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Professional Engineers and Trade Unions

OVER recent years groups of professional engineers have demanded that their Institution, or the Council of Engineering Institutions, should act in the capacity of a trade union. For various well-founded reasons this has been deemed neither practicable nor desirable, and most Institutions, including the IERE, have officially stated that what action an individual engineer took in relation to trade union membership was entirely up to him and that no recommendation, for or against, would be forthcoming from the Institution.

But times change and it is to the credit of CEI that a thorny question has been grasped, an experienced Working Party set up and a report taking a definite line has been produced.* It is concluded by Mr. G. A. Dummett (now Chairman of CEI) and his Working Party that there are now compelling reasons why professional engineers should join a suitable trade union: furthermore they believe many engineers are not fully aware of the need for effective professional unions. The report points out the increasing pressures on professional engineers: falling real salaries, 'closed shop' developments, and the growing call for 'industrial democracy' in which it is essential, in the public interest, that professional engineers should be able to exert their proper influence.

Two classes of trade unions are distinguished, namely, 'closed' unions whose members are restricted to a particular calling or industry (typically IPCS, NALGO, AUT†), and 'open' unions whose membership is not thus restricted (typically UKAPE, ASTMS, TASS, APST); the former operate almost entirely in the public sector while 'open' unions draw their members mostly but not exclusively from private industry. Of the estimated number of engineers in unions—40%—only 1 in 6 in private industry has joined a union.

The report considers that the present group of 'closed' unions can be recommended to engineers in the appropriate fields and it then goes on to state criteria for an 'open' union for professional engineers:

Membership must be open to professional engineers regardless of discipline.

The aims and objectives must take into consideration the need for a professional man to abide by a suitable code of conduct.

The membership must be primarily professional—it should not be limited solely to chartered engineers but should be open to others qualified by responsibility of employment rather than by academic attainment.

It should be prepared to accept members of other professions in industry (scientists, economists, patent agents, etc.) whose aims are akin to those of professional engineers.

It should be ready to work with CEI and perhaps also CSTI.

It must provide suitable 'employment' personal services as well as negotiate salaries and conditions.

The only 'open' unions meeting these criteria are UKAPE, ASEE and APST (present combined membership about 20,000), although it is understood that EPEA (now a 'closed' union of 33,000 members and affiliated to the Trades Union Congress) is considering widening its scope beyond electrical power engineers to include all disciplines. The report believes there is a balance of advantages and disadvantages in a professional union being affiliated to the TUC.

If the CEI is regarded as the voice of the profession of engineering, then unions may be seen as the voice of the professional engineer. To quote Professor J. F. Coales, retiring Chairman of CEI, 'There was never a time when the country required the expertise of the professional engineer more urgently than now and if he is to make his contribution to the full, then this problem of his representation must be overcome. I hope this report will enable professional engineers to make up their minds about the vital question of trade union membership.'

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* 'Professional Engineers and Trade Unions'. Published by CEI, 2 Little Smith Street, London SW1P 3DL.

† APST—Association of Professional Scientists and Technologists; ASEE—Association of Supervisory and Executive Engineers; ASTMS—Association of Scientific, Technical and Managerial Staffs; AUT—Association of University Teachers; EPEA—Electrical Power Engineers' Association; IPCS—Institution of Professional Civil Servants; NALGO—National and Local Government Officers' Association; TASS—Technical, Administrative and Supervisory Section (of Amalgamated Union of Engineering Workers); UKAPE—United Kingdom Association of Professional Engineers.

Contributors to this issue*

Professor William Gosling (Fellow 1968) who graduated in physics from Imperial College in 1953, was appointed to the newly-founded Chair of Electronic Engineering at the University of Bath in January 1974. He was previously at the University College of Swansea for some 16 years and had been Professor of Electrical Engineering and Head of the Department of Electronic and Electrical Engineering since 1966. Professor Gosling is Chairman of the Professional Activities Committee and is also on the Executive Committee. He was elected a member of the Council in 1970, serving as a Vice-President from 1972 to 1975.

Dr. S. R. Al-Araji was born in Baghdad, and in 1963 won an Iraq Ministry of Oil Scholarship to Britain where he entered the University College of Swansea. In due course he obtained the B.Sc., M.Sc., and Ph.D. degrees of the University of Wales, his Ph.D. research being concerned with innovations in radio receiver design. After completing his doctorate, he participated in the Home Office joint research programme at Swansea, as a post-doctoral Fellow. He has now taken up a post at the University of Baghdad.

Mr. J. R. Olivera received the B.Sc. degree in electrical engineering from the University of Havana, Cuba, in 1968. Since 1968 he has been a lecturer at the School of Electrical Engineering of the same University. In 1972 he attended the University College of Swansea obtaining a M.Sc. in electronic instrumentation and he returned to the University of Havana where he lectures in instrumentation and signal processing.

* See also page 91.

Mr. John Malster (Member 1962) joined Standard Telephones and Cables Limited, New Southgate, in 1951, where he worked on ground controlled approach radar equipment until 1953 when he went to de Havilland Propellers Ltd., later Hawker Siddeley Dynamics. Here he helped to develop air-to-air guided weapons electronics and associated test gear and he studied part-time to qualify for exemption from the Institution's Graduateship Examination. In 1961 Mr. Malster joined the S.E. Regional Research and Development Department of the Central Electricity Generating Board where he was engaged on instrumentation and control projects related to generating plant. Since 1967 he has been with Rank Xerox Ltd., where he was Electrical Engineering Manager Communications Products, at Welwyn Garden City up to June 1975 and he is now Electronics Design Manager at Mitcheldean, Gloucestershire.

Mr. M. J. Bowden began his career at GEC Applied Electronics and studied electronics at Brunel College of Technology. After working for several years on the development of airborne radar equipment and guided missiles for the Ministry of Defence, he decided that the potential of facsimile offered a stimulating challenge in the business machine industry and he joined Rank Xerox Ltd. From 1968 to 1974 he was Communications Products Design Manager and Technical Programmes Manager based at Welwyn Garden City and responsible for a number of products using the telecommunications media. He was a founder member of the British Facsimile Industries Compatibility Committee (BFICC) which made a significant contribution to the Study Group XIV recommendations at the 1972 CCITT Plenary Assembly in Geneva. In 1974 he moved to Rank Xerox International Headquarters Central Strategy Group where he is now Office Communications Products Programme Planning and Analysis Manager.

Mr. C. J. Kelley (Member 1972) became senior engineer in the analogue computer section at the Cranfield Computing Centre in 1965. During his stay at Cranfield he has designed and developed the hybrid computer complex and is currently engaged in expanding the system in both hardware and software. Although originally intending to be an industrial chemist, Mr. Kelley became interested in electronics when he was assigned to this work during his period of national service with the R.A.F. He subsequently became head of the calibration and development section of Light Laboratories, Brighton, working on medical and industrial instrumentation. He then joined the computer section of the Government Communications Headquarters, Cheltenham, where he remained until 1965. Since 1975 he has been Senior Technical Officer in the Computer Research Centre (Mathematics Department).

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Facsimile—A review

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and

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Based on a lecture presented at a meeting of the IERE Communications Group held in London on 4th April 1973

SUMMARY

The development and potential of facsimile as an alternative means of communication over voice-grade telephone lines is discussed. The components of typical facsimile systems are described, and the characteristics of telephone channels in so far as they influence the performance of facsimile machines are covered, together with the problems confronting manufacturers. These include standardization, compatibility, and compliance with the requirements of national safety and telecommunications authorities. Future trends in the facsimile field are forecast.

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1 Introduction

For the purpose of this review facsimile is considered to be a method by which printed, handwritten and graphic data may be transmitted over communication channels and received in the form of a hard copy. Its origin dates back to 1843, when the Scottish inventor Alexander Bain patented an 'automatic electrochemical recording telegraph'. Next came Frederick Bakewell's cylinder and screw arrangement on which many of the present-day facsimile systems are based.

Traditional methods of sending written, printed or graphic information are well established. The postal service, being labour intensive, has for years been in economic difficulties and the trend is for costs to rise and the number of collections and deliveries to decrease. Facsimile communication can be accomplished in minutes regardless of distance. Unlike telex, it does not rely on an intermediate operator, and apart from the effect of telephone line characteristics it is essentially error free. Perhaps the most significant advantage facsimile has over all alternatives except post is its ability to transmit graphic information: for example graphs, diagrams, forms, signatures, etc.

In Europe facsimile equipment has been commercially available since 1946. In recent years the technology advances in electronics and the drastic fall in semiconductor prices have led to the replacement of bulky separate facsimile transmitters and receivers by small transceivers.

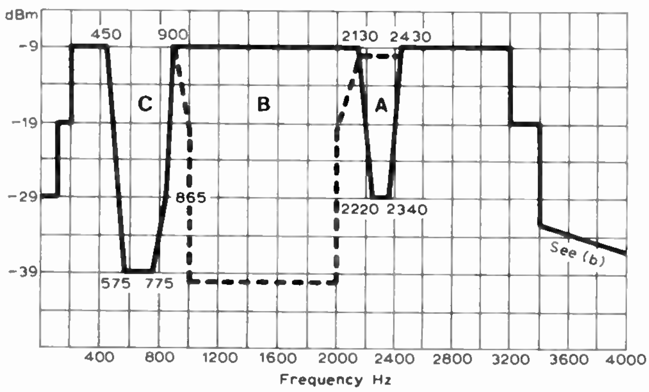
The growth of multinational companies has increased the importance of communications, including conveyance of graphic information. Within a plant or office complex, communication efficiency can be considerably improved by the use of a facsimile network. Where geographically remote plants are involved in information exchange with a central office the use of facsimile over leased telephone lines can be shown to yield dramatic savings annually in improved business efficiency and lower administrative costs. The economics of technology and the business environment may therefore be conducive to the exploitation of facsimile, and in the not so distant future it may become as common as the desk calculator, the typewriter and even the telephone.

For facsimile equipment to become widely available the machines must be capable of operation over public switched or leased voice-grade telephone networks. Operation over the limited bandwidth of telephone lines immediately imposes a restriction on equipment design, the average bandwidth available on voice-grade telephone lines being 300–3400 Hz. Because some of the passband is allocated for supervisory signalling, international switching frequencies, and facsimile supervisory control, the bandwidth available for the transmission of video signals is reduced to about 1200 Hz.

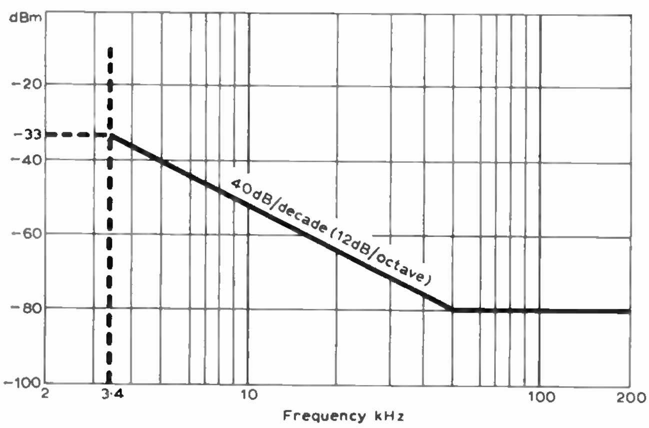
Figure 1 shows some typical restrictions imposed on the transmission of facsimile signals by a national telecommunications authority (P.T.T.). In this example (from the British Post Office) signals up to 2430 Hz are restricted as shown, to avoid false operation of trunk signalling equipment, and signals above 3200 Hz must be attenuated to preclude adjacent channel interference on trunk circuits.

Conventional techniques in analogue facsimile systems for using the available bandwidth permit transmission of an A4 document in 6 min. More recent improvements have reduced transmission time to 3 min. Digital transmission is now employed to increase speed further by removal of redundant data, but the hardware costs are still significantly higher than for a simple analogue system.

When considering the cost of facsimile transmission it is necessary to take into account the type of machines used and the speed capability, the capital cost or monthly rental, the cost of consumables, and the application or environment in which the machine is to operate.



(a) Maximum one-minute-mean power level of individual spectral components of the output signal from apparatus connected to the Public Switched Telephone Network.



(b) Maximum power level of individual spectral components above 3·4 kHz of the output signal from apparatus connected to voice-band circuits.

Notes: (1) Signals are permitted in Area A only if accompanied by signals in Area B at a power level not lower than 12 dB below the power level of the signal in Area A.

(2) Signals are permitted in Area C provided that there is no false operation of trunk signalling equipment (SSAC 1).

(3) The combination of tones 941 Hz + 1209 Hz is reserved for Post Office control functions and must not be used.

Fig. 1. Power level restrictions on facsimile transmissions. (Reproduced by permission of the Post Office).

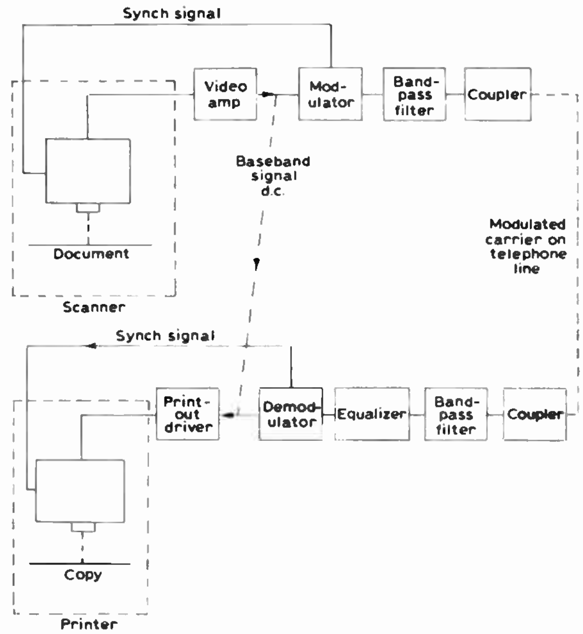


Fig. 2. The basic facsimile system: hard copy to hard copy.

Speed can significantly reduce telephone costs over long distances, although it may sometimes be achieved only at the expense of copy quality. The cost of transmissions will vary significantly according to whether operation is over local, short to medium distance, or trunk connexions. The economics may dictate that in certain situations it is cheaper to rent a leased line than to use the public switched network.

It might be asked why facsimile did not replace the post or telex years ago. As previously mentioned, the facsimile manufacturer is constrained to design an equipment to match the existing communication system characteristics. Improvements in world-wide telephone networks are necessarily slow owing to the high cost of installing new exchange and transmission equipment. To date facsimile has been mainly confined to specialist markets, such as the transmission of newspaper pictures and weather maps. Now, with the availability of machines which are competitive with the established forms of hard copy transfer, a whole new area of the communications medium is opened up offering great potential.

2 The Basic System

The basic facsimile system is shown in Fig. 2. The input document is scanned to convert visual images into an electrical analogue. This analogue or baseband signal contains a range of frequencies down to d.c. Where there is a d.c. path between transmitter and receiver the baseband signal may be transmitted directly. When the transmission path is a telephone line the bandwidth does not extend down to d.c. In this case a carrier modulated by the video signal is transmitted to the line, via a filter to limit the frequency spectrum of the signal, and a coupler to interface with either the line or telephone handset. At the receiver the modulated carrier wave is bandwidth limited by a filter. If necessary it is equalized to minimize the effects of linear distortion in the transmission channel, and then demodulated to recover the video signal. The recovered video signal is amplified to drive the writing process which reproduces the original document permanently on either plain or sensitized paper. A synchronizing system ensures that the scanner and printer movements remain in phase throughout the transmission period.

All the facsimile systems on the market work on this basic principle, but there are many variations in the realization of the system components.

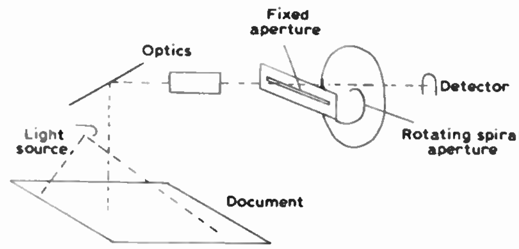


Fig. 4. Rotating spiral/fixed aperture scanner.

3 Scanners

The scanner illuminates the document and analyses the graphic image incrementally, deriving an electrical analogue of the light reflected by the image. There are two basic projection methods: spot and flood projection. In spot projection the document is illuminated by a spot of light which is projected by a lens and aperture. The best use is made of the available light but a more complex optical arrangement is required than for flood projection. In the flood projection arrangement the document is illuminated by diffused light and the light reflected by the image is projected through an aperture on to the photocell. The light source needs to be of higher intensity than for spot projection.

The scanners in current use may be classified in terms of document positioning and the method of scanning. Drum (or cylinder) scanners use the same principle as Frederick Bakewell's cylinder and screw arrangement in 1850. The document is wrapped around and fastened

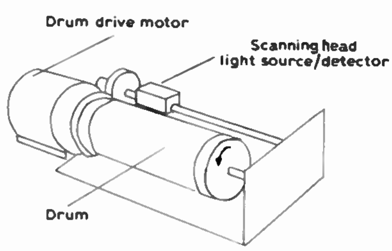


Fig. 3. Drum scanner principle.

to a drum which rotates at constant speed to provide one scanning movement. The other movement is usually obtained by moving the optical system along parallel to the axis (Fig. 3).

In flatbed scanners, the document is drawn between feeder rollers across a flat surface to provide one movement, while the optical system performs a series of transverse sweeps by any one of several different methods. The most popular of these is a system in which a disk with a spiral aperture rotates relative to a fixed aperture (Fig. 4). A line scan is obtained for every rotation of the spiral. In another example, a single row of light-conducting fibres forms a line extending over the width of the document. The other ends are shaped in a circle, and are scanned sequentially at constant velocity (Fig. 5).

The common disadvantage of all the mechanical scanning methods is the limitation on maximum scanning

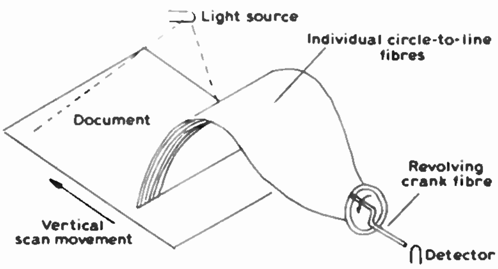


Fig. 5. Fibre optics line-circle array scanner.

rate and the need for precision dynamic components, but they are rugged and relatively inexpensive, and are used in most facsimile systems today.

Electronic scanners which suffer from none of these disadvantages are available commercially. Typically they comprise a cathode-ray tube generating a projected flying spot. The spot scans the document line by line, and the light reflected from the image is collected by a single detector (Fig. 6). High scan rates are possible and the scan rate may easily be changed throughout the scan to skip over redundant white spaces on the copy. Unfortunately this type of system is expensive, fragile and large.

The third main type of scanner is the curved bed or modified flatbed type, in which the document is drawn between feeder rollers for one scanning movement and the other scanning movement is provided by two diametrically opposite heads rotating on a yoke.

Up to now drum and flatbed types have been equal in popularity, with curved-bed types in the minority.

4 Recorders

The recorder converts the electrical analogue of the image on the input document into a hard copy at a remote receiver. The design of the recorder usually

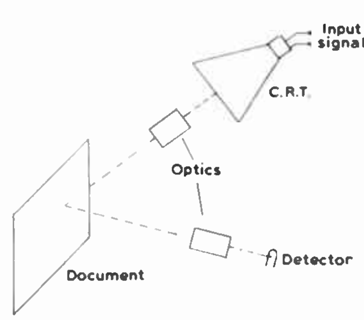


Fig. 6. C.r.t. flying spot scanner.

duplicates the scanner format, with some variation to accommodate the imaging process. This is particularly true of systems introduced after the mid-1960s, since when facsimile has been promoted as a low volume, two-way, office communications machine. The copy transport arrangement of a machine working in the receive mode would therefore generally fall into one of three categories—drum, flatbed or modified flatbed, as in scanners. Their common purpose is to transport the copy paper in synchronism with the remote scanner.

There are two main basic imaging processes in use:

Direct—which means there is no additional processing after the end of the transmission. Examples are electrolytic, electrothermal, electropercussive and ink offset.

Indirect—which can be sub-divided into electrostatic and photographic. Indirect imaging methods require additional processing after a latent image is produced.

4.1 Electrolytic Recording

The oldest and still the most popular method of facsimile recording is electrolytic, used in principle by Bain over 130 years ago. The recording paper is saturated with a solution of electrolyte and marking material which discolours when an electric current is passed through it (Fig. 7). The electrodes are usually formed by a fixed blade and a raised wire helix on a rotating drum. The degree of colour change is proportional to the current level, so the process has grey scale capability. The image has rather low contrast, and the paper is prone to developing wrinkles after drying. It must be kept moist before and during the process, and for this reason it is usually supplied in roll form. The resolution is limited to about 100 lines per inch (lines/in) or 4 lines/mm.

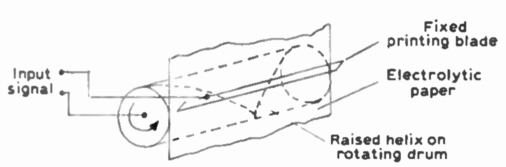


Fig. 7. The electrolytic recording principle.

4.2 Electrothermal

In the electrothermal process, the recording material comprises a paper base coated first with a black layer of conductive carbon, then an opaque top layer (Fig. 8). An electric current flowing between a stylus and the conductive layer burns off the opaque covering to expose the black material underneath.

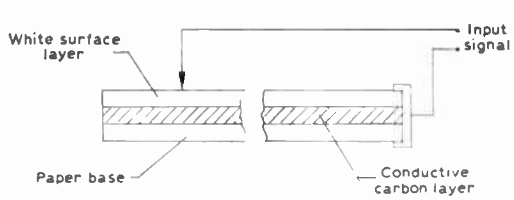


Fig. 8. Electrothermal recording process.

The size of elements exposed varies with current density, so the process has grey scale capability. The image has relatively high contrast. Writing speeds up to about 1 min for A4 coverage are possible, with a resolution capability of approximately 200 lines/in. The material is somewhat pressure sensitive, so the copy will be permanently marked by careless handling. Another disadvantage is the production of ash, smoke and odour during the process.

4.3 Electropercussive

Like the electrothermal process, electropercussive recording is about 40 years old. A carbon paper/plain paper copy set is exposed to a stylus driven by a transducer (Fig. 9). The stylus pressure varies with the signal current in the transducer, and so transfers an image onto the plain paper. The image density is proportional to the stylus pressure, so this process also has grey scale capability. The contrast is good and the material is relatively inexpensive. By adding extra copy sets, multiple copies may be produced simultaneously. Disadvantages are that the transducer limits the writing speed, and it is also noisy in operation.

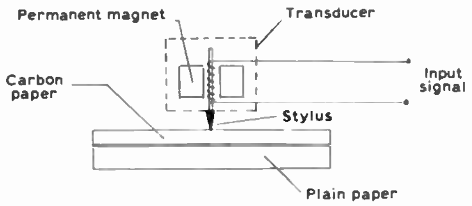


Fig. 9. Electropercussive printing.

4.4 Ink Offset

In the ink-offset process, an electromagnetic transducer responding to the signal current moves an inked roller to transfer marks onto a moving plastic ribbon. The image on the ribbon is transferred onto plain paper one line at a time. It is an inexpensive process with no grey scale capability.

4.5 Electrostatic

The most popular xerographic process for facsimile is one in which zinc-oxide-coated paper, known as the photoreceptor, is used. The paper surface is first charged electrostatically, and then exposed to a modulated light source which disperses the charge from all but the wanted image areas. The latent image is developed by application of a toner consisting of black pigmented thermoplastic resin particles suspended either in a liquid or on dry carrier particles, which cling to the charged image areas on the paper. After development, dry toner is fused into the paper, or fixed, by heating. In the plain paper process (Fig. 10) there is an intermediate stage in which the image is formed on, for example, a selenium-alloy-coated drum photoreceptor and developed with toner, which is then transferred to plain paper. Against the advantages of inexpensive copy material of archival quality, high writing speed and resolution, this

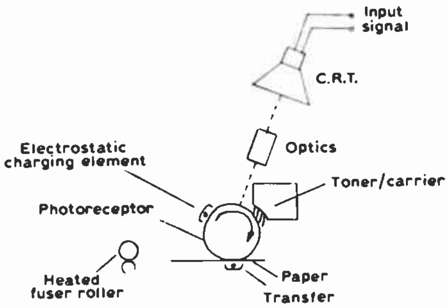


Fig. 10. Plain paper electrostatic (xerographic) process.

process has limited grey scale capability and it requires relatively complex machinery.

4.6 Electrographic

The electrographic method requires special paper coated with a dielectric. A latent image in the form of an electric charge pattern is formed on the surface by a high voltage applied by a stylus or a set of styli, then developed and if necessary fused, as in the xerographic process.

4.7 Photographic

Photographic recording has been used mainly for applications which need the high resolution and tonal range available from the materials used. An electro-optical transducer responding to the input current generates a latent image on sensitized material, which is then developed and fixed. There are now automatic processing systems contained within the recorder, and materials which simplify the process. The materials are expensive compared with all the other recording processes, and the recorder is relatively large.

5 Transmission—The Facsimile Signal

5.1 Resolution of a Facsimile System

Resolution is a design parameter, defined as the degree to which adjacent elements of the image are distinguishable as being separate, and it is fixed at whatever is the minimum level acceptable for reproduction of the images to be transmitted. The dimensions of the scanning aperture and the spacing between adjacent scans determine the vertical resolution. The horizontal resolution is limited by the ability of the system to follow the electrical analogue of the scanned image, and is usually determined by the usable bandwidth of the transmission channel. Usually the resolution in the two dimensions is approximately equal.

Assuming grey scale capability, average typescript can be reproduced with character legibility by a system resolution of about 100 lines/in (or 50 line/pairs per inch). Signatures require rather less, and photographs suitable for newspaper quality require 100 to 200 lines/in. A road map would require 200 lines/in, the same as for fingerprints. The transmission of Kanje (Chinese graphics), needs at least 135 lines/in. Half-tone screen pictures need a resolution of about 7 to 10 times the screen density—so a 65-line screen would require a resolution of between 450 and 650 lines/in.

The resolution of current systems ranges from about 64 lines/in up to 2000 for the transmission of fine detail photographs.

Consider a typical system with a 96×96 lines/in resolution, scanning an A4 document. The baseband signal produced by scanning a 96 elements per inch raster would have a fundamental frequency such that one cycle would be equivalent to two elements. Assume a scan length of 8·7 in, including a margin for synchronization or fly-back, a document length of 11·75 in and transmission over a voice-grade telephone channel allowing a maximum baseband frequency of, say, 1250 Hz. The two variables are the scan rate and the transmission time. The maximum fundamental baseband frequency is given by the product of maximum resolvable line pairs per inch (48), the scan length (8·7), and the scan rate. In this example the scan rate is therefore 3 per second. The total transmission time is given by the product of document length (11·75), number of scans per inch for 96 lines/in vertical resolution (96), divided by the scan rate (3). This is approximately 6 min.

5.2 Grey Scale Capability

In some facsimile systems the grey scales on the input document are preserved throughout the process, and in others the analogue signal from the scanner above and below a given threshold is sent as black or white. This process is known as two-level quantization. Grey scale capability can be provided by applying a range of thresholds in between white and black, and expressing each level as a binary number, but the number of levels will need to be high if an image having many tonal scales has to be reproduced.

5.3 Digital Systems

In a digital system the baseband signal is sampled and quantized. This provides opportunities for (a) processing the signal by application of compression and/or storage techniques and (b) encryption. In choosing the number of quantal levels and the sampling density, consideration would be given to the nature of the documents to be transmitted.

