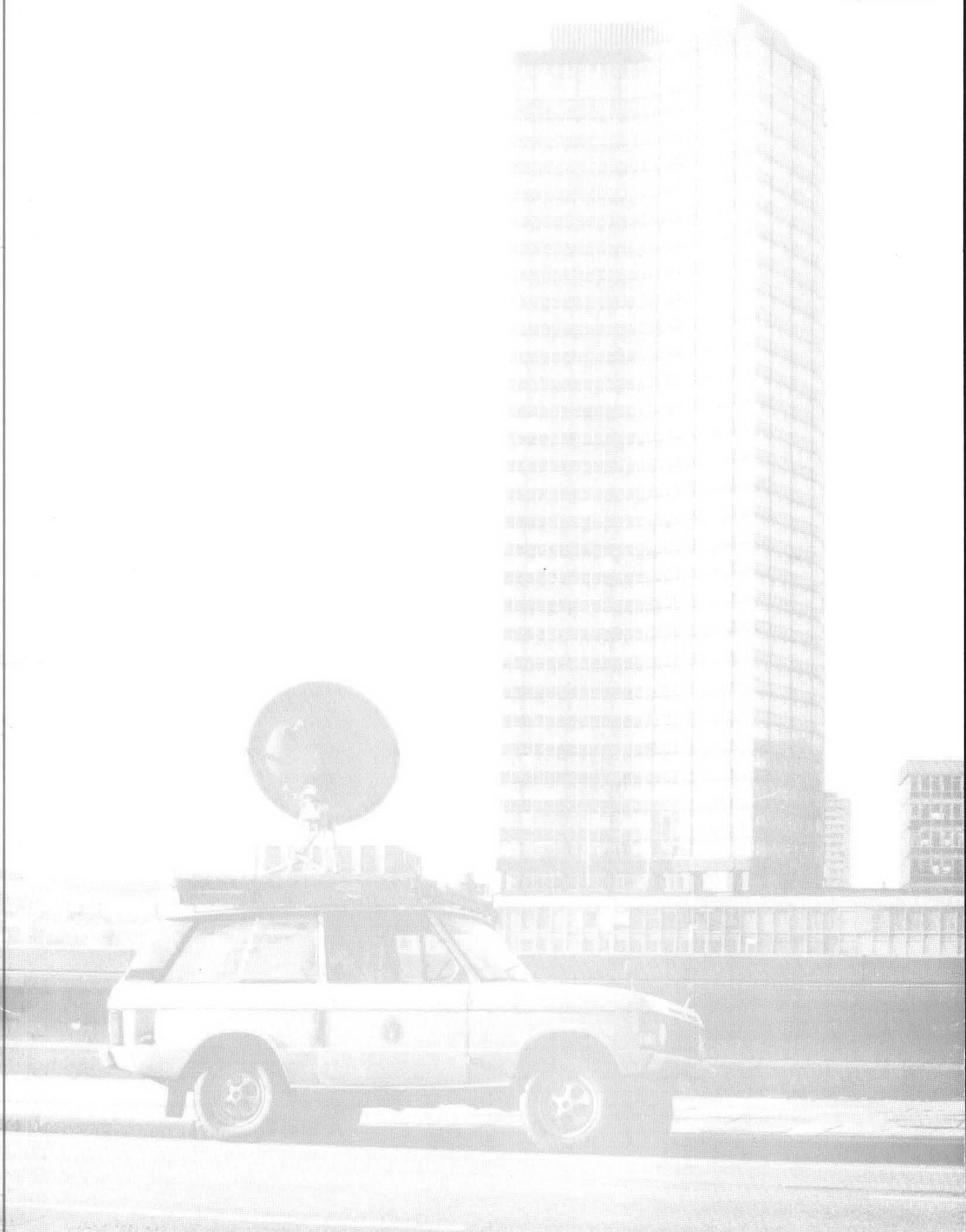
BBC ENGINEERING

Number 112 April 1979



Number 112 April 1979

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Contents

Notebook 2

Principal articles

ENG — Electronic News Gathering

1. The engineering planning 6
M. J. Stickler, D. W. Grant and S. M. Edwardson

2. Operational practice and experience during the experimental first year. 13
H. C. J. Tarner

The Choice of Aerial Support Structures for Broadcasting 21
R. L. Clapp

Electronic Tape Measure 30
J. R. Humphries

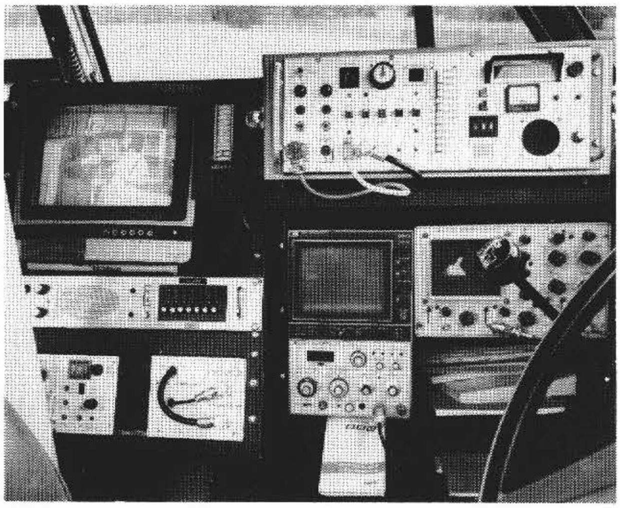
Contributors to this issue 32

The cover picture shows the BBC Television
News experimental ENG unit and Millbank
Tower, on the roof of which ENG radio-link
receiving equipment is installed.

Notebook

New Reception Survey Vehicles

New reception survey vehicle



Equipment installed in the new vehicle

The illustrations show the latest of three similar vehicles used by the Engineering Information Department for television and radio reception surveys and investigations throughout the United Kingdom.

The vehicles are based on British Leyland Range Rovers, which provide ample room for the equipment and a good standard of comfort. Externally the most obvious modification to the vehicle is the fitting of a pneumatically-operated telescopic mast which allows the receiving aerials to be used at a height of 10 m.

The bulk of the work of the survey vehicles is for UHF television and the fitted equipment reflects this. Two log-periodic aerials, one each for horizontal and vertical polarisation, are mounted at the masthead. UHF field strengths are measured by a BBC digital field-strength measuring receiver which has push-button selection for 12 channels. An internal memory takes note of the required channels and aerial polarisation. The receiver uses a high-stability crystal for its synthesised tuning and as a reference for checking the frequency and carrier offset of the transmitter which is being measured. A modified Sony Trinitron receiver is used for checking received picture quality and a Decca RU4011 tuner provides a video signal which can be viewed on an oscilloscope or used to feed other equipment such as a teletext decoding margin meter. A spectrum analyser is also carried. This is normally used to check for standing-wave patterns and variations in reception conditions but can also be very useful when searching for signals in remote areas.

Most of the equipment operates from 240V a.c., which is supplied by two 300-VA inverters powered from a second car battery.

Timecode Equipment

BBC Designs Department has recently engineered a new range of timecode equipment designed for use with the EBU Time and Address Code as defined in EBU tech. 3084-E. The equipment is designed in modular form and offers great flexibility to the user. The five units designed so far can operate as self-contained mains-powered units in a portable carrying case or can be mounted in 4U (178 mm) racks. The equipment has applications in the fields of videotape editing, machine synchronisation, audio dubbing and the control of subtitles with recorded programme.

Timecode Generator GE7L/501

This generates a standard EBU timecode waveform which is normally locked in phase and frequency to station pulses. If no reference is available it will run free to within 0·2% of the 25-Hz picture rate. The user bits can be inserted through an external connection allowing parallel loading of the 32 bits. Front-panel controls allow the time information in the waveform to be set as required, for example to time of day. Alternatively the time can be slaved to an incoming EBU timecode waveform in such a way that the output continues to count up from a point where the incoming waveform was disconnected.

Timecode Decoder CD3L/535

This unit accepts timecode over a wide range of speeds to allow for timecode being replayed at spooling speeds. The timecode signal from the machine can be reconstituted and reshaped when running at play speed so that replay distortion is virtually eliminated when dubbing timecode from one machine to another. The decoded time information is displayed in the television picture from the videotape machine using a built-in character generator. Front-panel controls allow some or all of the characters to be switched on or off, repositioned or enlarged. A 'hold' switch allows the time to be frozen during the replaying of timecode, so that an event or cue point can be registered. These controls can be made remote.

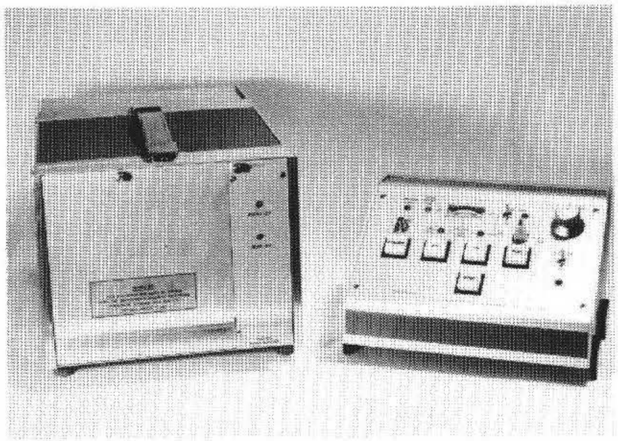
Timecode Offset Unit CO4P/2

This portable general-purpose unit introduces a time offset into an EBU timecode waveform. A set of 9 lever switches (8 time digits and a sign digit: hours, minutes, seconds and pictures) enables any offset, positive or negative, up to 23 59 59 24 to be introduced. The repetition rate of the output timecode waveform follows the input over a wide frequency range and in both forward and reverse directions so that the unit can be used with synchronisers or search-and-park units.

Timecode Comparator UN12M/511

Two EBU timecodes can be compared in this unit, in which an 8-digit LED display shows the difference time or one of the input times. The comparator can be used to manually synchronise two tape machines, using a variable speed on one machine, or as a piece of general-purpose test equipment for checking timecode generators, continuity of timecode on tapes, etc.

Timecode Tape Synchroniser RD4L/506 and Control Panel PA6/542



The synchroniser will control a slave tape machine so that it automatically achieves and maintains synchronism with a master machine, using timecode recorded on the master and slave machines. The equipment accepts two serial EBU timecodes over a wide range of speeds and generates control voltages for the slave machine. The control reverts to a 'pulse lock' mode once synchronism is achieved in the 'play' (normal) mode so that any timecode disturbances do not affect tape speed. The reference in the 'pulse lock' mode may be master machine timecode, mixed syncs or internal crystal oscillator.

A dedicated card is fitted in the synchroniser to convert the normal output voltages to those suitable for the machine being controlled. A preset timecode offset is introduced in the synchroniser to allow for any head-spacing offset in the slave machine.

The control panel permits control of the slave machine transport either by the master timecode ('follow' mode) or by manual control. It also provides monitoring for the synchroniser as well as other subsidiary machine synchronising and indicator controls.

The above equipment is typical of many items of BBC design which are available for licence to approved UK manufacturers. Further information is available from: Liaison Engineer, BBC Designs Department, Broadcasting House, London W1A 1AA.

VHF Radio Improvements

A series of test transmissions, now in progress from the Crystal Palace (London) transmitting station, is intended to assist in the planning of improvements to the BBC VHF radio services over the whole country.

The present VHF network was planned in the nineteen-fifties and most of the main transmitters were completed before 1960. At that time the usual type of receiver was operated from mains electricity and connected to an outdoor aerial. The transmitter network was planned accordingly and used horizontal polarisation. Since then the transistor portable receiver has become the commonest sort of receiver and VHF car radio sets have also become available. The usual aerial for both types is a telescopic rod and is much less efficient as a signal pick-up than the high outdoor aerial. In some parts of the country the available VHF signals are barely adequate for these aerials.

The test transmissions are on 90·3 MHz and normally carry the programmes of Radio 3. A number of different tests will be carried out and, in particular, an assessment will be made of the relative effectiveness of different types of signal polarisation in built-up areas.

Type 5 CMCR

The first of eight new general-purpose CMCRs is now complete and is undergoing intensive testing before being handed over to the London Television Outside Broadcasts Base at Acton. The photograph shows the vehicle just after it was driven out for the first time from the Andover factory of Link Electronics Limited.

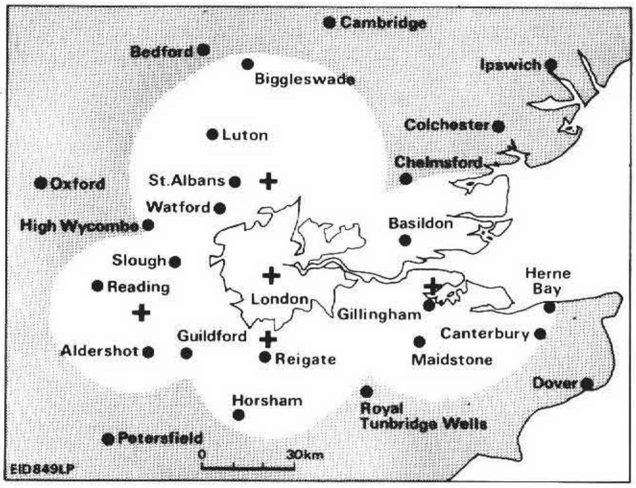
The Type 5 CMCR is equipped for eight Philips LDK5 cameras, using triax cable, although the normal complement will be four. It is designed for use on large-scale OBs without the need for additional monitors and switch boxes, which are commonly required with the present vehicles. The production area is equipped with 22 picture monitors and the vision mixer can simultaneously feed an output to network while other pictures are being recorded for later use.

The new CMCR will be described in detail in a later issue of *BBC Engineering*.

'CARFAX' trial authorised

'CARFAX', the proposed single-frequency road traffic information system developed by BBC Research Department, has been examined by a working group composed of representatives of the Transport and Road Research Laboratory, other Government Departments, Police Forces and the broadcasting authorities. This working group has recommended a public trial and on 12 February the Secretary of State for Transport, William Rodgers, authorised the initial phases of the trial. It is expected that these will occupy 12 to 18 months.

The trial will take place in southeast England, including London, as shown on the accompanying map, and will use five transmitters. The objectives of the trial are to assess the viability of a 'CARFAX' service and to determine the optimum design of the transmitter system. The frequency to be used is 526·5 kHz. A number of receivers are being manufactured and these will be distributed to a representative cross-section of potential 'CARFAX' users.



Area to be covered by 'CARFAX' trial

BBC Research Department Reports

BBC Research Department has recently published the following reports.

1978/26 Digital sound signals: tests to compare the performance of five companding systems for high-quality sound signals.

1978/27 The variation of absorption coefficient of absorber modules with ambient conditions.

1978/28 An error-correcting system for a multi-channel digital sound recorder.

1978/29 'CARFAX' traffic information service: a general description of the ring system.

1978/30 'CARFAX' traffic information service: preliminary field assessment of the ring system.

1978/31 'CARFAX' traffic information service: an analysis of the characteristics of the ring system and receiver activation.

1978/32 Digital transmission of multiplexed video and audio signals at 140 Mbit/s over an experimental optical-fibre transmission system.

1978/33 MF and LF reception: susceptibility of domestic receivers to interference.

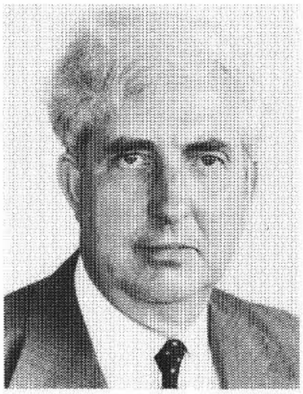
1979/1 Digital video: comb filtering in sub-Nyquist PAL codecs.

