ENG INF

The quarterly for BBC engineering, technical and operational staff

SUMMER 1991 No. 45

DIGITAL AUDIO BROADCASTING

Over 500 people attended the first UK demonstration of Digital Audio Broadcasting (DAB) mounted by BBC engineers in Birmingham at the end of July. The new DAB system — described in ***Eng Inf*** No. 44 — offers compact disc quality reception via simple push button radios at home, or on the move. It is very frequency efficient, offering up to twelve stereo radio channels in the space normally occupied by just two.

A coach driven round Birmingham was used to demonstrate the ruggedness of the DAB system in a typical city-centre environment, where normal FM radio can suffer from poor reception caused by the many tall buildings. Visitors listening on headphones were able to compare the DAB and FM signals which were being received from similar transmitters on 211 and 215 MHz, respectively, carrying identical programme material.

The demonstrations were received with acclaim from those who heard them. Comments from journalists, broadcasters, and industrialists alike ranged from "stunning" to "mind-blowing".

The BBC is the sole UK member of the European Eureka 147 consortium that has been researching DAB for several years. Previous demonstrations have been given by Eureka members in Geneva and Las Vegas, and the system will feature at the IFA Berlin later this year.

Research Department

The DAB demonstration bus sets off on its 20 min tour of Birmingham

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ENG INF

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You must be wondering why the summer edition of ***Eng Inf*** is so late this time. Well, EID got very involved in the Birmingham demonstration of DAB which required extensive in-house typesetting and graphics work. Still, I'm reliably informed that summer doesn't run out till 20th September so I think we'll just about make it with this edition!

By the time you receive this issue, I should be well advanced with the autumn edition. However, it's not too soon for you to be thinking about stories for our winter edition. Texts for that issue should be with me by 6th November.

Mike Meyer
23rd August

Transmitter News

The following services opened or changed between 29th March and 23rd August:

New TV relays

Chalford	Gloucs
Chitterne	Wiltshire
Greenwich	London
Pennsylvania	Exeter
Perranporth	Cornwall
Pillowell	Forest of Dean
Poplar	London
Presteigne	Powys
Rugeley	Staffs
Siston	Bristol
Warmley Hill	Bristol

Addition of Nicam

The following main stations and their relays are now Nicam-equipped: Belmont, Black Hill, Crystal Palace, Emley Moor, Mendip, Pontop Pike, Sandy Heath, Sutton Coldfield, Wenvoe and Winter Hill. However, some of Black Hill's more remote relays in Argyllshire and Inverness-shire are unable, at present, to rebroadcast Nicam stereo sound.

New FM stations

Abertillery	Gwent
Olivers Mount	Scarborough
Nailsworth	Gloucs
Pennar	Gwent

Radio 1 on FM

Morecambe Bay	Cumbria/Lancs
Redruth	Cornwall

Radios 1 and 4 on FM

Ashkirk	Borders
Darvel	Ayrshire
Divis	Belfast
Haverfordwest	Dyfed
Rosemarkie	Highland
Rosneath	Firth of Clyde

Radio Scotland (Main) on FM

Bowmore	Islay
Port Ellen	Islay

Local Radio

Radio Sheffield gained a new FM transmitter at Chesterfield on 5th June.

Mast flashing safety lights

Ashkirk	Borders
Divis	Belfast
Haverfordwest	Dyfed
Pontop Pike	Durham
Rowridge	Isle of Wight

The IEE's Residential Home

Present and past members of the IEE (and their dependants) who are undergoing hardship now have available a residential home on the outskirts of London. Known as ***Spiers House Residential Home***, it is on the Chesters Estate at New Malden, Surrey, within easy reach of Hampton Court, Richmond Park, Wimbledon Common and Kingston-upon-Thames.

The prestigious Chesters Estate was donated to the IEE's Benevolent Fund after the second world war by a late Honary Fellow of the Institution — Mr C. W. Spiers. In 1987, a decision was made to build an extension to the main Chesters House in order to provide a modern and well-designed residential home with additional nursing care facilities for thirty-four residents.