5.4 Data Compression

Methods of reducing redundancy in the facsimile signal come under the general heading of data compression. The two most popular techniques are white space skipping and run-length encoding. Both require variable velocity scanning/printing which can be applicable directly to scanner/recorder systems having extremely low inertia, for example the flying-spot scanner, and extended to other systems by buffering the facsimile signal with a data store. The oldest and best known data compression technique is run-length-encoding. The principle is based on statistical information on the scanned image. Assumptions are made concerning the sequential distribution of black and white elements along a scan line, and codes are sent to denote the occurrence of these element runs. The code structure would be chosen to suit the most frequently encountered document material. The effectiveness of compression schemes depends on the nature of the document because the actual compression ratio will vary according to the information density. Data compression ratios of up to 6 : 1 can be achieved for typical business letters, and 3 : 1 for a full page of typescript, at 100 lines/in. The major disadvantages of complex redundancy schemes are the high cost of hardware and the sensitivity to transmission errors.

6 The Modem

Facsimile scanners and printers may be connected together directly by wire, i.e. baseband to baseband. Since none of the telephone channels available for facsimile communications has a bandwidth extending much below 300 Hz the facsimile signal has to be impressed on an audio frequency carrier prior to transmission over a telephone line. For this purpose a modem is used. It consists primarily of a modulator, a filter to remove unwanted components resulting from the modulation process, and a coupler to provide electrical isolation from the telephone line. In the receive signal path there is a bandwidth limiting filter, a demodulator to retrieve the baseband signal, and sometimes an equalizer to compensate for linear distortion in the telephone channel. These basic functions are performed by almost all modems. The modem is usually supplied as an integral part of the machine, but for digital systems the P.T.T. generally provide a separate modem.

6.1 The Modulator

Frequency and amplitude modulation are most commonly used in analogue facsimile. In f.m. the facsimile baseband signal is made to modulate the frequency of a carrier and the resultant sidebands are spaced on either side of the mean frequency at intervals determined by the instantaneous baseband frequency. The amplitude of the sidebands is dependent on the modulation index, which varies throughout the facsimile transmission. The sidebands contain a significant proportion of the signal power, and have an important information content.

In an a.m. system the sidebands will cover the range from (carrier frequency − the highest baseband frequency) to (carrier frequency + the highest baseband frequency). As each of the pair of sidebands contains all the information in the signal, one can be suppressed without detriment. In practice a vestigial sideband technique, in which part of the upper sideband is suppressed, is sometimes used.

A sample of available facsimile systems reviewed indicates a slight preference for f.m. Some manufacturers offer a choice of either a.m. or f.m.

6.2 Equalization

Equalizers compensate for linear distortion in the telephone channel which may cause copy degradation. They generally take the form of the inverse of group delay/frequency and attenuation/frequency line characteristics, so that, ideally, the nett frequency transfer characteristics of the total signal path are flat. The permissible degree of deviation from this ideal depends on the required performance and the type of modulation used. The equalizer characteristics may either be fixed (preset) or adaptive: fixed equalization is commonly used on either dedicated lines with known, relatively constant characteristics or on a range of lines with a known spread of characteristics—on the switched network for example. The equalizer may need to be adaptive if the system cannot tolerate the distortion resulting from the use of a compromise equalizer on a wide range of different lines. An automatic or adaptive equalizer in the receiver can select its own characteristic (from one of a prescribed range) as a result of receipt of a test pulse transmission prior to the commencement of the message scan.

6.3 The Line Filter

Since the modulated signal may contain spectral components which are, for example, outside the limits defined in Fig. 1, a filter may have to be included to attenuate them to an acceptable level. A bandpass filter in the receive path contributes to the rejection of noise.

6.4 Bandwidth Compression

Another function of the modem is to provide the means of applying bandwidth compression, when used.

The simplest form of compression encoder in current use is one in which a two-level baseband signal is converted to three-level by inverting every other signal excursion. The fundamental baseband frequency is halved by this process, so the transmission speed over a fixed channel bandwidth may be doubled. The cost of this benefit is increased sensitivity to noise if, taking the case of an f.m. system, the total deviation for a white-black-white signal is the same as for non-encoded white to black. The technique can be extended to complex multi-level schemes achieving even greater compression, but only at the expense of noise sensitivity. On public switched networks, therefore, the high incidence of impulse noise limits the extent to which bandwidth compression techniques may be exploited.

7 The Transmission Medium

The characteristics of the transmission medium greatly influence the design and performance of the facsimile system. The following brief survey of the public communication services available in the UK and North America will serve to illustrate the variety of channels available to facsimile users.

United Kingdom:

The nominal bandwidth of 4 kHz on the switched network is dictated by channel spacings in frequency multiplexed carrier groups, but the usable bandwidth is limited to about 3·1 kHz to allow for a guard space between channels. Of this, only a small proportion is available for facsimile transmissions. Leased or dedicated lines (private lines) may be specially conditioned to have a guaranteed greater bandwidth and less group delay than a connexion on the switched network. Dedicated wideband lines intended for high speed, high volume data transmission are also available between a limited number of locations. The annual rental depends on the length of the line and the distance of the subscriber from the nearest wideband terminal at each end.

United States of America:

In the USA there are several carriers, not one P.T.T. monopoly. They operate a switched telephone network with a nominal bandwidth of 4 kHz and also an interstate direct dial network with access to international circuits, having a special tariff for heavy users. One company offers a switched network of broadband lines, which have a bandwidth of either 2 kHz or 4 kHz, for voice or data. There is also a range of leased lines, including wideband leased channels.

The characteristics of telephone channels which have an effect on facsimile copy quality are mainly:

Linear distortion, i.e. variations in amplitude and group delay with frequency. Group delay, the derivative of phase shift versus frequency, results from inductively loaded cables, bandpass filters in channel translating equipment, and low-pass filters in p.c.m. channels. The effect of linear distortion on facsimile performance depends on the modulation system used. Uncompensated, it can cause inter-symbol distortion.

Noise, relative to the signal level at the receiver. Signal/noise ratios below the working margin can cause 'peppered' copy background, or in the case of impulse noise, spurious black or white dashes on the copy.

Echo, caused by mismatches in the connexion, which can result in double or multiple images.

8 Coupling to Line

The facsimile system may be coupled to the telephone channel in one of three ways: direct (hard wired), acoustic or inductive. The most commonly used are the first two. The British Post Office and other National P.T.T. authorities permit direct coupling, provided that certain requirements are satisfied. In the United States connexion must be made via a coupler provided by the carrier. The advantage of direct coupling is that the system is not influenced by the vagaries of the telephone handset, but on the other hand it can be installed only by the National P.T.T. concerned. Acoustic couplers can either be separate or integral with the machine. Their advantages of allowing easy transfer of the facsimile machine from one location to another is offset by susceptibility to interference from ambient noise, and signal distortion.

9 Phasing and Synchronization

The receiver and transmitter scans must be brought into phase before the start of the facsimile transmission, and the correct phase relationship or synchronization must be maintained throughout the message. A common phasing technique involves sending phasing pulses from transmitter to receiver before the start of transmission, where they are compared with locally generated pulses locked to the recording scan. The recorder scan rate is temporarily slowed until the pulses are co-incident. Synchronization during the transmission is achieved by one of three principal methods:

1. Crystal-controlled frequency standard in transmitter and receiver from which the scan rates are derived.
2. Common a.c. mains supply to transmitter and receiver scan drives—which of course precludes international use.
3. Transmission of synchronizing signals, one per line, throughout the message.

Number 1 is the most common, and is used in over 95% of the facsimile systems available today.

10 Manufacturers' Considerations

Present-day facsimile uses a communications system created for speech transmission and developed for almost a century, and must therefore be designed to operate within the constraints imposed by the communications media. Manufacturers' considerations include the following.

10.1 Safety Standards

Unfortunately there is in existence today a multitude of different safety regulations. In most countries there are safety standards to which a machine must conform before installation is permitted. For economic reasons the facsimile manufacturer aims to produce a single machine which meets all these National regulations.

10.2 Modulation System/Transmission

The options available now for analogue facsimile transmission over telephone channels fall into two basic categories, a.m. or f.m. and for years facsimile designers have been arguing the relative merits of these modulation techniques. The use of a.m. over a switched telephone line which has not been optimized for facsimile transmission usually results in random variations in picture quality due to amplitude changes, and therefore requires sophisticated automatic gain control. F.m. is considered to be less sensitive to these effects but it is more sensitive to group delay distortion and needs greater bandwidth. International facsimile standards organizations have, in recent years, recommended f.m. as the most suitable transmission method on the public switched telephone network for a transmission time of 6 min for an A4 document.

10.3 Coupling to Line

An advantage of an acoustically-coupled machine is that it permits instant connexion to the telephone line by means of a push-fit handset. A portable, acoustically-coupled machine may be used wherever there is a telephone and power source. However, characteristics of the telephone handset microphone and the variety of telephone handsets to be catered for often result in inferior copy quality compared with electrical coupling.

10.4 P.T.T. Constraints/Approvals

The facsimile designer and manufacturer, having determined the technical parameters of the machine, must seek approval by the P.T.T. authorities. Prior to granting approval, the P.T.T. would normally check that there is adequate protection from unsafe voltage levels being applied to the line, control of the transmission signal so as not to cause interference with other users' channels, spurious operation of signalling equipment, or overloading of network amplifiers. In the UK, the transmit level must be such that the level at the group switching centre does not exceed −13 dBm. The P.T.T. would also check for: non-interference with the telephone supervisory signalling systems over national, international and intercontinental circuits; correct line terminal impedance/reflexion coefficient; adjustable line hold resistance; capability of operating on the minimum line current; capability of satisfactory performance down to a receive signal level of −40 dBm; provision of an alarm system to prevent engagement of the telephone line as a result of a machine fault; provision of a self-test facility to check the machine transmit and receive circuits without operating over the telephone line or with another machine. In some countries automatic restoration of the telephone to line is mandatory within a preset period after a facsimile transmission has been completed.

The time taken to obtain P.T.T. approval can vary from a few days to two or three years. This often causes considerable complications during manufacture if a number of machine variations have to be produced for particular countries.

10.5 CCITT

Coupled with obtaining national P.T.T. approvals there is the international situation to consider. The International Telegraph and Telephone Consultative Committee (CCITT) is a part of the International Telecommunications Union. It is divided into a number of study groups, one of which deals specifically with facsimile (Study Group XIV). The function of the study groups is to review questions and proposals submitted by members before offering them as recommendations for ratification by a Plenary Assembly meeting every four years. Whilst these recommendations are not considered as rigid standards they do have the semblance of rules. After each Plenary Assembly the CCITT publishes a series of Recommendations which considerably influence P.T.T. authorities in their attitude towards granting approval.

Standards being considered in the current plenary period up to 1976 include: 1. Fast facsimile—for machines operating at up to three minutes using transmission techniques to which the existing recommendations do not necessarily apply. 2. Unattended transmit and receive—the supervisory signals and control techniques to be adopted on an international basis. 3. Digital techniques.

10.6 Compatibility

Compatibility is a major consideration in the design of facsimile products. In a network of facsimile machines it is desirable that any new machine introduced is capable of communicating with the existing population. The majority of office facsimile machines transmit an A4 document in 6 min. A high proportion of the machines in Europe conform to the CCITT recommendations for low-speed facsimile, but this is not true of equipment installed in USA and Japan, where most facsimile systems are to be found. As speeds increase it is important that certain specific speeds are established as a basis on which to build future machines.

Other important compatibility considerations are phasing, synchronization, and unattended supervisory procedures. The problem of maintaining compatibility without constraining technological progress or allowing unit cost to escalate may perhaps be solved by maintaining a minimum standard of compatibility as more features are offered in new machines.

It is on the subject of compatibility that national and international standards may be said to constrain rapid development of advanced facsimile machines. Unquestionably, establishing international standards in the future is going to be extremely difficult. It is encouraging that in the UK the importance of standardization has been recognized, and various manufacturers have over the past four years collaborated and agreed a compatibility standard for existing machines (6 min) which culminated in a revision of the CCITT Recommendation T2 for the standardization of facsimile apparatus for document transmission at the Fifth CCITT Plenary Assembly held in Geneva, December 1972.

11 The Future of Facsimile

We may consider the facsimile market as being divided into two main groups:

(a) the specialized applications such as microfilm, weather charts, police and military, mobile, high resolution photographic—including colour, and high-speed high-volume unattended systems for use mainly on wideband circuits, and

(b) low-volume low-cost systems for use on voice-grade telephone lines, particularly the public switched network.

The second type of system is likely to be the growth area in the near future, because the transmission medium already exists, and most people have access to it. The sort of traffic which will be handled by the small low-cost transceiver will be predominantly black and white office documents—for example line sketches, hand-written forms, and printed alphanumerics. The facsimile unit could become part of a total office system in which information is generated, copied, transferred and stored, and eventually could become as commonplace as the typewriter. Some of the present uses for facsimile systems, for example the transfer of information in banks, stores, airlines, shipping companies and railways, stockbrokers, etc., will develop, and these examples will include high-volume applications requiring complex unattended systems which can take advantage of the 24 hours a day rental of expensive leased wideband channels. Developments in wideband communications arising from greater demand, and leading to availability of switched networks, will no doubt promote this business area.

With regard to the office machine operating on the switched voice-grade network, growth in this sector would be assisted by a lower cost per copy to the user through higher transmission speeds, lower facsimile system and material costs, and compatibility between machines offered by different manufacturers.

As facsimile signalling becomes more complex, to include for example transmission speed information, message identification, and data compression algorithms, the already long list of compatibility features will grow. Perhaps compatibility will eventually be forced upon facsimile equipment manufacturers by P.T.T. authorities setting up their own facsimile services as with telephone, telex and data transmission.

Office facsimile may develop in networks with typically a relatively expensive unattended machine in the central office, and outstations equipped with low-cost manually operated transceivers.

Unfortunately the objectives of higher speed and lower cost tend to be inconsistent unless copy quality is sacrificed, but the trend towards the use of microprocessors could, in the near future, reduce hardware costs. The microprocessor could fill the gap between standard logic and custom-designed large-scale integrated circuits carrying a high development cost penalty. They will benefit the facsimile designer by providing a high degree of adaptability through software programming whilst enjoying the low cost of volume-produced standard products. The microprocessor could provide the dual function of machine housekeeping and video signal processing.

The cheapest copy material is plain paper. Plain paper electrostatic printers tend to be expensive, but the technology of ink recording may eventually provide the breakthrough to low-cost plain paper printing without the need for heat fusing.

Considerably more development is required in new scanning techniques to better the value for money of present-day incandescent-lamp/photoelectric-cell arrangements with mechanical transports. Laser scanners are already on the scene, but their capability of projecting a very small high intensity spot would be lost on low-cost systems with a resolution of 200 lines/in or less.

Self-scan solid-state arrays will no doubt supplement and eventually displace some of the scanners in use now, beginning with line-width arrays and leading to block matrices to read an entire page without mechanical transports. The more advanced scan/print and signal processing concepts will probably materialize first in the specialized systems where high capital or rental costs can be justified by special requirements such as very high resolution.

There will be opportunities to combine facsimile with other services. An example is the Teletext system, evolved by the British Broadcasting Authorities, to which a facsimile receiver could be coupled via a suitable interface to yield a hard copy of the displayed data.

Forecasts of phenomenal growth of the facsimile business, displacing other communications media, are already commonplace. One thing is certain; the facsimile market has the signs of growing to the level at which users will ask the question 'How did we manage without it?'.

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Hazards to inflammable fuels and vapours due to induced microwave radiation

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SUMMARY

Experimental results are presented for the minimum energy required for ignition of various gas/air mixtures in a microwave test cell.

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1 Introduction

Remote ignition of flammable vapours and gases by radio waves is a demonstrable fact: a relatively inefficient receiving structure with simple passive tuning will ignite flammable gases or vapours at a suitable termination. The field strength necessary to produce an incendiary discharge at the receiver terminals may be considerably less than the minimum level for a known biological hazard.

Although a detonation initiated by radio frequency radiation could lead to very serious consequences, and prior to the introduction of the British Standards Guide BS 4992 no general safety regulations were available in the UK, good management and general care by the oil companies and others seem to have averted any such disaster to date.

An exhaustive search of available literature has produced only one report of a small fire having been started accidentally by electromagnetic radiation.[1] One other possible case has never been verified despite several attempts to do so.[2] However, several mysterious fires have occurred in electromagnetic environments,[3, 4, 5, 6] and there have also been several reported incidents of hazardous sparks and arcs which could not have been caused by static electricity and where a strong electromagnetic environment existed.[7, 8, 9, 10, 11]

This investigation is concerned with the possibility of inadvertent extraction of energy from an electromagnetic field propagated from a microwave radar transmitter or other similar transmitter and presentation of this energy to a flammable vapour or gas in a manner able to initiate ignition or explosive reaction. There have been few experimental studies of the ignition of various gases or vapour/air mixtures caused by sparks produced by pulsed microwave sources.[8, 12] From the available material it was impossible to deduce general results, which was the reason for the programme to be described. Indeed it had previously been necessary to assume that minimum ignition energies for d.c. and microwave sources were the same in order to determine safety standards. Only worst case conditions at n.t.p. are considered at this stage.

A microwave test cell has been developed as shown in Fig. 1, in which power fed into the cell induces a field across the electrode gap, and the intensity is increased until breakdown occurs across the gap. The initial glow

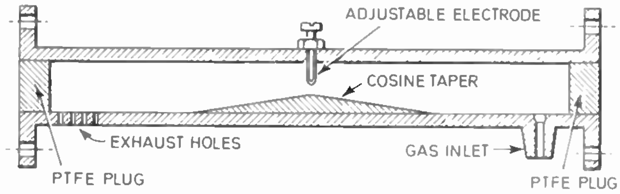


Fig. 1. The test cell.

discharge may become an arc discharge if the discharge temperature is sufficiently high. Energy is transferred from the spark to the surrounding gas molecules by heat radiation and collisions resulting in combustion of gas with oxygen which in turn releases more energy.

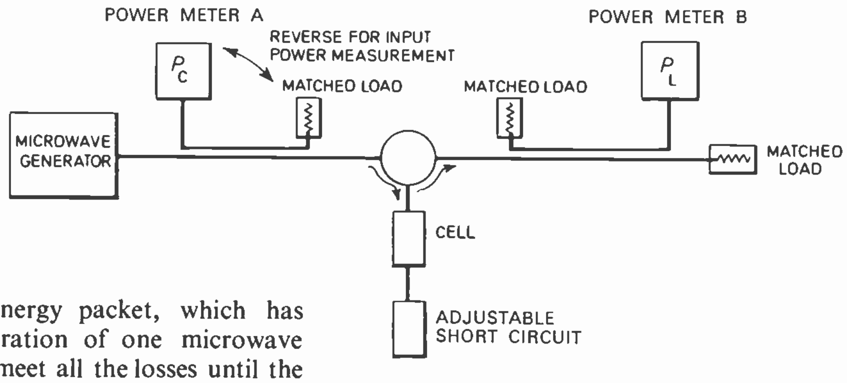


Fig. 2. Measuring set-up.

Ignition occurs when the energy packet, which has been released within the duration of one microwave pulse, is sufficient at least to meet all the losses until the flame kernel has reached its critical diameter some tens of microseconds later.[13] Self-propagating combustion can then occur. In short duration discharges the electrochemical interchange of energy is confined to the lifetime of the arc. Optimization of the electrical energy transfer is dependent on source power, impedance, frequency and electrode material and geometry.[14] It seemed likely from a comparison of our results with published direct current minimum ignition energies, that the system used is representative of the worst possible practical case.

The effects of initial temperature and pressure on d.c. ignition levels are well documented and since the mechanisms affected are the same there is no reason to suppose that the effects are different for high frequency ignition levels.

2 Experimental Results

Measurements of the minimum X-band peak power required to ignite various gases have been carried out. The initial series of experiments showed up weaknesses in the design of the test cell, but established the practicability of the programme reported here.

The microwave test cell, Fig. 1, consists of a section of WG16 waveguide, the two electrodes being respectively a 6BA screw with a rounded end protruding into the guide and a cosine taper wedge within the guide. The gas is contained in the cell by PTFE plugs in the waveguide, and in the latest version of the cell, holes at the bottom of the guide release the pressure due to explosions. One complete turn of the screw will result in moving it through a distance of 0·53 mm. The procedure for adjustment of spark gap is as follows. The probe is screwed until it touches the cosine taper. It is then unscrewed a predetermined number of turns that will give the required gap. The cell is similar in design to that of earlier workers.[8]

The final experimental equipment is shown in Fig. 2. The microwave generator used is a 900 p/s 0·7 μs 20 kW peak pulse power Decca Radar source. The output from the microwave generator measured by power meter A is fed into the cell via a directional coupler and circulator. The cell is followed by an adjustable short-circuit to reflect all the power back to the cell. By properly adjusting the short circuit it is possible to move the field pattern such that maximum field intensity occurs at the spark gap. Power leaving the cell is routed by the circulator to a matched load through a directional coupler; this makes measurement of output power (from the cell possible. Since the microwave circuit is terminated in a matched load no power should be reflected back to the source. Practical measurement of power reflected back to the source showed that it is less than 0·4% of the incident power. Power entering the cell is determined by measuring power entering the circulator and subtracting the power lost in the circulator. Power leaving the cell is determined by measuring the power going to the matched load to which is added losses in the cell and circulator.

Thus, if the power incident onto the circulator is denoted by P_C then power incident on the cell is given by

$$P_I = P_C/\alpha_C \tag{1}$$

where α_C is a constant greater than unity determined by the loss in the circulator. Also if the power incident on the matched load be denoted by P_L then output power from the cell P_O can be written as

$$P_O = \alpha_C P_L \tag{2}$$

Losses in cell under no spark conditions

$$= P_I - P_O = P_C/\alpha_C - \alpha_C P_L$$
$$= P_N$$

Let the power incident on the load and the output power from the cell under spark conditions be, respectively, P_{Ls} and P_{Os}, then

$$P_{Os} = \alpha_C P_{Ls} \tag{3}$$

Therefore, power in spark

$$P_s = P_I - P_{Os} - P_N = P_C/\alpha_C - \alpha_C P_{Ls} - P_C/\alpha_C + \alpha_C P_L$$

i.e.

$$P_s = \alpha_C (P_L - P_{Ls}) \tag{4}$$

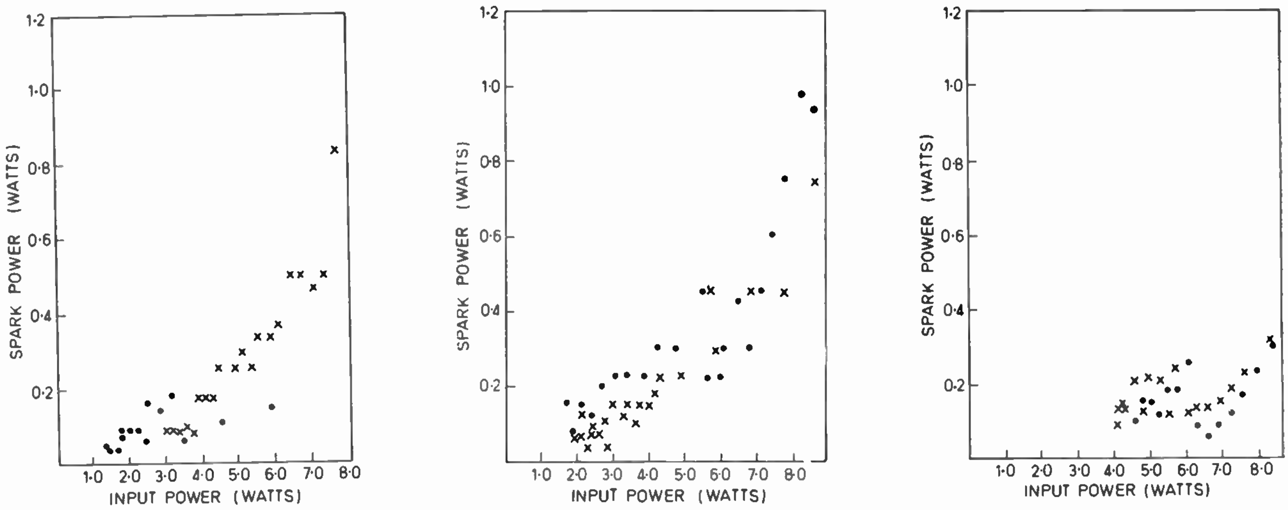
The estimated error is between 0·01 and 0·003W.

The above method was used to measure the minimum ignition power for the following gases and fuels:

(i) hydrogen, (ii) propane, (iii) methane, (iv) ethylene, (v) carbon disulphide.

Plots of spark power versus input power for the first four of the above gases and for different spark gaps are given in Figs. 3 to 6. The dots and crosses refer to the outcome of two different experiments.

The results show a non-linear relationship between input and spark power, with a minimum input power below which no ignition was obtained. For small



(a) Spark gap = 1·06 mm.

(b) Spark gap = 1·59 mm.

(c) Spark gap = 2·12 mm.

Fig. 3. Spark power versus input power for hydrogen.

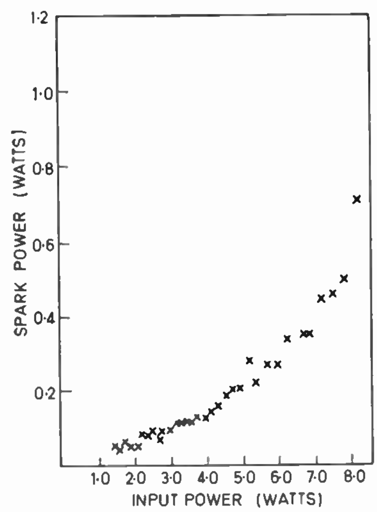


Fig. 4. Plot of spark power versus input power for ethylene. Spark gap = 1·06 mm.

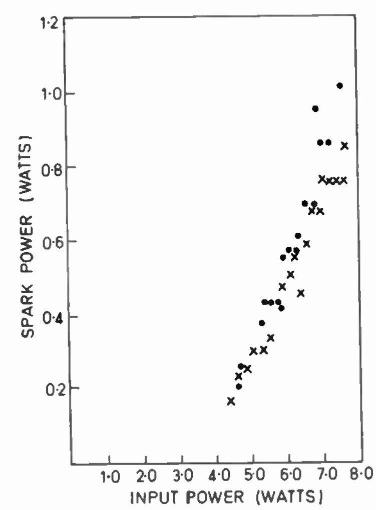
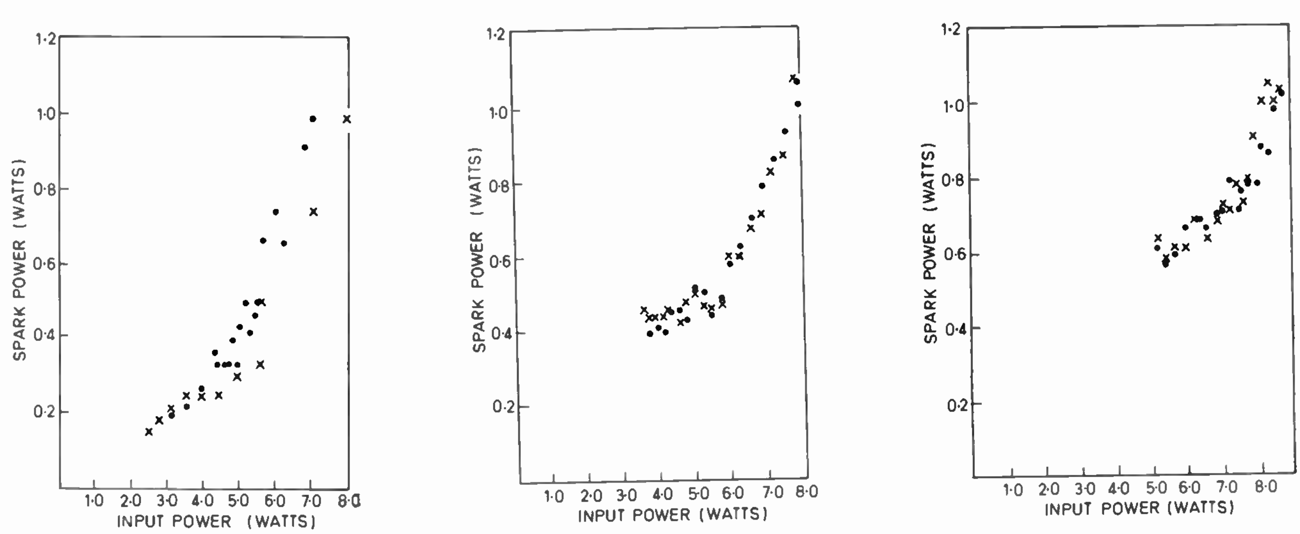


Fig. 6. Spark power versus input power for methane. Spark gap = 1·06 mm.