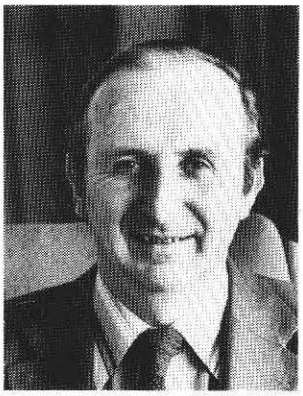
1979/2 Digital radio links for stereophonic outside broadcasts.

1979/3 Hearing risk to wearers of circumaural headphones: an investigation.

A subscription to BBC Research Reports, of which about 35 are published each year, costs £25.00. Further information and subscription forms are available from: *Research Executive, BBC Research Department, Kingswood Warren, Tadworth, Surrey, England.*

Staff Changes


George Mackenzie


Brendan Slamin


Bill Wood


Pat Leggatt

Chief Engineer, Transmitters

George Mackenzie, C.Eng, FIERE, MBIM is the new Chief Engineer, Transmitters, succeeding George Cook, C.Eng, FIEE who, as reported in our last issue, is now Assistant Director of Engineering.

Since 1971 George Mackenzie has been Chief Engineer, Regions, and before that he had been Head of Programme Services and Engineering, Northern Ireland. He joined the BBC in 1941 at the Edinburgh studio centre and later worked at Broadcasting House, London, and the Lime Grove television studios. He then spent some years on the staff of the Engineering Training Department, latterly as Head of Technical Operations Section.

Chief Engineer, Regions

Brendan Slamin, C.Eng, FIERE, succeeds George Mackenzie as Chief Engineer, Regions, with responsibility to the Director of Engineering for co-ordinating engineering developments outside London.

Brendan Slamin joined the BBC in 1946 and worked in operational and communications areas in radio and television. Since 1960 he has held senior posts in Wales, Northern Ireland and Scotland, latterly those of Head of Programme Services and Engineering and Head of Development in Scotland. In 1978 he was appointed Head of Engineering, Television Outside Broadcasts.

He is a fellow of the Royal Television Society and presently a member of its Council.

Head of Engineering Information Department

C.B.B. Wood, MBE, retired on 31 December 1978 after 32 years with the BBC.

Originally trained as a mechanical engineer, 'Bill' Wood spent the war years on radar work in the Royal Air Force and in 1946 he joined several former RAF colleagues in the BBC Research Department, where, in 1950, he became Head of Image Scanning Section. He was involved in film telerecording, the development of new electronic cameras and the cablefilm system. He was closely concerned with the development of BBC colour television from its earliest days and worked on the choice of system, cameras, film stocks and telecines. It is in connection with the last two that Bill Wood is best known. He received awards from the British Kinematograph Sound and Television Society (BKSTS), the Royal Television Society (RTS) and the Society of Motion Picture and Television Engineers (SMPTE) during the period 1967 to 1972, mainly for improvements in the integration of colour film with colour television. This work included the development of TARIF and the introduction of electronic masking. Further awards, of the Pye Colour Travelling Scholarship and a Special Commendation from the SMPTE, were made in 1972 and 1977 respectively.

In 1971 Bill Wood started a new career on his appointment as Head of Engineering Information Department. In this post he was responsible for informing the press, the public, trade and industry of BBC engineering developments. In 1974 he accepted an invitation to present the annual Fleming Memorial Lecture and chose as his subject 'The Status of British Broadcasting'. He also lectured in the USA, Australia and New Zealand.

He was awarded the MBE in 1971 and is an Honorary Fellow of the BKSTS and a Fellow of the RTS and the SMPTE.

The new Head of Engineering Information Department is

D.P. Leggatt, B.Sc., C.Eng, FIEE.

In his new appointment Pat Leggatt returns to the Department in which he served for two years from the time, in 1953, when he joined the BBC. Subsequently he served in senior posts in the Recording Department of the Television Service and in Studio Capital Projects Department before being appointed Head of the latter department in 1974. In that post he was responsible for the acquisition and installation of new studio and outside broadcasts equipment throughout the BBC.

ENG — Electronic News Gathering

1 The engineering planning

M. J. Stickler, B Sc (Eng), MIEE
Studio Capital Projects Department

D. W. Grant C Eng, MIEE
Transmitter Capital Projects Department

S. M. Edwardson C Eng, MIEE
Research Department

This article and the following one (page 13) describe the engineering planning and experimental use of the first United Kingdom ENG unit. The experiment is described in detail in the second of the two articles and was the culmination of a great deal of planning and design work which is described in the first.

At an early stage of planning, a special ENG Study Group was formed to investigate the engineering problems and recommend the methods to be used in setting up the BBC's experimental ENG unit. The Study Group comprises representatives of specialist engineering departments and Television Operations and Maintenance and includes the authors of the two articles.

1 Introduction
2 Basic requirements
3 The radio link
4 The future

Appendix
The radio link in practice

1 Introduction

In October 1978 the BBC completed a one-year experiment designed to assess the production, engineering and logistic problems involved in mounting an ENG operation in London. This article deals with some aspects of the engineering planning and system design to which we devoted most attention, and concentrates particularly on the radio link. The practical link is described in the Appendix.

It might be as well to begin by setting down once again what ENG is all about. It is the use of highly mobile electronic equipment — camera, videotape recorder and radio link operating in a mode similar to that of a news film unit. The advantages lie in the immediacy of transmitting news from location and the elimination of film-processing time. The story can be transmitted to the studio centre either by radio link or over the Post Office cable network if an injection point is conveniently situated. In either case, the signal can be transmitted direct from the camera output or can first be recorded on location and then be transmitted, perhaps only a few minutes later. At the studio centre it can either be routed live 'on air' or first recorded and edited. If time allows, the tape can even be physically transported, this would also have to be done, of course, if a satisfactory radio link or cable circuit could not be established. Whichever operation mode is chosen — and we have used them all — ENG provides operational flexibility and allows us to achieve a considerable reduction in the delay between the actual event and the transmission of the finally edited news material.

2 Basic requirements

Two factors have a decisive influence on the design of the ENG vehicle. The first is the speed with which each operational assignment has to be mounted and this requirement is inherent in the nature of ENG as already described.

The second is closely related to the first and concerns the size and appearance of the vehicle. It has been said that the arrival of the ENG crew on location should not constitute the news and this saying neatly summarises the need for the unit to be as unobtrusive as possible, consistent with engineering realities. Thus there are these two general criteria — the capacity for rapid operation and the need for unobtrusiveness — which distinguish the basic requirements for an ENG vehicle from those for a conventional outside-broadcast vehicle.

As far as the equipment is concerned, the above requirements have their greatest impact on technical standards, operational convenience and staffing. The equipment has to be light, reliable, rugged and as automatic as possible. In the present state of the art a standard of technical quality somewhat lower than that required for normal programme purposes has to be accepted. It is, of course, extremely difficult to set a minimum standard of acceptability; if the news is important enough, virtually any recognisable picture will be transmitted. Nevertheless, some criteria must be adopted for circumstances which are not extreme. To assist in establishing them it is worth distinguishing between limitations which are inherent in the equipment and quality impairments which are caused by poor operating conditions.

At present, the inherent limitations are such that we would regard the picture and sound quality that might be expected from good 16-mm reversal news film as being a reasonable target. There are ENG cameras which can produce pictures of better quality than those from film, down to quite low light levels. The main difficulty stems from the use of the U-matic 19mm (¾ inch) helical-scan videotape format, with its restricted bandwidth and 'colour under' system. The ability to transmit third-generation videotape is essential if we are to achieve full flexibility in ENG operations and, although we are now able to do so, it is still the recorder which is the limiting factor on inherent quality.

When we consider the effect of poor operating conditions, the CCIR 5-point scale provides an appropriate measure for subjective assessments. We have chosen to regard a level of impairment classified as 'annoying' (grade 2), or better, as being usable for ENG. This criterion has been used in arriving at the success rates which are quoted in later sections of this article in connection with radio-link performance. It is worth noting that the results of our test transmissions show that, if 'slightly annoying' (grade 3) had been adopted as the minimum acceptable level, the effect on the success rate would have been only marginal.

It was regarded as essential that the experimental unit should carry its own radio-link transmitter and so not be dependent on a second vehicle, and that the crew should be limited to two, including the driver. It was also thought important that the radio link should be established within 5 to 10 minutes of arrival on site, while remembering that the location of the site is normally determined by news considerations and not by technical needs. Early experience suggested that there would be considerable difficulty, to say the least, in establishing ad hoc radio-link circuits in a city such as London, without recourse to a very large number of fixed receiving points or a mobile tower for the transmitter aerial*. It was to this aspect of planning that the most time and research were devoted, with particular reference to choice of frequency, aerial systems and the effects of interference.

3 The radio link

3.1 Operating frequency

The suitability of a particular band of frequencies for ENG purposes is difficult to predict. The lower the frequency, the more tolerant it should be of path obstruction but, for any reasonably-sized transmitting aerial, directivity will be low and reflected signals will be relatively stronger and more troublesome. At higher frequencies, the advantages of high aerial gains and directivities can be exploited in terms of lower transmitter power and reduced multipath interference but the effects of obstructions then become more important.

*Consideration was given to the use of satellite circuits but this was not practicable in the short term.

The precise frequency chosen must be one which is available to the BBC, is free from interference, and for which suitable plant and aerials are available. Also to be borne in mind is the ultimate requirement for a number of ENG units which may sometimes operate simultaneously in the same area. Taking all these factors into account, it seemed that the optimum frequencies would be on uhf (Band V) or in the 2.5-GHz, 7-GHz or 12-GHz bands.

A series of test transmissions was arranged to assess the relative merits of the 2.5-GHz and 12-GHz bands. These tests were conducted from randomly selected sites in Central London to a single receiving point on the 61 m-high roof of the Department of the Environment building in Victoria, the most suitable site then available. The results showed that, at 2.5 GHz, the expected success rate was some 10 to 20% higher than that at 12 GHz. They also showed very clearly that the major signal impairment was caused by multipath reception; that is, interference caused by reflected signals arriving at the receiver delayed in time relative to the direct-path signal.

The results of the tests, combined with theoretical considerations, led us to the conclusion that the graph relating success rate to frequency is flat-topped and falls off significantly at 12 GHz and below Band V. The 2·5-GHz band was therefore chosen, although it was recognised that, if ENG operations were carried out on a large scale in the future, it might become necessary to look to other bands simply in order to find enough non-interfering frequencies.

It should be made clear that the above considerations apply to the main radio link from the vehicle to the reception point. There is a separate requirement for a portable low-power link to carry the picture and sound signals from the news point back to the vehicle; this is particularly important when the use of cable may be inconvenient or impracticable. For this purpose a highly-directional lightweight 12-GHz local link, which can be set up and operated by one man in a few minutes, is provided.

3.2 Aerial polarisation

Outside broadcast radio links usually use line-of-sight paths, with the radiated signal linearly polarised, either vertically or horizontally. In the situations usually found in ENG operations — obstructed paths in heavily built-up areas — circular polarisation can offer advantages. This is because unwanted reflected signals usually suffer a reversal in rotational direction (e.g. a clockwise-polarised signal becomes counter-clockwise-polarised after a perfect reflection from an object in the transmission path). Thus the receiving aerial discriminates against the reflected signal to a degree determined by the type of reflection and multipath interference is minimised.

If the direct signal path between transmitter and receiver is completely obstructed, it may be possible to circumvent the obstruction by using a large building in the vicinity as a reflecting surface. This technique is known as 'bouncing' and when it is used it is usually necessary to reverse the sense of circular polarisation of the receiving aerial with respect to that of the transmitting aerial.

An alternative method of overcoming an obstructed path is by diffraction; that is, illuminating the upper edge of the obstruction by the transmitted signal and thus causing the signal to be diffracted over it. This process usually distorts the polarisation and the receiving aerial may operate most effectively in the horizontally-polarised mode.

3.3 Aerial equipment

It was clear that at least one fixed reception point was necessary in Central London. It was required to be unmanned and the received signal would be carried to Television Centre on a permanent cable.

A conventional parabolic receiving aerial would give maximum gain, high directivity and minimum multipath interference. However, means would have to be provided for panning the aerial, either automatically or by remote manual control. Alternatively, an omnidirectional system offers greater simplicity and intrinsic reliability while putting the onus on a highly directional transmitting aerial to reduce multipath interference. Whichever system is employed, a return circuit of some kind back to the vehicle is desirable to allow the transmitting aerial to be orientated accurately and quickly.

Tests indicated that satisfactory results could be obtained with a Nurad receiving aerial system consisting of four horns arranged such that each covered a different quadrant in azimuth. The output of any one is selected as required. The Nurad system has the additional advantage that its four horns can be disposed around a building and it is therefore relatively unobtrusive compared with a conventional aerial, which would have to be mounted on a superstructure on the roof in order to reduce as far as possible the 'shadow' area around the base of the building. This environmental aspect would probably be regarded as important by a landlord when considering a long-term lease.

Consideration was given to the feasibility of a retractable mast for the transmitting aerial on the ENG vehicle. During the transmission tests arrangements had been made to vary the height of the transmitting aerial in order to assess the degree of dependence on line-of-sight operation and the results had shown that a height of about 21 m was required to give a success rate of two in three into the 60 m-high reception point. A mobile telescopic mast 21 m in height and of adequate stability unguyed is technically feasible but was not considered a practicable proposition for mounting on an engineer-driven ENG vehicle. The weight would be excessive and so would be the time to erect and extend the mast (with at least one person fully committed throughout) and, even when retracted to lie horizontally, the mast assembly would be unacceptably obtrusive.

Fortunately, negotiations for the use of the 122 m-high roof of Millbank Tower as a reception point were successful and an easier solution was available. A further and very extensive series of transmission tests was undertaken, using the Millbank Tower, to discover what might be achieved with the transmitting aerial on the vehicle roof, at a height of about 3 m, but with the receiving aerial at the greater height of 122 m. The results indicated that a success rate of at least two in three could still be obtained without the need for a high transmitting aerial mast on the vehicle. The higher receiving point was obviously an important factor in maintaining the same success rate, but equally important was our realisation that line-of-sight operation was not the essential prerequisite to success that we had thought. The tests showed — and this has been confirmed in operational use — that 'bouncing' of the signal was the rule rather than the exception.

Fig. 1 General view of experimental ENG unit.

The decision was therefore taken to use the effectively omnidirectional Nurad receiving aerial system on the roof of Millbank Tower and a directional 1·2-m parabolic transmitting aerial mounted on the vehicle roof. Figures 1 and 2 show respectively the vehicle with its roof-mounted parabolic aerial and one of the Nurad horn aerials on the roof of Millbank Tower.

3.4 Received signal level

In a normal television outside-broadcast single-hop radio link, receiver input carrier levels of 70 to 80 dB below 1 watt (−70 to −80 dBW) are usually achieved. Such signal levels yield weighted output signal-to-noise ratios better than 60 dB. In the ENG situation it has to be accepted that much lower input levels will sometimes be received and these may be as low as −110 dBW. The situation has been improved somewhat by the use of a low-noise pre-amplifier which gives a weighted signal-to-noise ratio of about 40 dB under

Fig. 2 One Nurad horn aerial on the roof of Millbank Tower.

these conditions. Should the input level fall significantly below 110 dBW, however, the receiver ceases to function properly in the frequency-modulation mode and no useful output signal is obtained.