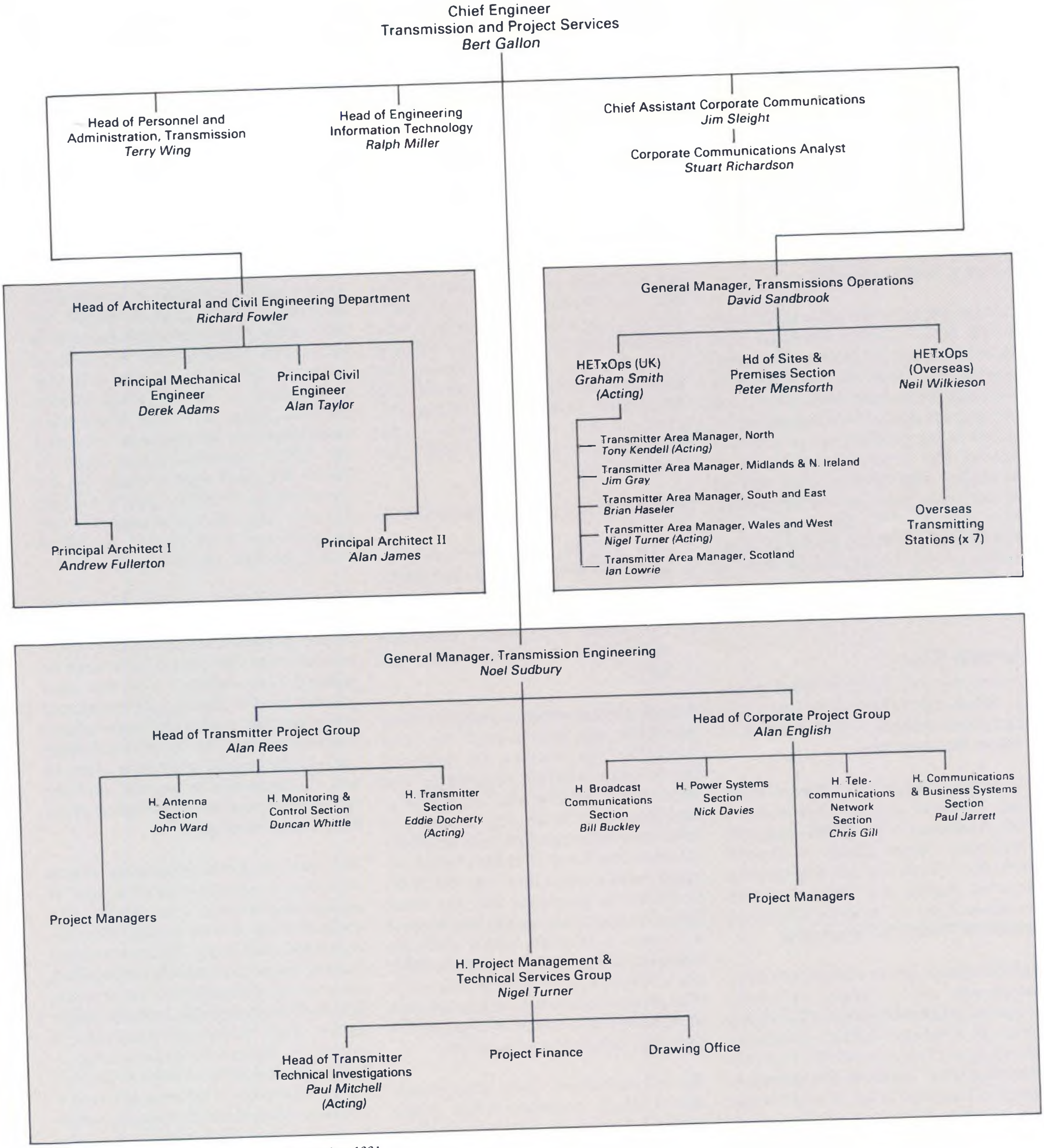
The new Spiers House was opened in August 1990 and provides high standard accommodation for up to twenty-six elderly residents in attractive single rooms and four couples in well-equipped flatlets. Being a single-storey building, there are no stairs. Televisions are provided in elegant lounges but each individual room is also provided with a television, and a wall socket for those who wish to provide their own telephone.

All rooms have en-suite toilet facilities and ample showers and baths are provided throughout the building. Three "Parker" baths have been installed which will be appreciated particularly by residents who find a standard bath difficult to use.

Anyone requiring further information on Spiers House should write to:

Miss Janet Nunns,
Benevolent Fund Officer,
Institution of Electrical Engineers,
Savoy Place, London WC2R 0BL.
(Tel: 071-240 1871 ext 291).