(a) Spark gap = 1·06 mm.

(b) Spark gap = 1·59 mm.

(c) Spark gap = 2·12 mm.

Fig. 5. Spark power versus input power for propane.

Table 1. Minimum spark power for different gaps. (All powers in watts)

Spark gap (mm)	Hydrogen Min. spark power	Hydrogen Min. input power	Ethylene Min. spark power	Ethylene Min. input power	Propane Min. spark power	Propane Min. input power	Methane Min. spark power	Methane Min. input power	Carbon disulphide Min. spark power	Carbon disulphide Min. input power
0·53	—	—	—	—	—	—	—	—	0·015	0·62
1·06	0·015	1·38	0·047	1·5	0·148	2·5	0·168	4·5	0·015	0·74
1·33	0·032	1·46	0·062	2·6	0·158	2·9	0·198	5·0	0·047	1·05
1·59	0·030	1·7	0·100	1·61	0·245	3·7	0·33	4·5	0·078	1·33
1·86	0·015	3·0	0·122	1·8	0·305	3·9	0·351	4·9	0·047	1·57
2·12	0·039	4·0	0·136	2·3	0·540	5·2	0·58	6·0	0·155	1·83
2·39	0·049	4·7	0·180	2·7	0·610	5·4	0·81	6·6	—	—

gaps (1 mm) the minimum ignition power was smallest. Table 1 summarizes the results as does Fig. 7. In all cases the most inflammable mixture of gas and air was chosen experimentally.

The ignition energy can be simply determined from the results in Table 1 if it is assumed that a single pulse is involved in the ignition process. The results of earlier workers[3] tend to confirm this. The Midwest Research Institute, in their X-band ignition experiments with JP4 and aviation gasoline, found an increase in average spark power for ignition when the pulse repetition rate was increased, but none when the pulse duration was increased. If our assumption that ignition by a single pulse is correct it follows that ignition energy was constant throughout Midwest's experiments. The results from these earlier tests are rather inconclusive, but support an argument which seems reasonable on the grounds of the likely duration of the spark in any case, since this may be significantly shorter than the shortest pulse.

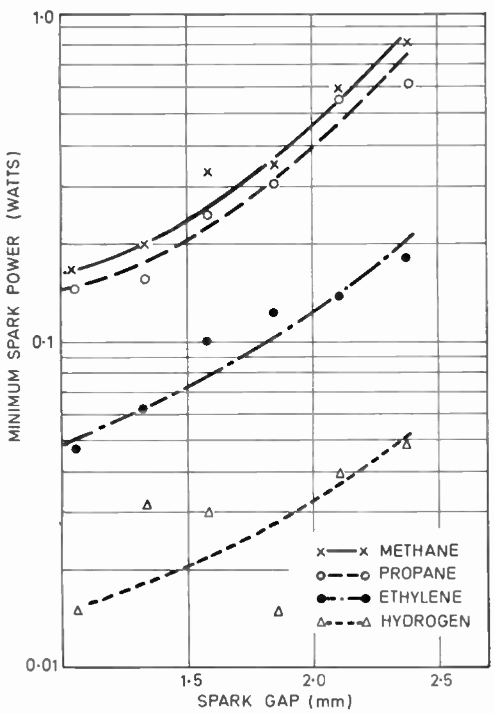


Fig. 7. Minimum spark power for different spark gaps.

Table 2 gives a comparison of X-band and d.c minimum ignition energies. The X-band figures are derived from the smallest values of average spark power in Table 1. It is of interest to note that the measured levels are less than those for d.c. sparks.

$$\text{m.i.e. (minimum ignition energy)} = P_s(\text{peak}).t \qquad (5)$$

$$= \frac{P_s(\text{avge}).T}{t}.t$$

$$= \frac{P_s(\text{avge})}{\text{pulse rep. freq}}. \qquad (6)$$

where P_s(peak) = peak spark power
P_s(avge) = average spark power
t = pulse duration
T = reciprocal of pulse repetition frequency.

From Figs. 3(a), 4, 5(a) and 6 it is seen that ignition of hydrogen, ethylene, propane and methane can be achieved with a spark gap of 1·06 mm. In fact it was possible to ignite these fuels at a spark gap of 0·53 mm. The results of these ignitions are not included since measurement of powers was impossible due to a continuous arc formed between electrodes. However, evidence from other workers[8] suggests that the power required for ignition at these small gaps is greater than for the 1·06 mm gaps. They showed that with aviation gasoline/air mixtures ignition at a gap of 0·7 mm

Table 2. Minimum ignition energies ($\times 10^{-4}$ joules)

Gas	X-band Measurement at Bradford	D.C. Measurements
Hydrogen	0·167	0·19†
Ethylene	0·52	0·96‡
Propane	1·64	2·5‡
Methane	1·87	2·9‡
Carbon disulphide	0·167	0·09†

† Calcote, C. A., *et al.*, *Indus. Eng. Chem.*, **44**, No. 11, pp. 2656–62, November 1952.

‡ Ballistic Research Lab., Report No. 1496, September 1970.

required considerably more source power than at 1·4 mm in a similar X-band cell.

D.c. measurements of quenching distances yielded results as given in Table 3. It therefore appears possible to achieve X-band ignitions at gaps significantly smaller

Table 3. Minimum gap for ignition (m.i.g.) compared with quenching distance

Fuel	M.I.G. (mm)	Quenching distance (mm)
Hydrogen	<0·27	0·6
Ethylene	<0·53	1·3
Propane	<0·53	1·9
Methane	<0·53	0·8
Carbon disulphide	<0·53	0·55

than the quenching distances. This is also possible at d.c. with the particular electrode configuration chosen, although the minimum ignition energy then increases. There is no evidence of a different mechanism operating in our microwave experiment.

3 Conclusions

It has been shown that the minimum energy required for the ignition of a number of gas/air mixtures is not significantly different from the d.c. figures when the power source is a 9·395 GHz pulsed radar transmitter. The minimum energy for ignition was calculated from the measured minimum power, assuming that a single radar pulse was involved in the ignition. The results on propane/air mixtures can be compared with those of other workers[8] on gasoline/air mixtures, and suggest the Bradford cell was more sensitive than earlier equipment, since ignitions were achieved with a minimum input power of 2·5 W, and spark power of 0·15 W compared with the published figures of 6·7 W and 0·9 W respectively.

If the results of Table 2 are accepted, this work can form the basis of a study to predict what levels of available powers and spark powers are hazardous in the 1–10 GHz band. This will require a determination of the form of likely parasitic antennae, and is outside the scope of this investigation.

Such results as are available at C-band[8]—6·48 GHz—do not depart significantly from those at X-band.

4 Acknowledgments

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An automatic clarifier for s.s.b. speech communication

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SUMMARY

By introducing certain inaudible distortion into the audio wave-forms used to modulate an s.s.b. transmitter it becomes possible to detect any frequency translations in the system. Audio frequency circuits in the receiver generate an a.f.c. voltage proportional to any such translation, and and this is used automatically to correct the frequency of the local carrier generator without the need for pilot tones or carrier. At present the system has a lock-in range in excess of $\pm$ 200 Hz, and a locked-in error of a few hertz. It may make practicable s.s.b. operation at v.h.f, as well as simplifying the operation of h.f. equipment.

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1 Introduction

Single-sideband transmissions are now widely used, particularly in the h.f. band. Relative to a.m., this type of modulation occupies a smaller bandwidth, gives improved signal/noise ratio (where noise is predominantly white) and is resistant to the effects of selective fading.[1] The full advantages of the system result when the carrier is suppressed. Thus demodulation depends on the generation of a carrier in the receiver, and it is well known that the frequency of this carrier must be close to that of the original if correctly demodulated audio is to be obtained. Specifically, the frequency error should be less than about 25 Hz for good speech quality and less than 5 Hz for music.

The need for this frequency stability has led to widespread adoption of crystal-controlled receivers, and a means for manual fine adjustment of the local oscillator is commonly provided (a 'clarifier'), to permit the operator to trim the frequency to give an audibly acceptable result. In this way the frequency stability specification is moderated and costs reduced. If such a clarifier could be made automatic in operation, however, receivers would be easier to operate.

It is easily possible to incorporate a.f.c. in an s.s.b. system if either a substantial carrier or an a.f. tone (outside the range of the normal modulation) is radiated, but this is wasteful of transmitter power, extends the signal spectrum, and increases electromagnetic pollution. It is thus not wholly acceptable, and attention has been directed to alternative methods of a.f.c. derived from the normally radiated modulation. Villard[2] has described a technique based on comparison of the output of the product s.s.b. demodulator with that from an envelope detector. The latter, although severely distorted, does contain Fourier components at the same frequencies as the correctly demodulated signal (as well as others) and may therefore be phase-compared with the product demodulated signal to yield an a.f.c. voltage. The method is ingenious and has the advantage that no modification of the radiated signal is required, but fails because the phase locking tends to occur as easily to harmonics as to the fundamental of the frequencies being compared, and thus locks with a large frequency offset occur.

Recently Gosling[3] proposed a new a.f.c. system for s.s.b., based on the detection of inaudible distortion introduced into the modulating signal at the transmitter. This paper describes the principles of operation of such a system and practical results achieved applying it to a simple military s.s.b. h.f. transceiver. Successful frequency locking was obtained, with a residual error of the order of a few hertz.

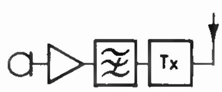
2 Subliminal Distortion of Speech

It has long been known that certain distortions of speech waveforms can be introduced without loss of intelligibility and Hill[4] has considered using deliberately introduced distortion as a means of subliminal signalling. For present purposes it is desired to detect a frequency translation in the demodulated signal, and the most useful approach is to introduce a narrow stop band into the middle of the speech spectrum. Hill's results, which are in excellent agreement with earlier work,[5,6] indicate that a stop band a few hundreds of hertz wide introduced at the middle or in the upper half of the speech spectrum can produce little perceptible degradation of speech. In terms of EBU impairment grades, for a stop band centred at 1 kHz, Hill found impairment just perceptible for a stop band 100 Hz between −3 dB points (maximum attenuation 50 dB). Impairment increased up to EBU grade 4 at a stop band width of 450 Hz. EBU impairment grade 4 is defined as 'somewhat objectionable' while grade 3 is 'definitely perceptible but not disturbing'. Even at grade 4 there is no measurable effect on speech intelligibility.

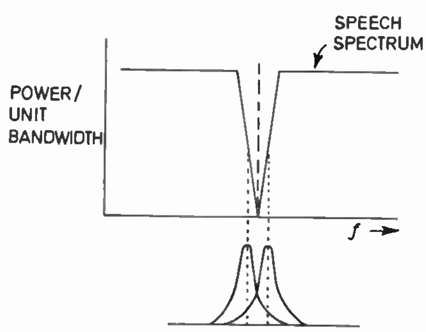
For the automatic clarifier it was decided to centre the speech stop-band at 1·6 kHz, as occurring at about the centre of the spectrum of communications quality speech. A stop band 300 Hz wide was found to give no perceptible reduction in the intelligibility of either male or female speech in a 300 Hz–3 kHz bandwidth. It proved impossible for listeners to determine reliably whether the filter was or was not in circuit.

3 Principles of the Automatic Clarifier

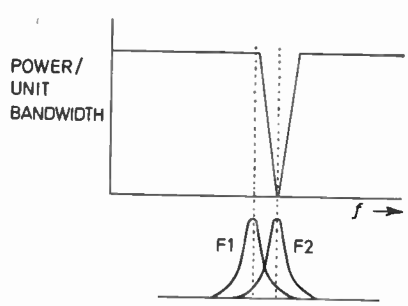
The modification required to the s.s.b. transmitter (Fig. 1(a)) is the incorporation of an audio band-stop filter before the modulator. As a result a stop-band is introduced into the speech spectrum (Fig. 1(b)).



(a) Transmitter block diagram.



(b) Demodulated speech spectrum with correctly aligned receiver filters (F1 and F2).



(c) Effect of a frequency translation of the demodulated spectrum.

Fig. 1

After transmission and demodulation, the spectrum may have suffered a frequency translation. The receiver detects the frequency translation and generates an a.f.c. signal, which can be used to 'pull' a voltage controlled oscillator toward the correct frequency, hence reducing the frequency error in the demodulated signal. One form which the receiver circuits take (Fig. 2) utilizes two band-pass filters F1 and F2. These have a narrow pass band and are centred on either side of the audio band stop. When there are no frequency errors in the system F1 and F2 give equal response (Fig. 1(b)), but if a frequency translation occurs (Fig. 1(c)) the output magnitude of the two filters is no longer equal. Thus the two outputs from the filters can be rectified and the difference will be usable as an a.f.c. voltage.

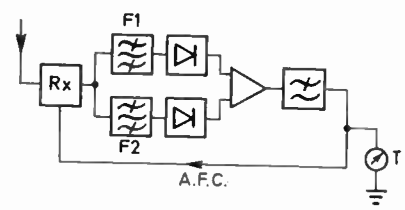


Fig. 2. Receiver block diagram.

To simplify the analysis of the system, a quasi-linear model of the transmitter band stop filter response (Fig. 3) is adopted, in which the attenuation (in decibels) increases linearly in the frequency range $\omega_0-\Delta\omega$ to ω_0, the centre frequency, and decreases again to $\omega+\Delta\omega$. This response is not too far from that of an actual filter, except that the latter would have a more rounded response curve. If $r(\omega)$ is the voltage transfer ratio of the filter, then the quasi-linear model leads to

$$r(\omega) = 1 \quad \text{for } \omega < \omega_0-\Delta\omega \text{ and } \omega > \omega_0+\Delta\omega \tag{1}$$

$$r(\omega) = \exp\{-a(\omega_0-\Delta\omega-\omega)\} \quad \text{for } \omega_0-\Delta\omega < \omega < \omega_0 \tag{2}$$

and

$$r(\omega) = \exp\{a(\omega_0+\Delta\omega-\omega)\} \quad \text{for } \omega_0 < \omega < \omega_0+\Delta\omega \tag{3}$$

where $a = \{L/20\} \log_e 10$,

L = rate of change of attenuation (dB/rad.s^{-1}).

So far as the receiver filters are concerned, it is obvious that responses well removed from the stop-band frequency cannot contribute to the a.f.c. voltage, but may,

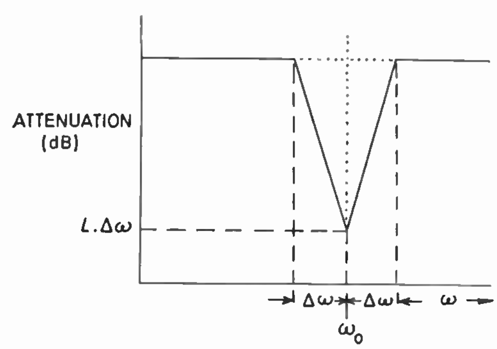


Fig. 3. Quasi-linear approximation to the band-stop filter characteristic.

due to the fluctuating nature of speech, result in a noise component added to the a.f.c. voltage. Evidently a very narrow band pass response is required, with minimal skirt response. It will be convenient, therefore, to approximate the receiver filters by assuming that they are of negligible bandwidth and have zero stop-band response. F1 will be taken as having its pass band at $(\omega_f - \varepsilon)$ and F2 at $(\omega_f + \varepsilon)$. When the system is correctly aligned $(\omega_f = \omega_0)$ the output of F1 and F2 will be equal if the speech spectrum is constant in the region of ω_0.

Under these conditions the a.f.c. voltage is proportional to y, where

$$y = |F_1(\omega).r(\omega)| - |F_2(\omega).r(\omega)| \quad (4)$$

Hence, writing for the frequency error Ω, where

$$\Omega = \omega_f - \omega_0$$

it is possible to calculate y as a function of Ω in four distinct frequency ranges (assuming $\varepsilon < \Delta\omega$).

(a) for $\Omega < -\Delta\omega - \varepsilon$

$$y = 0 \quad (5)$$

(b) for $-\Delta\omega - \varepsilon < \Omega < -\Delta\omega + \varepsilon$

$$y = 1 - \exp\{a(\Delta\omega + \varepsilon)\}\exp(-a\Omega) \quad (6)$$

(c) for $-\Delta\omega + \varepsilon < \Omega < -\varepsilon$

$$y = -2\exp\{a(\Delta\omega + \Omega)\}\sin h(a\varepsilon) \quad (7)$$

(d) for $-\varepsilon < \Omega < +\varepsilon$

$$y = -2\exp\{a(\Delta\omega - \varepsilon)\}\sin h(a\Omega) \quad (8)$$

This defines y for $\Omega < 0$. By inspection the function is antisymmetric, thus for $\Omega > 0$,

$$y(\Omega) = -y(-\Omega)$$

Equations (5) to (8) can be used to plot the error (or 'S') curve of the a.f.c. system (Fig. 4). The practical error curve will be similar, but with rounded corners. It will be noted that the error voltage falls to zero for $|\Omega|$ greater than $\Delta\omega + \varepsilon$. This represents the maximum attainable lock-in range of the system. Again in practice a slightly greater lock-in range is obtained, because the a.f.c. voltage does not fall quite to zero at this frequency. The slope of the curve near the origin tends to

$$\left\{\frac{dy}{d\Omega}\right\}_{\Omega=0} = a\exp\{a(\Delta\omega - \varepsilon)\} \quad (9)$$

It is thus dependent on the maximum insertion loss of the band stop filter, to which a is proportional. Evidently this should be large, but a practical limit is set by the noise level of the receiver, which sets a lower limit to the 'floor' of the stop band. Although the transmitter band-stop filter may be designed, typically, for a 40 dB maximum insertion loss, the demodulated signal will show a trough in its power spectrum no more than 20 dB deep if the signal/noise is 20 dB.

Implicit in these calculations is also the assumption that the power spectral density function of the signal before the band-stop filter is approximately constant near ω_0. If this is not so the y/Ω error curve will become asymmetrical and the zero of y and Ω will no longer coincide. For speech spectra such as are normally encountered the shift of zero is insignificant, but asymmetrical lock-in range is frequently observed.

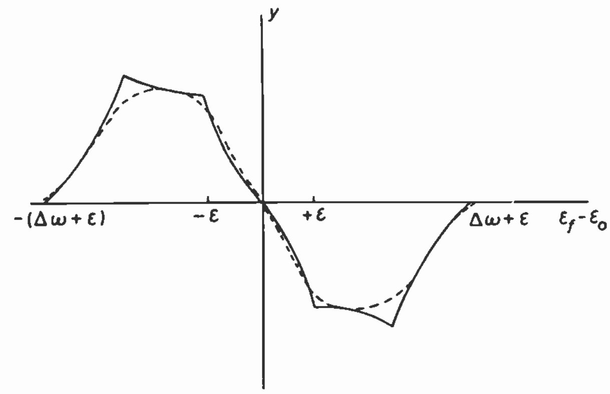


Fig. 4. Calculated 'S' curve (Practical curve shown dotted).

The 'S' shape of the error curve indicates that satisfactory a.f.c. voltage will be generated, and with sufficient loop gain the local oscillator will lock to its correct value to within a calculable error. In addition to this static offset, however, there will also be a noise component on the a.f.c. line. This arises because of intensity fluctuations in the signal occurring differentially at the frequencies of F_1 and F_2. There appears to be no published information on the correlation between the spectral density function of speech at two relatively close frequencies within the audio band, but the correlation might be expected to be high, in which event a.f.c. noise will be low. This is borne out experimentally.

4 Design Details

The block diagrams already given define the automatic clarifier: in practical terms there are many ways in which they can be realized and a number have been investigated.

Satisfactory band-stop filters for incorporation in the transmitter have used twin-T networks in feedback configurations and simulated inductance networks. One of the latter was described by Harris.[8] A typical circuit is shown in Fig. 5. Here the lower operational amplifier is used to simulate inductance so that a selective bridge type of circuit can be used to obtain the required null. Typical frequency response of this filter is shown in Fig. 6. The characteristics of the filter are maintained

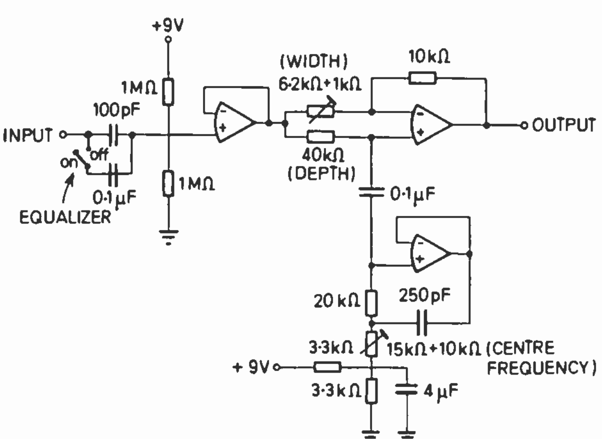


Fig. 5. Band stop filter, with spectrum pre-emphasis input circuit. (Amplifiers type 741).

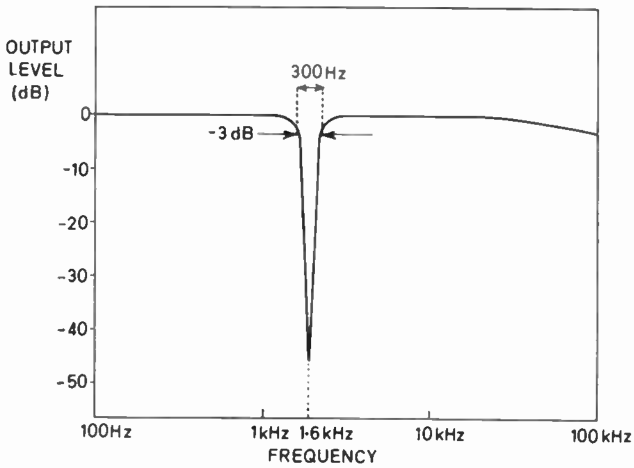


Fig. 6. Measured band-stop filter characteristics.

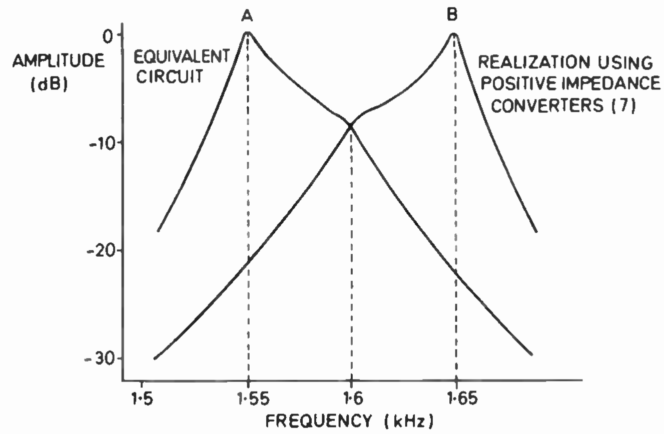


Fig. 8. Practical receiver filter characteristics.

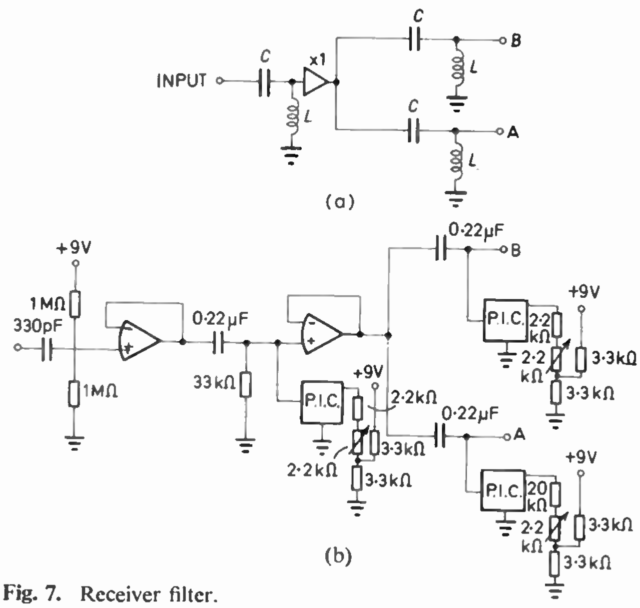


Fig. 7. Receiver filter.
(a) Equivalent circuit.
(b) Realization using positive impedance converters.

for signals up to 560 mV peak, beyond which limiting occurs and the stop band rejection rapidly decreases.

So far as the receiver circuits are concerned, assuming the block diagram of Fig. 2, the principal problem is the realization of the narrow band-pass filters F1 and F2. Here again simulated inductors have been used successfully, based on the positive impedance converters described by Antoniou,[7] (Fig. 7). To obtain small skirt responses the filters are preceded by a resonant circuit at 1·6 kHz, and after a buffer amplifier (which serves to isolate them from each other and from the preceding circuit) F1 and F2 are in the form of single resonant circuits tuned to 1·55 and 1·65 kHz respectively. The overall response is indicated in Fig. 8. The subsidiary peak of response at 1·6 kHz in each channel is unimportant, since it produces no differential output.

Thus the complete circuit of the receiver clarifier is as in Fig. 9. The filter section is preceded by a buffer amplifier, and each of the two outputs is also buffered before rectification, to avoid loading the filters. The outputs from the two rectifiers are combined in a summing amplifier which has a gain of × 100, and therefore limits on receiver frequency deviations of greater than

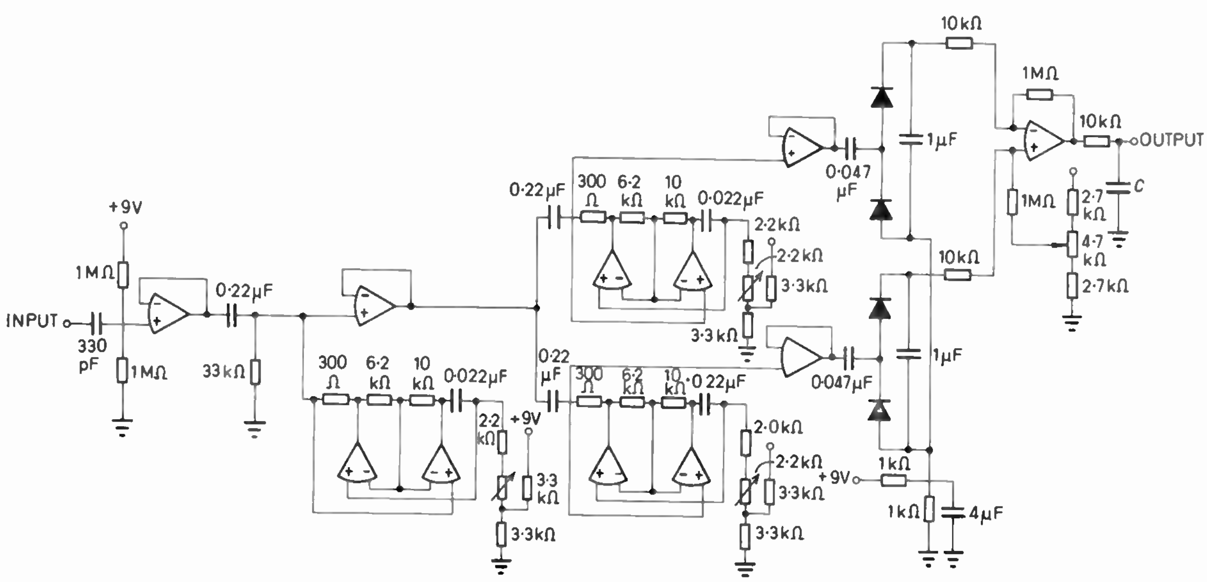


Fig. 9. Full receiver automatic clarifier circuit. (Amplifiers type 741).

