels. *Paisley.*
Hughes, William Robert. *Broadstairs.*

Ing, Dennis Victor. *Birmingham.*
Ivers, George Joseph. *Manchester.*

James, Leslie John. *Bexley.*
Jenkin, Kenneth John. *Redruth.*
Jenks, Thomas Henry. *Liverpool.*
Johnson, Robert. *Glasgow.*

Kennedy, Daniel. *Clydebank.*
Kilkelly, John Francis. *London, N.7.*
Kirkman, James Sumner. *Blackpool.*
Knifton, Adrian Richard. *Ripley.*
Knott, Graham Trevor Peter. *Ely.*

Latter, Rex Walford. *Bognor Regis.*
Lewis, Ivor. *Bristol.*
Ling, F. A. *Lincoln.*
Litman, Mitchel. *Canvey Island.*
Loakes, Michael Brian. *Hugglescote.*
Luttrell, Edward Richard. *Glasgow.*

McGeachie, Alexander. *Glasgow.*
McIntyre, James. *Glasgow.*
McKenzie, Ian. *Huddersfield.*
McNaught, Stewart. *Alexandria, Dumbartonshire.*
Macpherson, Michael Bernard. *Cambridge.*
Margerison, James. *Blackburn.*
Marsh, Peter. *Nottingham.*
Martin, John Arthur. *Horsell.*
Mathews, Michael. *Bridgwater.*
Middleton, Laurence. *Ayr.*
Miller, Frederick Henry. *London, S.E.18.*
Minns, Ralph. *Croydon.*
Mitchell, Gordon Alec. *Croydon.*
Mohan, Gerald. *Belfast.*
Moore, Geoffrey Frank. *Morecambe.*
Moore, Joseph. *Glasgow.*
Morris, Alan. *Bolton.*
Mulcrone, Thomas. *Blackpool.*

Noyce, Peter Frederick. *Eastleigh.*

Odoom, Robert Acquaah. *London, N.W.1.*
Osborne, Stanley. *London, W.1.*

Partridge, David John. *London, N.16.*
Perry, Raymond Charles. *Walsall.*
Petto, John. *Ayr.*

Pierce, William Percival. *Mold.*
Pladgeman, John Derek. *Leicester.*
Pond, Cyril Arthur. *Stroud.*
Povall, Charles John. *Birkenhead.*
Pownall, Harold. *Compstall.*
Presbury, Peter Wilfred. *Nottingham.*
Price, David John. *Bristol.*
Printer, Kersee Dinshaw. *London, S.E.2.*

Raynor, Alan Walter. *Grantham.*
Renshaw, Fred. *Cheadle.*
Riby, Gordon William. *Leeds.*
Richards, Stanley Ralph. *Plymouth.*
Richardson, Colin William. *Newcastle-upon-Tyne.*
Rose, Edmund Richard. *Radcliffe-on-Trent.*
Rose, Frank Albert. *Addiscombe.*
Rowlingson, Dennis Robert. *Welling.*
Rushworth, Arthur. *Huddersfield.*
Ryan, Peter Leo. *Auchterarder.*

Sakoshansky, Raymond. *Nottingham.*
Sharpe, Donald. *Orpington.*
Shaw, John Boler. *Brighouse.*
Sike, Edward. *London, S.E.23.*
Smith, Alan Hilton. *Shorne.*
Smith, Michael David. *Grantham.*
Smith, Raymond George. *Birmingham.*
Snape, Harry. *Sheffield.*
Soman, Vishnu Damodar. *London, S.W.19.*
Southgate, Leslie Herbert. *Hurstmonceux.*
Sowter, James George. *Cambridge.*
Sparkes, Edward Ernest Victor. *Rhondda.*
Spick, Oliver. *Nottingham.*
Stafford, Derick Roy. *Bredbury.*
Stalker, William. *Kilmarnock.*
Stanley, Joseph William. *Bradford, Yorks.*

Tansley, Albert Cameron. *London, S.W.4*
Taylor, Cyril Robert. *Bridgwater.*
Tennent, Brian Harry. *Brighton.*
Thaker, Kantilal J. *London, N.19.*
Thomson, George Peter. *Stockport.*
Thomson, John. *Glasgow.*
Threadingham, Roy Lawrence. *Portsmouth.*
Turner, Brian. *Halifax.*
Tymm, Gordon Turner. *Fence.*