FAMILY TREES
Transmission and Project Services



Transmission and Project Services — 1st September 1991

CHARTER REVIEW
The BBC as Technical Innovator

Fifteen Task Forces have been set up to assist the recently-created Charter Review Group, which is looking at the full range and scope of the BBC's activities – and its future role – in the lead up to Charter Renewal at the end of 1996.

Here, Michael Starks – Chairman of the Task Force on Technical Innovation – introduces his team and describes their brief and how they are going about their task.

The BBC has been a technical innovator in the past. It is a technical innovator today. But should it retain this role for the future? And, if so, should it do so in the same way as at present — or does the changing shape of British broadcasting require a fresh approach?

These issues are at the heart of the work of our BBC Charter Renewal Task Force looking at the subject of technical innovation. Since we are genuinely addressing them with open minds, and have a great deal of work ahead of us, we are in no position yet to give any answers. But those with an interest in the subject might like to know who we are and what questions we are asking. We're very keen to gather views and relevant evidence at this stage and, if any readers of this article wish to write to us with thoughts and proposals, they would be most welcome.*

The Task Force

So who are we? We're a mixed group — including technical experts and programme makers — with a range of relevant backgrounds.

Our three professional engineers come from different output Directorates. **Peter Marchant** is the Chief Engineer, Television; **Simon Shute** is General Manager Operations and Engineering, Network Radio; and **Fiona Lowry** is Assistant Head of the World Service's Broadcast Coverage Department.

Phil Harding is Editor of Radio's Today programme and a former Television producer. **Adrian Davies** is a Television News & Current Affairs producer currently working for the BBC Policy & Planning Unit. **Gwyneth Henderson** is Head of Training for the World Service and a radio producer by background. And **Lawson Brown** is Head of Broadcasting Developments, Enterprises.

My own background, before coming to my present job, was in BBC Radio management, regulation of commercial radio at the IBA, and BBC television production.

Our Mission

Our first task was to formulate our brief. We had been given the heading "The BBC, the Technical Innovator", but it was our job to develop this into what our McKinsey adviser calls our Mission. I should say, in parenthesis, that McKinsey consultants are advising all the Charter Renewal Task Forces "on process but not content": the recommendations will be the BBC's, not the consultants'.

We decided that our Mission should be:

> ***"To consider what future developments in broadcasting are likely, whether technical innovation is a key ingredient in the BBC's future strategy, what areas of technical innovation the BBC should concentrate on, and why".***

We felt it was essential to go back to first principles, and the choice of the word "whether" in relation to technical innovation's strategic importance was therefore very deliberate. Traditionally, technical excellence and innovation have been an integral part of the BBC's picture of itself and, in today's world, we could readily argue that if we didn't do it, there's no guarantee that any other British broadcaster would. But there is a school of thought which puts the emphasis differently and sees the BBC as a distinctive public service on account of its programme services, not on account of its technical innovation. We need to recognise and explore that debate.

We will also check what other broadcasters do — especially other public service broadcasters in other countries — in the field of technical innovation. Do they undertake their research and development themselves or do they pursue it in partnership with universities and with the electronics, receiver manufacturing and telecommunications industries? What financial criteria do they apply to their involvement?

This analysis is likely to lead into other issues. How does partnership and cooperation in technical innovation square with achieving a competitive advantage? What position should the BBC adopt in transmission? And which electronics industries are our natural partners these days — the Japanese firms based in the UK which sustain British jobs, or their European competitors on the continent on whom the EEC's industrial policy tends to focus? We shall want to tease out the connections between public service broadcasting and public policy — and to take views from outside, as well as inside, the BBC on this theme.

We have already visited Kingswood Warren and Avenue House and have invited a number of speakers to come and talk to us. We have started work on selected case studies — to see what lessons for the future can be learned from specific technical innovations made in the past. We are also exploring the criteria used for investing in research and for assessing its success, and the scope which technical innovation offers for revenue earning.

We shall no doubt vigorously debate whether technical innovation is engineering-led and, if so, whether this is good or bad. Do we set high technical standards and spend disproportionate sums of money on improvements which are scarcely detectable by viewers and listeners? Alternatively does the public expect ever increasing standards of quality — witness the compact disc — and is it competitive death to cling too long to yesterday's technology? And if engineers should not be the only people leading technical innovation, then who else should also be involved? The programme-makers looking for competitive advantage? The resource managers and accountants looking for cost reductions? The marketing managers looking for revenue? If the answer is 'yes' to some or all of these, how could their involvement be sensibly organised?