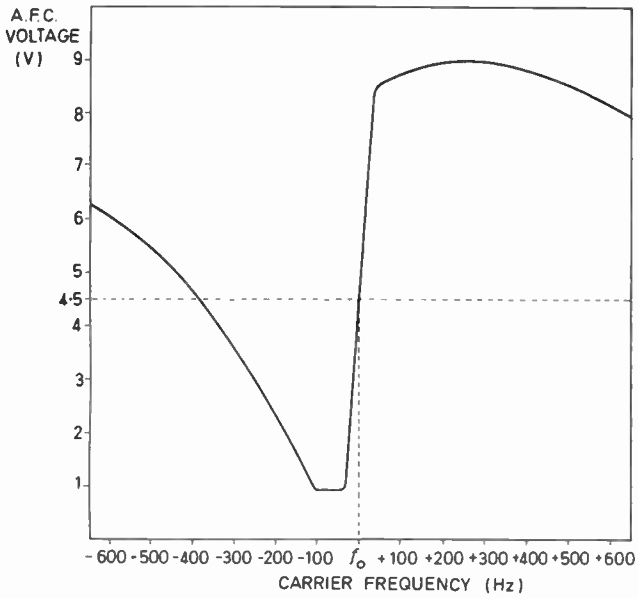


Fig. 10. Measured 'S' curve (pre-emphasized male speech).

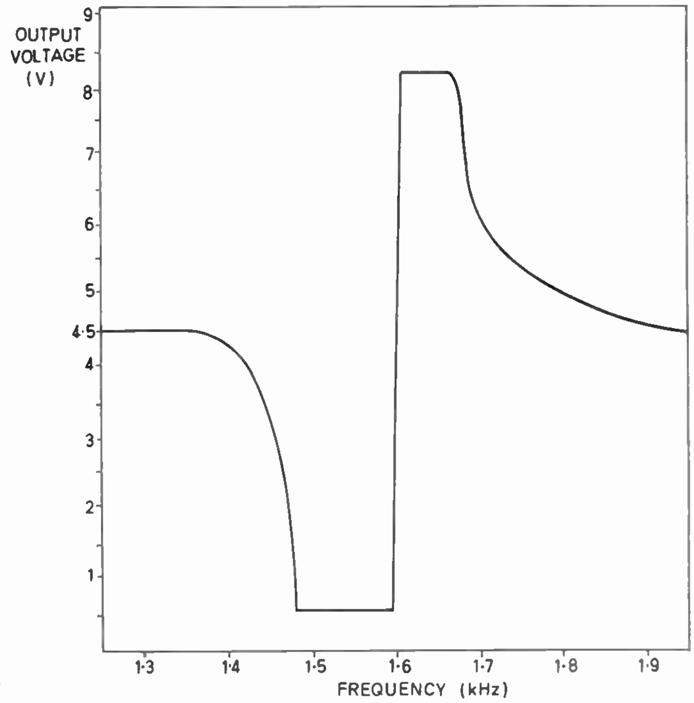


Fig. 11. Measured 'S' curve (noise).

a few hertz. The amplifier is followed by a passive integrator with a time-constant chosen to give adequate suppression of a.f.c. noise without being long enough to give poor transient response when locking in.

A typical error curve obtained with the system transmitting male speech pre-emphasized +6 dB per octave is shown in Fig. 10. The asymmetry suggests that a more modest degree of pre-emphasis would have been preferable, but in practice some asymmetry in lock-in range is not an important disadvantage. The circuit is designed to operate from a 9 V supply, and thus +4·5 V is the effective zero of the system. As predicted, the skirts of the error curve are modified in shape by the non-ideal shape of the filter characteristics and the speech spectrum. By comparison (allowing for limiting in the summing amplifier) the error curve obtained passing white noise through the system (Fig. 11) is more in accord with theoretical prediction.

A.f.c. noise is very small, as shown in Fig. 12 for C = 10 μF. For this measurement, which was made when the clarifier was operating on a white noise 'signal'

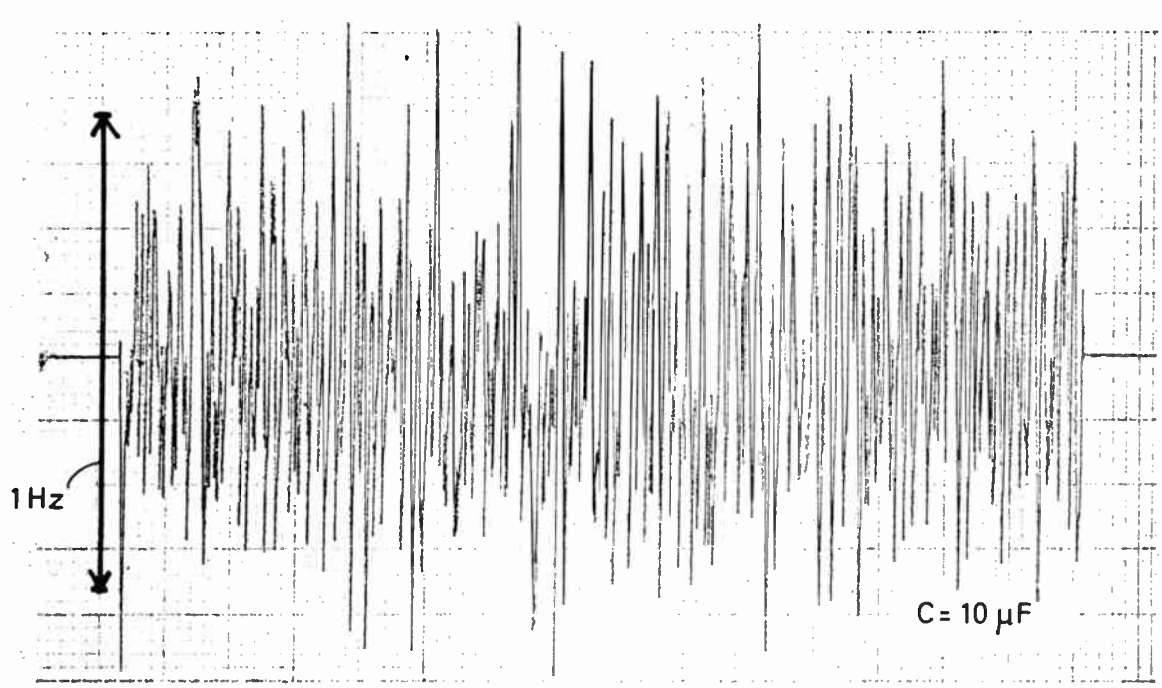


Fig. 12. A.f.c. line noise when locked to a received signal (vertical scale in equivalent frequency offset).

(with band stop), the noise amplitude had been expressed in terms of equivalent frequency offset, since this is the significant parameter, and it will be seen that the noise has a peak amplitude only occasionally in excess of 0·5 Hz. It is difficult to give similar curves for speech because the noise is masked by inter-word transients.

The clarifier was incorporated in h.f. s.s.b. transceivers (Racal Communications Limited, type TRA 906). These are relatively simple portable equipments intended for military use. Unfortunately the local oscillator has a pulling (clarifier) range of -150 to $+80$ Hz, so it was not possible to check the system over its full lock-in range. However, with the locking range of which the transceiver was capable, the automatic clarifier gave immediate locking for both male and female voices. The frequency error when locked was too small to be detected by ear, and of the order of a few hertz, depending on receiver gain control settings and the initial frequency offset.

5 Discussion

It has been demonstrated that a practicable automatic clarifier for suppressed carrier s.s.b. can be made to operate using a speech stop-band. At present the static error resulting is imperceptible and it may be that some deterioration in this respect would be acceptable to secure an increase in the capture range of the system. It must, however, be borne in mind that the a.f.c. noise level will increase with falling S/N ratios, and it is essential that the a.f.c. system should continue to give acceptable results down to the lowest acceptable voice S/N ratios (perhaps 10 dB).

It is obvious by inspection of Fig. 10 that the lock-in range could be greater than ± 200 Hz with a local oscillator capable of being pulled over a larger range, and still greater lock-in ranges could be achieved by increasing the width of the stop band. Provided that the rate of increase of attenuation at the edges of the stop band is not too rapid loss of intelligibility remains slight. Preliminary indications are that a lock-in range of at least ± 400 Hz is practicable.

The effect on the clarifier of interference from unwanted transmissions is a matter of concern, given the present state of congestion of the h.f. bands. It will be noted that the combined response of filters F1 and F2 is 20 dB down at ± 500 Hz relative to 1·6 kHz, and thus the system is insensitive to interference outside this range. Noise, or noise-like signals such as speech, which have a reasonably uniform spectrum in this range will not cause a frequency offset, but will reduce the a.f.c. loop gain and increase a.f.c. noise. More serious is the effect of a carrier or other c.w. signal. This can cause an offset of frequency, depending on the relative power of signal and interference. However, its effects will only be significant if it falls within the stop band of the transmitted signal ($\omega_0 \pm \Delta\omega$).

Experimentally, the frequency deviation caused by tuning a carrier through the band-stop frequency was investigated for a number of carrier/signal power ratios. The 'signal' consisted of white noise, and to detect frequency offset a sinusoid was added of the same r.m.s. value and at a frequency (750 Hz) sufficiently remote from the stop band that it had no effect on receiver locking. A carrier was then tuned through the stop band frequencies and the variation in frequency of the received 750 Hz tone was measured. Figure 13 is a plot of the peak value of this perturbation against signal/interfering carrier power ratio. The offset only reaches an appreciable value when the carrier is of the same order as the received signal.

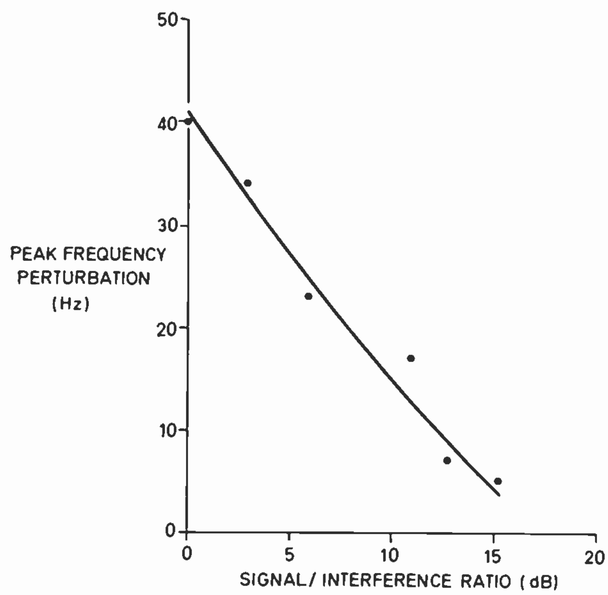


Fig. 13. Peak value of received signal frequency translation as an unmodulated sinusoid is tuned through the stop band of the signal. (Plotted against signal/interference ratio.)

Because the system locks on to speech it should not be assumed that it loses lock between words. There will often be enough residual white noise entering the transmitter modulator to hold the receiver weakly in lock during the inter-word silences. This has the effect of eliminating locking transients at the beginning of words. Noise locking of this type is virtually certain to occur if a VOGAD is used in the transmitter audio circuits.

The automatic clarifier described overcomes one of the principal practical disadvantages of s.s.b. speech communication. It may also make possible the use of s.s.b. at v.h.f., where present-day crystal oscillator stability is hardly adequate for s.s.b. operation without a.f.c.

For example, it is known that the typical drift of crystal controlled oscillators in land mobile radio equipment is ± 3 parts in 10^6 for the newer temperature compensated crystals now coming into use. Amounting to ± 300 Hz at 100 MHz, this offset precludes the use of s.s.b. without a clarifier, and manual adjustment is not acceptable in vehicle use. The automatic clarifier should have adequate lock-in range for v.h.f. operation, however. It is interesting to speculate whether this could make possible 6·25 kHz wide channel allocations (in place of the present 12·5 kHz) with a consequent doubling in the number of available speech channels.

Trials of the automatic clarifier in a v.h.f. s.s.b. land mobile system are under way, and results will be published in due course.

6 Acknowledgments

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Standard Frequency Transmissions—December 1975

(Communication from the National Physical Laboratory)

December 1975	Deviation from nominal frequency in parts in 10^{10} (24-hour mean centred on 0300 UT)	Relative phase readings in microseconds NPL—Station (Readings at 1500 UT)	
	Droitwich 200 kHz	*GBR 16 kHz	†MSF 60 kHz
1	−0·2	697·8	612·2
2	−0·2	698·3	612·5
3	−0·2	698·7	612·2
4	−0·2	698·3	612·4
5	−0·2	698·8	612·4
6	−0·2	698·2	612·4
7	−0·2	698·3	612·5
8	−0·2	700·4	612·4
9	−0·2	698·2	612·6
10	−0·2	698·2	612.0
11	−0·2	696·8	612·0
12	−0·2	697·4	611·9
13	−0·2	697·8	612·0
14	−0·2	699·9	612·0
15	−0·2	699·7	612·2
16	−0·2	697·5	612·0
17	−0·2	698·7	611·9
18	−0·2	698·0	612·2
19	−0·1	698·0	612·2
20	−0·1	699·1	612·2
21	0	698·5	612·1
22	−0·1	697·2	612·1
23	−0·1	695·6	612·0
24	−0·1	696·6	612·1
25	−0·1	695·9	612·2
26	−0·1	697·8	612·1
27	−0·1	697·4	612·2
28	−0·1	696·4	612·2
29	−0·1	698·2	612·3
30	−0·1	698·0	612.3
31	−0·1	698·3	—

All measurements in terms of H-P Caesium Standard No. 344, agrees with the NPL Caesium Standard to 1 part in 10^{11}.

* Relative to UTC Scale; (UTC_{NPL}–Station) $= +500$ at 1500 UT 31 December 1968.

† Relative to AT Scale; (AT_{NPL}–Station) $= +468{\cdot}6$ at 1500 UT 31 December 1968.

UDC 681.322: 681.327

A peripheral-sharing interlinked mini-computer system

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SUMMARY

The system described allows several interlinked mini-computers to communicate with each other and to share a range of peripherals under software control, thus giving a wide variety of configurations depending upon program requirements.

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1 Introduction

The basic Cranfield hybrid computer system became operational in 1971.[1,2] This system was based on the Applied Dynamics AD256 analogue computer, and the Digico M16 digital mini-computer. The characteristics of these computers are summarized in the Appendix. The experience gained in the initial period of use of the system led to the conclusion that, on many occasions, a user required the mini-computer as a separate unit, which meant that other users were obliged to operate the analogue computer without hybrid facilities. This led to the purchase of a second mini-computer and with increasing work load, a third. As the use of the computers expanded so did the demand for a variety of peripherals. At first, an attempt was made to provide each computer with a different complement of peripherals, in order to permit the simultaneous running of various projects. This approach appeared to be particularly unsuitable and resulted in the constant changing of peripherals from one computer to another. It rapidly became apparent that, as far as users were concerned, the only satisfactory solution would be to provide all computers with a full complement of peripherals. With the introduction of low-priced mini-computers, it is often found that the cost of peripherals is as great or greater than the cost of the central processor.[3] In order to avoid the great expense of this method, it was decided to switch the peripherals between computers.

An alternative method suggested was to connect the computers and peripherals to a unibus. However, this suffers from the obvious drawback that only one computer at a time could have access to the bus. Thus during any current bus operation, all further peripheral operations would have to be suspended. There would also be problems of indeterminancy with concurrent operations. Both of these problems are non-existent when each computer has an independent bus and its own selected complement of peripherals.

At approximately the same time, a requirement arose for the operation of the hybrid computer using more than one digital computer. This led to a need to communicate between the digital computers, and thus to a decision to link all three as a multiprocessor. The final stage was the addition of a link to a further mini-computer which was itself connected as a front end processor to the large central digital computing facility.

2 General Description

A simplified block diagram of the overall system is shown in Fig. 1. The peripherals are shown connected to the eight bus switching units (b.s.u.s) which are used to connect the various peripheral groups to any computer bus. The switching units are operated under the control of software and therefore may be allocated or de-allocated during the course of a program.

The computers are interlinked in delta formation by inter-computer buffers (i.c.b.s); these are bidirectional sixty-four word first-in first-out (f.i.f.o.) buffers. The buffer transfer was preferred to a single word transfer, in order to reduce problems of synchronization between computers especially when using real-time peripherals. The buffers provide the facility of program or data exchange between computers, and also interaction by means of interrupt and busy signals. The buffer link to the front end processor is only connected to one of the group of mini-computers as this gives sufficient access between the two systems. An alternative link via a British Standard interface is also available.

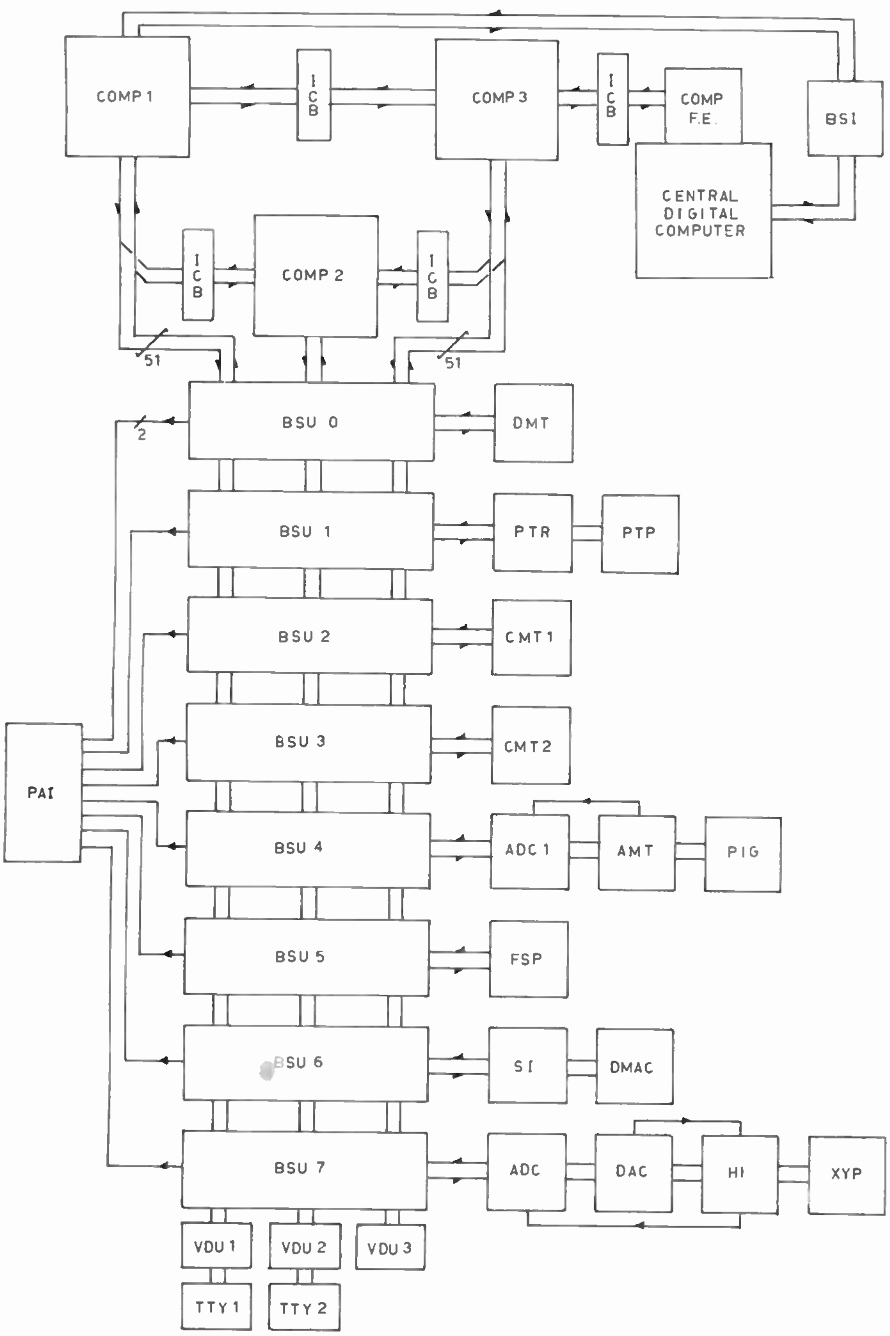
3 The Bus Switching Unit

The bus switching unit is a device for connecting a peripheral to any one of a number of mini-computers. Given a number of computers and a range of peripherals fitted with these units, a wide selection of configurations may be constructed, depending on program requirements. The unit is a multi-channel electronic switch, which is software-controlled and accessible by all computers. A block diagram of a unit is shown in Fig. 2.

3.1 Operation

A b.s.u. may be addressed by any computer, using a common instruction set. An unallocated unit may be selected by any computer. Once a unit has been allocated to a particular computer, it may only be de-allocated by *that* computer. Should another computer attempt to select the unit under these conditions, a 'busy' signal will be generated together with the identification of the computer to which it is currently allocated.

The Digico M16 computer has the following format for peripheral instructions. The sixteen-bit word must



KEY

ADC	Analogue to digital convertor
AMT	Analogue magnetic tape unit
BSI	British standard interface
BSU	Bus switching unit
CMT	Cassette magnetic tape unit
DAC	Digital to analogue convertor
DMAC	Coordinate digitizer
DMT	Digital magnetic tape unit
FSP	Fast serial printer
HI	Hybrid interface
ICB	Inter-computer buffer
PAI	Peripheral allocation indicator
PIG	Periodic interrupt generator
PTP	Paper tape punch
PTR	Paper tape reader
SI	Serial interface
TTY	Teletypewriter
VDU	Visual display unit
XYP	XY plotter
COMP 2	Digico Micro 16 S computer
COMP 1, COMP 3, COMP F.E.	Digico Micro 16 V computers

Fig. 1.
Block diagram of the overall system.

have the four most significant bits (m.s.b.s) set to logic zero and the next m.s.b. set to a logic one. The five next m.s.b.s specify a function while the six least significant bits specify an address or peripheral number:

15,	14,	13,	12,	11,	10, 9, 8, 7, 6,	5, 4, 3, 2, 1, 0
0	0	0	0	1	function	address

It can be seen that if each peripheral has a specific address, then up to thirty-two functions may be created for each peripheral.

In order to minimize the use of addresses in specifying b.s.u.s, the format was modified for one specific address, as follows:

15,	14,	13,	12,	11,	10,	9, 8, 7, 6,	5, 4, 3, 2, 1, 0
0	0	0	0	1	func	channel number	b.s.u. address

This is possible with the b.s.u.s as there are only two functions or instructions. The new format then permits up to sixteen b.s.u.s to be allocated using only one address.

There are two instructions available to the unit; a select or PON instruction and a deselect or POF instruction. All units use the same instructions but with a different channel number. These instructions are:

Mnemonic		Action
PON (X)	Peripheral on	Select unit X and skip next instruction if selected, read into the accumulator the identification of the bus to which the unit is selected.
POF (X)	Peripheral off	Deselect unit X.

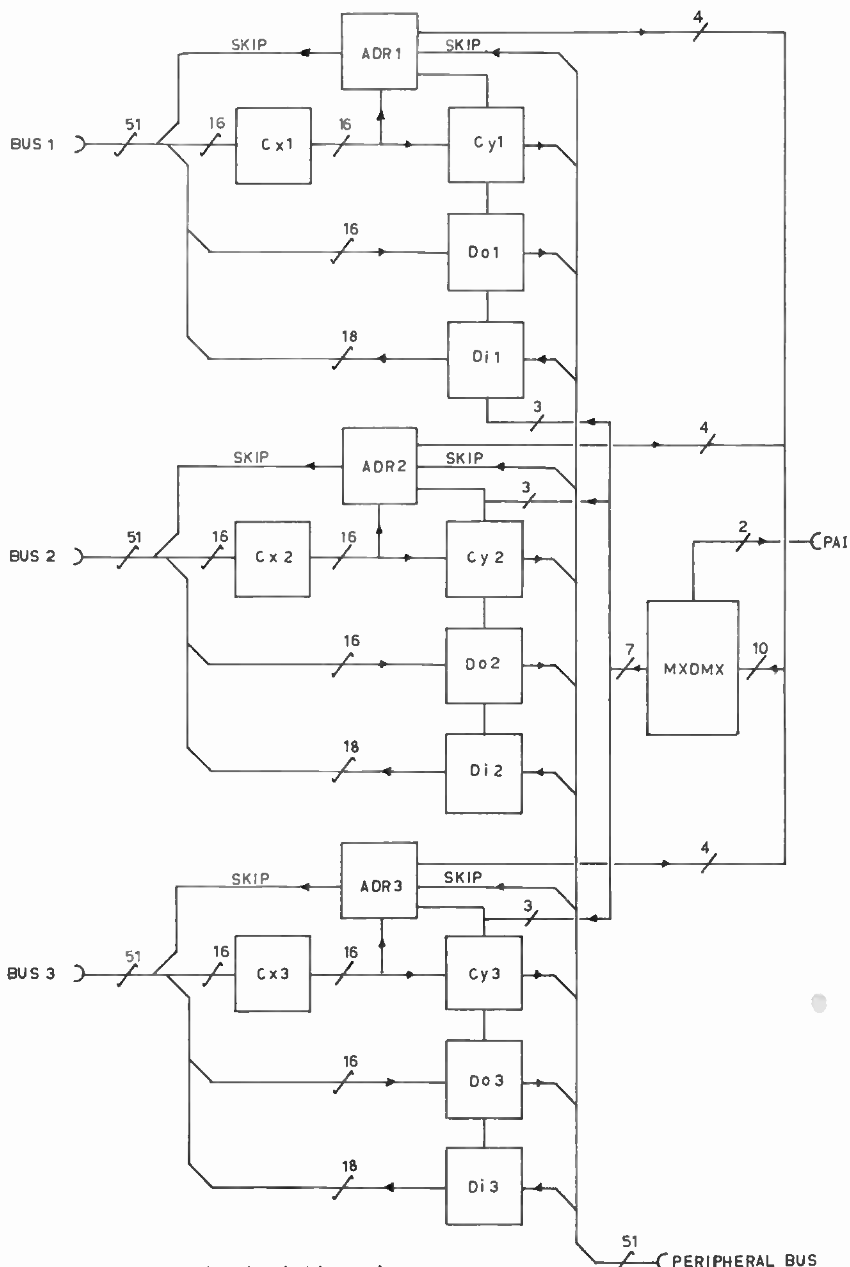


Fig. 2. Block diagram of an individual switching unit.

3.2 Circuit Description

The lines from all computer buses are switched to the peripheral bus by three gating elements Cy, Do and Di, which switch the control, data out and data in lines, respectively. The signals appearing on the peripheral bus are identical to those on a computer bus, except for an improvement in noise levels due to the use of Schmidt gates with filtered inputs, in the gating circuits. The Cx elements act as buffers to present a single load to the computer bus prior to distributing the control lines to gating elements Cy and to the instruction and address decoding elements (ADR).

The ADR elements accept the unswitched control ines and use these to generate the PON and POF instructions. The POF instruction is only permitted if the ENABLE signal is applied to the relevant ADR element, and thus only the computer to which the unit is selected may be read into the accumulator of any computer attempting to allocate the unit.

The heart of the switching unit is the multiplexor/demultiplexor element, the circuit of which is shown in Fig. 3. This element sorts the select or deselect instructions and distributes the signals needed to provide the switching of selected lines and the disabling of further instructions from other sources.

Simultaneous selection of peripherals is handled by scanning the instructions from the computers, sequentially, and locking on to the first active line scanned.