Upson, Walter. *Leigh-on-Sea.*

Vandome, Ignatius Gerald. *Preston.*
Vanstone, Bernard. *Salisbury.*

Walsh, Patrick John. *Dublin.*
Ward, James Frederick. *Wolverhampton.*
Watkinson, Thomas. *Leeds.*
Watson, Ivor George. *Westgate-on-Sea.*
Webb, Harold George. *Hazel Grove.*
Webster, Robert. *Bedford.*
White, Leslie. *Birmingham.*
Williams, John Andrew. *London, S.E.4.*
Woodhead, Roy. *Rochdale.*
Wright, David Frank. *Alverston.*

The following candidates, referred in the Practical Test in 1954, now qualify for the Certificate:

Adams, Bertram Kenneth. *Bristol.*
Adamson, Arnold William. *Hull.*
Alleyne, William John. *Southend-on-Sea.*

Bagnall, John William. *London, S.W.17.*
Bateson, Peter Lanaway. *Halton, Lancs.*
Bennett, Ronald. *Liverpool.*
Bennett, Robert John. *Kirkby.*
Berry, Peter Leslie. *Oxford.*
Black, Norman. *Newcastle-upon-Tyne.*
Bolton, Ivor. *Canterbury.*
Bracegirdle, Cecil Albert. *Birmingham.*
Bradeley, William Joseph. *Stoke-on-Trent.*
Brown, John Murray. *Romford.*
Burns, Robert Alan. *Gillingham.*

Cleobury, John. *Walsall.*

Finch, Norman. *Birmingham.*

Gilchrist, Angus Graham. *London, S.W.19.*

Gordon, John. *Much Hoole.*
Greenwell, Robert. *Gateshead.*

Heckles, Keith Rhoto. *Liverpool.*
Henderson, Alan. *Durham.*
Hermalyne, Desmond. *Sidcup.*
Heywood, Fred. *Huddersfield.*
Hill, Eric Roland. *Harrogate.*
Hindmarsh, Kenneth John. *Castleford.*
Hirst, Cyril. *Oldham.*
Holmes, Leslie. *Carnforth.*

Jesinskis, Theodor Eric. *London, N.16.*
Jones, Donald. *Doncaster.*

Kenney, Terence. *Leicester.*
Kirby, Lawrence Walter. *Westcliff-on-Sea.*

Lammers, Leslie Albert. *Rochford.*
Lazenby, Arthur Wood. *Withernsea.*

McCann, Alec William. *London, S.E.9.*

Mitchell, Albert David. *Shrewsbury.*

Nelson, Alan. *Leyland.*
Newman, Roger Robert. *Fareham.*
Newport, Cecil Joseph. *Dublin.*

Parkes, Ronald. *Hessle.*

Quinlan, Harry. Oldham.

Schneiderman, Harry Lewis. *Manchester.*
Seymour, Dudley Henry. *Bexleyheath.*
Smith, George Frederick. *Sunderland.*
Sweatman, Leslie Eric. *Emsworth.*

Trapps, Charles Irvine. *Scarborough.*

Weids, Rae Keith. *Clevedon.*
Wells, Donald Thomas. *London, S.W.2.*
Wernham, George Clifford. *Reading.*
Willey, Kenneth E. *Canterbury.*
Worsell, Roland James. *Sevenoaks.*

THE RADIO TRADES EXAMINATION BOARD—*Contd.*

TELEVISION SERVICING CERTIFICATE EXAMINATION–1955

Of the 110 candidates who sat the examination which took place in May of this year, 43 candidates satisfied the examiners in both the written and practical parts; 12 candidates passed the written examination but were referred in the Practical Test, and 13 candidates completed the examination, having previously been referred in the Practical Test in the 1954 examination.