Final objectives

At the end of our deliberations we aim to have:

1) a statement of whether and in what ways technical innovation supports the BBC's overall strategy;

2) a clear idea of those areas of broadcasting technology where the BBC should concentrate its own resources and those where it should form partnerships with others;

3) a range of options for the BBC as a technical innovator (and for the public debate over Charter renewal it will be important that we have thought through the arguments for and against various possible courses), together with our recommendations on these options.

What will happen then? Well, our work will need to be integrated with that of the fourteen other Task Forces and that will be quite a task in itself!

Michael Starks
General Manager
Radio Administration

* *Any written submissions to the Task Force on Technical Innovation should be addressed to: Michael Starks, Room 402, Brock House.*

NETWORK RADIO

New studio facilities for Radio 1

Martin Bravery describes Egton Studio 2 which has recently been refurbished for Radio 1, while overleaf Tim Mountain describes Radio 1's new Production Workshop.

STUDIO 2

With the start of round-the-clock broadcasting on FM, Radio 1 needed a simple DJ-operated studio. No new accommodation could be made available, so Egton Studio 2 has been technically refurbished to provide three new modes of operation:

- Day-to-day general programme-making
- Late-night presenter (DJ) operation
- Limited emulation of the BBC-designed Maxicon facility which is available in Radio 1's other studios.

View of the DJ's hotseat in Egton Studio 2

McNeill Photos

For day-to-day general programme-making, a Clyde 'Producer' series mixer has replaced the original 1979 Audix GP Mk2 desk. In addition, a Clyde 'Presenter' series mixer has been installed as a presenter-operated (DJ) facility for the starlight hours of broadcasting.

Both installations can operate independently: they are fed to the network separately and they can select their own outside sources. At the moment each facility's output covers a different portion of the 24hr day. On average this means eight to ten hours of general programme-making during the day, and about six hours of DJ operation occupying the small hours.

The third facility is the limited emulation of the Maxicon equipment format, which is used in Radio 1's existing on-air studios (4 and 5 in Egton House). This allows programmes normally done in the Maxicons to be moved into Studio 2 without changing the programme format or significantly retraining the DJs.

In this mode, subgrouped outputs from the DJ desk are fed into the control room desk for SM-controlled programming (where it is too complex to operate with one person). An example of this is when bands are playing in the same studio (which is quite common, even though it measures only 4m x 5m!) and when complex mixing is necessary using the full facilities of the control room desk.

Switching between the three modes of operation happens at the touch of a button and no replugging is required.

The multipurpose facilities were installed by Elliott Bros (Audio Systems) Ltd to a design brief produced by Radio Projects in conjunction with Radio 1 and Studio Operations.

The inaugural broadcast from Studio 2 took place in the dead of night on the 1st of May — successfully launching Radio 1's 24-hour service.