The select signal PON+ from any computer is fed to the multiplexor A and simultaneously the PON− signal is fed into the gate B which gives the OR of all PON signals. The rising edge of this pulse will trigger the bistable C (unless the unit is already selected) and set $\bar{Q}$ to a logic O, thus permitting the gated Schmidt oscillator H to start.

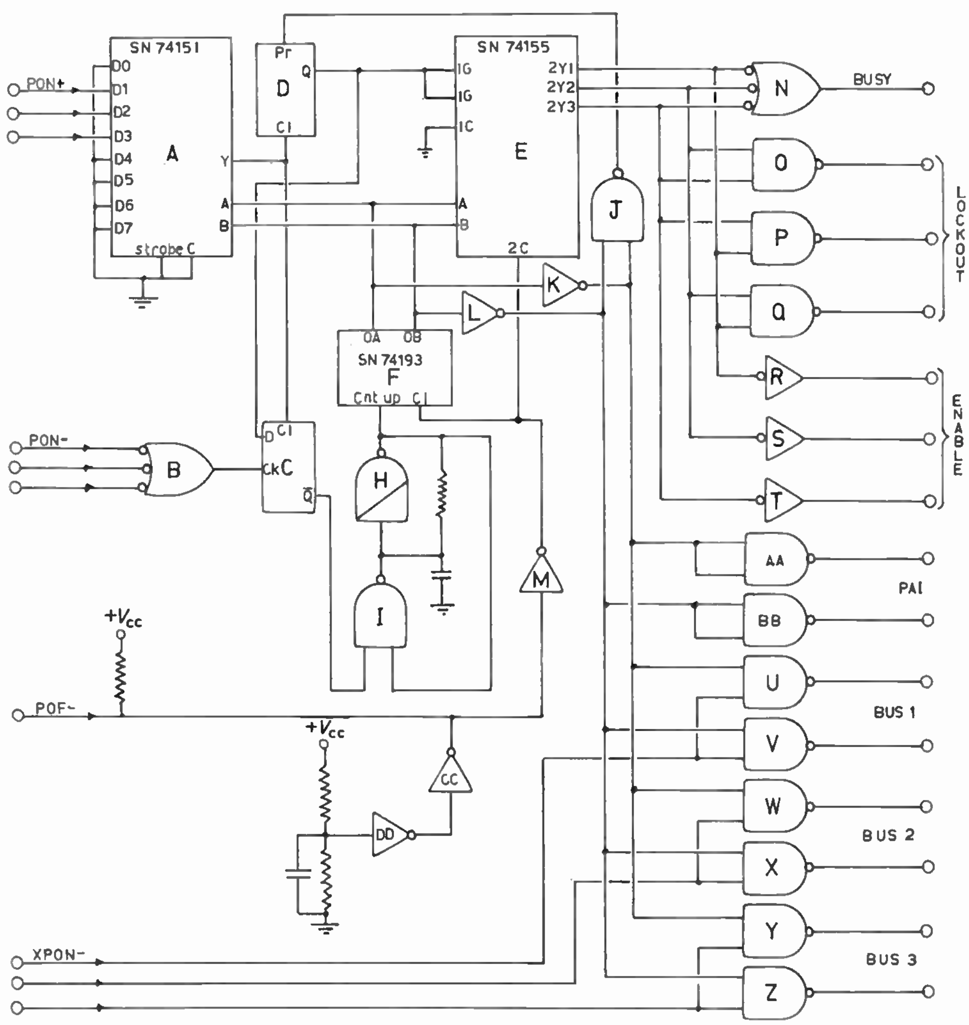


Fig. 3. A switching unit multiplexor/demultiplexor

switch it off. The PON instruction produces two logic signals, one of which operates the selecting circuit and is disabled by the LOCKOUT signal when another computer has the b.s.u. selected. The other signal, called XPON, is not affected by LOCKOUT and will permit the number of the bus, to which the unit is selected to

Pulses from this oscillator are fed into the counter F which varies the binary code on the address inputs of selector A. When this address corresponds to the position of the selected input line (PON+), A produces an output pulse which clears the bistables D and C thus stopping the oscillator. At this point, the count is held on F and its input to the demultiplexor E is decoded to give a logic O on the relevant output line. This signal is inverted to produce an ENABLE signal and ORed by N to produce a BUSY signal. The remaining two output lines from E are ANDed to suppress the LOCKOUT signal to the selecting ADR element. This method is used, because the unselected state, which is all 1's on E outputs, must not produce LOCKOUT signals.

When selected, the count held on F is also used to provide the identification address via pairs of gates UV, WX and YZ to the data input lines of the computer currently requesting allocation. This identification is permitted by the relevant XPON signal which is always enabled. The fourth gate pair AA,BB routes the address to a numerical indicator on a visual 'peripheral allocation indicator' (PAI).

Deselection of a b.s.u. is achieved by applying a logic O deselect pulse (POF—) to M. A 'power on' reset is also provided and is wire ORed at this point. These signals are inverted and applied to F and E, the effect being to clear the counter and disable the demultiplexor outputs. When the counter is cleared, the inverted outputs are ANDed by J to provide a reset signal to D which will in turn raise the D input of bistable C thus permitting select pulses (PON—). When reset, D will also maintain the disabling of E.

4 The Inter-computer Buffer

This unit is a device for transferring program and data from one computer to another. Each unit consists of two sixty-four word f.i.f.o. buffers, one for each direction of transfer and is completely asynchronous. For the purpose of describing the operation of the delta arrangement between the three main computers (Fig. 1), the data transfer is considered to be cyclic. If we define a clockwise transfer to be 'up' and an anticlockwise transfer to be 'down', it is apparent that an individual computer will require two sets of instructions. These instruction sets, one for up and one for down, are identical in all computers, and only require a difference of one 'bit' between the sets to specify direction. A single set of instructions is as follows:

Mnemonic	Action
WRB	Write to buffer (up or down) and skip next instruction if effective
RDB	Read from buffer (up or down) and skip next instruction if effective
CWR	Clear write buffer (up or down) and skip next instruction if cleared
CRD	Clear read buffer (up or down) and skip next instruction if cleared

As a buffer is always shared by two computers the decision to clear the buffer must be taken jointly by both computers. In order to achieve this, the clearing circuits are interlocked and the relevant clear instruction must be given in both computers in order to unset the interlock. This procedure will generally only be required at the start of a program when the buffer may contain previously loaded data.

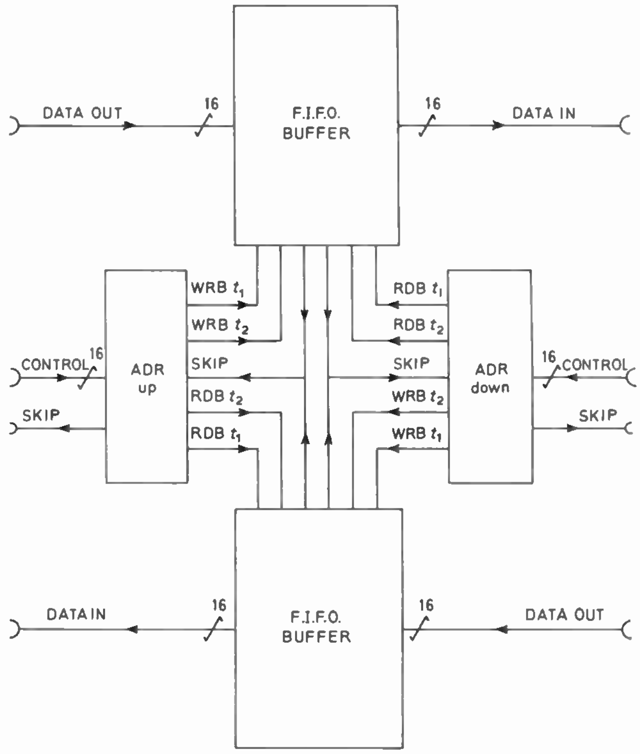


Fig. 4. Block diagram of an inter-computer link.

4.1 Circuit Description

A block diagram of a single bidirectional link is shown in Fig. 4. The instructions are decoded by the ADR elements and distributed to the relevant up or down buffers. The read or write instructions produce signal pulses at two successive time intervals t_1 and t_2, while the clear instructions only produce single pulse signals. Figure 5 shows the circuit used to operate the f.i.f.o. buffer, which is composed of a group of f.i.f.o. memory integrated circuits.

Before any data transfer sequence begins the f.i.f.o. buffer is given a clear or general reset (GR) which is a negative signal produced by M. The GR is generated by the occurence of a logic 1 at the Q outputs of both the SET CLEAR bistables K and L. As these bistables are triggered by the clear instructions CWR and CRD, it requires a clear instruction from both computers before the GR is activated. The SKIP signals to both computers are produced by monostables U and V which are triggeredby the CWR or CRD gated with GR+ by gates W or T. This means that each computer must wait for GR to occur before accepting the clear instruction as effective. The trailing edge of the relevant SKIP signal will then trigger the UNSET CLEAR bistables P and R, the $\bar{Q}$ outputs of which will be ANDed by S to clear the SET CLEAR bistables. Thus, both computers must have received a SKIP signal before GR is removed. A 'power on reset' is provided by the RC network via X and is wire ORed with the output of S.

Having received a general reset the f.i.f.o. buffer will be empty and therefore will not produce an output ready (OR) signal. This means that a read instruction will not be accepted until some data are loaded into the buffer.

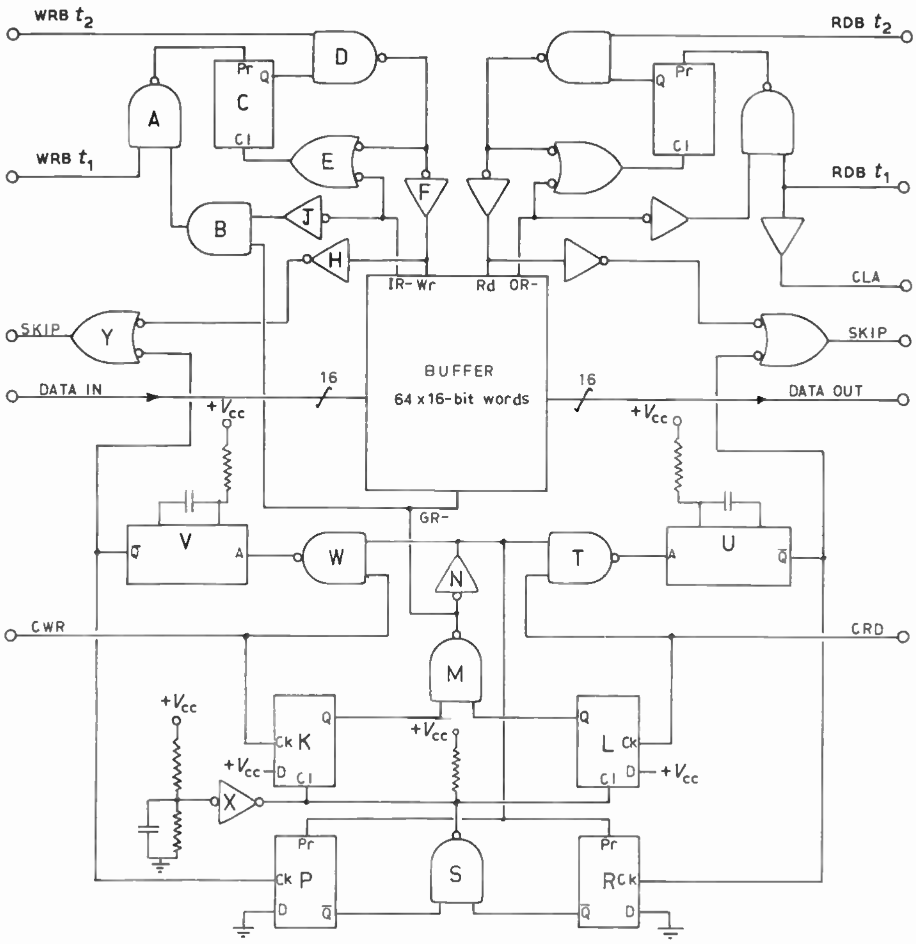


Fig. 5. An inter-computer buffer.

On the input side, the write instruction will be gated out by B until the general reset is removed.

In order to write to the buffer, gate B must be enabled by $\overline{\text{GR}}-$ and input ready (IR). This will in turn enable gate A and permit WRB t_1 to preset the bistable C. The output of C is then used to gate the pulse WRB t_2 which actually loads the buffer. WRB t_2 will also produce a SKIP signal, to indicate that it has been accepted. Bistable C will be cleared after WRB t_2, during the period when the input is not ready ($\overline{\text{IR}}$) due to data being transferred. The bistable 'C' will be held clear until IR indicates that the input is ready again.

The circuit for reading data from the buffer is similar in operation to that for writing data, except that the relevant flag is output ready (OR). This circuit also provides a pulse CLA which will clear the computer accumulator at RDB t_1 prior to loading it at RDB t_2.

5 Inter-computer Interrupts

In order to complete the communication between computers, a system of inter-computer interrupts was added. The purpose of this is to provide the facility for one computer to indicate to another that communication between them is required. This is especially useful if the timing of the inter-computer data transfers is critical. As with the inter-computer buffers, the interrupts in each of the three main computers are bidirectional, with a one bit difference between instruction sets to indicate direction.

When an interrupt is set by a computer, it must be unset by the computer to which it was transmitted. The computer which initiates the interrupt may then check whether it has been unset. A single set of instructions is as follows:

Mnemonic	Action
SIU	Set interrupt to 'up'
STU	Skip next instruction if interrupt to 'up' unset
SFU	Skip next instruction if interrupt from 'up' unset
CFU	Clear interrupt from 'up' computer

6 Comments

The circuits shown were designed with certain restraints, for example, the type and size of general-purpose printed circuit boards available, the number of contacts on standard connectors and the types of integrated circuit held in stock. With regard to the latter, the types of logic gate shown in the circuits may differ from those actually used.

The bus switching units described are used to switch peripherals between three computers. However this number could easily be expanded and an example of expansion for seven buses is explained below.

The m.x.d.m.x. element (Fig. 3) could be made to handle seven separate buses by using the extra inputs on A, outputs on E and multiplexing these by adding an extra bit from the counter F to the C and 1C controls of A and E respectively. The OR gates B and N must be expanded to seven inputs, seven gates, each with six inputs must be provided to give LOCKOUT signals and the number of ENABLE lines must be increased to seven. The gates U to Z would have to be increased in number to provide three lines for each of the seven buses, these three lines being fed from the three bits of the counter F.

Finally gate J would need to be expanded to three inputs to detect the O state of the three counter outputs.

With the addition of the necessary address decoding elements (ADR) and control and data line gating elements Cy, Do and Di, the system would handle up to seven buses.

Although this system uses similar computers, it should be possible, within limits, to use different computers and alter the word structure within the switching units. For example, if a computer uses common, time shared, data lines, the enabling of input or output data would be switched depending on the type of instruction. The common lines could also be converted to separate input and output lines if required.

As the author has not yet examined this possibility in any depth the problems are not covered in this paper. However, it is probable that among the wide range of mini-computers available there will be groups that are reasonably compatible in this respect.

7 Conclusions

After a comparatively short time in service, the system had complete acceptance by the users. In fact, if for any reason a peripheral was not switchable, the programmers would soon complain bitterly. One aspect which may seem surprising, is the lack of conflict over the use of peripherals. In practice, the peripherals are constantly switched from computer to computer with the minimum of inconvenience. In this respect, the software control of the switching units has proved invaluable.

Programmers have found a variety of applications for the overall system, some of which are listed below.

(a) The use of one computer as a processor and another as a peripheral controller.

(b) The use of a common data area for two or more programs operating in parallel.

(c) Parallel processing and parallel operation of peripherals.

(d) In a particular hybrid application[4] one digital computer controls the dynamic operation of the analogue computer while another is updating input data.

From an engineer's viewpoint, one of the most useful assets is the ability to write system test programs using the duplication of computers and switching units to obtain comparative results. This makes it easier to isolate sources of error.

8 Acknowledgments

The author wishes to thank Mr. M. Maric and Mr. C. Bluck for their assistance with the construction of the system and particularly for their entirely independent contribution of the peripheral allocation indicator.

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Appendix: Computer Characteristics

AD 256 Analogue Computer

The AD 256 is a large general-purpose analogue computer, having solid-state switching throughout and a linear component accuracy of 0·01%. It comprises:

192 summing amplifiers/integrators

30 quarter square multipliers

120 servo and 30 hand-set potentiometers

8 variable function generators

sine-cosine and log generators

non-linear equipment including resolvers, limiters, comparators and analogue gates

parallel logic, including gates, bistables, monostables and shift registers

Digico M 16

The Digico M16 is a digital mini-computer comprising:

central processor, having 8k 16-bit words of 950 ns core store

hardware multiply/divide

hardware floating point

multilevel interrupt

console teletype or v.d.u.

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Performance of an *M*-ary p.s.k. system in the presence of additive noise, intersymbol interference and fading

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and
IRENEUSZ PROTASEWICZ, M.Sc.*

SUMMARY

The results of an investigation of the evaluation of energy signal degradation of an *M*-ary p.s.k. system due to intersymbol interference and fading are analysed.

Attention is concentrated upon the influence of intersymbol interference caused by the limited band of the receiver filter as well as the transmitter one. As far as the channel is concerned, it has been assumed there is nonselective fading in it.

Part 1 presents the analysis method being applied;
Part 2 analyses the energy degradation characteristics of *M*-ary signals resulting from intersymbol interference in the case when no fading occurs in the channel;
Part 3 analyses the influence of intersymbol interference and fading jointly.

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Part 1
THEORETICAL ANALYSIS

1. Introduction

There are three main sources of degradation performance (i.e. transmission errors) in radio systems of transmitting digital information by means of p.s.k. signals: additive noise occurring in the channel or produced in the receiver, intersymbol interference, and fading. The problem of estimating the performance of the *M*-ary p.s.k. system in the presence of noise as well as the intersymbol interference has been analysed by a number of authors.[1–7]

However, their works have not taken into account the occurrence of fading in the channel. Moreover, the presented computation results do not give a general characteristic of the phenomena associated with the occurrence of intersymbol interference in *M*-ary systems.

In this work, which has been based on the method being applied by Calandrino, Crippa and Immovili,[1, 2] there have been achieved a number of general and, from the practical point of view, interesting characteristics of *M*-ary p.s.k. system, in particular the one which refers to the performance of the system during a joint interaction of noise, intersymbol interference and fading.

2. Definition of the Problem

We will consider an *M*-ary coherent p.s.k. system (to be referred to as *M*-ary c.p.s.k.) of a signalling rate T^{-1} and carrier angular frequency ω_0, the block scheme of which has been presented in Fig. 1. The properties of the transmitting and receiving filters applied in this system treated as linear and time invariant ones are defined by the impulse response functions of these filters $h_t(t)$ and $h_r(t)$. However, the channel characteristics will be assumed to be linear ones but time variable at random. This kind of channel may be defined by means of the random impulse response function $H_c(t, \tau)$.

Let the *M*-ary p.s.k. signal being observed at the modulator's output take the form of

$$s_m(t) = \sum_{i=-\infty}^{\infty} u(t-iT)\cos\left(\omega_0 t + \frac{2\pi M_i}{M}\right) \tag{1}$$

which corresponds to

$$s_m(t) = \cos\left[\omega_0 t + \alpha(t, \{A_i\})\right] \tag{2}$$

where the instantaneous phase deviation $\alpha(t, \{A_i\})$ is defined as

$$\alpha(t, \{A_i\}) = \sum_{i=-\infty}^{\infty} u(t-iT)\frac{2\pi M_i}{M} \tag{3}$$

where $u(t)$ is a function the form of which is a rectangular impulse

$$u(t) = \begin{cases} 1 & \text{for } 0 \leqslant t < T \\ 0 & \text{for } t < 0 \text{ and } t \geqslant T \end{cases} \tag{4}$$

while M_i may assume one of the values $0, 1, 2, \ldots, M-1$. Further on we will assume the elementary *M*-ary information to be independent and equiprobable, hence magnitudes M_i will also be independent and equiprobable.

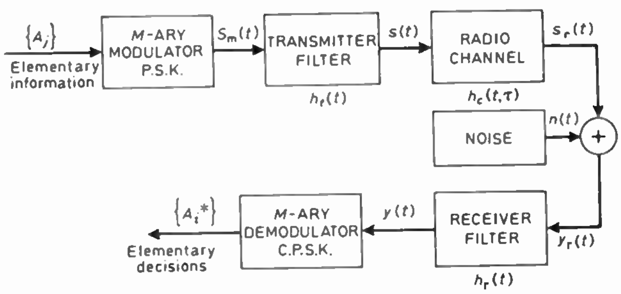

Fig. 1. *M*-ary coherent p.s.k. system.

Before we give the model of received signal $y(t)$ we will concentrate our attention upon the characteristics of the investigated channel.

As has been assumed from the beginning, it is a linear channel with fading. The occurrence of fading in the channel result in variations of amplitude and the received signal phase as well.

In order to simplify the description of amplitude and phase relation, we will apply complex form of signals, denoting appropriate complex magnitudes† by printing them in bold face type.

For every realization of the transmitted signal $\mathbf{s}(t)$, the noiseless signal $\mathbf{S}_r(t)$ at the output of such channel which can be expressed by

$$\mathbf{S}_r(t) = \int_{-\infty}^{+\infty} \mathbf{H}_c(t-\tau, \tau)\mathbf{s}(\tau)\, d\tau \tag{5}$$

is to be considered as a stochastic process.

We will concentrate our attention upon a channel with non-selective fading which occurs in the case where for every instant t, the value of correlation function $|H_c(t, \tau)|$ for the parameter τ ($\tau \neq 0$) approximates to zero. In such case we deal with an approximate equality

$$\mathbf{H}_c(t, \tau) = \delta(\tau)\mathbf{L}(t) \tag{6}$$

where $\mathbf{L}(t)$ is considered to be a random time-variant channel attenuation. Taking into account (5) and (6) we obtain

$$\mathbf{S}_r(t) = \mathbf{L}(t)\mathbf{s}(t) \tag{7}$$

Process $\mathbf{L}(t)$ may be expressed as follows:

$$\mathbf{L}(t) = 1+\mathbf{B}(t) \tag{8}$$

where $\mathbf{B}(t)$ is a complex Gaussian process the real and imaginary components of which are statistically independent stationary processes of zero expected values and equal autocorrelation functions (compare, e.g. Stein and Jones[8]). Let us denote their autocorrelation function by

$$\Gamma(t_1, t_2) = \sigma_B^2\gamma(t_1-t_2)$$

where σ_B^2 is the variance of each of the components $\mathbf{B}(t)$.

According to the above, the substitution channel scheme will be as shown in Fig. 2.

Taking into account this scheme, the received signal may be expressed for every received signal realization (i.e. with an accepted sequence $\{A_i\}$) in the following way

$$\mathbf{Y}_r(t) = \mathbf{S}_r(t)+\mathbf{N}(t) = \mathbf{s}(t)+\mathbf{s}(t)\mathbf{B}(t)+\mathbf{N}(t) \tag{9}$$

where $\mathbf{s}(t)$ = regular component of the received signal,

$\mathbf{s}(t)\mathbf{B}(t)$ = fluctuating component of the noiseless received signal,

$\mathbf{N}(t)$ = additive noise.

Let us also assume that the additive noise is of Gaussian white type with the spectral power density N_0. On the basis of this assumption as well as the accepted channel model we may state that value

$$\mathbf{Z}(t) \triangleq \mathbf{s}(t)\mathbf{B}(t)+\mathbf{N}(t) \tag{10}$$

also possesses the Gaussian probability distribution. Let us further assume the applied phase demodulator in this system to be synchronized with the regular component of the received signal and operate according to the following decision rule: information a_i^* has been transmitted if

$$|\arg[\mathbf{y}(t_d)]-\arg[\mathbf{s}_{mi}(t_d)]| \leqslant \frac{\pi}{M} \tag{11}$$

where t_d = sample time of the received signal,

$s_{mk}(t)$ = signal at the modulator's output subordinated to the kth elementary information ($k = 1, \ldots, M$).

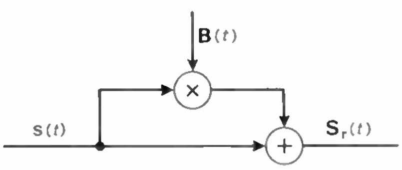

Fig. 2. Substitution channel scheme.

We will assume the average error probability of the elementary decision as the criterion performance (transmission quality) denoting it by $P_e^{(M)}$.

We have

$$P_e^{(M)} = \sum_{j=1}^{M} P(A_i = a_{ij})P_{ej}^{(M)} \tag{12a}$$

where $P_{ej}^{(M)}$ is the error decision probability provided that jth elementary information has been transmitted.

According to the above accepted assumptions

$$P(A_i = a_{ij}) = \text{const} = \frac{1}{M}$$

$j = 1, 2, \ldots, M$ and for every i

while $P_{ej}^{(M)}$ does not depend on j; therefore

$$P_e^{(M)} = P_{ej}^{(M)} = P\left\{|\arg \mathbf{Y}(t_d)-\arg \mathbf{s}_{mj}(t_d)| > \frac{\pi}{M}\right\} \tag{12b}$$

Further on our major purpose will be to determine the dependence between value $P_e^{(M)}$ and the characteristic parameters of the investigated system.

Let us introduce the following characteristic parameters:

1. Signal/noise ratio:

$$\rho_T \triangleq \frac{1}{2\sigma_T^2} \tag{13a}$$

† $s(t) = \mathrm{Re}[\mathbf{s}(t)\exp(j\omega_0 t)]$ where $\mathbf{s}(t)$ is the complex instantaneous amplitude of the signal.

being determined as the ratio of half of the square power of the amplitude signal† on the modulator's output to the additive noise variation computed for band $B_r = 1/T$. So

$$\rho_T = \frac{1}{2N_0 B_T} = \frac{T}{2N_0} \tag{13b}$$

2. Relative bandwidth of the receiving filter:

$$b_T \triangleq \frac{B}{B_T} \tag{14}$$

where B indicates the effective noise bandwidth of the receiving filter.

3. Depth measurement unit of fading in the channel

$$d^2 \triangleq 2\sigma_B^2 \tag{15}$$

So we will search for dependence

$$P_e^{(M)} = f(\rho_T, b_T, d^2)$$

3. Obtaining the Dependence $f(\rho_T, b_T, d\ )$

The distortion magnitude of the signal being received at the moment of sampling time is determined in the investigated transmitting system by three factors: additive noise, intersymbol interference connected with the limited bandwidth of the transmitter and receiver filters, and fading in the channel.

Let

$$P_{ek}^{(M)} \Delta\, P_{e|\{a_i{}^k\}}^{(M)}$$

where $P_{e|\{a_i{}^k\}}^{(M)}$ is the error probability provided that the sequence of the transmitted elementary information $\{A_i\}$ possesses the kth form. The unconditional error probability of the elementary decision $P_e^{(M)}$ will be computed from equation

$$P_e^{(M)} = \sum_k P_{ek}^{(M)} P(\{A_i\} = \{a_i^{(k)}\}) \tag{16}$$

According to the mathematical model which has been presented previously, received signal is a sum composed of two components regular and stochastic.