The following candidates satisfied the examiners in the entire examination:

ALLISON, Glen. *Burgess Hill.*

BATTIN, William James. *London, N.11.*
BENNEWITZ, Fritz Otto Max. *Bradford.*
BURBIDGE, William John. *Leicester.*

CHALMERS, Alexander James. *Dundee.*
CLARKE, John Henry. *Chichester.*
CLEMENT, Peter Ernest. *Leigh-on-Sea.*
CRAWFORD, John. *Cambridge.*
CROSS, Dennis. *Knutsford.*

DICKINSON, George Gregory. *Liverpool.*

FAULKNER, Eric Brian. *Birmingham.*
FLOWER, George William. *Pickering.*

GOLDSMITH, Dennis Alfred. *Broadstairs.*

HARRIS, William. *Glasgow.*
HASLEM, Kenneth Leslie. *Greasby.*
HAUXWELL, Peter. *Middlestown.*
HOOLE, Anthony William. *Southampton.*
HOPKINS, Thomas Gwilym. *Swansea.*

JOHNSTON, William. *Paisley.*
JONES, Ronald Edgar. *Llanrwst.*

LANDON, Edwin John. *London, S.E.13.*

McNAMARA, Edward. *London, W.3.*
MAJOR, Kenneth. *Leeds.*
MAPPLEBECK, Raymond. *Leicester.*
MARSHALL, Matthew. *Bathgate.*
MAUDE, Roger. *Huddersfield.*
MEAD, Albert William. *London, S.E.9.*
MOORES, Harold. *Manchester.*

NASH, Cyril Victor. *Warminster.*
NORTON, Harry. *Rotherham.*
NUNN, Eric Hamilton. *Wallasey.*

OAKLEY, Robert Wilfred. *Huddersfield.*
O'LOAN, Daniel. *Belfast.*

PALMER, Albert Edward. *Southampton.*

RAYNER, Frank. *Wakefield.*
REDDISH, George. *Kirkby-in-Ashfield.*
RUSSELL, Robert Pollock. *Paisley.*

SADLER, David Reid. *Ayr.*
SCOTT, James Simon. *Acomb.*

TAYLOR, Stanley. *Rossendale.*
TURNER, Raymond Stanley. *Northampton.*

WATSON, Reginald Arthur. *Spalding.*
WAUD, George. *Leeds.*

The following candidates passed the written papers but were referred in the Practical Test:

ASHLEY, Raymond James George. *London, S.E.18.*

BOWLING, Cyril James. *Parkstone.*
BUTLER, George James. *London, S.W.11.*

COCKITT, Michael Clare. *Congleton.*

DICKINSON, Bernard. *Preston.*

EARNSHAW, Henry Lawrence. *Brighton.*
EWEN, Charles. *Clydebank.*

GILBERT, Michael. *Barrow-upon-Soar.*

RAWE, Dennis Gerald. *Hadleigh.*
REECE, Raymond Dennis. *Gosport.*

STEWART, Donald. *Bathgate.*

WALTON, Brian. *Ossett.*

The following candidates, referred in the Practical Test in 1954, now qualify for the Certificate:

APPLEBY, Peter William. *St. Albans.*

BAMPFIELD, Thomas Anthony. *Wolverhampton.*
BUCK, John. *Leeds.*

DURLING, Bernard Maurice. *London, S.W.1.*

FRASER, Alasdair Mackintosh. *Glasgow.*
FRIEND, Alan Walter. *London, W.12.*
FYFE, Charles Alexander. *Glasgow.*

HEWES, Sherwood Robin. *Leicester.*

KNIGHT, David Richard Joseph. *Salisbury.*

McCARTHY, Thomas Bilizeria. *Leeds.*

POUSTIE, Alan. *Kirkinch.*

SALISBURY, Thomas Harry. *Nuneaton.*

WOOD, Richard Robert. *Blaby.*

. . . Radio Engineering Overseas

A selection of abstracts from European and Commonwealth journals received in the Library of the Institution. 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.

338:620.1:621.37/9

General principles and importance of statistical control of quality of materials.—A. H. SCHAAFSMA. *Onde Electrique*, **35**, pp. 768-772, August-September 1955.

The ordinary methods of tests for quality control in the electronics industry are often not very economic, being sometimes negative in character. The merits of statistical quality tests are put forward.

538:621.37/8:681.14

Magnetic drum equipment, unit of a digital computer.—A. ALBIN. *Onde Electrique*, **35**, pp. 665-671, July 1955.