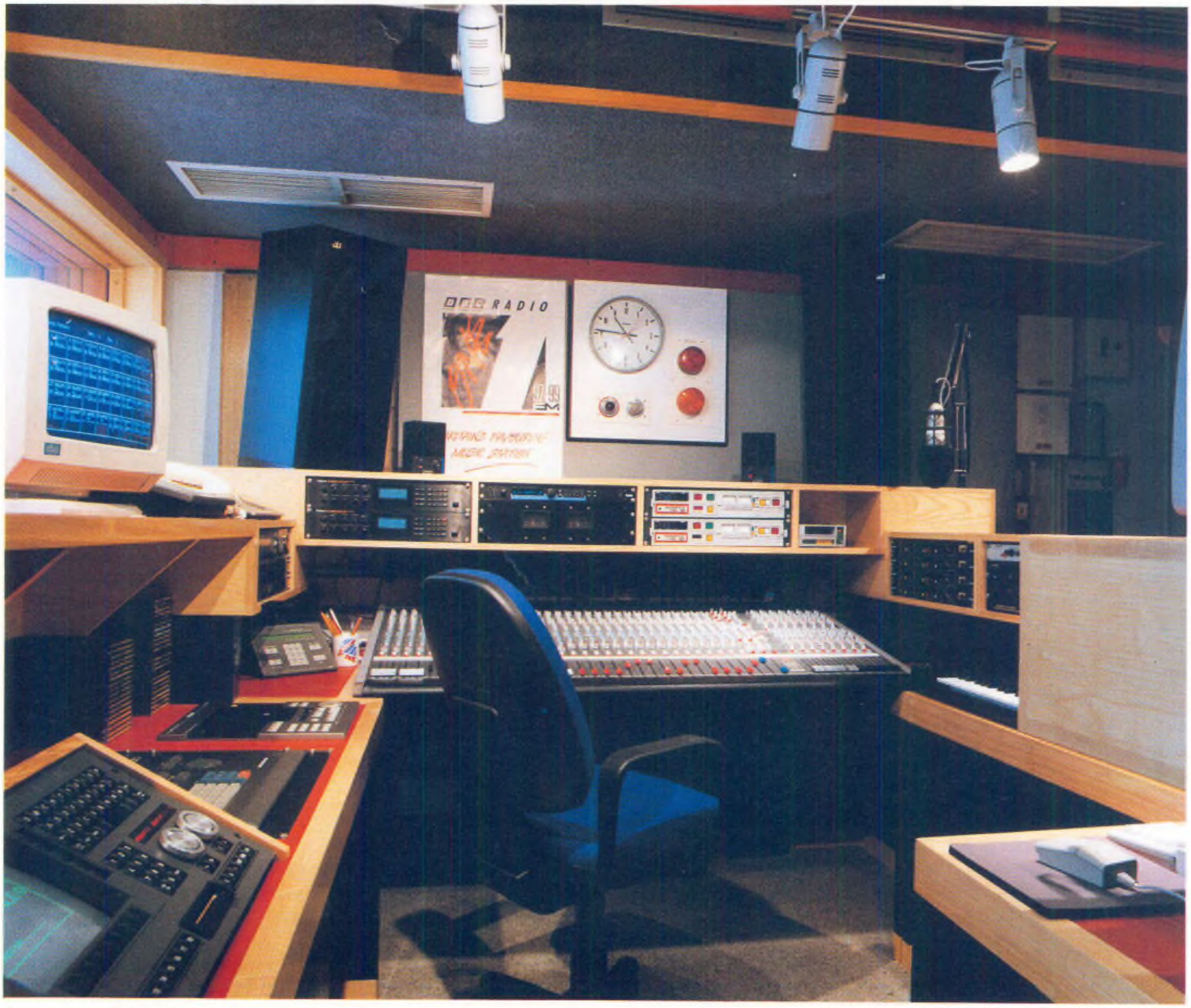
Martin Bravery
West 1 Project Group
Radio Projects

PRODUCTION WORKSHOP

Radio 1's Workshop is a pre/post-production type of area which is responsible for the creation of the majority of trails, promotions and jingles for the network, as well as producing general 'wackiness' for the Steve Wright afternoon show. It is capable of handling anything from a simple dubbing exercise to a full musical production, achieving the desired results in the minimum possible time.

The previous facility was far from ideal so the area has been completely re-equipped as a hi-tech studio by Harris Grant Associates (HGA). It was designed by Ray White of Radio Projects and includes the following equipment:

- **Mixing desk:** Allen and Heath Saber 32-16-16 console
- **Turntables:** EMT 938
- **Tape machines:** Sonifex cart, Radio Systems DAT and Studer A807 ¼-inch
- **Multitrack:** AMS Audiofile Plus 8-track digital editor, fitted with the 8-simultaneous-input upgrade
- **Samplers:** Akai S1000 & Roland S50
- **Effects units:** Roland E660 equalisers, Eventide H3000 harmoniser and Yamaha SPX 1000 multi-effects unit



McNeill Photos

General view of the Production Workshop

- **Computer sequencer:** Atari Mega 4ST, running Steinberg Cubase software

The desk is used in conjunction with an Akai audio router of four 32 x 32 matrices, configured to provide assignment of channel inputs, record source selection, monitor inputs, effects to send/returns, inserts etc. This was felt to give the most flexibility as well as the ability to instantly configure the studio for different requirements.

Although both ***digital editors*** and ***sampling*** have been used within BBC Radio for some time, the integration of both in a single area is a first for the Workshop.