On condition that $\{A_i\} = \{a_i^{(k)}\}$, the regular one may be considered as deterministic, while the latter is of a non-stationary Gaussian stochastic process. Based on the above model, it has been shown in Appendix 1 that dependence

$$P_{ek}^{(M)} = f_k(\rho_T, b_T, d^2)$$

is as follows

$$P_{ek}^{(M)} = \tfrac{1}{2} g_M \operatorname{erfc}\left\{\sqrt{\frac{\rho_{Tn}}{b_T + d_n^2 \mu_k(t_d)\rho_{Tn}}} \times V_k(t_d) \frac{\sin[\pi/M - \delta_k(t_d)]}{\sin \pi/M}\right\} + \tfrac{1}{2} g_M \operatorname{erfc}\left\{\sqrt{\frac{\rho_{Tn}}{b_T + d_n^2 \mu_k(t_d)\rho_{Tn}}} \times V_k(t_d) \frac{\sin[\pi/M + \delta_k(t_d)]}{\sin \pi/M}\right\} \tag{17}$$

where

$$g_M = \begin{cases} \tfrac{1}{2} & M = 2 \\ 1 & M \geqslant 4 \end{cases}$$

The above equation holds for $M \geqslant 4$ in case when $P_{ek}^{(M)} \ll 1$. The normalized parameters appearing in equation (16) are given by the formula

$$\rho_{Tn} \triangleq \rho_T \sin^2 \frac{\pi}{M}$$
$$d_n^2 \triangleq d^2 \sin^{-2} \frac{\pi}{M} \tag{18}$$

while the values of the other terms are as follows:

$V_k(t_d)$ = amplitude of the regular component of the received signal $y(t)$,

$\delta_k(t_d)$ = instantaneous phase deviation of the component being measured with regard to the instantaneous transmitted signal phase,

$\mu_k(t_d)$ = variance of the noiseless received signal being normalized with regard to σ_B^2. As presented in Appendix 2,

$$\mu_k(t_d) = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \gamma(\tau_1 - \tau_2) \mathbf{s}(\tau_1) \mathbf{s}^*(\tau_2) \times \mathbf{h}_r(t_d - \tau_1) \mathbf{h}_r^*(t_d - \tau_2)\, d\tau_1\, d\tau_2 \tag{19}$$

In order to obtain $P_e^{(M)}$ it is only necessary to determine the probability distribution $P_{ek}^{(M)}$, $k = 1, 2, \ldots,$ i.e. the probability distribution of the interference realization sequences of the elementary signals.

From the practical point of view, the number of the elementary signals which affect the quality of the elementary decision concerning the signal being actually received is limited.

Assuming this number to be I, then the number which corresponds to the realization of interference sequences of elementary signals in the case of an M-ary system is M^I.

Thus the described method of procedure (equations (16)–(18)) may be a constructive one provided that I is not too big. For most of the bandpass filters (transmitter, receiver) applied in practical systems, in particular filters of Butterworth type which we will deal with later on, it is only necessary to assume $I_{max} = 4$.

However for $M > 2$, the number of sequences to be analysed is still very great.

It appears that in order to counteract these difficulties one may apply the modified average method described in Appendix 3.

By regarding all the elementary information as equiprobable and independent the following dependence applies:

$$P_e^{(M)} = \frac{1}{M^I} \sum_{k=1}^{M^I} P_{ek}^{(M)} \tag{20}$$

Part 2

4. Energy Degradation Characteristics of M-ary Signals in C.P.S.K. System without Fading

We will next concentrate our attention upon the investigation results which have been achieved by the application of method described in Part 1. The results

† Considered as unit.

concern the evaluation of the transmission performance in the M-ary c.p.s.k. system in the case when there is no fading in the channel. For that purpose we will have to assume in the formulae mentioned before that

$$d^2 = 0 \tag{21}$$

i.e. we will assume zero fading depth.

Let us assume that probability value of the elementary decision error $P_e^{(M)}$ is settled. Our aim will be to determine the dependence between its corresponding value, noise/signal ratio ρ_T, and parameter b_T characterizing the receiver filter applied in this system.

The dependence will be known as the energy degradation signal characteristics due to the intersymbol interference.

Further on the object of our analysis will be the band filters of Butterworth type. For that class of filters bearing in mind the previous assumption (21) we may express formula (17) in terms of the following:

$$P_{e(k)}^{(M)} = g_M \operatorname{erfc}\left[\sqrt{\frac{\rho_{Tn}}{B_T}}\, V_k(t_d)\cos\delta_k(t_d)\right] \quad (P_{e(k)}^{(M)} \ll 1) \tag{22}$$

Before we begin to describe the numerical results based on this formula, let us notice the signalling alphabet index M affects only factor g_M (where for $M_e \geqslant 4$, $g^M = 1$). Value $P_e^{(M)}$ will additionally be under the influence of the fact that the probability distribution of values V_k and δ_k are dependent on M.

Strictly speaking, they are discrete probability distributions. However, for $M \to \infty$, each of these distributions aims at a certain settled continuous distribution (independent of M). Therefore there exists such value M_0 where for $M > M_0$ one may assume $|P_e^{(M)} - P_e^{(\infty)}| \approx 0$. It means that for $M > M_0$ the degradation characteristics are being standardized.

One of the aims of computing was to find the value $M = M_0$, necessary to start the assumptions that the degradation characteristics do not depend on M. The above dependence was required to be right for $M \geqslant 4$ with an error of 0·1 dB.

5. Energy Degradation Characteristics

Let us first consider the numerical results† obtained while applying only the receiver filter (the transmitter filter band is infinite).

The characteristics obtained for the energy degradation of the M-ary signal as well as the binary ones have been presented in Fig. 3. The values of the normalized bandwidth of the receiver filter b_T are plotted on the axis of abscissae, while values of the normalized signal/noise ratio $\rho_{Tn}^{[\mathrm{dB}]}$ on the axis of ordinates, where

$$\rho_{Tn}^{[\mathrm{dB}]} = \rho_T^{[\mathrm{dB}]} - \Delta_M^{[\mathrm{dB}]} \tag{23}$$

Δ_M is the scale coefficient (comp. equation (18)) defined as follows:

$$\Delta_M^{[\mathrm{dB}]} \triangleq -20 \log_{10} \sin\frac{\pi}{M} \tag{24}$$

† Computation according to equation (22) carried out with Polish computer ODRA 1204.

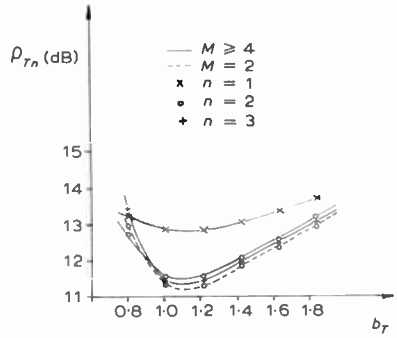

Fig. 3. Energy degradation characteristics.

The computations have been made for one-, two- and three-pole Butterworth filters.

The latter energy degradation characteristics have been found by the optimalization of sampling time t_d in such a way as to minimize signal/noise ratio relating to the value $P_e^{(M)}$.

From the results obtained one may conclude that the optimal value b_T is given by $b_T \approx 1{\cdot}1$ independently of M. Taking into consideration the known characteristic (see equation (9)) $P_e = f(\rho_{Tn})$ of the ideal system (without intersymbol interference) we can conclude that the intersymbol interference for optimal parameters of the receiving filter prevents the degradation of the signal/noise ratio from being equal:

(a) 1 dB for $n = 2, 3$

(b) 2 dB for $n = 1$

where n denotes the number of Butterworth filter poles.

6. Sampling Time Optimization at the Receiving Point

The delay dependence of the optimal sampling time upon the time corresponding to the end of the received impulse has also been the object of the investigation. It turned out that the delay determined in this way does not depend in practice on M, but only on the receiving filter characteristic. Figure 4 illustrates the characteristics obtained. They indicate that for the filter in practical application ($n > 1$) the optimal delay value of the sampling time is

$$\tau_{0\,\mathrm{opt}} > 0, \quad \text{if } b_T = 1, 1$$

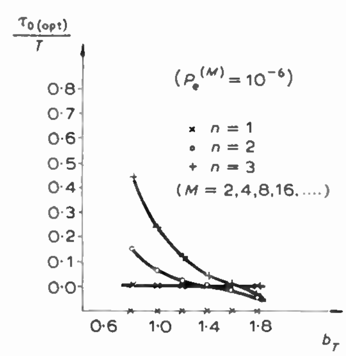

Fig. 4. Sampling time optimization.

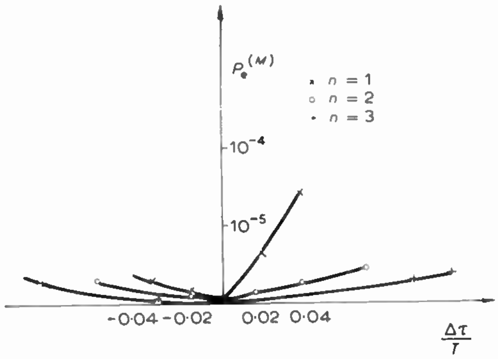

Fig. 5. Influence of sampling time deviation on error state.

7. The Influence of Time Synchronization Error upon the Elementary Value of the Rate of Errors $P_e(M)$

There has also been analysed the influence of deviation from the optimal sampling time upon the elementary value of the rate of errors. The computations have been carried out on the assumption that $M = 4$, and the results obtained are illustrated in Fig. 5.

It is evident that for filters of higher order than 1 the sampling time deviations within the ranges $\pm 5\%\ T$ do not cause any significant changes of $P_e^{(M)}$. However, in the case of a one-pole filter, the deviations towards the positive direction are followed by a fast rise of $P_e^{(M)}$.

The similar effects are expected to be for the signals of $M > 4$. The remarks in Section 4 prove this.

Taking into account the characteristics presented in Figs. 3–5, we may conclude that the two-pole filter satisfies the accepted optimal assumptions. All its characteristics are the most favourable.

8. Energy Degradation of *M*-ary P.S.K. Signals with a Simultaneous Use of Transmitter and Receiver Filters

Further on there has been analysed the influence of the transmitter filter upon the energy degradation characteristics of the M-ary p.s.k. signals. For this reason the following assumptions have been made.

1. The receiver filter is of a two-pole Butterworth type (see item 3).
2. The transmitter filter is also a two-pole Butterworth filter. The normalized effective bandwidth of the filter B_T (comp. equation (14)) has been accepted a variable parameter.
3. The sampling time of the received signals to be optimalized as formerly.

On the basis of the previous assumptions there have been determined the energy degradation characteristics for the three different bandwidth values of the receiver filter as well as for all the investigated M-ary system. (There is a similar regularity here as described in point 1.) Figure 6 illustrates the results obtained.

The conclusions to be drawn are as follows:

1. For a settled receiver filter band b_T, the increase of the transmitter filter band B_T results in a rise of the energy degradation characteristic towards the one which corresponds to the situation where only a receiver filter has been used. It is evident that if the transmitter filter band $B_T \approx 2$ then the existing differences are of order 0·5 dB.
2. The place of the energy degradation minimum, i.e. the optimal value of the receiver filter band, is dependent on the transmitter one. The influence of the application of the transmitter filter upon the optimal sampling time was the object of later investigations. The result obtained is illustrated in Fig. 7 including the characteristics (with B_T as a parameter)

$$\frac{\tau_{0\ \mathrm{opt}}}{T} = f(b_T)$$

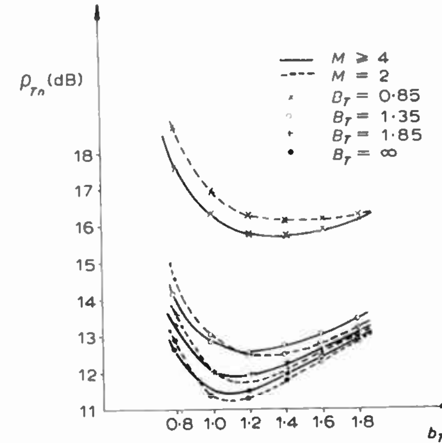

Fig. 6. Energy degradation characteristics for different bandwidths.

It is to be noticed that the application of the transmitter filter exerts a substantial influence upon the optimal sampling time delay. For a transmitter filter of bandwidth $B \geqslant 2$ (i.e. under conditions in which the increase of the energy signal degradation due to the applied transmitter filter is practically negligible) the delay also differs significantly from the optimal one in case of using only the receiver filter.

It has been observed that the above characteristics do not depend on the signalling alphabet index M in the same way as has been noticed with the application of receiver filter only.

Similar results are expected to be achieved by using another type of transmitter filter (e.g. of one-pole number). The presence of the transmitter filter only

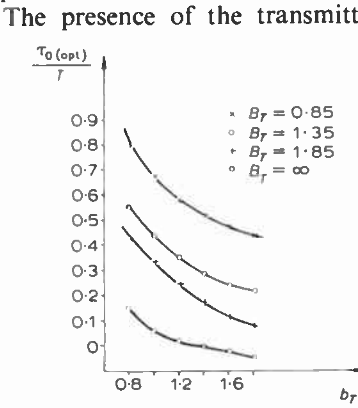

Fig. 7. Dependence of sampling time on bandwidth.

tends to increase the received signal interference component (the compensation of interaction of both filters is possible only by an appropriate choice of phase characteristics[9]).

9. Recapitulation

Taking into account the presented results we may assert the following:

1. From the qualitative point of view the influence of intersymbol interference on binary c.p.s.k. systems and M-ary ones is identical. The degradation characteristics of these systems have a similar shape with a tendency towards the top of axis of ρ_T together with the increase of M.
2. The place of the minimum of energy degradation from the practical point of view does not depend on M and amounts $b_T \approx 1{\cdot}1$.
3. The influence of the transmitter filter upon the analysed binary and M-ary characteristics is also analogous.
4. When comparing the presented binary and M-ary c.p.s.k. system characteristics, we may assert that the quantitative differences occur only for appropriate characteristics for $B_T < 1$ and $b_T < 1$. The differences are of the order of 1 dB.

Part 3

10. Energy Degradation of M-ary P.S.K. Signals due to Intersymbol Interference and Fading

We will next consider intersymbol interference and fading jointly and observe their influence upon the reception quality of the M-ary p.s.k. signals. For this reason it is necessary to assume the following:

1. Depth of fading $d^2 \neq 0$.
2. As in Part 2 we will assume the applied band filters to be of Butterworth type.
3. We will assume that the fading is so slow that the amplitude and phase of the noiseless signal in time interval $I\,T$ (comp. Part 1) may be considered to have been settled. Since the elementary signal situated beyond that division does not in practice affect the quality of the elementary decision, to simplify the analysis it is possible to assume that the above values are settled for the whole sequence of the received elementary signals and hence assume in equation (19), $\gamma(t) = 1$. For the above assumptions the conditional probability of the elementary decision error $P^{(M)}_{e(k)}(t_d)$ may be expressed by equation

$$P^{(M)}_{e(k)}(t_d) = g_M \operatorname{erfc}\left\{\sqrt{\frac{\rho_{Tn}}{b_T + d_n^2 \rho_{Tn} \bar{V}_k^2(t_d)}}\, V_k^2(t_d) \cos \delta_k(t_d)\right\} \tag{25}$$

The probability of error $P^{(M)}_e(t_d)$ will be obtained if we average $P^{(M)}_{(k)}(t_d)$ on the set of realization of the elementary interference signal sequence, i.e. on the set of realization of the variable $V_k(t_d)$ and $\delta_k(t_d)$.

It may be noticed here that if the intersymbol interferences are small, the fluctuations $V_k(t_d)$ along with variable k are much smaller than their average value $\bar{V}_k(t_d)$.

Therefore one may assume that the probability of the event is near unity

$$V_k(t_d) \approx \bar{V}_k(t_d) \tag{26}$$

However, taking into account assumption 2, one may conclude that for small intersymbol interferences the phase deviation $\delta_k(t_d) = 0$, and thus $\cos \delta_k(t_d) = 1$.†

Hence, the error probability of decision $P^{(M)}_e(t_d)$ is expressed by the following approximate formula

$$P^{(M)}_e(t_d) = g_M \operatorname{erfc}\left\{\sqrt{\frac{\rho_{Tn}}{b_T + d_n^2 \rho_{Tn} \bar{V}_k^2(t_d)}}\, \bar{V}_k(t_d)\right\} \tag{27}$$

Determining value $P^{(M)}_e(t_d)$ and using the above formula we get

$$\rho_{Tn} = \frac{\rho^0_{Tn}}{1 - \left[\operatorname{erfc}^{-1}\left(\dfrac{P^{(M)}_e}{g_M}\right)\right]^2 d_n^2} \tag{28}$$

where ρ^0_{Tn} is normalized signal/noise ratio corresponding the probability of decision error equal to P_e and where there is no fading (i.e. $d^2 = 0$). This value is given by (see (27)) the next formula:

$$\rho^0_{Tn} = \frac{\left[\operatorname{erfc}^{-1}\left(\dfrac{P^{(M)}_e}{g_M}\right)\right]^2 b_T}{\bar{V}_k^2(t_d)} \tag{29}$$

Notice that

$$\rho^{[\mathrm{dB}]}_{Tn} = \rho^{0[\mathrm{dB}]}_{Tn} + \Delta\rho^{[\mathrm{dB}]}_{Tn} \tag{30}$$

where $\Delta\rho_{Tn}$ = energy signal degradation‡ resulting from fading so we have the dependence

$$\Delta\rho^{[\mathrm{dB}]}_{Tn} = -10 \log_{10}\left\{1 - d_n^2 \left[\operatorname{erfc}^{-1}\left(\frac{P^{(M)}_e}{g_M}\right)\right]^2\right\} \tag{31}$$

From dependence (28) we may conclude that for

$$d_n^2 > \left[\operatorname{erfc}^{-1}\left(\frac{P^{(M)}_e}{g_M}\right)\right]^{-2} \tag{32}$$

it is impossible to accomplish the desired error probability $P^{(M)}_e$ by an increase of the signal/noise ratio. Since $d_n^2 = d^2(\sin \pi/M)^{-2}$, therefore d_n^2 increases with the rise of the signalling alphabet index M and enters the area limited by inequality (32) earlier for larger values of M.

The above equations have been derived on the basis of the approximating average method. To estimate the accuracy of the method, i.e. the accuracy of formula (31), there have been made numerical computations where the error probability $P^{(M)}_e$ was computed by averaging the values of V_k.

Bearing in mind that V_k depends on time, the latter has been so determined as to minimalize the signal/noise ratio ensuring the given error probability (compare Part 2). On the basis of these computations it was possible to determine the energy characteristics of signals

† When $\delta_k(t_d) = \pi$ then $P^{(M)}_{ek} = 1$.

‡ With regard to the case being considered in Part 2.

resulting from fading $\Delta\rho_{Tn}$, according to the assumption that the average error probability $P_e^{(M)} = 10^{-6}$. Only receiving filters have been considered, assuming them to be one-, two- and three-pole Butterworth types.

Figure 8 presents the dependence being computed according to formula (31) (continuous line 1). The accurate computation results for a standardized receiving filter bandwidth $b_T \geqslant 1{\cdot}1$ have been plotted within the area marked by lines 1 and 2.

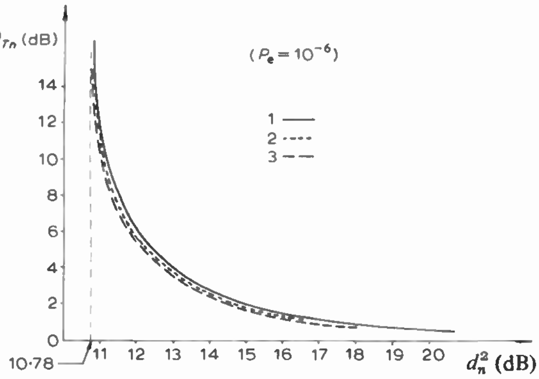

Fig. 8. Energy degradation for intersymbol interference and fading.

The area between curves 1 and 3 includes points corresponding to increases $\Delta\rho_{Tn}$ for $b_T \geqslant 0{\cdot}8$.

It can be seen that the above dependences hold for every M.

The optimal sampling time t_d depends in an identical way upon the standardized receiving filter band similarly to that one without fading (see Part 2).

The observed deviations from the curve defined by dependence (31) allow it to be regarded as a universal dependence characteristic as is being investigated here.

11. Conclusions

We have estimated the energy degradation of M-ary p.s.k. signals in two cases:

(a) for transmission system with a non-fading channel and limited bandwidth filters causing intersymbol interference,

(b) for intersymbol interference and fading.

When comparing the energy degradation characteristics obtained in both cases, one may state that for local optimization parameters of a receiver (appropriate selection of value t_d and b_T) the signal fading in the channel—if there is any—exerts the greatest influence upon the transmission quality.

We have observed in particular the existence of the standardized value of boundary fading depth below which it is impossible to achieve the desired transmission quality by an increase of the signal energy.

A consequence of this regularity is that along with the increase of the M-signalling alphabet index of the p.s.k. signals, the boundary fading depth value decreases, corresponding to the possible fading variance in the channel.

12. References

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13. Appendix 1 Deriving the dependence $P_{e(k)}^{(M)} = f_k(\rho_T, b_T, d^2)$

The error probability of the elementary decision in the M-ary ($M \geqslant 4$) p.s.k. system is a probability event that the received signal phase differs from the transmitted signal phase more than $\pm\pi/M$.

Let us denote the transmitted signal phase by $\varphi_t(t_d)$ while the received signal phase by $\varphi_{0k}(t_d)$ in sampling time t_d.

Then the error probability will be:

$$P_{e(k)}^{(M)}(t_d) = P\left(|\varphi_{0k}(t_d) - \varphi_t(t_d)| > \frac{\pi}{M}\right)$$

$$= P_1\left(\frac{\pi}{M} < \varphi_{0k}(t_d) - \varphi_t(t_d) < \frac{\pi}{M} + \pi\right) +$$

$$+ P_2\left(-\pi - \frac{\pi}{M} < \varphi_{0k}(t_d) - \varphi_t(t_d) < -\frac{\pi}{M}\right) -$$

$$- P_3\left(\pi - \frac{\pi}{M} < \varphi_{0k}(t_d) - \varphi_t(t_d) < \pi + \frac{\pi}{M}\right) \quad (33)$$

The two first components of the right-hand side of equation (33) represent the error probability in the binary system, where the constant phase component is $\pm(\pi/2 - \pi/M)$ which is added to the phase difference between the receiving signal and the transmitted signal.

The values of these components may be computed by using the known formulae concerning the binary system. We have (comp., e.g. refs. 1 and 2) thus:

$$\begin{aligned} P_1 &= \tfrac{1}{2}\,\mathrm{erfc}\left\{\sqrt{\rho_k(t_d)}\cos\left[\delta_k(t_d) + \frac{\pi}{2} - \frac{\pi}{M}\right]\right\} \\ P_2 &= \tfrac{1}{2}\,\mathrm{erfc}\left\{\sqrt{\rho_k(t_d)}\cos\left[\delta_k(t_d) - \frac{\pi}{2} + \frac{\pi}{M}\right]\right\} \end{aligned} \quad (34)$$

where $\rho_k(t_d)$ = signal/noise ratio at the sampling time,

$\delta_k(t_d)$ = instantaneous phase deviation of the regular received signal component with regard to the instantaneous transmitted signal phase.

In the case of the model of a channel with fading investigated here, the value $\rho_k(t_d)$ is expressed by the equation

$$\rho_k(t_d) = \frac{\frac{1}{2}V_k^2(t_d)}{\sigma_1^2+\sigma_2^2(t_d)} \tag{35}$$

where σ_1^2 = noise variance at the receiving filter output expressed by equation

$$\sigma_1^2 = \frac{2b_T.N_0}{T} \tag{36}$$

while σ_2^2 = variance of the noiseless received signal due to the fading in the channel expressed by

$$\sigma_2^2(t_d) = \sigma_B^2\mu_k(t_d) \tag{37}$$

$\mu_k(t_d)$ = function which is defined in Appendix 2.

Utilizing formulae (36) and (37) it is possible to express formula (35) as follows:

$$\rho_k(t_d) = \frac{\rho_T}{b_T+d^2\rho_T\mu_k(t_d)} \tag{38}$$

We restrict our attention to investigating the situation in which $P_e^{(M)} \ll 1$, and hence also $P_{e(k)}^{(M)} \ll 1$. We may state that to accomplish such a condition, it is necessary to fulfil the inequality

$$|\delta_k(t_d)| < \frac{\pi}{M} \tag{39}$$

otherwise we have the approximate equalities

$$\begin{matrix} P_1 \approx 1 \\ P_2 \approx 1 \end{matrix} \quad \text{(comp. eqn. (34)} \tag{40}$$

As far as component P_3 is concerned it is not difficult to prove on the basis of assumption $P_{e(k)}^{(M)} \ll 1$, that its value is of several orders smaller than components P_1 and P_2. Therefore it may be neglected.

We will introduce the following normalized values:

$$\begin{aligned} \rho_{Tn} &\triangleq \rho_T\left(\sin\frac{\pi}{M}\right)^2 \\ d_n^2 &\triangleq d^2\left(\sin\frac{\pi}{M}\right)^{-2} \end{aligned} \tag{41}$$

Taking into account the above dependences, formula (33) may be transcribed in the following way:

$$\begin{aligned} P_{e(k)}^{(M)} = \tfrac{1}{2}\operatorname{erfc}&\left\{\sqrt{\frac{\rho_{Tn}}{b_T+d_n^2\rho_{Tn}\mu_k(t_d)}}\times \right.\\ &\left.\times V_k(t_d)\frac{\sin[\pi/M+\delta_k(t_d)]}{\sin\pi/M}\right\}+ \\ +\tfrac{1}{2}\operatorname{erfc}&\left\{\sqrt{\frac{\rho_{Tn}}{b_T+d_n^2\rho_{Tn}\mu_k(t_d)}}\times \right.\\ &\left.\times V_k(t_d)\frac{\sin[\pi/M-\delta_k(t_d)]}{\sin\pi/M}\right\} \end{aligned} \tag{42}$$

Let us remember that the above formula is true for $M \geq 4$. For $M = 2$ $P_{e(k)}^{(M)}$ is expressed by formula (34). So it is easy to see that this value can also be computed by means of formula (42), by multiplying the value obtained by 0·5.

14. Appendix 2: Defining Function $\mu_k(t)$

Let us denote by $W(t)$ the stochastic component of the received signal $y(t)$ resulting from the presence of fading in the channel.

Its variance $\sigma_2^2(t)$ is

$$\sigma_2^2(t) = E[W^2(t)] \tag{43}$$

Signal $W(t)$ may be expressed in the form of

$$\begin{aligned} W(t) &= \mathrm{Re}\,[\mathbf{W}(t)\exp(j\omega_0 t)] \\ &= \tfrac{1}{2}\mathbf{W}(t)\exp(j\omega_0 t)+\tfrac{1}{2}\mathbf{W}^*(t)\exp(-j\omega_0 t) \end{aligned} \tag{44}$$

thus

$$\begin{aligned} \sigma_2^2(t) &= E\{\tfrac{1}{4}[\mathbf{W}(t)\exp(j\omega_0 t)+\mathbf{W}^*(t)\exp(-j\omega_0 t)]^2\} \\ &= \tfrac{1}{4}E\{\mathbf{W}^2(t)\}\exp(2j\omega_0 t)+\tfrac{1}{2}E\{\mathbf{W}(t)\mathbf{W}^*(t)\}+ \\ &\quad +\tfrac{1}{4}E\{[\mathbf{W}^*(t)]^2\}\exp(-2j\omega_0 t) \end{aligned} \tag{45}$$

According to the analysed model of channel and system (see Fig. 1 and Fig. 2) $\mathbf{W}(t)$ is:

$$\mathbf{W}(t) = \int_{-\infty}^{+\infty}\mathbf{B}(\tau)\mathbf{s}(\tau)\mathbf{h}_r(t-\tau)\mathrm{d}\tau \tag{46}$$

where $\mathbf{h}_r(t)$ = impulse transfer function of the receiving filter.