Considerations which influenced the development are discussed. Emphasis is placed on the relation between the drum and the computer, on the one hand by describing the functioning of the storage arrangement as an integral part of the calculating machine and on the other hand by describing the electronic circuits associated with the magnetic drum only.

538:621.37/8:681.14

Magnetostriction delay line.—R. BIBRON and A. TARABELLA. *Onde Electrique*, **35**, pp. 682-686, July 1955.

Describes a storage delay line capable of storing 100 numbers comprised between 0 and 2,000 on the binary system. All the elements of the delay line are considered in discussing their mode of manufacture.

538:621.37/8:681.14

Memory magnetic materials, alloys and special ferrites.—A. VASSILLIEV. *Onde Electrique*, **35**, pp. 672-681, July 1955

After showing the field of use of storage materials in modern cybernetics a brief account is given of the working of the storage element, which comprises a ferromagnetic toroid. The necessity for using a material with a rectangular hysteresis loop is shown. The properties which are special to metals and ferrites with rectangular hysteresis loops are studied and compared. Ferrites show superiority as soon as speed of operation is required. Moreover, it is only the ferrites which lead to a new technique, namely that of micro-core rings.

621.317.761

Resonant frequency measurements of high accuracy at decimetric wavelengths.—H. GROLL and G. PUSCH. *Fernmeldetechnische Zeitschrift*, **8**, pp. 462-466, August 1955.

Describes how high Q-values, which are required for precision wave meters, can be obtained by a suitable design of the cavities. The tuning to resonance is controlled by phase measurements with a standing wave indicator fitted with automatic display. Calibration is with a multiplied standard crystal frequency and the temperature response and atmosphere pressure response are investigated theoretically and experimentally.

621.37/8:621.9

The duplicatron—high precision electronic duplicating equipment in two dimensions.—M. JEUDON. *Onde Electrique*, **35**, pp. 655-664, July 1955.

An electromagnetic feeler follows with great precision the contours of either a model or a template. The process is carried out at a constant speed whatever the control. As a result of indications of the feeler an electronic calculator gives instructions regarding speed and position to the motors governing the position of the machine tool. The feeler is sensitive in two directions for controlling milling machines. Some equipments have already been over a year in operation without breakdown.

621.373.421.13

A new method of determining the "Q" factor of piezo-electric crystals.—H. MAYER. *Onde Electrique*, **35**, pp. 692-699, July 1955.

An experimental and theoretical study of the response of a piezo-electric crystal to a generator frequency modulated by a unit pulse is applied to the determination of the "Q" factor of these crystals.

621.374:621.395.73

Line fault location by pulse technique.—T. K. MAHADEVAN. *J. Instn Telecom. Engrs*, **1**, pp. 14-19, March 1955.

Relates to the application of pulse fault localization methods to the testing of certain land lines in India. Actual field test data of certain lines tested with an electronic fault locator are analysed.

621.392.1:621.396.11

Propagation trials on 530 Mc/s beyond the optical range.—E. PROKOTT. *Fernmeldetechnische Zeitschrift*, **8**, pp. 430-437, August 1955.

Describes propagation tests which were performed over two radio links in central Germany on 533·5 Mc/s. The aim of the experiments was to determine the technical equipment required for satisfactory communication.

621.396.1

On radio measurements at Jabalpur during the solar eclipse of 30th June, 1954.—A. K. GHOSE and others. *J. Instn Telecom. Engrs*, **1**, pp. 20-34, March 1955.

Observations made of (1) field strength, (2) angle of incidence of down-coming ray, (3) intensity of atmospheric noise, of transmission on 15·170 Mc/s from Moscow.

621.396.1

Analysis of sky-wave field intensity. S. N. MITRA and R. B. L. SRIVASTAVA. *Indian Journal of Physics*, **29**, pp. 167-178 and 227-242, April and May 1955.