3.5 Sound transmission

In considering the transmission of the sound signal, two methods were assessed:

i) the conventional method used in f.m. television links whereby the sound signal is frequency-modulated onto a 7·5-MHz subcarrier which is then combined with the video signal for modulation onto the main f.m. carrier;
ii) the use of sound-in-syncs (SIS).

SIS presents some difficulties. When the television signal for transmission is derived from a U-matic recorder, direct SIS encoding is precluded because of the discontinuity in the recorder output waveform. Tests confirmed that the use of a time-base corrector would overcome this difficulty (provided that the output timing jitter lay within the 'window' of the corrector) but the weight and power requirements of present time-base correctors rule out their use for ENG. In addition, it is by no means certain that the SIS signal would be robust enough for radio-link operation in the presence of severe multipath interference.

It was therefore concluded that the conventional method, using a 7·5-MHz subcarrier should be adopted for sound transmission when using the radio link.

As stated earlier, it is sometimes desired to inject ENG signals into the Post Office cable network and a difficulty has been encountered when attempting to do this. Owing to the bandwidth limitation of normal video circuits, a conventional sound subcarrier at 7·5 MHz cannot be used, and separate music circuits cannot easily be provided from the injection points in questions. The feasibility of using a sound subcarrier within the normal video band was investigated recently and it was concluded that the signal impairment would be acceptable for ENG purposes.

It has therefore been decided that, for the immediate future, while time-base correction and SIS encoder equipment remains relaively heavy and bulky, and requires mains power, the in-band subcarrier system appears to be the only answer for cable injection purposes. In the longer term, SIS is the more attractive proposition, even if the conventional 7·5-MHz system has to be available for radio-link purposes. The feasibility of developing new SIS equipment to meet the requirements is being investigated.

3.6 Alternative modulation systems

It has already been mentioned that all the transmission tests had indicated that the most significant signal impairment was that due to multipath propagation. It was therefore decided that alternative transmission systems which might be less susceptible to this type of interference than conventional f.m. should be investigated. For example, it was considered that a digital transmission system might have performance advantages.

Setting aside the considerations of cost, complexity, size of equipment, and spectrum requirements, digital transmission could be expected to give a signal quality limited only by the parameters chosen for the digital system. Progressive increases in interference (noise, multipath signals, etc) would leave the received signals unimpaired, up to the point when an abrupt breakdown occurred. On the other hand, analogue systems such as those used in f.m.

television links show increased impairment of picture quality with progressive increase in interference or distortion. They do not, however, generally collapse in quite such a catastrophic manner as digital systems.

A brief series of tests was carried out, using the same radio link at each site, first for a.m. pulse transmissions (for the measurement of multipath signal levels) and then for conventional f.m. television signals. Echoes of short delay were very common, with levels sometimes as high as −1 dB (relative to the main signal) but it was found that the f.m. television signal was either unimpaired or certainly quite acceptable. However, if these levels of multipath interference were to occur in a high-bit-rate digital system, they would almost certainly render it unusable. It was therefore concluded that the use of a digital transmission system for ENG television links would not be practicable.

Attention was then directed to the possibility of improving the resistance to multipath effects of the *conventional analogue transmission system*. It was noted that the present f.m. parameters were designed to achieve the best received signal quality whereas, for ENG purposes, maximum success rate might be a more suitable criterion.

A laboratory investigation was carried out to determine whether any improvement could be gained, either in the impairment caused by multipath propagation or in the proportion of successful sites, by changing the f.m. parameters of the link.

The tests showed that, in general, an alteration of the f.m. signal parameters gave no significant improvement in the picture impairments caused solely by multipath propagation. However, when the signal strength was also low, the effect of multipath propagation was sometimes to increase the noise level a great deal in certain areas of the received picture due to f.m. noise-threshold effects. It was found that, when the signal was affected by noise to a degree that is typical at marginal sites, a useful overall improvement could be achieved by increasing the f.m. deviation and *reducing* the receiver bandwidth. There are several constraints which limit the extent to which the signal parameters may be varied on this basis and the 7·5-MHz sound subcarrier, in particular, must be taken into account. It was found that, by using also a sound system with a narrower bandwidth and a higher injection level (relative to the video signal level) for the sound subcarrier, values for the overall deviation and the receiver bandwidth were obtained which gave an improvement equivalent to a 4-dB to 5-dB increase in transmitter power. This would increase the number of sites at which the link could be used for ENG purposes. Moreover, using these parameters, sound and vision failed at about the same r.f. signal level.

The proposed parameters cause a very small degradation in the quality of the received sound and vision signals at good sites, but this is considered acceptable in view of the increased coverage of the link.

Unfortunately, because of operational commitments, it has not yet been possible to apply these parameter changes to the service equipment. However, some other improvements were made in the link equipment compared with that used in the engineering test transmissions and as a result we have achieved in operational use a success rate of about four in five. It will be remembered that the basis of our assessment of usability is that signal impairments shall not be worse than grade 2 on the CCIR scale. Thus, quite apart from devising ways of achieving a higher success rate, there must clearly also be scope for improvement in the quality of those links which, although classed as successful, are only marginally so. From our experimental work it seems certain that application of the modified f.m. parameters would give improvements under both headings, the latter in particular.

4 The future

Our operational experience with the experimental unit showed that the radio link was used on about one story assignment in four. It is of interest to note that a truly live transmission — camera output direct to network without intermediate recording — took place only once during the whole period. Far more common was the situation where material was recorded and subsequently replayed over the radio link or was transmitted direct from the camera output but recorded at Television Centre. These two operating techniques, the former predominating, thus accounted for almost all our radio-link usage.

If this pattern of usage is likely to be typical, and given that there will be a significant number of vehicles on the road, future service requirements might be best met by a mixture of differently equipped vehicles. A number of camera/recording cars, without radio links (but with provision for cable injection), backed up by one or two dedicated ENG radio-link vehicles with VTR facilities could cover the majority of all assignments in a large city. Perhaps only one fully-equipped vehicle based on the design of the experimental unit would be required for the remainder.

Although this departs from the original concept of completely self-contained units capable of operation by a crew of two, without supporting facilities, there are several potential advantages. The ratio of the numbers of radio-link and camera/recording vehicles could match the estimated ratio of 'link' to 'non-link' assignments, with some capital savings. From the engineering point of view, the present limitation on the equipment that can be carried, due to vehicle loading considerations, would be eased. This has been an important problem with the experimental vehicle, which is loaded to nearly the maximum permitted level. A larger vehicle is not desirable because it could be more obtrusive and would probably necessitate an increase in the crew. On the operational side, the use of separate vehicles would give much greater freedom in siting the transmitter and would remove one of the constraints with which the operational crew has to contend. Nature, no doubt due to an oversight in early planning, does not ensure that all newsworthy events occur at good transmission sites.

Appendix

The radio link in practice

Following the tests and theoretical considerations described in section 3, it was decided that the practical radio link for experimental operational use should be engineered on the following basis.

i) The vehicle-to-base radio-link system should operate in the 2·5-GHz band and employ conventional f.m. techniques.
ii) The transmitting aerial should be a circularly-polarized 1·2 m-diameter paraboloid, mounted on the vehicle roof.
iii) The receiving equipment should be installed on the roof of the Millbank Tower.
iv) The receiving aerial system should be capable of being switched to any of four modes of polarization, vertical, horizontal, circular clockwise and circular counter-clockwise.
v) The sound channel transmission should be by 7·5-MHz subcarrier.

Transmitting terminal

The 2·5-GHz transmitter installed in the vehicle was manufactured by Microwave Associates Limited and delivers 18 W into the aerial. In conventional outside-broadcast use, the aerial would be mounted on a tripod on the roof, both tripod and aerial being stowed within the vehicle when not in use. This approach was not possible here because, not only would the roof rigging and derigging be difficult and time-consuming, but also the small size of the ENG vehicle precluded the stowage of these items internally. It was decided, therefore, to install the aerial permanently on the vehicle roof on a small purpose-built tower; when not in use the aerial and tower would lie flat on the vehicle. An electrically operated ram (figure 3) was provided to erect and lower the aerial assembly: this operation takes only a few seconds. Interlocks and alarms are included in the system so that the vehicle may not be driven with the aerial system erect. Rotating coaxial joints are used to avoid mechanical stress on the cable when the aerial is rotated on its panning head.

Receiving terminal

The complete receiving terminal, including aerials and receiver, has been installed on the roof of Millbank Tower, a 122 m-high office block, with the electronic equipment contained within a weather-proof cubicle 1·37 m high, 0·5 m deep and 0·61 m wide (figure 4). The equipment comprises the link receiver, radio-telephone terminal, remote-control equipment and test-signal generators. Landlines for video signals and control circuits to Television Centre also terminate in this cubicle.

The complete aerial system consists of four individual horn aerials (see figure 2) which are arranged such that each covers a horizontal quadrant. The maximum gain of each horn is 13 dB (with respect to an isotropic radiator). This gain falls to 10 dB at the 72° beam-width points and to 8 dB at the 90° beam-width points. The output of each aerial is routed to a coaxial selector switch which allows any one horn to be selected for connection to the receiver. A feature of the aerial system is its ability to operate in any one of the four required polarisation modes — horizontal, vertical,

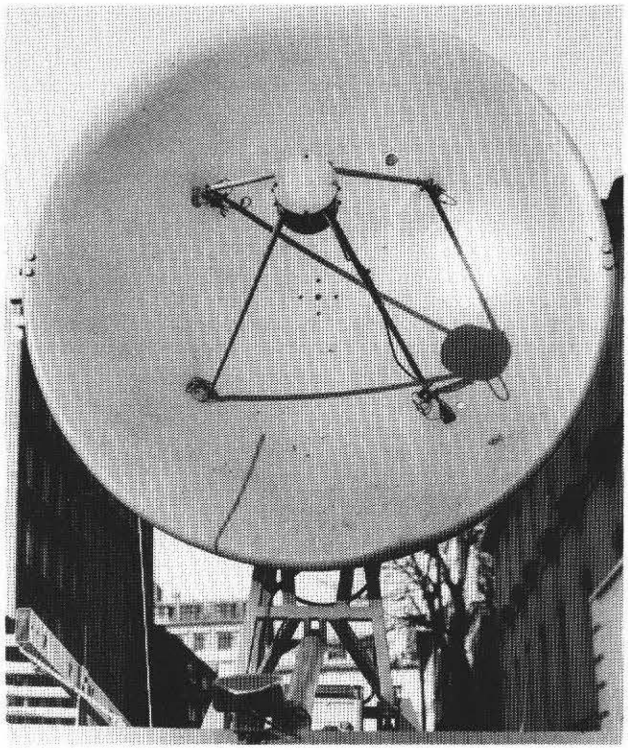


Fig. 3 Parabolic aerial and electrically-operated ram on roof of vehicle.

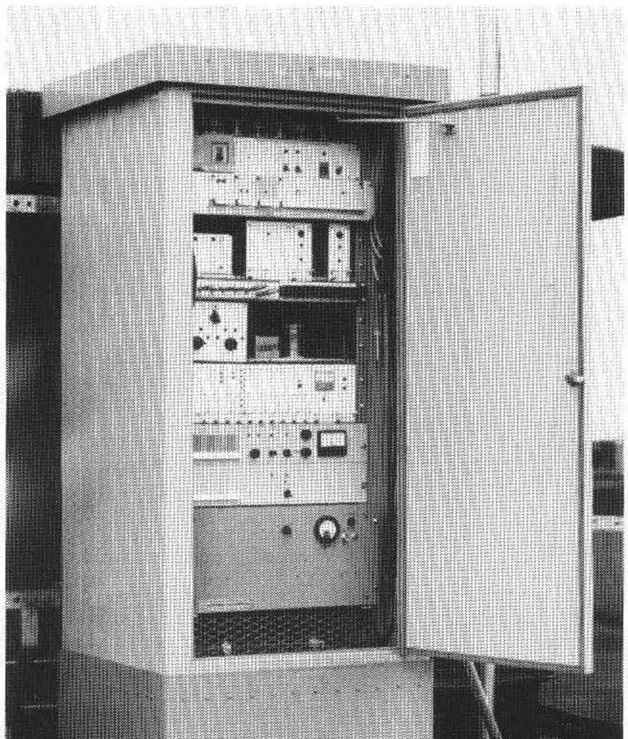


Fig. 4 Receiving terminal equipment on the roof of Millbank Tower.

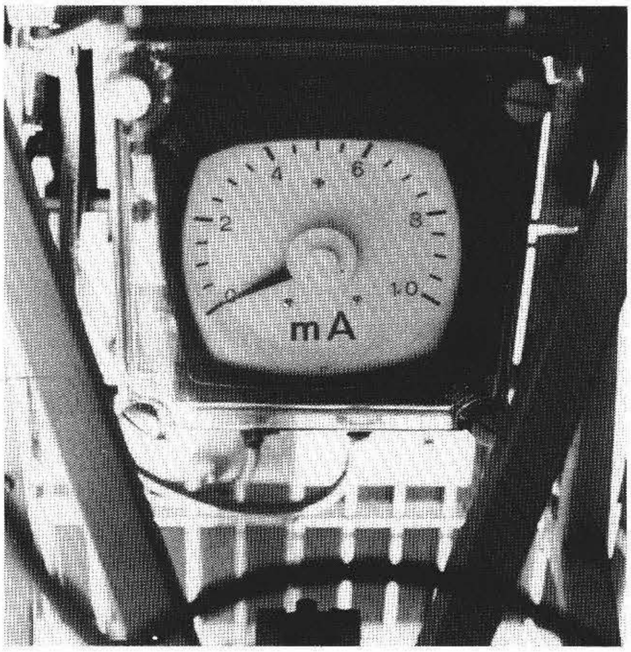


Fig. 5 Panning-aid meter on vehicle.

clockwise circular and counterclockwise circular. The receiving equipment is remotely controlled by an operator at Television Centre over a landline, using a 14-channel switching system. The system enables the remote operator to switch any one of the four aerials to the receiver input, to select any one of the four aerial polarisations, to select either the receiver output or locally-generated test signals and to control the v.h.f radio-telephone terminal to enable him to communicate with the ENG vehicle.

The control system also feeds back to Television Centre a number of system-alarm signals and an analogue signal from a panning aid for display as a meter reading at the control position at Television Centre. As described in the next section, a similar meter reading can be made available on the vehicle.

Panning aid

The very nature of ENG demands that, when a radio link is employed, it must be established as quickly as possible. The most time-consuming part of the operation is the panning (alignment) of the transmitting aerial so that it is pointing in the right direction — usually the direction which gives maximum signal strength at the receiver. In normal practice this panning is achieved by staff at the receiving terminal 'talking-in' the staff at the transmitting terminal on a communication channel but this process is tedious, even when unobstructed propagation conditions prevail. In ENG operations such conditions are rare and, because of multipath transmission, panning is frequently more difficult. Moreover, panning requires assistance which may not always be available.

It was decided to evolve a system to enable the transmitting aerial to be panned without assistance. This has been achieved by a telemetry system which uses the v.h.f. radio-telephone channel and provides a meter indication of the received signal strength at Millbank Tower to the panning operator at the transmitting end.

A voltage derived from the level of the incoming signal at the receiving site is encoded and used to vary the frequency of an audio-frequency tone. This tone, and a reference tone, are transmitted back to the vehicle (using the radio-telephone communication channel) and the difference between the frequencies of the two is detected and displayed on a large meter at the aerial panning position on the vehicle roof (figure 5).