Utilizing equation (46) we obtain

$$\begin{aligned} E[\mathbf{W}^2(t)] = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} &E\{\mathbf{B}(\tau_1)\mathbf{B}(\tau_2)\}\mathbf{s}(\tau_1)\mathbf{s}(\tau_2)\times \\ &\times\mathbf{h}_r(t-\tau_1)\mathbf{h}_r(t-\tau_2)\,\mathrm{d}\tau_1\,\mathrm{d}\tau_2 \end{aligned} \tag{47}$$

Following the assumptions concerning the statistical characteristics $\mathbf{B}(t)$, the average value

$$E\{\mathbf{B}(\tau_1)\mathbf{B}(\tau_2)\} = 0$$

hence

$$E[\mathbf{W}^2(t)] = 0$$

Since

$$E\{[\mathbf{W}^*(t)]^2\} = \{E[\mathbf{W}^2(t)]\}^*$$

therefore (comp. equation (45)

$$\sigma_2^2(t) = \tfrac{1}{2}E[\mathbf{W}(t)\mathbf{W}^*(t)]$$

Making use of equation (46) we finally obtain

$$\sigma_2^2(t) = \sigma_B^2\mu_k(t_d) \tag{48}$$

where

$$\begin{aligned} \mu_k(t) = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} &\gamma(\tau_1-\tau_2)\mathbf{s}(\tau_1)\mathbf{s}^*(\tau_2)\times \\ &\times\mathbf{h}_r(t-\tau_1)\mathbf{h}_r^*(t-\tau_2)\,\mathrm{d}\tau_1\,\mathrm{d}\tau_2 \end{aligned} \tag{49}$$

15. Appendix 3: Average Error Probability on the Realization of the Elementary Interference Signal Sequence Set

Let us consider the following problem: The value of the expression

$$u = \underset{X}{E}f(a+X) \tag{50}$$

is to be computed, where X is the random variable able to assume with equal probability one from k values x_i, where

$$a \leq x_i \leq b \quad i = 1, 1, \ldots, k \tag{51}$$

If k is a small number, the value of expression (51) may easily be computed directly from the equation. However, in case of large values of k and a complex function f we may apply the following procedure:

1. Intervals $\langle a, b\rangle$ is divided into n disconnected subintervals filling up completely the interval $\langle a, b\rangle$. Let us denote i-th subinterval by $\langle a_i, b_i\rangle$.
2. The average conditional variable X is being computed on an i-th interval on condition that
$$X \in \langle a_i, b_i\rangle \quad i = 1, 2, \ldots, n$$
3. Probability P_i of the event that
$$X \in \langle a_i, b_i\rangle$$

is being computed.

Defining the new random variable Y where

$$P(Y = y_i) = P_i, \quad i = 1, 2, \ldots, n, \quad n \leqslant k \tag{52}$$
$$(Y = y) \rightarrow y \in \{y_i\} \quad i = 1, 2, \ldots, n$$
$$y_i = \underset{X|X \in \langle a_i, b_i\rangle}{E} X$$

Instead of expression (50) it is possible to use the following approximate equation:

$$u \approx \underset{Y}{E} f(a+Y) \tag{53}$$

The accuracy of the above estimation rises with the increase of the number of subintervals. It also depends on the way of dividing segment $\langle a, b\rangle$ into subintervals $\langle a_i, b_i\rangle$.

The above method has been applied for averaging the error probability on the realizations of the interference component of distortion set.

The random variable X represents here the above component; function corresponds to the error probability dependence upon the signal amplitude of the demodulator's input. By an appropriate selection the number of the subintervals k, the speed of computing increases considerably (function f is seldom computed) providing a sufficient accuracy as well.

Manuscript received by the Institution on 29th November 1974. (Paper No. 1705/Com. 126).

The authors

Dr. J. Nowakowski received the M.Sc. degree in telecommunication from the Technical University of Gdańsk in 1959 and spent the following eleven years in the Institute of Fundamental Problems of Technics and the Institute of Automatic Control, both of the Polish Academy of Sciences, Warsaw. In that period he was working on the problems of adaptation in information reception and processing systems particularly for data transmission. He gained his D.Sc. degree from the Institute of Fundamental Problems of Technics of the Polish Academy of Sciences, Warsaw, in 1966. In 1970, Dr. Nowakowski returned to the Department of Electronics at Gdańsk as an Adjunct (lecturer) and in the same year he was appointed a Docent (assistant professor). He has continued research on adaptive information processing and reception. He has been co-author of two text-books for students on information theory and automatic control, and author or co-author of more than 20 papers on statistical communication theory and control.

Mr. I. J. Protasewicz received the Magister degree in electronic engineering from the Technical University of Gdańsk, Poland, in 1971. Since then he has been employed as a senior teaching assistant at the University's Telecommunication Institute. His main interests are in statistical communication systems, numerical analysis and digital simulation methods. Author or co-author of four papers to date Mr. Protasewicz is currently working towards his doctorate thesis in the field of digital unsupervised learning data communication systems.

IERE News and Commentary

CEI Board Agrees Reorganization Programme

At the CEI Board meeting on 22nd January there was overwhelming agreement for all the essential principles which the Institutions wished to see incorporated in the reorganized CEI Constitution. The draft Supplemental Charter and changes in the By-laws required to put into effect the Board's decisions that have been taken since last July with a view to reorganizing the structure of the Engineering Profession can now be completed.

This draft will be printed in February and made available to all Chartered Engineers and other concerned parties for their consideration by the end of next April so that any criticisms can be taken into account when drafting the final petition to be submitted to the Privy Council early this summer.

Thus, a comprehensive plan for the reorganization for the Engineering Profession as a whole has been agreed which will not only permit the participation of chartered and non-chartered institutions but all chartered engineers will be able to elect the majority of members to the Governing Body of the reorganized CEI.

A modification to the original proposals, reported in the December 1975 Journal, has now been incorporated which could well have an important bearing on the general acceptability of the reorganization. The smaller institutions have recognized the wide disparity in the size of electorates based on the Engineering Institutions as constituencies and have agreed that the possibility of the chartered engineers in membership of a large institution electing more than one member of the Governing Body should be considered. This would imply an increase of perhaps 3 or 4 members on the Governing Body over the earlier figure of 15 to be elected by Chartered Engineers in membership of each Constituent Institution.

New Director for City and Guilds

Mr. Harry Knutton, C.B., M.Sc., C.Eng., F.I.E.E., M.B.I.M. will take over as Director-General of the City and Guilds of London Institute in succession to Sir Cyril English on 1st May 1976.

Mr. Knutton was recently a Director-General in the Ministry of Defence, responsible for research, development and production of equipment. He was a Tutor and Lecturer in Control Engineering, Royal Military College of Science, from 1955 to 1958, and then joined the Ministry of Aviation. He has been a Visiting Lecturer at the Royal Military College of Science, National Defence College, Royal School of Artillery and Royal Naval College, Greenwich, and he was a Fellow of Loughborough University of Technology from 1969 to 1970.

Electronic Tuning Aid

In 1972 a short paper by Mr. L. H. Bedford was published in the Journal discussing the design of electronic aids for tuning musical instruments.* The most developed design described in the paper has now been engineered and is being marketed as a compact battery-powered unit. Manufactured by Lloyd Instruments Ltd. of Banbury for RB Instruments†, it is known as the ETA Mark VI Electronic Tuning Aid and the crucial problem of visual display has been solved in a novel manner which avoids the use of either cathode-ray rube or meter presentation. A conventional alpha-numeric display made up of light-emitting diodes of the type normally used to form characters in a static mode is used dynamically to produce a rotating pattern. The six outside bars are illuminated by progressively phase-shifted versions of the reference signal so that when the note being tuned is flat the pattern rotates clockwise and anti-clockwise when sharp. The display is stationary when the note is exactly in tune with the note that has been set by the accurate oscillator in the instrument. The display is insensitive to false beats and there is also an aural indication through headphones which is a useful additional aid under certain circumstances.

Harwell Ion Implantation Service extended to the U.S.

Harwell is extending to the United States its service of ion implantation, one important application of which is the production of high-quality semiconductor devices. The service is based on the most comprehensive range of implantation accelerators in the world, together with a wealth of experience acquired by Harwell scientists in pioneering the technology and its industrial applications.

Ion implantation has found many applications in m.o.s. and bipolar technologies as well as in the fabrication of special discrete devices. The technique is also valuable in the doping of compound semiconductors and some manufacturers have built up extensive facilities and expertise to exploit the technology. However, other manufacturers would welcome the opportunity to assess the benefits to their products before committing too much of their resources. In this situation, Harwell is able to play a major part by providing ion implantation services and consultation. It is particularly well placed to carry out assessment requiring unusual dopant ions or very high beam currents.

The machines developed at Harwell cover the range of implantation energy from 100 eV up to over 5 MeV and ion beams from nanoamperes to milliamperes are available; wafers up to four inches diameter can be implanted. An implantation facility capable of handling pilot scale trials for organisations not yet possessing their own equipment is available which is able to handle several hundred large diameter wafers per day.

Other services offered at Harwell include atom location studies, electron microscopy and the measurement of the electrical parameters of implanted material and devices. The implantation and diagnostic equipment are complemented by semiconductor processing facilities.

Implantations can be carried out to customers' requirements for a simple tariff charge, while more detailed collaborative studies can be made under appropriate contractual arrangements. All commercial work is carried out on a

*Electronic aids for the tuning of musical instruments, *The Radio and Electronic Engineer*, 42, pp. S. 131–5, September 1972.

†The ETA Mark VI is distributed by H. J. Fletcher-Newman Ltd., 39–41 Shelton Street, London WC2H 9HL.

strictly confidential basis. The service has been operating successfully for several years but has been limited primarily to European users, and particularly to the United Kingdom.

For further information please contact: Dr. J. H. Stephen, Building 152, AERE, Harwell, Oxfordshire, OX11 0RA.

A Safety Mark for BSI

The British Standards Institution is to adopt a distinctive safety certification mark in addition to its famous Kitemark. This is necessary because under article 10 of the EEC Low Voltage Directive, Community Members are required to conform to the safety requirements of the Directive in the field of electrical equipment by providing safety marks or certification or declarations of conformity.

Bodies authorized to grant such marks or issue such certificates have to be nominated by member governments. BSI, with other certification bodies (e.g. the Association of Short-Circuit Testing Authorities (ASTA), the British Approvals Service for Electric Cables (BASEC) and the British Electrotechnical Approvals Board for Household Equipment (BEAB)) has been nominated by the UK Government for certain categories of electrical products.

The new mark, based on a triangle incorporating the letters BSI in a stylized form, will be a mark of conformity with a British Standard dealing only with safety, or with those parts which relate to safety characteristics in British Standards of wider application. Kitemark testing and surveillance methods will be used in the certification of product safety, and as with Kitemark procedures, a separate scheme will be devised for each standard, discussed and agreed with manufacturers, and then lodged with the Registrar.

The mark will be used to certify electrical products only for the time being, but there may be wider applications in future. Alongside the special BSI Safety Mark, the Kitemark may be used as a symbol of wider conformity to meet the demand for standards and related approval schemes concerning more than safety.

One essential corollary to nomination of BSI under the Directive is the establishment of Certification Committees. Competent, experienced and representative committees are needed to undertake responsibility for issuing marks, certificates and licences and for dealing with questions, appeals and complaints. In relation to the Safety Mark the Quality Assurance Council, which is responsible for the Kitemark operations of BSI, has authorized the formation of two Certification Committees—the Certification Committee for Lamps and Lighting Equipment (formed several months ago, following a long-standing commitment); and the Certification Committee for Electrical Equipment. This second Committee is to be formed immediately, and nominations for membership have been sought from the appropriate manufacturing, approval, research and consumer interests.

Increase in Companies' Annual Return Fee

New draft regulations contained in the Draft Companies (Fees) Regulations 1975 increased from £3 to £20 the fee payable with the filing of companies annual returns at the Companies Registration Office. The new fees came into operation with effect from 2nd June.

Plessey Capacitors Establishes Marketing Facilities in Japan

Plessey Capacitors has established a marketing and sales office in Japan. The office, based in Tokyo, is designed to service the growing requirements of the Japanese and Far Eastern markets and will handle and develop sales from Plessey Capacitors' eleven production centres at the headquarters in Bathgate, and in Scotland, continental Europe, Australia, Africa, South America and the US. Initially, the office will concentrate on marketing an extensive range of advanced film capacitors. Manufacturing facilities in the Far East and sales of other types of capacitors are expected to be developed in due course.

Omega Navigator Transmitting Stations Come on Air

Three more transmitting stations in the Omega network—the world wide hyperbolic navigation system—have been brought into operation, so that seven of the eight stations which make up the complete system now give coverage over more than 90% of the Earth's surface compared with 50% eight months ago. The new stations are located in La Réunion (a small French island in the Indian Ocean), Argentina and Liberia.

Orders for more than 700 Omega Navigator equipments have been placed with Redifon Telecommunications by leading shipping lines, along with several of the world's navies, particularly those belonging to NATO. The Royal Navy have just ordered additional equipments worth £¼M for naval surface ships bringing their total number of Redifon receivers to well over one hundred.

The Redifon Omega Navigator, which is designed specifically for marine use, continuously tracks signals from all Omega transmitters to give three hyperbolic lines of position throughout the area of coverage to an accuracy of within 1—2 nautical miles irrespective of weather conditions or time of day. A brief description of the operation of the Omega system and the navigation equipment was published in the July 1972 issue of *The Radio and Electronic Engineer*.

Desktop Programmable Calculator

A new medium-priced desktop programmable calculator, the HP 9825A, with many features previously found only on minicomputers, has recently been introduced by Hewlett-Packard. Designed primarily for use in the fields of engineering and science, the 9825's speed, interfacing abilities and computer-like features are stated to make it particularly well suited for use as the controller of an instrument system, for pilot process control applications, remote data collection and production control. It can also be used as a powerful stand-alone calculator.

Significant features of the 9825 include: vectored priority interrupts, live keyboard, and direct memory access with input speeds up to 400,000 16-bit-words per second. Plug-in read-only memories are an optional extra.

The 9825 uses a high-level programming language, called HPL, which gives the power and efficiency of FORTRAN, coupled with ease of use of BASIC. This formula-oriented language is easy to learn and ideally suited for controller applications, as well as for data processing. The language allows the use of as many as 26 variables and 26 multi-dimensional array variables limited only by the size of the calculator memory.

A new 32-character l.e.d. display and built-in 16 character thermal printer provide upper and lower case alpha-numeric readout. The display and printer provide the full ASCII character set. Some European and Greek character sets are r.o.m. addressable. With search and rewind speeds of 90 in/s and read/write speed of 22 in/s, the built-in tape cartridge drive gives an average access time of six seconds.

Japan Decontrols Integrated Circuit Imports

Japan's imports of integrated circuits have been completely decontrolled since 25th December 1974. I.c.s with less than 200 circuit elements were liberalized in April 1974, but at a cabinet meeting in June 1974 the government decided to extend liberalization to i.c.s of any capacity.

Indian Scientific Satellite

The first Indian scientific satellite, *Aryabhata*, named after the great Indian astronomer and mathematician of the fifth century, was successfully launched from the Soviet Cosmodrome with the help of a Soviet rocket carrier on 19th April, 1975. The satellite's orbit has the following parameters:

apogee 623 km; perigee 560 km; inclination: 50·4 degrees; orbital period around the Earth: 96·41 minutes.

The preliminary information obtained by the ground tracking stations in Sriharikota, near Madras, and Bear's Lake, on the outskirts of Moscow, indicated that all instruments on board were functioning normally. Although a partial equipment failure occurred after a relatively small number of orbits, some radio and optical observations have been satisfactorily carried out.

The satellite weighs 360 kg and has a multi-faceted shape. It was intended that it should obtain energy from solar batteries and be spin stabilized, with thermal regulation being achieved through a passive thermal control system. On the satellite are mounted apparatus for conducting three scientific experiments intended to measure respectively X-rays from celestial sources, look for neutrons and gamma radiation from the Sun, and measure ionospheric parameters.

Ferranti in Hong Kong

Ferranti and the Hong Kong company Wheelock Marden have formed a £256,000 company to make semiconductors in the British Colony.

Suppressing Radio Interference on Marine Installations

Operation of electrical equipment in ships may cause rapidly fluctuating currents and voltages, usually distributed over a wide frequency range. The degree of interference suppression required is an economic compromise because both the susceptible equipment and the offending equipment are part of the ship's installation.

BS 1597 'Radio Interference Suppression on Marine Installations', published by the British Standards Institution and now revised, specifies limits and methods of measurement for the electromagnetic interference which is generated by the electrical and electronic equipment of a marine installation. Limits in the frequency range 15 kHz to 100 MHz are specified for the radio frequency voltage or current appearing at the terminals of the electrical and electronic equipment, and for the radio frequency voltage appearing in the aerial feeder.

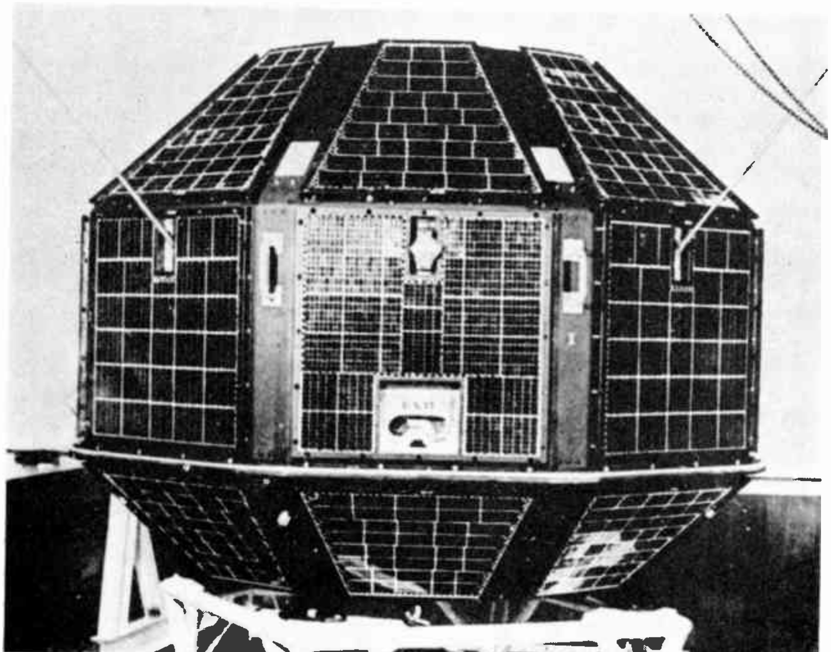
The measurement of interference voltage caused by energy picked up on the aerial and feeder as specified in the earlier edition is now changed to the measurement of that caused by energy picked up only on the feeder. The limit of 2μV for the voltage on the terminated feeder, together with the limits for the power terminal voltages of interference sources, will give the same degree of control as limits for voltages at the feeder output with the aerial connected.

Because the coupling between the power system wiring and the radio equipment on metal ships with metal subdivisions will be different from that on ships constructed of non-conducting materials, two classes are specified for the limits for the radio frequency voltages or currents appearing at the terminals of the electrical and electronic equipment.

Suppression components specified are selected so as to avoid detriment to the operation or safety of the equipment and to withstand marine conditions.

Guidance on measures which may be necessary to obtain compliance with the specified limits, formerly given as appendices of BS 1597: 1963, has been revised and will be published separately in the near future as BS 5260 'Code of practice for radio interference suppression on marine installations.'

Copies of BS 1597 are available from BSI Sales Department, 101 Pentonville Road, London N1 9ND.



India's first satellite launched by a Soviet launch vehicle from a cosmodrome in the Soviet Union on April 19th 1975.

Applicants for Election and Transfer

THE MEMBERSHIP COMMITTEE at its meeting on 13th January 1976 recommended to the Council the election and transfer of the following candidates. In accordance with Bye-law 23, the Council has directed that the names of the following candidates shall be published under the grade of membership to which election or transfer is proposed by the Council. Any communication from Corporate Members concerning the proposed elections must be addressed by letter to the Secretary within twenty-eight days after publication of these details.

Meeting: 13th January 1976 (Membership Approval List No. 217)

GREAT BRITAIN AND IRELAND

CORPORATE MEMBERS

Transfer from Member to Fellow

IRISH, Reginald Tom. *Swindon, Wiltshire.*

Direct Election to Fellow

DAVIES, Alan Venables. *Egham, Surrey.*

Transfer from Graduate to Member

AHMAD, Hamid Karim. *London*
ROBINSON, Roy. *Barrow-in-Furness, Cumbria.*
TURNER, Brian Roy. *Tewkesbury, Gloucester.*
WEIGHT, John Philip. *Crowborough, Sussex.*

Direct Election to Member

McCUNN, William James S. *Shifnal, Salop.*

NON-CORPORATE MEMBERS

Direct Election to Graduate

EXETER, George Ronald. *Plymouth Devon.*
WALKER, John Richard. *Reading, Berkshire.*

Transfer from Graduate to Associate Member

LURKINS, Peter George. *Maldon, Essex.*

Direct Election to Associate Member

DUNNE, Joseph Francis. *Eastleigh, Hampshire.*
GRIGG, Thomas Henry C. *Askerswell, Dorset.*
KENT, Anthony Ross. *Stanmore Park, Middlesex.*
MORRIS, James Edward. *High Wycombe, Buckinghamshire*
NARIMISSA, Abraham. *Cambridge.*

STUDENTS REGISTERED

ALDWORTH, Colin Paul. *Stourbridge, West Midlands.*
AL-TALL, Atef Mohammed A. *Nottingham.*
BANWAIT, Jagjit Singh. *Coventry.*
BEARNE, Robert. *Paignton, Devon.*
BOWELL, David Brian. *Nottingham.*
CARR, David Michael. *Nottingham.*
CARTER, Paul. *Nottingham.*
CARTWRIGHT, Peter Nigel. *Stoke-on-Trent, Stafford.*
CLARKE, Stephen Gerald. *Nottingham.*
COULSON, Stephen Howard. *Hull, North Humberside.*
COOK, Gerald Paul. *Nottingham.*
CORBETT, John Colin. *Kings Lynn, Norfolk.*
DAVIDSON, Andrew Neil. *Nottingham.*
Da SILVA, Michael John. *Woking, Surrey.*
DE GRAFT ROSENIOR, Lauren E. O. (Miss). *Nottingham.*
DIXON, Ian Roger. *Skipton, North Yorkshire.*
EVANS, Christopher John. *Helsby. Warrington.*
EVANS, Graham Arthur. *Chilwell, Nottingham.*
FADARE, Saibu Olasupo. *London.*
FINNAMORE, Neville Albert. *Walton-Le-Dale, Preston.*
FOULKES, Robert Lloyd. *Abingdon, Berkshire.*
GLENNY, Michael. *Nottingham.*
GREIG, Frank. *Edinburgh.*
HARKER, Michael. *Grassington, North Yorkshire.*
HAWKINS, John Michael. *Nottingham.*
HOOKER, Trefor James. *Crowthorne, Berkshire.*
JACKSON, Andrew Martin. *Bartley, Southampton.*
KINGE, Nigel. *Nottingham.*
KNIBBS, Graeme Keith. *Nottingham.*
LEES, Russell Hedley. *Nottingham.*
LINDSAY, John Watt. *Nottingham.*
McEWAN, Ronald Andrew. *Mansfield.*
MAGHERA, Munmohan Singh. *Nottingham.*
MUGHAL, Mohammad Afzal *Sneinton, Nottingham.*
MURRAY, Gavin. *Maryport, Cumbria.*
NAYLOR, Stephen Robert. *Sheffield, Yorkshire.*
NORMAN, John Francis. *Nottingham.*
NORTON, David. *Ilkley, West Yorkshire.*
NOURI, Hassan. *Nottingham.*
NYE, Andrew Stephen. *Croydon, Surrey.*
PETROVIC, Alex. *Nottingham.*
QUARMBY, Neil Anthony. *Nottingham.*
RAFFAN, Neil Fraser. *Nottingham.*
RAHIM, Tehseen. *London.*
RALPH, Graham Alan. *Nottingham.*
READMAN, Colin Keith. *Nottingham.*
REINECK, Leonard James. *Beeston, Nottingham.*
RICKETTS, David James. *Nottingham.*
ROBERTS, Roger William W. *Nottingham.*
RUFFLES, Paul Robert. *Nottingham.*
SCOTT, Malcolm John. *Taunton, Somerset.*
SCOTLAND, Ronald Ian Henry. *Nottingham.*
SHARPE, Anthony Norman. *Nottingham.*
SMITH, Leslie George. *Nottingham.*
SMITH, Mark Sharman. *Nottingham.*
STEER, Graeme Leslie. *Nottingham.*
TAYLOR, David Russell. *Nottingham.*
TOPHAM, Peter James. *Nottingham.*
TURNER, Michael. *Reading, Berkshire.*
WALDECK, Peter Michael. *Newbury, Berkshire.*
WATTS, Colin Brenden. *Solihull, West Midlands.*
WEBB, Edward Wilfred. *Nottingham.*
WILLIAMS, David John. *Sheffield.*
WILSON, John. *Cambuslang, Glasgow.*
ZAMMIT, Anthony Stephen. *Colne, Lancashire.*

OVERSEAS

CORPORATE MEMBERS

Transfer from Graduate to Member

DUTTA, Ajoy Kumar. *Calcutta, India.*

NON-CORPORATE MEMBERS

Transfer from Student to Graduate

LAM, Ar Fu Peter. *Hong Kong.*

Direct Election to Graduate

ARIYARATNAM, Kandiah. *Colombo, Sri Lanka.*
LEE, Kang Kuen. *Hong Kong.*

Direct Election to Associate Member

LAM, Sai-Cheong. *Hong Kong.*
TANG, Tak. *Hong Kong.*
TEO, Eng Kuan. *Singapore.*

Transfer from Student to Associate

WILLIAMS, John Harding. *Melville Heights, Western Australia.*

STUDENTS REGISTERED

CHAN, Kang Chiu. *Hong Kong.*
CHAN, Kwan Hung. *Hong Kong.*
CHEW, Shee Fuee. *Selangor, Malaysia.*
CHOE, Yaw Choon. *Singapore.*
CHOW, Kin Wah. *Hong Kong.*
DIAMANT, Yariv Haim. *London.*
EE, Peck Lian (Miss). *Singapore.*
FUNG, Ki-On Patrick. *Hong Kong.*
GOPAL, Saminathan. *Singapore.*
HOON, Tien Shiong. *Singapore.*
LAI, Yen On. *Hong Kong.*
LEONG, (George) Pak C. *Singapore.*
LIM, Boon An. *Singapore.*
LO, Wai Hung. *Hong Kong.*
MAINA, Julius N. *Nairobi, Kenya.*
NANDI, Jyoti Shankar. *Poona, India.*
NILAWEERA, Rulwan Santha. *Nugegoda, Sri Lanka.*
ODEYEMI, Morohunfolu O. *Ibadan, Nigeria.*
PANG, Chi Ming. *Hong Kong.*
TAN, Thiam Chye. *Singapore.*
TAN, Swee Beng. *Kuala Lumpur, Malaysia.*
TSUI, Chuen Cheong. *Hong Kong.*
WU, Wai Hung. *Hong Kong.*
YUEN, Tak Sing. *Hong Kong.*

Addenda

Meeting: 4th September 1975 (Membership Approval List No. 212)

GREAT BRITAIN AND IRELAND

NON-CORPORATE MEMBERS

Direct Election to Associate Member

DRAPER, Bryan. *Haxby, York.*

Meeting: 6th November 1975 (Membership Approval List No. 214)

GREAT BRITAIN AND IRELAND

NON-CORPORATE MEMBERS

Direct Election to Associate Member

WILLIAMS, Iestyn Glyndwr. *Surbiton, Surrey.*

Members' Appointments

NEW YEAR HONOURS

The Council has congratulated the following member of the Institution, whose name appears in Her Majesty's New Year Honours List:

MOST EXCELLENT ORDER OF THE BRITISH EMPIRE

To be an Ordinary Officer of the Civil Division (M.B.E.)

Wilfrid Henry Moore (Associate Member 1973, Associate 1958). Senior Scientific Officer, Freshwater Biological Association; Ambleside, Cumbria. (Mr. Moore first joined the Association in 1936 and, including war service in the Royal Navy, has therefore completed nearly 40 years' service.)