Presents a statistical analysis of field intensity of the internal short wave stations of All India Radio over the period of a complete solar cycle (1942-52). The yearly, seasonal and monthly variations of the field intensity and their correlation with sunspot numbers have been shown in a series of graphs. The night-time field intensity has been found to be correlated with solar activity. This is rather inexplicable since no ionosphere absorption is usually assumed for the night-time propagation. In the second part of the paper the results of these observations are compared with theoretical deductions. It has been pointed out that these theoretical methods are not strictly applicable to the calculation of sky-wave field intensity as observed in tropical countries. A modified method applicable to tropical conditions has yet to be developed.

621.396.41:621.376.53

Pulse multiplex telephone system in Greece.—J. J. MULLER. *Onde Electrique*, **35**, pp. 711-713, August-September 1955.

This is an introductory paper to a series describing various aspects of a 23-channel p.p.m. multiplex system operating in the frequency band 1760-2005 Mc/s.

The 3 supporting papers are:—

High quality radio links over sea paths in Greece.—R. CABESSA, pp. 714-727.

24 of the 32 radio links in the system are over the sea. The extent to which theory is confirmed in practical trials is discussed and the effect of height diversity at the receiving point on the circuit quality is particularly examined.

Synchronization of Greek radio systems.—G. X. POTIER, pp. 728-732.

The use of parallel synchronization in pulse multiplex systems permits the composition of star systems at the junction point of different branches, without demodulation. Different methods of using this system of synchronization are described for linear systems and star connected systems. In each case the influence of a variation in the refractive index on the respective positions of the groups of pulses of different origins is examined. The use of this method of synchronization in the Greek radio telephone network, had verified that it works satisfactorily in long distance systems.

Operational reliability of radio installations in Greece.—R. BASARD, pp. 733-738.

The extent and causes of interruptions are analysed.

621.396.662.34

Computation of intermediate-frequency filters.—B. BERKES, *Elektrotehniski Vestnik*, **23**, pp. 237-242, July-August 1955.

Intermediate frequency filters can be computed in various ways, the selection of which depends on the preference of the designer for a simpler or more difficult mathematical procedure. All computing methods, however, lead to approximately the same result. A method is described which, with the approximations given, most accurately complies with practical conditions. Inductive coupling is best suited for manual bandwidth control and an i.f. filter of this type is described.

621.396.712

On the effect of delay distortion and frequency bandwidth restriction on the transmission of radio programmes.—E. BELGER, E. A. PAVEL and H. RINDFLEISCH, *Fernmeldetechnische Zeitschrift*, **8**, pp. 445-455, August 1955.

The results of tests carried out during the years 1950 and 1951 by the Federal German Post Office in co-operation with the West-German broadcasting companies are reported in this paper. The investigation covers the effect of delay distortions in broadcast circuits as used in Germany on the quality of the broadcast transmission and also the possibility of compensating these distortions in the critical range, as well as the effect of reductions in the bandwidth particularly in the higher region of the transmitted band.

621.397.5

Colour television.—R. G. ANTHES. *Journal of the Engineering Institute of Canada*, **38**, pp. 1047-1053 and 1069, August 1955.

After dealing with some pertinent general information on colour television, the paper deals principally with the basic colour signal. Brief mention is made of the shadow mask picture tube and a typical receiver. Changes in picture tube and receiver design will occur, but the signal-processing systems considered will still apply.

621.397.5:621.317.34

Bandwidth reduction in television relaying.—A. J. SEYLER, *Proc. Instn Radio Engrs. Aust.*, **16**, pp. 218-225 and pp. 261-276, July and August 1955.

Surveys theoretically possible methods of bandwidth reduction in relay links for television signals. In Part I the possibilities of standard conversion and of utilizing the discrete character of the frequency spectrum of television signals are discussed. Part II deals with the application of information theory to the problem of bandwidth reduction in television relaying. The statistical properties of television signals are discussed and various kinds of statistically matched codes are demonstrated. Instrumentation considerations point to the amount and kind of equipment development which would still be required to put the theoretical results into a practical system design.

621.397.6

Differential equalizers for television studio equipment. A. KROLZIG. *Fernmeldetechnische Zeitschrift*, **8**, pp. 426-429, August 1955.

The method for improving the sharpness of television pictures by electrical means which is based on the application of the time-differential of the video signal is described. The limitations are shown to be partly fundamental and partly economic. Some cases in which differential equalizers have been employed profitably are discussed.