The normal system provided in f.m. television link receivers for monitoring the received signal level is too insensitive for the low levels which are of interest for ENG. It was therefore necessary for the manufacturer to develop and include in the receiver a narrow-band intermediate-frequency amplifier to enable a d.c. signal to be derived specifically for this system. The encoding and decoding system was designed and built by the BBC and includes the facility of altering the law of the meter reading if this is required.

The system is operated by sending a 'panning-aid command signal' from the panning position on the vehicle and this causes the information to be routed over the radio-telephone system. On completion of the line-up the radio-telephone reverts to its normal purpose of providing a speech channel between the vehicle and Television Centre.

The panning aid has proved to be very effective. The only co-operation required from the operator at Television Centre is the initial selection of the aerial covering the correct quadrant. In a large number of cases the aerial has been successfully aligned within five minutes of parking the vehicle. On occasions when the position of maximum signal strength has yielded pictures which were marred by multipath interference it has sometimes been possible to achieve better picture quality, albeit with a lower level of received signal, by repanning the transmitting aerial on verbal instructions from Television Centre.

ENG — Electronic News Gathering

2 Operational practice and experience during the experimental first year

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Head of Engineering, BBC Television News

1 Introduction
2 Staffing and trade union negotiations
3 Organisation and control of the experiment
4 Trials before the experimental year
5 Staff training
6 ENG operational methods
7 Advantages of ENG
8 Disadvantages of ENG
9 Equipment for ENG
10 The vehicle and its installed equipment
11 Mobile power supply problems
12 The year's ENG experience
13 Conclusions

1 Introduction

The BBC is the first broadcasting organisation in the United Kingdom to operate ENG equipment. It started broadcasting with the experimental ENG unit on 10 October 1977 by covering an interview with Mrs. Margaret Thatcher, the Leader of the Opposition. It is interesting to note, however, that BBC Television News has had an outside broadcast unit for electronic coverage of news since 1964; it was converted to colour in 1972. This conventional two-camera unit has covered many news stories, sometimes at a rate of three a day.

The need for really lightweight electronic cameras and recording machines was realised some years ago but at that time suitable equipment was not available. When, some time later, broadcasters in the United States began to use miniaturised equipment (often of Japanese origin) for news gathering, the BBC followed the developments with great interest. This included a visit to the first all-ENG station, KMOX-TV, St. Louis, Missouri, where film operations were stopped overnight by CBS. Subsequently, CBS introduced ENG into the major city of Chicago and it was obviously time to take the American development very seriously and find out whether their operations, which at that time were very much concentrated on local news, were applicable to the BBC's national and international broadcasting operations.

2 Staffing and trade union negotiations

The BBC decided to go ahead with an experiment and started technical planning and negotiations with the Association of Broadcasting and Allied Staff (ABS) the union which represents most categories of staff including engineers, film cameramen and film editors in Television News.

Needless to say, the consultations and negotiations took a long time but they led to an agreement, some of the salient points of which were as follows.

a) The ENG experiment was to be conducted by BBC Television News over a period of one year.
b) The objectives of the experiment were to be
   i) to provide experience in the use of ENG in the news-gathering role.
   ii) to assess the staffing arrangements for ENG.
c) The progress of the experiment was to be monitored and subjected to regular local review meetings between BBC News Management and the ABS.
d) The ENG editing would be carried out by videotape recording engineers and film editors.
e) The ENG field equipment would be operated during the period of the experiment by a crew of two who would be interchangeable. One would be selected from the Television News engineering department and the other from the News Film Unit. It was agreed that it was the intention, for all normal purposes, including the operation of radio links, to use a crew of two. The manning levels would, however, be regularly assessed at the local review meetings.
f) The output of the ENG experimental unit was to be used only in Television News programmes.
g) The area of radio link operation was not to exceed that which was in the capacity of the ENG Unit's own transmitter.
h) The Post Office Central London coaxial cable could also be used for local injects to base or the signal could be fed down the Post Office system from BBC Regional stations.

The BBC ENG Unit on location

i) It was the agreed intention of the BBC and the ABS that during the latter part of the experimental period the BBC would undertake a work grading study and that the normal procedures would be carried through with a view to reaching an agreed grading conclusion.

j) BBC Management provided an assurance to the ABS on the following points.

   i) There would be no redundancies of staff in Television News or Television News Engineering as a result of the introduction of ENG.
   ii) There would be no forced redeployment of staff.

k) The vehicle to be used on the experiment would be a Range Rover, carrying a portable camera, recorder, microwave transmission and communication equipment, etc.

The shared duties of the crew would include driving the vehicle and operating the radio links. Staff working on the unit would be considered to be of equal status.

The staff selected had to be able to demonstrate an aptitude for photojournalism and be able to absorb the additional technical training which would allow them to operate and maintain their equipment. The intention was that the team would integrate their skills after suitable training and experience. The basic training would be of about six weeks' duration and would be undertaken by the BBC's Engineering Training Department. It was anticipated that at least two training courses could be mounted during the one-year experimental period.

The unmanned radio link reception point was to be on Millbank Tower in Central London. It would be remotely controlled from Television Centre and would consist of four Nurad horn aerials each covering one quadrant of the city. The selection and polarization of these aerials could be changed to reduce multipath distortion and obtain the maximum field strength. The solid-state receiving equipment would be housed in a cabinet on the roof of the Millbank Tower. This reception point would be used for ENG only.

3 Organisation and control of the experiment

The ENG staff worked to Editor, Television News on all programme and editorial matters, because it was from him, via the Newsroom, that they received their instructions by radio regarding movement from one location to another and instruction on programme assignments and journalistic matters.

They were also responsible to Head of Engineering, Television News for all engineering arrangements, operational and technical standards. This was very important in order that we could establish suitable criteria for picture and sound quality, examine ways of improving them and properly control a complex technical operation.

4 Trials before the experimental year

During the preceding few years we had been testing equipment of different types, from many manufacturers, which seemed suitable for ENG. These included: cameras checked in high, low and mixed conditions of lighting; editing equipment, videotape recorders and digital timebase correctors. We also carried out experiments with radio links in the London area from a modified Land Rover using different receiving aerials, horns, dishes, 'golden rods' etc.

We were particularly worried about radio link reception. American cities have advantages for this, with their grid-pattern layout and flat-sided steel-framed buildings, often with aluminium-coated windows. Usually, too, there is a very tall building in the centre of the city which provides a very good reception point. A good example is the Sears Tower in Chicago, with a height of 440 m. Our reception point on the Millbank Tower is only 122 m.

5 Staff training

The problems of training staff from different types of background, different departments and having different levels of experience were obviously very great. However, a compromise training programme was worked out which gave two weeks for News engineers to do film editing and gain road experience with camera crews. Simultaneously, staff with a film background went to the Engineering Training Department at Evesham for instruction on electronic and television principles. At the end of the two weeks the two groups combined at Evesham for a further three-week course on ENG equipment, covering both theoretical and practical aspects. These training sessions were followed by one week at Television Centre for more operational training on the newly-delivered ENG equipment.

Bearing in mind that this was the first ENG course, it was most successful. It achieved in everyone the right attitude of mind and helped to produce an understanding of journalistic concepts and engineering problems. By the end of the course the staff had become a close-knit team and the main objective had therefore been realised.

A second course was run during the experiment and another one at the end of it and we have now built up a number of road and editing teams.

6 ENG operational methods

ENG is very flexible in operation and can be used in any of the following ways, or can use various combinations of them.

i) The story can be recorded on location with the videotape being replayed there for checks of content and quality before being taken by car or dispatch-rider to the News headquarters.

ii) The camera or the recorder can be connected to permanent circuits and the signals fed direct to the News base.

iii) The story can be covered live by the camera and simultaneously recorded on location, the camera pictures being fed back by radio link to Television Centre.

iv) The camera signal can be carried by a second, short-range, radio link ('window unit') back to the vehicle, from which the main radio link with its high-gain dish operates. The window unit obviates the need for rigging long cables up the side of a building, which is expensive in manpower and time.

There are occasions, of course, when a story is covered near the Television Centre and the window unit can be used alone to carry the signal back. An example occurred during the experimental period with coverage from a football stadium close to Television Centre. All that was needed was to set up the 12-GHz receiver on a tripod near a window in the Newsroom.

v) On arrival at Television Centre the news story can either be transmitted live or recorded for editing and later transmission. If a local recording is made as well as transmitting the signal back to base, the reporter can check the contents and discuss the story with the newsroom before editing.

vi) It is sometimes convenient to take the ENG editing equipment into the field and operate from a BBC local centre or a temporary base at, say, a convention. In this way the editors keep in fairly close contact with the field crew and can present 'package' stories back to base for further recording or live transmission.

It should be noted that whenever the ENG signal is originating from a U-matic recorder, which does not meet the requirements of stability and compatibility for use with conventional sources, a time-base corrector has to be inserted before the signal is broadcast. The output of the digital time-base corrector (DTBC) meets these timing parameters with sufficient accuracy to interface with the broadcasting chain.

7 Advantages of ENG

The immediate verification of the picture, both on location and at Television Centre, is a great advantage. Another benefit from ENG on tape with electronic editing is that the story can be edited into different forms for different news bulletins without the original tape being physically cut, as would be the case when editing original news film. The making of copy prints on film is also a costly and time-consuming process. ENG operation saves operating revenue in comparison with film and there are no chemical costs. Also the ENG videotapes can be reused many times. Although the processing time for film has been and is being reduced, ENG saves some 40 minutes which would be required for this. Another big advantage in time stems from the use of radio link or cable transmission, thus saving travelling time that can be significant in a conurbation such as London, with its serious traffic congestion. All these advantages compared with film mean that much time is saved and in turn this means that more careful editorial decisions are possible.

ENG camera signals can be transmitted live or can be recorded. Camera sensitivity is almost as great as that for the fastest film emulsion when uprated by forced film-processing procedures. The ability of the electronic camera to balance automatically to the available lighting colour temperature makes them, however, effectively more sensitive than most film cameras because light is not lost in correction filters in front of the lens. Our experience is that the signal-noise ratio and resolution characteristics of ENG pictures are much better than those from film.

The television viewfinder on the ENG camera makes focusing, framing and exposure-setting somewhat easier in low-light conditions than with a film camera. The picture quality from the electronic camera is superior to that from film with an improved grey scale and better colour rendering. This all helps to match to studio pictures. At some locations the quietness of the ENG camera, with no moving parts for film traction, is an asset. Videotape recorders using cassettes offer the operator the freedom of rapidly changing tape whenever convenient.

In some parts of the world it is becoming very difficult to get news film processed or edited, but most countries have terrestial or satellite circuits for the transmission of television signals. Portable ground stations for satellite transmission are also available.

8 Disadvantage of ENG

ENG incurs high capital costs. The equipment is complex and so maintenance is complicated and expensive. A certain amount of retraining and redeployment of staff is needed, with the usual union negotiations which can take a lot of time.

The cost of renting sites for receiving aerials must be taken into account but, in general, revenue costs are low compared with those for film.

ENG cameras and recorders are normally set up for only one standard, 625 or 525 lines and this means that the taped news items are not so readily exchanged between broadcasters using different systems as the international 16-mm film format.

9 Equipment for ENG

One of the problems in operating ENG is that technological advances and refinements are appearing so rapidly that equipment is obsolescent before it is delivered. There is great impetus in broadcast equipment manufacturing to bring out new equipment and improve old in terms of size, weight, stability and technical refinements. The right time to buy is difficult to decide. During our one-year experiment we changed our camera, field recorders, base recorders, and editing system.

The camera we started with was the Philips LDK11, with three 18-mm Plumbicon tubes. It is a very good camera but is intended as a hand-held adjunct to the cameras used on a conventional outside broadcasts unit. Its main disadvantage is that it has a back-pack which is inconvenient for ENG. Nonetheless it worked very well and it was eventually redeployed in a small interview studio. It was replaced by an Ikegami HL77, which is a 'one-piece' camera, only the batteries being separate. Both types of camera which have been used could be operated from mains or batteries and have 10:1 zoom lenses.

The video cassette recorders at the start of the experiment were Sony VO-3800 U-matic, using a 19-mm (¾-in.) tape and a 'colour under' system. These recorders have a tape duration of 20 minutes and are capable of battery or mains operation. They have auxiliary pieces of equipment for replaying the signal in colour and adapting mains to the low voltages required by the recorder.

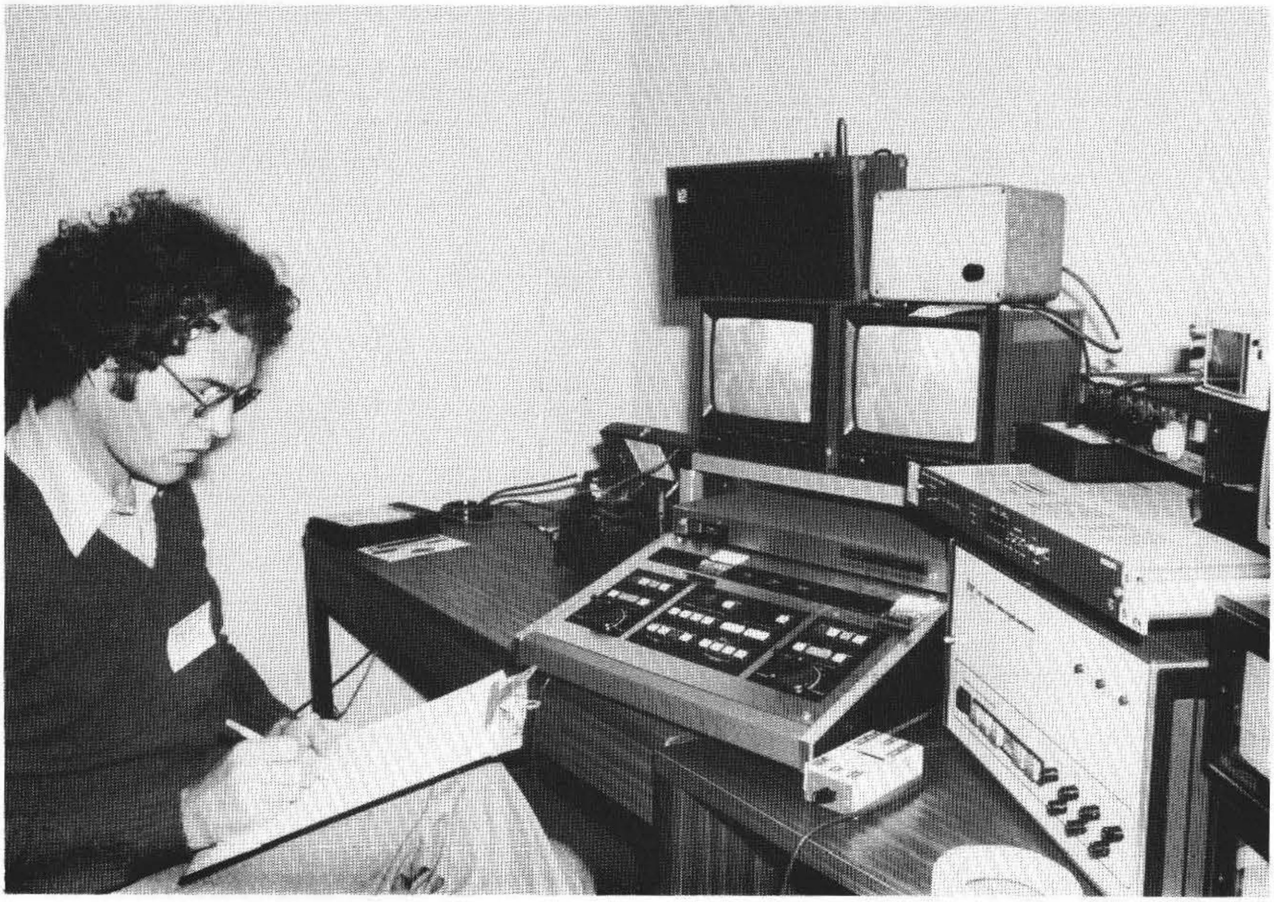
These field recorders were modified to have a 2-way microphone mixer with facilities for capacitor microphones, bass cut and zero level inputs. The U-matic tape format has two audio tracks and this is a very useful facility.