CORPORATE MEMBERS

H.R.H. The Duke of Kent, G.C.M.G., G.C.V.O. (President) will retire from the Army on 13th April after 20 years' commissioned service, latterly in the Royal Scots Dragoon Guards with rank of Lieutenant Colonel. Later this year the Duke will become Vice-Chairman of the British Overseas Trade Board of which he has been a member since last summer and in this capacity he will visit Kuala Lumpur to open the British Technology for Malaysia Exhibition on 5th April. This is the first major British exhibition to be held in Malaysia and over 320 British companies and their South East Asian associates are taking part, including a number from the electronics industry.

Mr. Stuart Sansom (Fellow 1974, Member 1959, Graduate 1954) who worked in Independent Television in Great Britain from 1957 and was latterly Director of Studios and Engineering with Thames Television, has taken up an appointment as Television Adviser with the South African Broadcasting Company.

Mr. J. S. Shayler, B.Sc. (Fellow 1975, Member 1959) has recently taken up the post of Minister, Defence Research and Development, at the British Embassy in Washington, D.C. From 1971 to 1975 Mr Shayler was Head of Military and Civil Systems and Deputy Director at the Royal Radar Establishment, Malvern. Before that he was Director of Electronics Research and Development (Telecommunications) with the Ministry of Technology for several years; he had previously been Superintendent of the Blind Landing Experimental Unit where he took a leading part in the initial development of the Autoland system. He described this work in a paper published in the Journal in 1961, for which he was awarded the Brabazon Premium. Mr. Shayler was a member of the Aerospace, Maritime and Military Systems Group Committee from its formation in 1960 until he took up his present appointment. He served on the Council from 1967 to 1969.

Mr. B. L. Anand, M.Sc., B.Sc., (Member 1969) is now a Senior Lecturer in the Engineering Science and Mathematics Resource Centre of Middlesex Polytechnic. He joined Enfield College of Technology as Lecturer II in Control Engineering in 1970 and obtained the M.Sc. degree of the University of London in Computer Science in 1972.

Mr. G. Galliver (Member 1968) who joined Data Technological Corporation of California as Director of European Operations in 1973, has been appointed Manager for the Systems Division of Fairchild Camera and Instrument Corporation in the U.K. and is based in Bracknell.

Mr. R. O. Ifidon (Member 1965) has been appointed Chief Engineer of the Midwest Broadcasting Corporation at Benin City, Nigeria. After gaining technical qualifications and industrial experience in the UK, Mr. Ifidon worked for the Western Nigeria Broadcasting Station from 1959, being appointed Deputy Chief Engineer in 1969. In this capacity he was responsible for many of the aspects of the establishment of the Corporation's television service.

Mr. J. H. Kelly (Member 1972, Graduate 1963) who joined the Kenya Polytechnic, Nairobi, as a Lecturer in 1967 and was appointed Head of the Electrical Engineering Section in 1971, is now with the UK Ministry of Overseas Development as an Electrical Engineering Adviser. He is currently advising the Trinidad Government on the setting up of an Electrical Department in the new Southern Technical Institute being built at San Fernando.

Mr. M. D. K. Kendall-Carpenter, O.B.E. (Member 1972, Associate 1969) who was Manager and Engineer of Cable & Wireless (W.I.) Limited, Grand Cayman Island, from December 1969 to August 1975, has returned to the United Kingdom to join the recently established Group Business Review Unit of Cable and Wireless Ltd. His appointment as O.B.E. in the recent New Year Honours List was reported in the January Journal.

Mr. E. W. Marsden (Member 1957) who was for a number of years Manager of the Audio/Radio Developments Department of the Decca Radio & Television Company Limited, has left the Company and is now consultant radio and electrical engineer, technical author and publisher.

Lieut. R. M. Prynn, RN (Member 1973, Graduate 1969) has completed German language training and has taken up an appointment as a lecturer in electronic engineering at the School of Marine Navigation of the Federal German Navy at Bremerhaven.

Mr. J. M. F. Spalding (Member 1973, Graduate 1963) has completed a two-year secondment to the Zambia Broadcasting Services as Chief Engineer and has returned to the Studio Capital Projects Department at the BBC.

Sqdn. Ldr M. H. Taylor, B.Sc., M.Sc. RAF (Member 1972) has been posted from Headquarters RAF Training Command. Brampton, where he occupied a staff post concerned with electronic ground training, to the RAF College, Cranwell to command No. 2 Systems Techniques Squadron which trains RAF Engineer Officers in mathematics, electronics and computer sciences.

Mr. T. Vudali, M.Sc., (Member 1973, Graduate 1972) has completed a year's postgraduate studies in microwave solid state physics at Portsmouth Polytechnic and has joined Marconi Instruments Limited, Stevenage, as a microwave design engineer.

Mr. P. Whattam, (Member 1965) has recently been appointed to a position in the Directorate of Heavy Weapons Projects, Ministry of Defence, as a Principal Professional and Technology Officer. He was previously a P. & T.O. II at the Royal Ordnance Factory, Blackburn.

NON-CORPORATE MEMBERS

Mr. M. Briggs (Graduate 1965) has been appointed Product Manager of the industrial controls division of Gould Advance Ltd. Mr. Briggs joined Advance Electronics in 1970, prior to which he was with General Instrument Microelectronics.

Flg. Off. J. W. Grubb, RAAF (Graduate 1970) has been posted to 486 Squadron of the Royal Australian Air Force as Engineering Officer, in charge of Hercules Simulators. His previous appointment was as Instrument Engineer with Honeywell Australia Pty Ltd. Before emigrating to Australia in 1972 he was a Research Engineer with ICI Fibres, Pontypool.

Mr. H. K. Koh (Graduate 1968) has been appointed Engineer in Charge of the Jalan Mata Kuching station of the Department of Broadcasting in Malaysia. He was formerly with the Telecommunications Training Centre of the Malaysian Telecommunications Department.

Sqn. Ldr. A. H. E. Welch, D.F.C., RAF (Ret.) (Associate Member 1973, Associate 1963) has joined Avon Pneumatics as Sales Manager on his retirement from the RAF. During his 36 years in the Service, he held many different flying and technical appointments and was Station Commander at RAF Rudloe Manor, Wiltshire, prior to his retirement.

Mr. S. Kannan (Associate 1955) has been appointed Quality Control Manager with Pye Industries, New South Wales, Australia. He was previously Technical Editor with Australian Industrial Publications, New South Wales.

Mr. M. P. Singh (Associate 1975) has taken up the post of Lecturer in Electronics and Telecommunications at the Zambia Institute of Technology in Kitwe. He was formerly employed by the Tanzania Electric Supply Company as a Light Current Engineer (Telecommunications).

CERTIFIED DIPLOMA IN ACCOUNTING AND FINANCE

The result of the June examination for the Certified Diploma in Accounting and Finance were recently announced by the Association of Certified Accountants. Out of 492 candidates sitting for the examination, 283 were successful. The following members of the IERE have gained the Diploma.

Mr. D. R. Gibby, M.Sc. (Member 1973, Graduate 1968), Head of Computer Applications Branch, Mathematics and Computer Division at SHAPE Technical Centre in the Netherlands.

Mr. B. J. Goldsmith (Member 1973, Graduate 1967), Senior Development Engineer with International Aeradio Ltd., Southall, Middlesex.

Mr. T. E. Longden (Member 1962), Head of Section in the Operational Programming Department of the Post Office Telecommunications Headquarters, London.

Mr. P. C. Piegrome (Member 1967) Test Equipment Engineering Manager with Plessey Telecommunications, South Shields.

Mr. M. R. Weaver (Graduate 1969) Service Specialist, with the Technical Service Division of Instrumentation Laboratory (UK) Ltd., Stockport.

MEMBERSHIP ROLL FOR FIRST DECADE

Mr. P. H. George (Fellow 1944, Member 1926) was inadvertently omitted from the list of members with over 40 years' service to their credit which was published in the October 'Golden Jubilee' issue of the Journal. After commissioned service during the First World War in the RFC and RAF, Mr George spent much of his professional career as a radio engineer with Posts and Telegraphs administrations overseas. These included five years in Brunei and over 18 years in Malaya. During the war he was with the Directorate of Supplies, South Africa, and from 1944 to 1945 was attached to the War Office in London. He returned to Kuala Lumpur after the war and in 1948 went to work in South Africa, retiring in 1957. He celebrated his 80th birthday on 7th December last.

Obituary

The Council has learned with regret of the deaths of the following members:

Malcolm John Barnett, B.Sc. (Member 1973) died as the result of a car accident in March 1975. He was 32 years of age and unmarried.

After graduating in electrical engineering from Birmingham University in 1962, Mr Barnett worked for a year with Burrows Machines Ltd. in Sweden as a data processing engineer. He then moved to International Computers Ltd., Kidsgrove, subsequently being promoted to Senior Engineer and working mainly on circuit design of magnetic tape equipment and on test problems generally. In 1970 he joined A. M. Lock & Co. Ltd. as a Technical Sales Engineer, and in February 1972 took up the post of Group Electronics Engineer with the North Staffordshire group of hospitals. In this capacity Mr Barnett had responsibilities for a wide range of electronic equipment spread over five hospitals in the group.

William Harold Dockerty (Member 1958, Graduate 1957) died on 22nd July 1975 aged 51. He leaves a widow, two daughters and one son.

Mr Dockerty started his professional career with Aron Electricity Meters Ltd., Kilburn. From 1946 to 1949 he served with R.E.M.E. and on demobilization went to the National Gas Turbine Establishment, where he worked as a technician. During this period he studied at technical colleges and completed the Higher National Certificate in 1954. At that date he had transferred as a technical officer to the Headquarters of 90 Group R.A.F. He then moved to the Headquarters of the Ministry of Supply where he was concerned with the procurement of electronic equipment for the Army. In 1958 Mr Dockerty transferred to the Professional class of Engineer III and took charge of the planning and progressing of radar equipment production at R.O.F. Blackburn. He remained here until 1968 when he returned to London as a Project Manager in the Ministry of Defence, with responsiblity for the procurement of u.h.f. and v.h.f. ground communications equipment for the Services. He suffered a heart attack in April of this year but returned to work in early June; just over a month later he died while on holiday.

Abraham Frisch (Member 1967, Graduate 1963, Student 1957) died on 31st May 1975 aged 54.

Born and educated in Hungary, Mr Frisch worked with Olivetti in Italy before going to Israel in 1949. He served in the Israel Army Signal Corps for a year and then joined the Engineering Branch of the Police Force, eventually becoming Head of the Teleprinter Department. In 1962 he went to the Electronics Corporation of Israel where one of his principal projects was the design of a new communications centre for the Israeli Department of Civil Aviation.

Maurice Terrance Jones (Member 1973, Graduate 1969) died on 30th July 1975 aged 41. He leaves a widow and a son and daughter.

Following a short service engagement in the Royal Air Force as an air radar fitter, Mr Jones worked for five years with the Midlands Electricity Board as a television service engineer. He studied City and Guilds subjects and in 1959 obtained the Final Certificate in Telecommunications Engineering. He subsequently held appointments with commercial television service companies in the West Midlands area, and during this period became a part-time lecturer for the City and Guilds television servicing course at Shrewsbury Technical College. In 1967 he entered Wolverhampton Technical Teachers College to take a year's full-time course, and then obtained an appointment as lecturer at Derby and District College of Technology. Here he taught radio and television servicing and in 1971 he received an appointment as Civilian Education Officer at RAF Cosford teaching radio communications and advanced electronics to radio fitters. Since September 1973 Mr Jones had been a Lecturer I in charge of radio, electronics and television courses at Bridgnorth College of Further Education.

Norman George Sykes (Fellow 1963. Member 1949) died on 9th November 1975 leaving a widow and one son.

Born in Rutland, Mr Sykes studied at the London Radio College and from 1927 to 1932 was a sea-going Radio Officer, first with the Marconi International Marine Company and later with the Cunard Steamship Company. In 1933 he entered the radio industry, working for a short time at McMichael Radio and then with Gambrell Radio Communications, eventually becoming Acting Marine General Manager. In 1938 Mr Sykes joined the Admiralty at H.M. Signal School, subsequently the Admiralty Signal Establishment, and during the early part of the war he was responsible for final acceptance tests and repair of radio and radar equipment. Later in the war he was commissioned as Lieutenant Commander RNVR and was seconded to the Staff of Vice Admiral Q, British Pacific Fleet, as technical adviser on telecommunications and radar in the Pacific theatre, based in Australia and Ceylon.

After the war he spent 15 years at the Admiralty Surface Weapons Establishment; from 1951 to 1963 he was Head of Telecommunications and Electronic Warfare Production, responsible for all aspects of the production of equipment in this field for the Royal Navy.

In 1963 Mr Sykes moved to the Government Communications H.Q. as a Superintendent Grade Engineer, and he was for four years Chief Engineer of the Government Communications Radio Organization with the grade of Assistant Director prior to his retirement in 1970.

CEI News for Members

President of CEI

Lord Hinton of Bankside, K.B.E., F.R.S., has been elected President of the Council of Engineering Institutions and took up office on 10th February 1976, the date of the Council's Annual Meeting. Lord Hinton succeeded His Royal Highness the Duke of Edinburgh, K.G., K.T., F.R.S., Founder President of CEI since its inception in 1965.

Christopher Hinton is widely regarded as being one of the outstanding British engineers of our generation. After serving a five-year apprenticeship at the Great Western works at Swindon and working for a time in the drawing office, he was awarded the William Henry Allen Prize by the Institution of Mechanical Engineers and with this went to Trinity College, Cambridge. He took first-class honours in the Mechanical Sciences Tripos at the end of his second year and spent his last year in research on vibration of bridges. He then worked from 1926 to 1940 in companies which later became part of Imperial Chemical Industries and during the war he was loaned to the Ministry of Supply, becoming Deputy Director-General in charge of the Royal Filling Factories. After the war he took charge of production organization of the newly formed Department of Atomic Energy. He was later appointed first Managing Director of the Industrial Group of the UK Atomic Energy Authority and from 1957 to 1964 he was Chairman of the Central Electricity Generating Board.

Created a Life Peer in 1965, Lord Hinton was President of the Institution of Mechanical Engineers in 1966/67, is a Fellow of the Institution of Chemical Engineers and an Honorary Fellow of the Institutions of Mechanical Engineers, Electrical Engineers, Civil Engineers and Gas Engineers. He was elected a Fellow of the Royal Society in 1954 and has received numerous British and overseas prizes and distinctions recognizing his contribution to British nuclear power developments over the past thirty years. Lord Hinton has been Chairman of the MacRobert Award Evaluation Committee since the inauguration of the Award in 1969.

Elections of Officers for 1976

Chairman

Mr. George Anthony Dummett, M.A., C.Eng., F.I.Chem.E., has been elected Chairman of the Council of Engineering Institutions and assumed office on 10th February.

Mr. Dummett has been Vice-Chairman since January of last year, as well as Chairman of the CEI Committee on Registration, Education and Training. He was also Chairman of a CEI Working Party on 'Professional Engineers and Trade Unions', whose report has just been published (See p. 53).

Mr. Dummett became a Member of the Institution of Chemical Engineers in 1940, a Fellow in 1958 and President in 1968–1969. He was educated at Pembroke College, Cambridge, where he took his first-class honours in the Natural Sciences Tripos in 1929. In 1935 he joined APV Company Ltd. with who he remained for the rest of his career eventually became Research Director in 1956 and Deputy Managing Director in 1965.

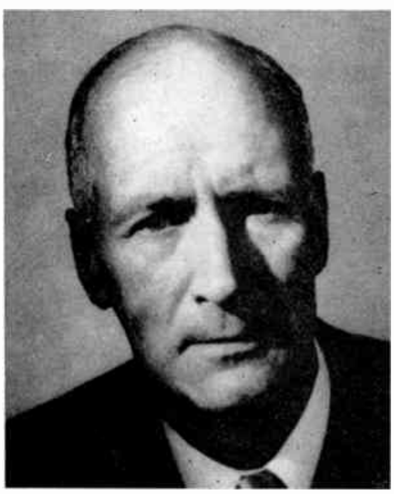
Additionally, Mr Dummett was a Director of APV Holdings Limited and Deputy Chairman of APV International. He retired from these Boards at the end of 1972.

Mr. Dummett is Chairman of the British National Committee of FEANI, and an honorary member of the Société de Chimie Industrielle. From 1958 to 1965 he was Chairman of the Research Committee for the FBI (now CBI) and he has been a member of various Government Committees including the Industrial Grants Committee and the Advisory Committee on Chemical Engineering.

Vice-Chairman

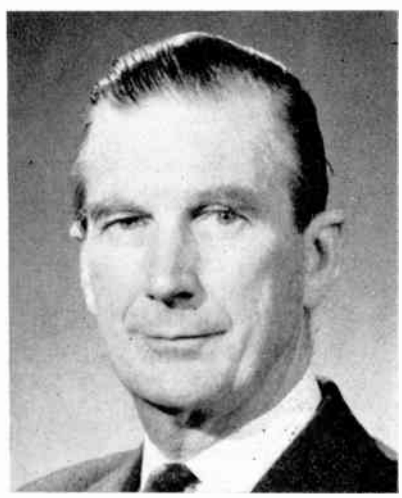
Air Marshal Sir Charles Pringle, K.B.E., M.A., C.Eng., F.R.Ae.S., Controller of Engineering and Supply (RAF) at the Ministry of Defence, has been elected Vice-Chairman of CEI and took office on 10th February, 1976, in succession to Mr G. A. Dummett.

Sir Charles, who is President of the Royal Aeronautical Society, has been a member of the CEI Board since mid-1974. Educated at St. John's College, Cambridge where he took his engineering degree, he joined the Royal Air Force in 1941 and attended the Royal Air Force School of Aeronautical Engineering. He served from 1942 to 1946 in India and Ceylon, and held varied engineering staff appointments in the United Kingdom and overseas in the next 25 years. He became Director General of Engineering in 1969, Air Officer in charge of Engineering at Headquarters Strike Command in 1970 and took up his present post in November 1973.



Lord Hinton of Bankside

G. A. Dummett



Air Marshal Sir Charles Pringle

Forthcoming Institution Meetings

London Meetings

Wednesday, 3rd March

COMMUNICATIONS GROUP

Colloquium on TROPOSPHERIC SCATTER COMMUNICATIONS

IERE Lecture Room, 2 p.m.

Advance registration necessary. For further details and registration forms, apply to Meetings Secretary, IERE.

Thursday, 18th March

COMMUNICATIONS GROUP

Global Communications

By D. Weedon (*Cable and Wireless*)

IERE Lecture Room, 6 p.m. (Tea 5.30 p.m.)

Wednesday, 31st March

JOINT IEE/IERE COMPUTER GROUP

Colloquium on SYSTEMS SIMULATION

IERE Lecture Room, 2 p.m.

Advance registration necessary. Registration forms available from the Meetings Secretary.

Wednesday, 21st April

ELECTRONICS PRODUCTION TECHNOLOGY GROUP

Colloquium on AUTOMATIC PRODUCTION

IERE Lecture Room, 2 p.m.

Advance registration necessary. For further details and registration forms, apply to Meetings Secretary, IERE.

Wednesday, 28th April

AUTOMATION AND CONTROL SYSTEMS GROUP AND COMPONENTS AND CIRCUITS GROUP

Colloquium on STEPPING MOTOR DRIVES

IERE Lecture Room, 10 a.m.

Advance registration necessary. For further details and registration forms, apply to Meetings Secretary, IERE.

Thursday, 29th April

AEROSPACE, MARITIME AND MILITARY SYSTEMS GROUP

A Novel Approach to Marine Surveying

By J. M. Thompson (*Decca Survey*)
IERE Lecture Room, 6 p.m.

Thames Valley Section

Thursday, 22nd April

ANNUAL GENERAL MEETING

followed by a lecture on

Mobile Radio in the Era of Spectral Congestion

By Professor W. Gosling (*University of Bath*)

Caversham Bridge Hotel, Caversham Road, Reading, 7 p.m.

South Western Section

Tuesday, 16th March

JOINT MEETING WITH IEE

Some Aspects of Telecommunications Engineering

By T. M. Coleman and J. Little (*Post Office*)

Techno Centre, Swindon, 7 p.m.

An exhibition entitled 'The Centenary of the Invention of the Telephone' will be on display in the Techno Centre from 10th March to 3rd April and will be open to the public each day from 9 a.m. to 5.30 p.m. (Wednesdays and Saturdays 9 a.m. to 12.30 p.m.)

Wednesday, 24th March

JOINT MEETING WITH IEE

Applications of Microprocessors

By Dr. B. A. White and R. Lipczynski (*Bath University*)

Canteen, Westinghouse Brake & Signal Co., Chippenham, 6 p.m. (Tea 5.30 p.m.)

Wednesday, 28th April

JOINT MEETING WITH IEE

Developments in Marine Navigation Aids

By S. F. Appleyard (*Marconi International Marine*)

Lecture Room, School of Chemistry, University of Bristol, 6 p.m. (Tea 5.30 p.m.)

Monday, 3rd May

ANNUAL GENERAL MEETING

Royal Hotel, College Green, Bristol, 7 p.m.
(Coffee available afterwards)

Southern Section

Tuesday, 2nd March

Signal Processing without Tears

By D. Cox (*School of Signals, Blandford Camp*)

Bournemouth College of Technology, 7 p.m.

Wednesday, 3rd March

Magnetic Bubbles and their Applications

By G. B. Scott, Ph.D. (*Mullard Research Laboratories, Redhill*)

Brighton Technical College, Pelham Street, 7 p.m.

Wednesday, 10th March

ANNUAL GENERAL MEETING OF THE SECTION

Followed by a lecture on

Concorde Electronics

By N. Brenchley (*British Aircraft Corporation*)

Lecture Theatre F, University of Surrey, Guildford, 7 p.m.

Wednesday, 17th March

JOINT MEETING WITH IEE

Ambisonics

By Professor P. B. Fellgett (*University of Reading*)

RAE Farnborough Director's Mess, 7 p.m.

Thursday, 18th March

Electronics in Yachts

By P. I. Pelham (*Brookes & Gatehouse Ltd.*)

South Dorset Technical College, Weymouth, 6.30 p.m.

Wednesday, 24th March

JOINT MEETING WITH IEE

Symposium on Current Trends in Digital Image Processing

Portsmouth Polytechnic, 4 p.m.

Kent Section

Wednesday, 17th March

Education and Training for the Electronic Engineer

By K. J. Dean (*S.E. London College*) and K. J. Coppin (*IERE*)

Medway & Maidstone College of Technology, 7 p.m.

Wednesday, 7th April

ANNUAL GENERAL MEETING

followed by a lecture on **Radio Astronomy**

By Dr. M. J. S. Quigley (*Appleton Laboratory Slough*)

Europa Lodge, Tollgate Hotel, Watling Street, Gravesend, 7 p.m.

Beds & Herts Section

Thursday, 18th March

The Technology of Scientific Satellites

By G. G. Lewis (*Space Projects Management, BAC*)

Synopsis: The design and development of scientific spacecraft have led to considerable advances in a number of technological fields. The environment of space demands the solution of mechanical, thermal, electrical and electromagnetic problems not normally encountered on earth, and the impossibility of access for maintenance and repair of equipment requires ultra-reliable components with a working life often of many years and the development of redundancy techniques whereby defects may be rectified automatically or by radio control or command. The paper describes some of these environmental problems and their technical solutions.

Hatfield Polytechnic, College Lane, Hatfield, 7.45 p.m.

Tuesday, 27th April

ANNUAL GENERAL MEETING

followed by an address by L. H. Bedford

Hatfield Polytechnic, College Lane, Hatfield, 7.45 p.m.

South Wales Section

Wednesday, 10th March

Wave Generation and Shaping

By W. A. Evans (*University College, Swansea*)

Department of Applied Physics and Electronics, UWIST, Cardiff, 6.30 p.m. (Tea 5.30 p.m.)

Thursday, 8th April

JOINT MEETING WITH IEE

Transducers for Modern Automobile Systems

By J. Moore (*Joseph Lucas*)

University College, Swansea, 6.15 p.m. (Tea 5.30 p.m.)

West Midlands Section

Tuesday, 2nd March

An Introduction to Microprocessors

By F. Arthur and D. R. H. Baggs (*City of Birmingham Polytechnic*)

City of Birmingham Polytechnic, 7 p.m. (Tea at 6.30 p.m.)

Tuesday, 16th March

JOINT MEETING WITH IEE

Telephone Switching—the Next Twenty Years

By M. Ward, (*GEC Telecommunications*)

Lanchester Polytechnic, Room L13, Coventry, 6.30 p.m. (Tea 5.45 p.m.)

Wednesday, 7th April

ANNUAL GENERAL MEETING

followed by a lecture on

Horn Loudspeakers

By J. Dinsdale (*Cranfield Institute of Technology*)

The Polytechnic, Wolverhampton, 7 p.m. (Tea 6.30 p.m.)

East Midlands Section

Thursday, 11th March

JOINT MEETING WITH IOP

Acoustical Holography

By Professor J. W. R. Griffiths (*Loughborough University of Technology*) Lecture Theatre W.001, Loughborough University of Technology, 7 p.m. (Tea 6.30 p.m.)

Tuesday, 11th May

JOINT MEETING WITH IEE

Special Effects in Colour Television

By A. B. Palmer (*BBC TV Studios*)

EMEB Offices Sports and Social Club, Wigman Road, Bilborough, Nottingham, 7.30 p.m. (Refreshments available after the lecture.)

South Midlands Section

Wednesday, 17th March

Electronics in Motor Vehicles

By L. Phoenix (*Lucas Electrical Co.*)

Foley Arms Hotel, Malvern, 7.30 p.m.

Tuesday, 27th April

Guided Weapons

By Captain J. Maltby (*RRE*)

To be followed by the

ANNUAL GENERAL MEETING

Golden Valley Hotel, Cheltenham, 7 p.m.

Yorkshire Section

Wednesday, 24th March

The Impact of Digital Electronics on TV Illustration

By A. A. Trainer (*ITN*)

Yorkshire TV Studios, Leeds, 7.30 p.m.

Friday, 2nd April

ANNUAL GENERAL MEETING

University of Leeds, No. 2 Refectory, 7 p.m.

North Eastern Section

Wednesday, 3rd March

JOINT MEETING WITH BRITISH COMPUTER SOCIETY

Privacy and Security of Information Systems

By C. P. Marks (*President, BCS*)

University of Newcastle-upon-Tyne, 7 p.m. (Tea 6.30 p.m.)

Tuesdaty, 6th April

Charge Coupled Devices

By Professor W. D. Ryan (*Queens University Belfast*)

YMCA, Ellison Place, Newcastle-upon-Tyne, 6 p.m. (Tea 5.30 p.m.)

North Western Section

Wednesday, 31st March

JOINT MEETING WITH IEE

Ceefax

By a speaker from the BBC Research Department

University of Manchester Institute of Science and Technology, 6.15 p.m. (Light refreshments available at 5.45 p.m.)

Thursday, 22nd April

ANNUAL GENERAL MEETING

followed by a lecture on

The Philips Video Disc

University of Manchester Institute of Science and Technology, 6.15 p.m. Light refreshments will be available beforehand.

Further details to be confirmed.

Merseyside Section

Wednesday, 10th March

Electronic Calculators and their Development

By I. Jennings (*Texas Instruments*)

Department of Electrical Engineering and Electronics, University of Liverpool, 7 p.m. (Tea 6.30 p.m.)

Wednesday, 7th April

ANNUAL GENERAL MEETING

followed by

An Evening with Quad

By D. McDowell (*Acoustical Manufacturing Co.*)

Department of Electrical Engineering and Electronics, University of Liverpool, 7 p.m. (Tea 6.30 p.m.)

Northern Ireland Section

Wednesday, 10th March

Megaw Memorial Prize Lectures

Ashby Institute, Stranmillis Road, Belfast, 6.30 p.m.

Tuesday, 6th April

ANNUAL GENERAL MEETING

followed by a lecture on

Ceefax

By M. O. Elliott (*BBC*)

Cregagh Technical College, Montgomery Road, Belfast, 6.30 p.m.