The playback of samples triggered from a sequencer, and the power of an editor (including it's almost instant roll-back, auditioning capabilities, etc), makes it possible to build up a production with many sounds — effectively many tracks — in this kind of virtual multitrack environment. Thus any number of instantaneous samples of speech, music, etc, can be synchronised to the real audio tracks of the editor, using timecode. Another advantage is that there is no need to waste a track striped with code for synchronisation purposes, as most editors provide a synchronised SMPTE output.

The multitrack facility is integrated into the routeing system, allowing great flexibility as to what can be recorded and edited. Due to the noise of the cooling fans in the hard disk and processor, these units are installed in a remote apparatus room which is connected by a 35m cable to the control surface housed in the workshop.

MIDI control

The benefits of MIDI control are becoming more apparent in the BBC and the system is gradually being adopted in studios throughout the country. It is used extensively within the Radio 1 Workshop to provide control and data communication links between most of the studio devices. The MIDI signals — on a serial bus — are electronically patched via a Real World MIDI router.

By storing sequences of events in a computer, MIDI provides great potential for readily creating very complex productions in real time. For example, information on the timing and structure of musical notes can be stored by the Atari computer sequencer, thus enabling the playback of either sampled or synthesised instruments. Similarly, by storing information on individual equipment patches and the control of parameters (eg, level, delay or EQ), complicated effects can readily be recalled. Control of routeing configurations, desk channel muting, etc, is also possible in real time.

MIDI can additionally be used to memorise the configuration of the whole studio, the desired routeing, the effects programs required, etc. Hence, different studio setups can be recalled instantly at a later time or date.

The custom-made console was built off site at HGA's Wembley premises in late 1990. The system was then tested and commissioned by the BBC, also off site, before being installed in February. With the help of Engineering Operations, the refurbishment of the area, including equipment installation and on-site testing, was completed within a week.

Tim Mountain
West 1 Project Group
Radio Projects

HDTV

HDMAC broadcasts from Kingswood Warren

The BBC's first live HDTV broadcasting experiments via satellite took place from Kingswood Warren towards the end of 1990 and are described here by Andrew Lyner and Chris Nokes.

Late last year — as a result of contributions from members of the Eureka 95 HDTV initiative, and from several departments within the Corporation — the BBC was able to broadcast an hour or more of HDTV programmes each evening on the experimental high power Olympus satellite (described in ***Eng Inf*** No 38). These replaced some of the normal evening programmes on the 'Enterprise Channel'.

At Kingswood Warren, pictures were coded to the Eureka 95 HDMAC standard, fed to the Olympus satellite and received off air on HDMAC decoding equipment. There was similar decoding equipment at Bonn and Mannheim in Germany. In addition, compatible 625-line D2-MAC pictures were received by Olympus subscribers throughout Europe.

The transmitted programmes were compilations of the ever-growing stock of HDTV material, such as the IFA World Cup sequences, the opera 'The Prince of the Pagodas' and material produced by other European broadcasters. There was also first-time screening of the Kenneth Branagh film version of 'Henry V'.

The main purpose of the experiment was to assess some of the technical problems associated with an HDTV production, coded with HDMAC for transmission in an operational DBS channel. HDMAC is essentially a signal format intended for transmission. By its nature, it is an unsuitable medium for assembling programmes and, consequently, all editing and mixing must be done using the full bandwidth signal.

The equipment was arranged as shown overleaf. This divides into three main areas: production, HDMAC coding, and transmission.

Production

The production was carried out from the BBC's HDTV OB vehicle (described in ***Eng Inf*** Nos 34, 37 and 41) with all HDTV material being sourced from four multiplexed D1 digital tape machines. To allow for a continuous production during the more lengthy items, four additional D1 recorders were required, and these were situated in a building close to the OB vehicle and connected via a digital signal switching matrix to produce seamless programme joins.

An Aston caption generator was used to provide special channel ident captions, in high definition, which were inserted using the downstream keyer in the HDTV vehicle. Additionally, some HDTV camera pictures were used to provide high definition captions from the studio and, on the last day, there were some outside shots of Kingswood Warren.