Back at base the tapes were edited and reproduced on two Sony VO-2850 U-matic recorders. These machines will accept cassettes of up to one-hour duration and the pair were linked by a Convergence editing console.

Throughout the experiment it was obvious that we needed more audio facilities at base and eventually a ¼-inch tape recorder and a small sound mixer were made available in the editing cubicle.

Signals could be selected for recording in the cubicle and transmissions into our News broadcasts were made direct from the 19-mm (¾-in.) U-matic cassette machines. Sometimes, of course, a videotape 'package' of a news story was made, using U-matic material, news film and conventional 2-inch VTR material combined on the standard quadruplex tape format.

The ENG editing system is not equipped with time-code but it would be possible to record this in the field if it were needed.



The ENG editing equipment rigged at a news location

About half way through the experiment the field videotape machines were replaced by the improved Sony BVU100 U-matic model. As this uses a slightly different format from the previous model the new tapes were not normally interchangeable with the old. The new field recorder was slightly heavier than the old one and, like it, needed ancillary equipment for mains operation and colour replay.

The base tape recorders, also of the improved format, were the Sony BVU200 type and the editing system was replaced by a Sony 500P. This meant that, operationally, we changed from the 'joystick' type of control of tape transport for edit-point location to a calibrated rotating control which set the tape speed.

The improvements in the new videotape equipment were very important, notably in allowing us to go to three, and occasionally more, generations of recording instead of being limited to two with the original equipment. This was significant operationally in respect of deciding whether to take the editing equipment to the location. If a recording were made on location and the recorded signals were fed back to base and re-recorded we were already into the second generation before any editing had taken place. Thus the new recorders gave us greater flexibility while the quality remained fairly high.

Various digital time-base correctors have been tried; the one which was in use during most of the experimental period was the CVS503.

10 The vehicle and its installed equipment

The choice of vehicle was determined by its suitability for carrying all the equipment needed and the requirement that it should be driven and operated by the two crew members. After consideration a Range Rover was chosen. It was not strictly necessary to have a four-wheel-drive vehicle but it has proved useful on a number of occasions.

The coachwork was strengthened to support a platform roof rack and its load. Primarily this is the 1·2-m radio-link dish aerial but the roof rack is also used as a camera platform and a mounting for the 12-GHz window-unit receiver.

The rear seat was removed and in its place small racks for equipment were fitted. The equipment is operated from a small rear-facing seat between the normal front seats. The rear section of the vehicle is used for storage of the portable equipment and can also house a small trolley to help in moving the equipment at the news location. The side windows of the Range Rover are treated to reduce glare and heat from the sun and to make the contents less obvious from outside. A security alarm was fitted and a low-voltage strip light for general illumination was installed. An entry point for cables was provided in the side of the body.

Six whip aerials are mounted on the vehicle; they include one spare. One is normally used for television reception but a small portable yagi aerial is also carried for use where the field strength is low.

The radio links were not available until April 1978 and effectively were not in operation until the last third of the experiment. The short-range window unit operates on 12 GHz and the main transmitter on 2·6 GHz. The output from the latter was limited to 18 W and fed to the 1·2 m parabolic dish aerial which was used in a circular-polarization mode. As already mentioned, the dish aerial is fixed to a roof rack. It is carried in the prone position and its support is raised to the vertical by an electrically driven (12-V) ram. The aerial is panned and tilted manually for maximum field strength (or minimum interference) at the receiving site, using data on signal strength fed back to the vehicle.

A pulse generator provides test signals for establishing the radio link or cable circuit and also acts as a reference source for the video recorder.

The normal selection of capacitor and moving-coil microphones, including lapel types, is carried, as well as a radio microphone and receiver.

A three-channel sound mixer can be used to control the levels from microphones in a 'live' situation and the output from the audio tracks of the video recorder, line-up tone etc. A 5 by 5 video matrix can select the output of the camera, recorder, 12-GHz window unit, test waveform generators etc.

The programme sound from the vehicle is put onto a subcarrier before radio transmission or injection into a Post Office cable circuit. Sound-in-sync transmission of sound is not possible without using a timing corrector because of the sync-pulse discontinuity which occurs at the recorder video head switching and is present on the output. The DTBC would also pose problems of power and weight in the vehicle. Multipath distortion on the radio link would also cause distortion of the sound-in-sync signal.

There is a talkback system which can be combined with the output from a colour television receiver/monitor to enable the reporter to be fed a mixture of 'off air' sound and cues from the ENG radio-telephone system or from a local talkback microphone. The talkback microphone output can also be injected into the outgoing music circuit. A small battery/mains monochrome television receiver is supplied for use by the reporter.

The ENG vehicle is equipped with comprehensive communication facilities on both the News radio-telephone network and its own simplex ENG network for detailed editorial and engineering discussions, link path lineup etc. The vehicle carries a 10-W transceiver and two 'walkie-talkies' for this work.

The ENG crew can communicate with the Television Centre communications control room staff, who control the base transmitter, and with the ENG editing suite, News studio control rooms and the Newsroom. This circuit also carries the data on the signal strength of the received radio-link signal.

A portable battery-operated Post Office radio telephone is carried as an alternative means of communication.

11 Mobile power supply problems

A major problem with powering the ENG equipment arose because of the number of different supply voltages required. At present it is not possible to get all broadcasting equipment in versions to operate from low-voltage d.c. supplies although the situation in this respect is improving. The power supply problems were solved in the following manner.

During the planning of the vehicle a 'silenced' petrol-electric generator was considered but the volume and weight would have been too high for the Range Rover and there would still have been a noise problem. It was therefore decided that the main power source would be a 24-V 120-Ah battery. This is recharged on the road from the extra alternator which is belt-driven by the vehicle's engine. During the early part of the experiment, a mains pulse charger was also fitted but this was removed to save weight when the alternator proved adequate. The pulse charger is now kept at base for overnight battery charging from the mains.

The 24-V supply powers the radio link and the sound system direct and also drives an inverter which supplies 240 V a.c. to other equipment.

The existing 12-V vehicle battery was duplicated and used to supply the radio telephones and extra lights inside and on the roof, etc. A battery-powered oscilloscope and chargers for the portable power supplies in the camera and recorders are available and carried when the vehicle is away from base for protracted periods.

12 The year's ENG experience

An important feature of the experimental year was the great enthusiasm of all staff concerned, both editorial and technical, and consequent eagerness to use the new system as much as possible. It was used on both 'hard' and 'soft' news stories and the immediacy and flexibility of ENG enabled many deadlines to be met which might otherwise have been missed.

During the year we gathered some 425 separate stories with the single ENG unit; a few of them were not used for editorial reasons. Some were transmitted only in the lunch-time bulletins; the story then changed and was not used in the original form again. Some stories were only available for the last news transmission of the day. A story about football would probably only be used once. Quite often there were differently edited versions of a story for different bulletins or for the two BBC networks. Productivity seemed to be somewhat higher than with film. The ENG unit often covered two stories in a day and sometimes four, and the overall total of ENG inserts in news bulletins was 645.

There were two notable royal stories successfully gathered under great pressure of time and before the radio link was available. On 14 October 1977 H.M. the Queen boarded a plane at London Airport at 12.40 pm, five minutes before the start of the quarter-hour lunch-time news bulletin. The ENG crew recorded the event on their portable video recorder, drove across the airport and through the cargo tunnel to replay the signal into the permanent cable from the airport to Television Centre. The pictures were re-recorded and on the air before the end of the bulletin. The 'second generation' pictures were so good that some viewers thought that they were from our conventional outside broadcasts unit — and this was with the old recorder and camera.

The experimental ENG unit

The second occasion was when the announcement of the birth of a son to Princess Anne was issued just as the lunch-time bulletin started. The statement was recorded at St. Mary's Hospital, Paddington and a dispatch rider rushed the videotape cassette via the motorway to Television Centre where it was on the air 12 minutes after being recorded.

Throughout the year, ENG was responsible for many stories in the lunch-time bulletins which would not have been possible if the processing of film had been required.

In the sports field we covered many football matches which were edited down for the coverage of the goals. We also covered rugby, cricket and squash matches. The editing equipment can be made mobile and taken to, say, BBC Birmingham. The editing could be carried out there and the tape played direct from the Region concerned into the network transmission.

An ENG crew was sent to Aberdeen by air with its equipment and a car with editing equipment followed by Motorail. This was to cover a story about a lost submarine. We have covered at least two stories on moving trains and have also had the ENG unit operating at locations associated with industrial disputes. On such occasions the crew sometimes suffered severe jostling from crowds. 'Gyroscopic' errors were evident from the U-matic recorder although these can be corrected by a 'wide-windowed' time-base corrector.

The ENG camera with a new nickel-cadmium battery has a duration of about 1½ hours, say 1¼ hours in practice,and even less if the power zoom is used. Manual zoom was often preferred because it was quicker in operation and saved battery power. For checking purposes the output from the recorder is replayed, in monochrome, into the camera viewfinder and this is useful in giving confidence to the crew and report that all is well.

The original video cassette recorder suffered a lot from head clogging caused by changes of temperature and humidity and this was particularly troublesome when equipment was brought in from the cold and operated in a warm room. Warm air from a hair-dryer, directed at the recording heads, provided the solution. The new recorders seem better in this respect.

As already mentioned, the radio links were effectively available for only the last four months of the experiment. The link was, nevertheless, used on 76 occasions, either for operational testing of sites or for transmitting the story back to base for recording or live transmission. Roughly one in four of the stories covered during the four months were sent by radio link back to base. (It may not, of course, have been a programme requirement to do so on others). Of the 76 sites, 62 were satisfactory, giving a success rate of 82%. On the way back from a location the crew would often stop on the approaches to London and test whether the 2·6 GHz signal could be received at base even if radio link transmission were not a requirement on that particular assignment. The transmission path was often not direct, but involved reflections from buildings or other objects. Indeed, within the heavily built-up areas of London this was usually the case.

In general the radio links worked surprisingly well and successful reception was obtained at a range of more than 30 miles on several occasions. Sometimes the vision and sound link was still working well at a range where the radio telephone was on the verge of failure. This led to difficulty in using the aerial panning aid because the radio telephone carried the data signal which gave the indication of received radio-link signal strength. On such occasions the visual indicator could not be relied on and it was necessary to pan the aerial while listening on headphones to the data pulses. This panning aid was developed by BBC engineers and is described in the accompanying paper. It was of great assistance to the ENG teams and normally only a few minutes were needed to set the aerial on the correct bearing.

The News Communication Control Room kept comprehensive records of radio link operations, including the best bearings, the polarization used and advice could, therefore, be given by radio telephone of the most likely position on any site. The mobile transmitter radiated with clockwise circular polarization. At the receiving site the signal was 'monitored' in vertical polarization and then clockwise, anticlockwise or horizontal polarization was selected for best quality of received picture.

The reporters in the field were able to talk by radio telephone to the Newsroom and editing staff to help shot selection and save time in the critical period before a news broadcast.

13 Conclusions

ENG has proved itself to be technically acceptable and a valuable system for news gathering. Developing technology will undoubtedly make it possible to increase mobility and effectiveness. One of the most valuable improvements would be an even smaller and lighter camera and so we are following with great interest the development of the solid-state camera using charge-coupled devices (CCD).

Our experience has confirmed that we were right to base the experiment on a crew of two. On certain assignments, however, for example a continuing story which requires the camera and a recorder to be in operation whilst previously recorded material is being transmitted back to base, a third person is desirable. This would also be the case if lighting support were needed.

The rapidly developing field of ENG will enable BBC Television to provide an even better and faster news service in the future.

The Choice of Aerial Support Structures for Broadcasting

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Summary: The bewildering variety of support structures offered by structural engineers to meet broadcasting needs arises from the equally diverse constraints imposed on them. The task of the designer of the structure is to find a solution which best meets the often conflicting requirements.

This article discusses the types of support structure in common use from the low-cost timber pole to the tallest cylindrical mast. It examines the factors to be taken into account at the planning stage, such as wind loading, statistical probability of failure, foundations, erection problems, aesthetics, aerial loading capacity, safety, maintenance, and cost. It shows how modern computer-aided methods of structural analysis can often assist in increasing the permissible aerial-carrying capacity of the structure.

Close co-operation between aerial and structural engineers is required to produce optimum solutions.

1 Introduction
2 Design parameters
2.1 Codes of Practice
2.2 Wind loads
2.3 Aesthetics
2.4 Maintenance
3 Types of structure
3.1 UHF relay stations
3.1.1 Slimline tower
3.1.2 Lightweight tubular tripod tower
3.1.3 Motorway pole
3.1.4 Timber pole
3.2 Guyed masts for UHF and VHF aerials
3.3 Guyed masts for HF and MF aerials
4 Additional loading
5 Conclusion
6 References

1 Introduction

The task of the structural engineer in broadcasting is to produce economical designs which can safely support the loads applied to them and perform satisfactorily with minimum maintenance during their predicted lives.

The aerial engineer not only requires the support structure to be secure against total failure but is also interested in its behaviour under static and dynamic load. At UHF and SHF the deflected shape of the structure under load is important if the aerials are to fulfil their function adequately.

The primary load to be resisted by aerial support structures is that of wind blowing on the structure itself and on the aerials. Other civil engineering structures such as buildings and simple bridges carry a high proportion of dead and superimposed vertical loads whose values can be accurately determined and wind load is of secondary importance. Unfortunately for mast designers the properties of the wind have only been studied in detail during the past 10-15 years and currently considerable research is being carried out into its dynamic properties and the effect of wind acceleration over hills. Much remains to be done. For the past 15 years the BBC, as the major user of masts in the UK, has been joint sponsor of two major research projects into wind properties and the dynamic analysis of guyed masts. Its engineers have therefore been able to guide the work of aerodynamicists to produce a practical design approach suitable for inclusion in future codes of practice.

Having determined the loads likely to be encountered in service the engineer must select suitable structural members to provide satisfactory support. The structural form may be lattice or cylindrical and self-supporting or guyed, usually of steel but occasionally of reinforced concrete or aluminium. The economics of each form vary and depend on height, aerial loads, access provision, cost of the site, and annual maintenance costs. The choice must be made carefully in conjunction with the aerial engineer, town planners, site finders, and operational engineers.

2 Design parameters

2.1 Codes of Practice

There is at present no British Standard Code of Practice for masts and towers, so use is made of codes applicable to

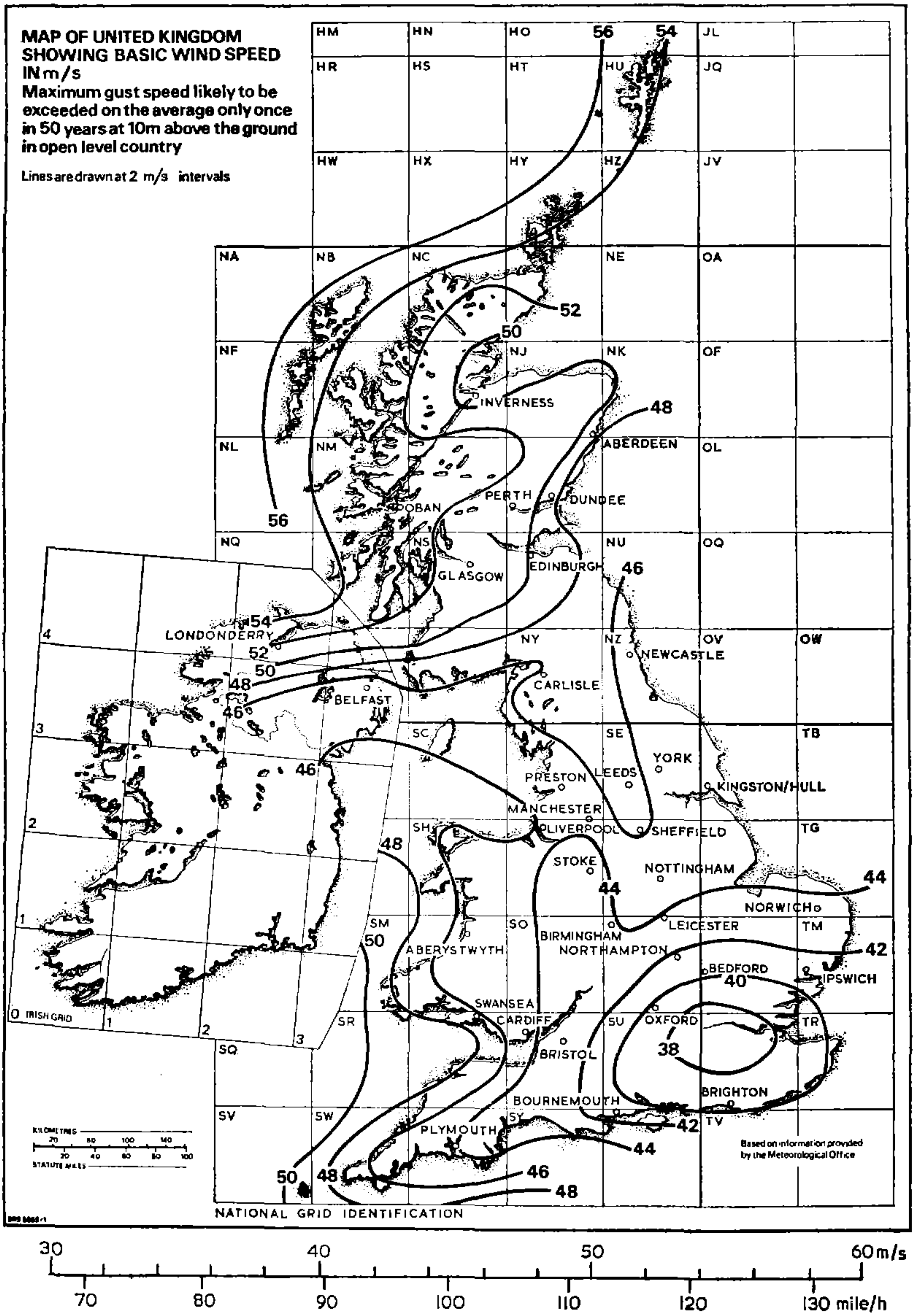

Fig. 1 Basic wind speed.

buildings. Wind loads are covered by CP3 (Chapter V)[1] and structural elements by BS449[2] and CP114[3]. While these codes have served us well for many years there has for some time been a need for a special code to cover loading and performance requirements for lattice masts and towers because the building codes need modification to make them suitable for special structures. The first part *'Lattice Towers — Loading'* is now in draft form and has been circulated for public comment.

Structural codes are at present undergoing considerable revision. It is the practice at present to apply an all-embracing (global) factor of safety by which the loads must be multiplied or stresses reduced to ensure a margin against failure. This factor has to cater for the following[4]:

the effect of secondary stresses
the quality of workmanship
the effect of repeated application and release of load
the effect of ageing and corrosion
the risk of exceeding predicted loads
the risk of unexpected loads.

The nominal load factor against buckling of compression members is currently 1·7.

New codes, however, are likely to be based on limit state design. The limit state corresponds to the condition in which the structure performs at the appropriate limits. It is thus possible to specify the ultimate limit state (maximum load-carrying capacity) and the serviceability limit state (functional limit for deflections etc.) and to ascribe various partial load factors for different types of load. Different load factors may also be used depending on the reliability required, environment, material, workmanship, and maintenance. Limit state design permits the choice of appropriate risk levels, giving due consideration to the risk to life in the event of a collapse and the potential economic and social consequences of failure. It is obviously uneconomic to use the same load factor for a small tower on an unmanned site in open country as for a major tall structure in an urban environment serving millions of people with several programmes. Until the new codes are published, however, we must rely on global safety factors and structural engineers' experience to determine acceptable risk levels.

2.2 Wind loads

The basic wind speed used for design is the three-second gust speed estimated to be exceed on the average only once in 50 years. This speed has been assessed for the United Kingdom by statistical analysis of continuous wind records from meteorological stations after adjustment to a common basis. The value are shown in figure 1 as lines of equal velocity at 2 m/s intervals. While the map incorporates the effects of the general level of ground above mean sea level additional factors must be applied for local topography, ground roughness, height above ground, and required reliability. These additional factors vary the basic speed considerably. The BBC transmitting station at Bressay in Shetland was designed for a wind speed of 70 m/s at a height of 10m. This great variation in speed from 38 m/s in the London area to

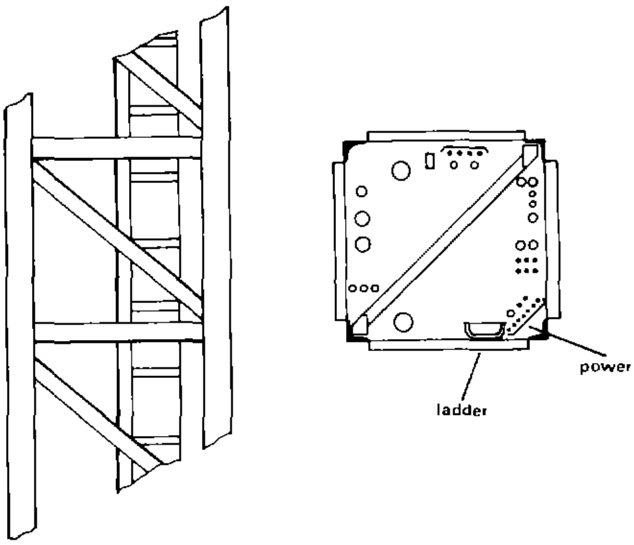

Fig. 2 The mast at Tacolneston: elevation showing structural members and ladder only, and section indicating the many additional obstacles to wind flow. These include feeders to transmitting aerials in Bands I, II, and V, feeders from aerials picking up signals from other stations for re-broadcasting in emergencies, feeders for permanent and temporary (Outside Broadcast) links, and power cables for lighting, hoist, etc.

70 m/s in isolated parts of Scotland makes completely standard designs for countrywide use uneconomic unless the aerial complement is varied according to the location.

There is a simple relationship between wind velocity and pressure but calculation of the aerodynamic drag of each structural member is more complex and relies, in the main, on results of experiments in wind tunnels. Most experiments, however, have been limited to simple lattice frames with no ancillaries but in practice masts at important stations have many obstructions to natural wind flow as shown in figure 2 (elevation and cross section).

Ice loading can reach massive proportions (figure 3), but this subject has received little attention in this country although the BBC is now trying to collect data on coincident ice and wind at some 20 stations throughout the UK. Iced masts are difficult and dangerous to climb for study at close range, but television masts in Finland are constantly monitored and much work has been done on the effect of asymmetrical icing on the guys and on the aerodynamic effects of the change in shape of iced members. The simultaneous occurrence of heavy icing and high winds is extremely rare in the UK; ice accretion normally takes place in light winds at or near freezing point. The risk of sudden change in wind velocity and direction must, however, be considered.

Wind-excited oscillation is a phenomenon of which engineers have been well aware since the failure of the Tacoma Narrows Bridge in the USA in 1940. Lattice structures in general present complex aerodynamic shapes and rarely suffer in this way, but cylindrical masts and all guy-ropes may be subject to this type of problem which can arise at relatively low wind speeds.

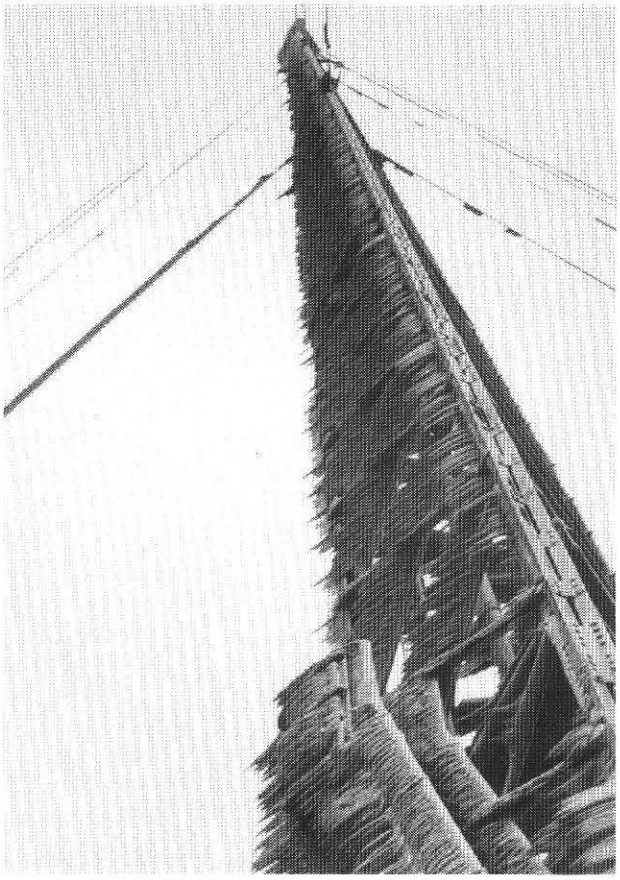

Fig. 3 The mast at Holme Moss with severe icing. This result was produced by a combination of low cloud, strong wind, and a temperature just below freezing point.

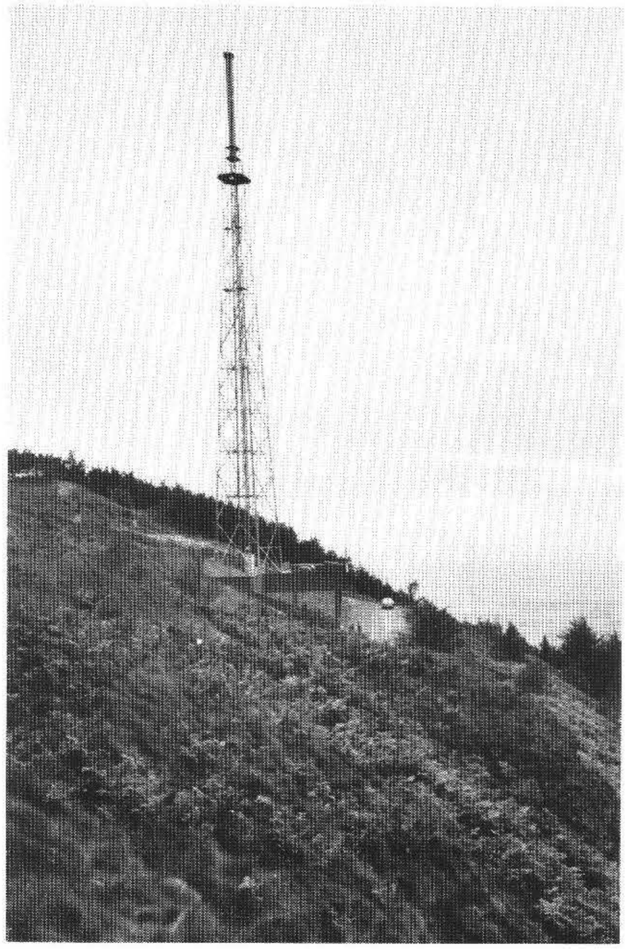

Fig. 4 The UHF television transmitting station on The Wrekin.

2.3 Aesthetics

With the advent of UHF television and the increase in the number of local radio stations and communications networks the number of aerial support structures in the country has increased greatly in the last 10 years. It is right, therefore, that broadcasting authorities should take some care with the siting and appearance of transmitting stations to lessen their impact on the environment. Local planning officers carefully control the types of structure in their own area: what may look acceptable in a rural area may be completely out of place in a town. In general, however, local authorities prefer tall structures to present the slimmest possible profile. This fits well with economic and technical requirements.

Three examples of structures designed to meet planning requirements are shown in figures 4, 5, and 6. The Wrekin transmitting station (figure 4) is situated on a steep-sided isolated ridge rising about 300m above the Shropshire plain. The ridge is surmounted by an iron-age double round hill fort and is visited by many people throughout the year. To keep the whole installation as compact as possible the tower is supported on the roof of the transmitter building which is benched into the hillside and semi-underground so that it can hardly be seen by walkers approaching the summit. Several alternative tower designs were considered but the lattice tower with its semi-transparent outline was finally accepted and proves to be almost invisible from the nearby A5 trunk road.

UHF television in the Peak District required eleven stations to be sited in or near the National Park. The Peak Park Planning Board was naturally anxious to preserve an area of outstanding natural beauty. The preferred design, selected from eight possibilities which included reinforced concrete towers and guyed masts, is shown in figure 5. It has a slim shape and a limited number of bracing members. Access ladders and platforms are contained within the tower body. This shape is so popular among town planners that it has become a standard for Phase I UHF Relay Stations and 102 such towers have so far been erected by the BBC.

Figure 6 shows a special 50 m tubular steel tower at Woolwich close to the Thamesmead Development where town planners required the structure to be integrated with the building and to have a pleasing appearance at close range. The tubular construction with its smooth aerodynamic profile reduced the load transmitted to the foundation piles and hence the cost.

2.4 Maintenance

Maintenance must be considered at the design stage if overall costs are to be kept to a minimum. Water traps in

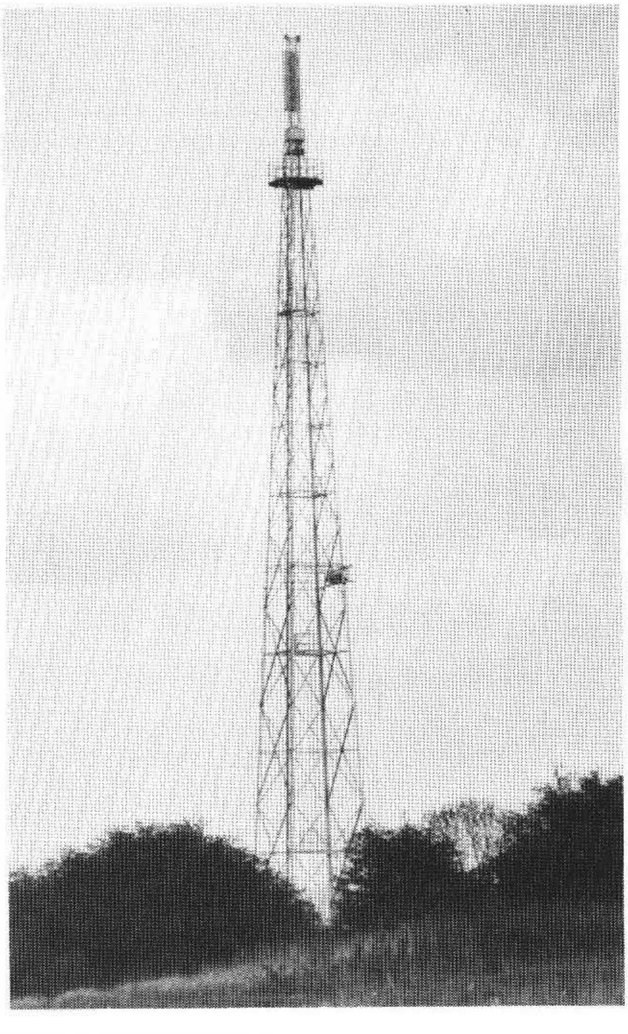

Fig. 5 The 'slimline' tower.

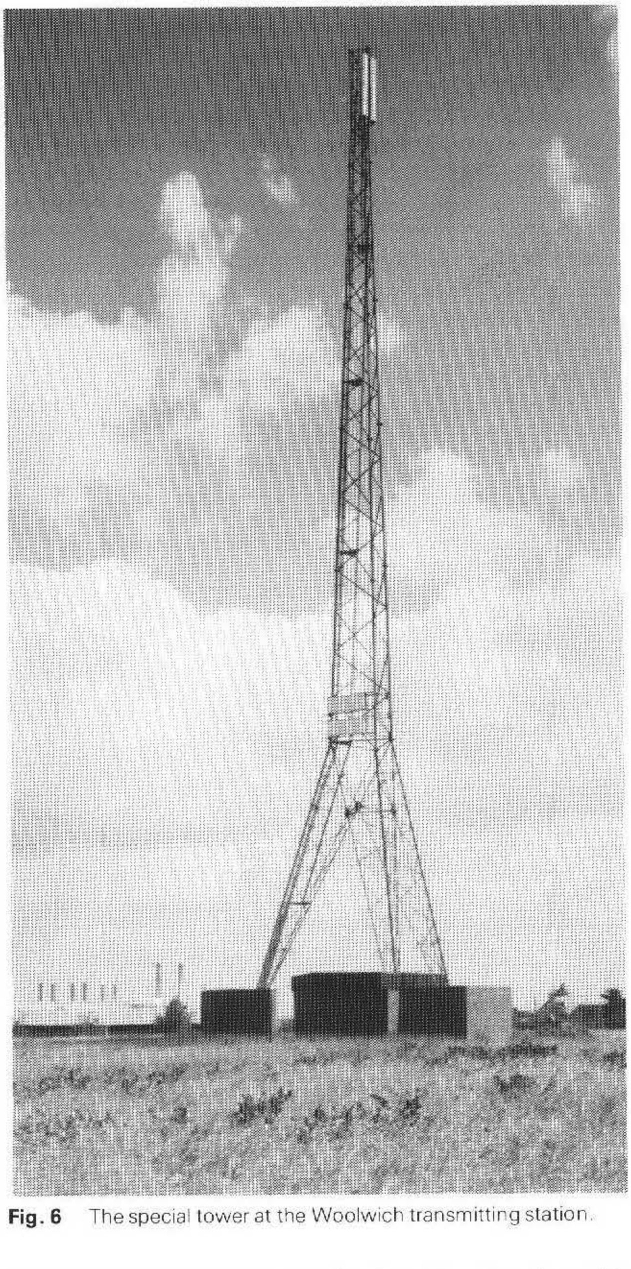

Fig. 6 The special tower at the Woolwich transmitting station.

structural steel should be avoided particularly in tubular members where corrosion can rapidly advance unseen. Galvanising is the preferred method of protection and while this may last 15-20 years in a relatively unpolluted environment it has been found worthwhile to overpaint galvanising during its early life. Some examples of advanced corrosion of ungalvanised steelwork are shown in figure 7.

Guy-ropes are prestressed at the manufacturer's works by repeated cyclic loading until a constant Young's Modulus of Elasticity is achieved. This removes all the initial stretch in the ropes. Re-coiling on the drums for delivery removes some of the prestress however and ropes require retensioning at regular intervals to maintain the mast column vertical within close limits.

Fig. 7 The fate of steel nuts and bolts unprotected by galvanising and exposed for 40 years.

3 Types of structure

3.1 UHF relay stations

3.1.1 Slimline tower

In the early stages of the UHF relay station programme several different standard towers evolved. It was common

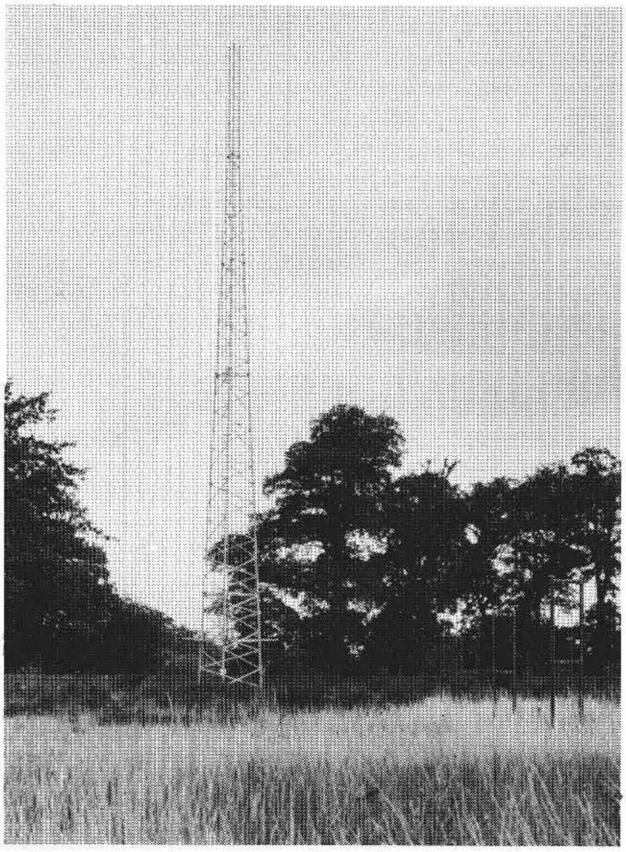

Fig. 8 The standard lightweight tubular tripod adopted for many relay stations.

practice at that time to invite competitive tenders for the complete design, supply, and installation of several towers near the same geographical location. These early towers also had to be capable of supporting a VHF aerial load to cater for viewers still unable to receive UHF.

It was not until 1971 that aerial loading became sufficiently standardised to require a 'UHF-only' tower. The tower designed for the Peak District National Park proved to be economic when ordered in quantities of 10 or more and since its appearance was acceptable to many planning authorities it was adopted as a standard design. In order to capitalise on savings in time and cost towers were bought for stock in batches of 10 or 20 and tenders for the installation of foundations and erection were invited as sites became available.

The tower is square in section and constructed from lattice steel angle sections (see figure 5). The standard height is 45 m but it may also be erected in 25 m or 35 m heights or extended to 52 m or 60 m. The tower was primarily designed to support at wind speeds up to 48 m/s a 0.4 m diameter glass reinforced plastic (g.r.p.) aerial cylinder enclosing a 16λ UHF aerial and two trough receiving aerials with a small allowance for other users' aerials. Other aerial configurations are, of course, possible.

As relay stations have spread into windier and more mountainous regions and aerial patterns have in many cases become more directional a need has arisen for a strengthened version of this tower, known as the 'heavy slimline', capable of supporting panel aerials in wind speeds up to 52 m/s. The tower is more costly and 30% heavier than the standard as can be seen in the table above.

Average Cost for Supply and Erection of Support Structures for UHF Relay Station Aerials

	Wind Speed (m/s)	Nominal Aerial Load (m^2)	Cost (thousands of pounds) at specified height						
			17m	25m	30m	35m	45m	52m	60m
Timber pole	48	1·1	1.3						
Tubular tripod	54	2·1		6	7	8			
Motorway pole	51†	1·7*			7	8			
Standard slimline	48	9·0		11		15	17	21	25
Heavy slimline	52	11·8		13		18	21		

*Aerial tilt is about 5° at full load.
†Climbing ladder will reduce wind speed to 44 m/s

3.1.2 Lightweight tubular tripod tower

A tower was specially developed by BBC structural engineers for use at Phase II UHF relay stations serving populations of between 500 and 1000 people[5]. On small transmitting stations the aerial support structure accounts for a significant proportion of the cost and a number of different designs were studied and costed.

In order to keep the wind-load to a minimum the log-periodic aerial was chosen for both transmitting and receiving. This aerial was model tested in a wind tunnel at Imperial College, London. The tests confirmed its low drag. The aerial requirement was for eight log-periodic transmitting aerials, mounted in the top 5 m of the structure, and four similar receiving aerials either vertically or horizontally polarised. Two tower heights (25 m and 30 m) were specified. The design was based on a basic wind speed of 54 m/s.

Reference to figure 1 shows that this is exceeded only in the Outer Hebrides, Shetland, and part of Orkney providing there are no unusual topographic features near the site. Clearly it may still be possible to use such a structure in these areas with a reduced aerial load.

It was intended to standardise and buy the tower in batches of at least ten in order to keep fabrication and templating costs to a minimum.

A three-legged lattice tower in hollow circular-section members produced the lowest wind drag and overall weight but fabrication in this form can be expensive if tolerances are kept low. The main leg connection is by simple ring flanges butt-welded to the tubular leg. Tests on this type of flange carried out earlier for the BBC at the British Welding Research Association had shown that its fatigue strength was adequate but high-strength friction-grip bolts were required to develop the full fatigue life, because the joints are required to take many fluctuations in tensile and compressive load as the wind changes in direction.

There were several possibilities for the diagonal bracing joint. A fully welded sealed joint would lead to large prefabricated sections to be transported to site, while open-ended 'spade' or 'fork' terminals are expensive. A simply flattened-end bracing was chosen after sample tests had shown that the galvanising penetration was adequate.

Lattice angle-section designs proved to be heavier and more expensive even though the joint details are simpler.

Conventional tower foundations use under each leg a buried pyramid of concrete of suitable size to limit the ground bearing pressure. The weight of backfilled earth provides resistance to uplift. With the narrow base of this tower (3 m) such a design is impracticable because the edges of the pyramids would almost touch and the effect of undisturbed earth resistance would be lost. Instead, therefore, a reinforced concrete raft is used. It requires greater care during installation but has a maximum depth of 0·8 m and serves as a convenient base for the g.r.p. equipment cubicle. It also incorporates a steel grillage which acts as a template for the first tower section and is cast in place to ensure an accurate fit for the tower when erected.

The resulting tower weighs only 2 tonnes and so can be erected in one piece if site space permits. It has proved to be popular among town planners. It has been adopted as a standard and is bought in batches of at least ten in order to keep fabrication and templating costs to a minimum. The IBA has also accepted the design. So far BBC staff have installed 11 towers and IBA contractors 25. An example can be seen in figure 8.

3.1.3 Motorway pole

For some time the standard steel tubular motorway lighting pole has been examined as a possible alternative to a lattice structure for Phase II relay stations. Its clean uncluttered appearance is an advantage but no economic solution has yet been found to the main problem of access to the aerials. A conventional climbing ladder is unattractive (being out of proportion with its support) and adds greatly to the wind drag. Motorway lights are lowered to the ground by means of a small powered winch in the base of the pole but aerials cannot be similarly lowered for inspection because of the feeder connections.

The IBA has experimented with a climbing cage which can be rigged at the base of the pole (see figure 9) and electrically driven to the level of the aerials. Its disadvantage is that four men need to spend about two hours to rig and de-rig the chair and ascend 35 m.

Because of its small base area large bending moments are produced at ground level and a high standard of engineering is required for the reinforced concrete foundation: this increases the cost.

The pole is delivered to site in three sections which are squeezed together to form a horizontal structure up to 40 m long. The pole is then erected by crane in one piece. A clear, fairly level, site about 40 m long is therefore required.

3.1.4 Timber pole

The timber pole is at present the cheapest form of support structure but is only suitable for heights up to 17 m and is limited in aerial loading to 1·1 m² at 48 m/s wind speed. Climbing access is limited to pole steps. Since the pole has to be in one piece an access route suitable for such loads is essential.

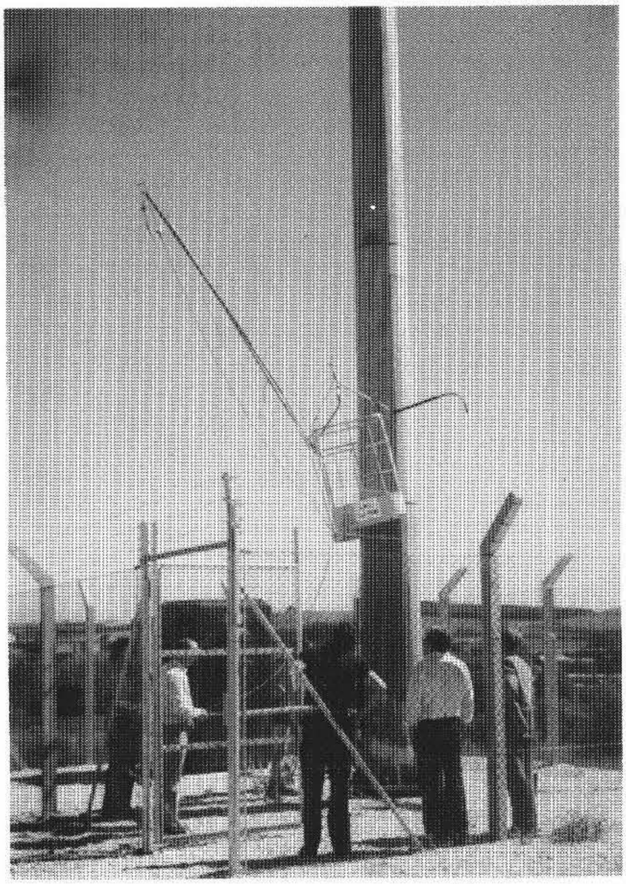

Fig. 9 The climbing cage for access to aerials mounted on a motorway pole.

3.2 Guyed masts for UHF and VHF aerials.

Guyed masts are economic at heights above about 75 m where the additional steel in self-supporting towers generally outweighs the cost of guy ropes, their anchorages, and additional land. Below this height however towers are usually preferred because they take up little space and require no maintenance apart from painting.

The tallest structures (above 300 m) ideally require a lift to provide all-weather access to aerials for maintenance. It is for this reason that the cylindrical shell has been preferred. The lift is enclosed from the elements and can function in even the most severe wind and ice conditions. The cylindrical shape produces low wind drag but is unfortunately liable to problems of aerodynamic vortex excitation of both mast and stays during erection and in service. These phenomena can lead to failure of members or joints either due to straightforward overstress or due to fatigue, unless measures are taken at the design stage to provide adequate structural or aerodynamic damping.

Erection of tall masts is not generally possible in high winds. The problem is particularly serious with cylindrical masts where the high ratio of area to weight of the steel segments tends to have a 'sail' effect when they are lifted outside the mast column by conventional winch. This was overcome at Bilsdale West Moor, North Yorkshire, where a g.r.p. erection chamber was mounted at the mast head. The erectors were thus protected from the wind and all segments

Fig. 10 The mast at Bilsdale West Moor under construction. Even with snow on the ground work continued inside the g.r.p. erection chamber at the top with access via the inside of the mast.

were raised inside the mast. The erection chamber was lifted as work proceeded and construction was able to continue throughout the winter months (see figure 10).

Although cylindrical masts solve the problems of fast access, lattice steel structures present the cheapest solution and a triangular cross section is structurally preferred. Many of the early television masts were nevertheless square in section because the aerial configuration required four faces.

It is structurally acceptable to allow masts to deflect from the vertical by a horizontal distance of between three quarters and one per cent of the height at any point under maximum wind load. This amount is however unacceptable for UHF cantilever aerials where the tilt of the aerial must be limited to ensure that the service area is maintained.

The problem is tackled by determining a satisfactory serviceability limit: that is to say the aerial engineer must decide for what percentage of the time a deflection exceeding the theoretical maximum is permissible. Wind records are available which will predict the number of hours per year that a given wind speed will be exceeded from any direction. In this way a reduced speed may be specified for aerial deflection limits. The ratio of serviceability speed (see section 2.1) to maximum speed currently in use in the BBC is 0·63.

3.3 Guyed masts for HF and MF aerials

With the increasing use of wideband arrays, masts supporting aerials are required to carry large concentrated loads resulting from tension in the triatic ropes and weight of suspended cables and halyards. It is customary for aerial tensions to be calculated for still air conditions and without ice loading. In the past any additional loading in the array due to wind and ice has been prevented by attaching the halyard to concrete weights corresponding to the permissible aerial tension. As tension increases the weight lifts clear of the ground thus limiting tension by allowing the aerial to lower. This somewhat crude method has been known to fail during severe icing because of the inertia of the weights and the consequent slow response to gusts. It has therefore been replaced in the BBC by hydraulic tensioning units. These units were specially developed for the BBC and automatically extend when tension increases beyond a preset limit. They are unaffected by icing and react very quickly to changes in aerial tension caused by short-duration gusts.

Tall masts for MF use normally carry only light aerial loads such as T aerials or sloping wires. If the mast is used as a radiator however is it necessary to insulate steel guy ropes. Insulator costs are very high and can amount to 20% of the total cost of masts of about 150 m height for transmitter powers of the order of 100 kW. Where transmitter power is low (i.e. 5 or 10 kW) parallel-lay terylene rope (Parafil) has been used with success but it is still a wise precaution to insulate the guys at the top level to prevent any possibility of radio-frequency burning if water seeps into the end fitting.

4 Additional loading

Most tall structures are required at some time during their lives to take additional loads which were not envisaged at the design stage. It is normal practice in the BBC to make some allowance for future BBC aerials and for other users who may eventually wish to share the site. This is wise from a national planning viewpoint because it helps to keep the number of masts to a minimum. Where the proposed additional loads exceed the mast design values it is necessary to undertake a full structural appraisal. With the increasing use of computer-aided structural design this is not such a time-consuming task as hitherto. Analysis of different aerial configurations, wind directions, and guy tensions can be quickly undertaken once the basic geometry and material sizes have been recorded on tape or cards. In this way it is often possible to 'tune' guyed masts by changing guy tensions to take more load than the original design envisaged.

As an illustration of this an existing fixed-base 60 m mast used for VHF broadcasting on Skye was required to support a cantilever UHF aerial. In its existing form, the mast was quite unsuitable for supporting the new aerial. The problem was to restrain the mast by means of an additional set of stays without increasing the column thrust sufficiently to overload either the mast legs or the existing base foundation.

The computer enabled structural engineers to consider many different stay sizes and tensions, using each intermediate result to guide them to the final solution. Quite surprisingly, the new stays at mid height are of larger diameter than those at the top level and have ten times the still-air tension. The result is a mast which is supporting considerably more load yet has an improved dynamic performance. The expense of replacing the mast and existing VHF aerial system has been saved.

Structural analysis has been made even more convenient by the purchase of a desk-top computer which will eventually use information on all BBC masts stored on tape cartridges in library fashion so that proposals for additional loads can be checked with the minimum of input data. Although the computer allows a faster turn-round of aerial requests, which are currently running at about one a week, it is still necessary to exercise engineering judgment for the final solution. A full dynamic analysis is rarely possible and detailed joint connections, slight imperfections in the original mast, and fatigue analysis are not at present covered by the computer programme. These matters, together with a knowledge of the past performance of the structure and the detailed topographical features of the site, must be taken into account in the structural engineer's assessment of the maximum aerial load which can be supported with the required reliability and serviceability.

5 Conclusion

The aerial support structure accounts for a substantial part of the cost of any transmitting station: examples for the lower heights are given in the table on page 26. Taller masts are much more expensive, a 200 m structure costing perhaps £200,000 to £300,000 depending on the requirements. There is therefore a strong motive for seeking ways of reducing the costs.

The adoption of standard types of structure in the BBC has effected some economies and if bulk contracts can be placed for the erection of many towers at different sites further reductions might be achieved.

New limit-state codes are being prepared and will allow more precise determination of risk levels and lead to reduction of material costs, particularly at remote sites where the risk to life is extremely small. It will probably be many years before a full dynamic analysis of a guyed mast is undertaken as a normal design procedure, but it is likely that static analysis will become more sophisticated, simulating dynamic effects by varying the load on each stay span.

The International Association for Shell and Spatial Structures has for some time been drafting recommendations for the design and analysis of guyed masts, and documents to be published this year should bring us nearer to an internationally unified approach and stimulate further research into the behaviour of guyed masts.

6 References

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Acknowledgements

Figures 6, 9 and 10 are reproduced by courtesy of Balfour Beatty & Co. Ltd., the Independent Broadcasting Authority, and J. L. Eve Construction Co. Ltd. respectively.

Electronic tape measure

J. R. Humphries

Television Studio Engineering

Summary: The principle of measuring the time taken by a test pulse to travel to a point at which a cable is misterminated and back again to deduce the distance involved is well established. A small unit exploiting modern devices to implement this principle has been developed. The instrument is cheap, easy to use, and accurate enough for all the practical applications.

1 Introduction
2 Circuit arrangement
3 Method of use
4 Test waveform

1 Introduction

The distance between a conveniently accessible test point and a cable fault can be deduced by measuring the time taken by an injected pulse to return to the test point after reflection by the fault. This principle has long been established and has been exploited by many instruments and collections of instruments. A device produced recently in the Television Service, however, has the merits of cheapness and simplicity while being quite accurate enough for all the proposed applications: the accuracy of any such device is in any case limited by the uncertainty in our knowledge of the velocity of propagation in the cable being tested.

The unit was originally developed to perform the mundane task of checking the physical lengths of cables in a store where they are kept in reserve for occasional very complex programmes requiring large amounts of studio equipment with multiple interconnections. Although the task is basically very simple it can be extremely laborious if attempted without the aid of the electronic tape measure. Once the original purpose had been accomplished, further development was undertaken to permit it to indicate the distance to cable faults and to compare path lengths for equality in colour installations. Comparisons can be carried out to an accuracy of 0·2° at colour subcarrier frequency. This corresponds to about 25 mm of cable where the velocity ratio is 0·67. The unit can also be switched to provide a simple video test signal producing three vertical bars on a monitor.

2 Circuit arrangement

The basic waveform generator in the unit is a 555 timer producing a square wave at a frequency of four times line frequency (see figure 1). From the positive-going transitions of this square wave a pulse generator (74121) gives 80-ns pulses for sending to the cable under test. Pulses of either polarity can be obtained by switch; this is necessary to ensure that the reflected pulse is positive whether the cable is open- or short-circuited.

The pulses are fed to the cable under test via a short delay line to ensure that there is a distinguishable reflection even for a zero cable length. They also go directly into a pulse gate which removes the sending pulse, leaving only the reflection to be passed on to a coincidence detector (74121). The other input to this detector is derived from the original square wave via two switched calibrated monostable circuits which in effect act as time delays from the basic reference transitions. The calibration of the monostables is straightforward because, within the required range, the time constant is linearly related to the externally connected resistance.

One of the two calibrated monostables is switched to provide increments of time constant corresponding to twice the propagation time in a hundred feet of the cable most commonly used in BBC television studios. The other is switched to give ten increments of time constant representing ten feet each and also has a continuously variable adjustment with a total range of ten feet. It is convenient for the current application to have a unit calibrated in feet but there is, of course, no problem in arranging for calibration in any other units of length, physical or electrical, though it must always be remembered that a particular velocity ratio is implicit in any calibration in physical length.

When both monostables are set to their minimum time constants they revert to their stable states before the reflected pulse from the cable under test reaches the coincidence detector: the latter, therefore, does not fire and the light-emitting diode (LED) does not light. Progressively lengthening the time constants preserves the corresponding input to the coincidence detector for a longer period and the point is eventually reached at which that input is maintained until the arrival of the reflected pulse from the cable: this event then triggers the detector and the LED lights throughout the recovery period. That period is made sufficiently long in relation to the interval between pulses (16 μs) to ensure that the LED glows brightly.

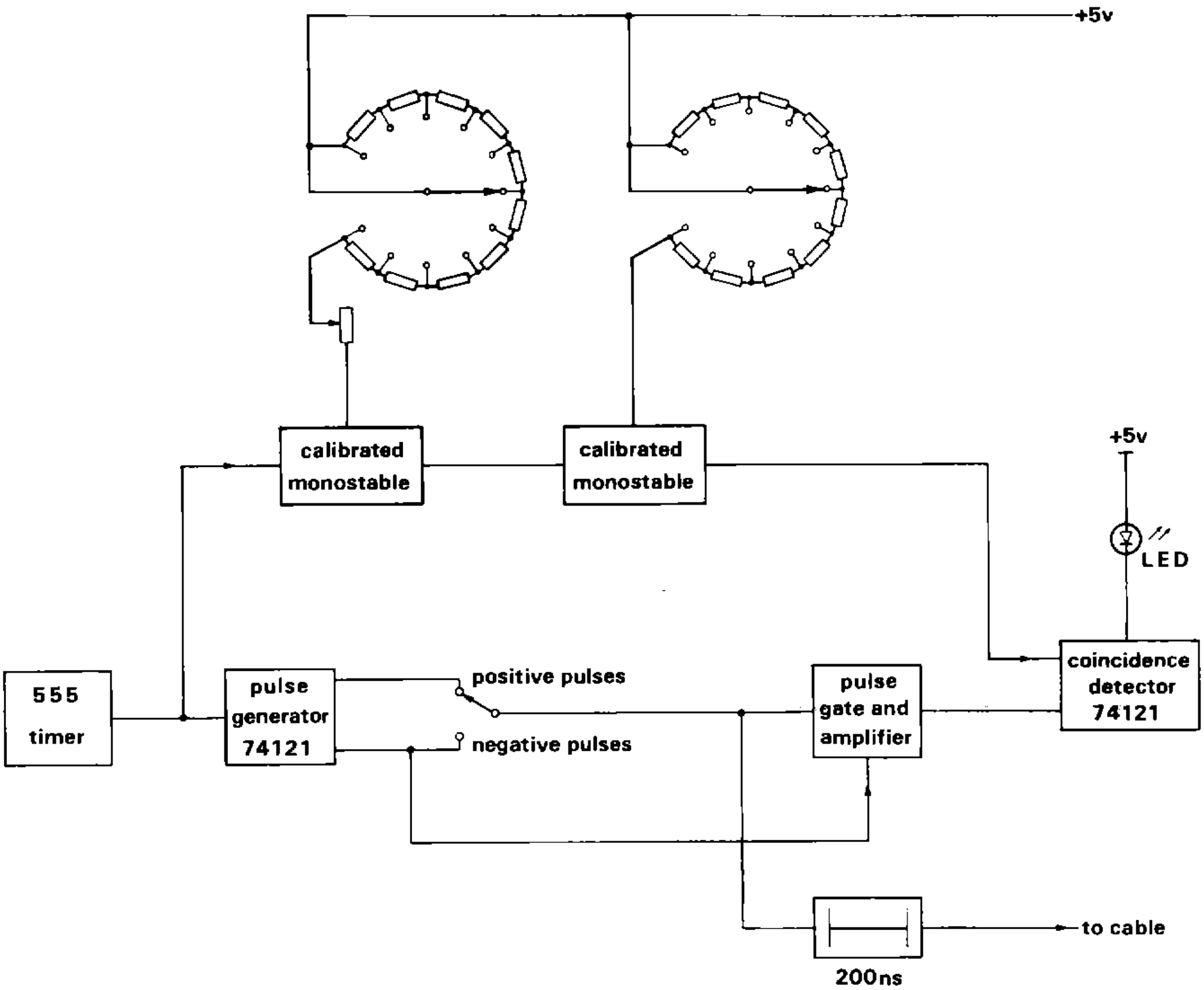

Fig. 1 The electronic tape measure block diagram.

3 Method of use

The measurement procedure is simple. All three calibrated dials are set to zero and in this situation the LED cannot light with any finite length of undamaged cable connected to the unit. The 'coarse' dial is then turned until the LED lights and turned back one step so that it goes out. Next, the 'fine' dial is treated in the same way. Finally, the continuously variable control is set to the point at which the LED lights. The measurement of length can then be read off the dials.

4 Test waveform

Straightforward internal switching can rearrange the sub-units to provide a simple video test waveform. The basic square wave at four times the line frequency produces four bars during a complete line period, one of which is inverted to act as the synchronising pulse. Once the levels have been suitably controlled this results in a waveform giving three vertical white bars on a monitor.

Contributors to this issue

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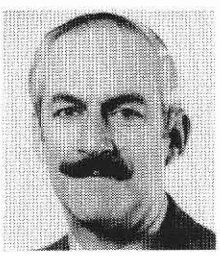
Stanley Edwardson has been in Research Department ever since 1942 except for three years spent at a short-wave transmitting station. During that time he has worked in many fields, including technical service planning, camera-tube measurements, Cablefilm, and field-store standards conversion. More recently he has been engaged in the development of CEEFAX and the 'CARFAX' traffic information system.

He has twice received the Royal Television Society's Geoffrey Parr Award: in 1969, with three others, for work on field-store standards conversion; and in 1976, with two others, for work on teletext.

David Grant joined the BBC in July 1953 as a Technical Assistant at Daventry. He transferred to the Television Section of Communications Department one year later. In 1961 he moved to the Links Unit of Planning and Installation (later Transmitter Capital Projects) Department, and has been Head of that Unit since 1970.

John Humphries joined the BBC in 1957 and since that time has been working in Television Studio Engineering. His work is concerned with the maintenance of all types of electronic installation in television studios, including effects and lighting control equipment. He has also been involved in the temporary installation of special equipment for very complex programme operations such as the reporting of General Election results.



Mike Stickler graduated at University College, London, in 1953 and joined the BBC in the same year. He worked in Operations and Maintenance at first but moved in 1956 to Planning and Installation (later Studio Capital Projects) Department, where he hs remained ever since.

Up to 1969 he was associated with telecine, but then he was appointed Head of Television Recording Unit. He was Project Manager, Bush House Development, from 1972 to 1976 when he was appointed to his present post of Head of Studio and Outside Broadcasts Section.

Henry Tarner has been with the BBC since 1944, apart from a period of service with the Signals Branch of the RAF. In 1949 he transferred from radio to television at Alexandra Palace, which then housed the whole of the BBC's television studio and transmitter facilities. After working at the Lime Grove television studios from 1951, he returned to Alexandra Palace in 1956 to join the Television News Service and he was appointed Head of Engineering, Television News, in 1967. Since then, Henry Tarner has supervised the great expansion of News engineering facilities in its new premises at Television Centre and the moves into colour and ENG.