HDMAC coding

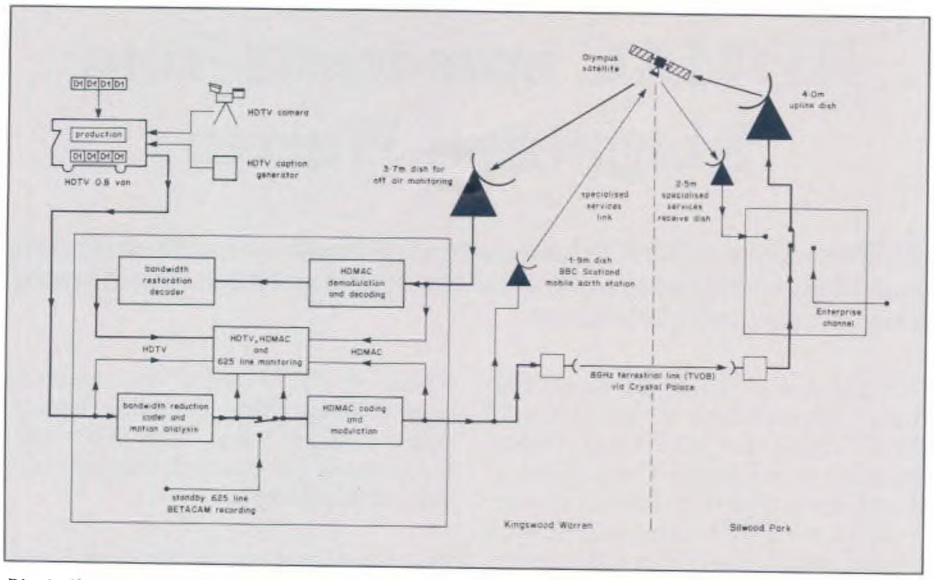
The HDMAC coding equipment is in two parts. The first part — the coder — converts 1250-line pictures into 625-line pictures together with the associated digital assistance information (indicating the motion vectors appropriate to the picture). This consists of ten standard 19-inch bays, linked together by a mass of 25-way ribbon cable that would make a telephone exchange envious! The second part — the D2 HDMAC multiplexer — consists of a further three bays to add the various sound and data signals and to deliver the signal in HDMAC form.

The HDMAC coder is the only one in existence and, at the time, was only at the advanced prototype stage. Also, with 'only' eight D1 digital VTRs at our disposal (to provide continuous HDTV replay), it was not possible to operate with a spare equipment channel.

This caused a few worrying moments when it was noticed that there were errors in the off-air decoded HDTV pictures. Fortunately, these errors did not affect the 625-line picture (which the vast majority of viewers were watching) but, in case the HDMAC coder might fail, a Betacam recording of the day's programme was always available. This could have been switched in at a moments notice to provide almost continuous reception for the 625-line viewers but, luckily, was never required.

An alternative strategy was considered for providing a standby programme source. It would have involved the production, in advance, of digital recordings of bandwidth-reduced versions of each programme. This would have required only two digital D1 recorders — one for playout and another as a standby — but would not have allowed any flexibility of production during the transmissions. It was thus rejected.

The HDMAC equipment was made by Thomson, Nokia, Philips and CCETT (Centre Commun D'Etudes De Telediffusion et Telecommunications — the French equivalent of a combined Kingswood Warren and British Telecom research lab). It was shipped over from Mannheim during the week before transmissions started and installed most efficiently by teams representing the respective manufacturers.



Block diagram of equipment used for HDMAC broadcasting tests from KW

The film of 'Henry V' was transferred to video tape using a telecine machine kindly loaned by Rank Cintel. The film had been shot on 35mm with an aspect ratio of 4:3 — for conventional television — and was not compatible with HDTV's 16:9 format. Thus, in order to fill the HDTV display width, the top and bottom of the picture were clipped during the scanning of the film.

It proved necessary to specify the dominant field when scanning 25 Hz film at 50 Hz field rate — in order to minimise movement artifacts due to HDMAC processing. Eureka 95 has now specified **field 1** as dominant.

Transmission

The UK DBS uplink to the Olympus satellite is from a site at Silwood Park, near Ascot. To get the HDMAC signals to Silwood for transmission, two possible forms of link were considered — a conventional 8 GHz terrestrial TV outside broadcast link, or an extra satellite link via the Specialised Services package of the Olympus satellite. This is a low power transponder on the satellite, often used for TDMA (time-division-multiple-access) data and other experiments. In the event, the Specialised Services transponder was not available for continuous service during the three week period of transmissions, so we used the terrestrial TVOB link.

The baseband HDMAC signal has spectral components extending to 12 MHz. However, there is a component around 10.125 MHz which can be regarded as low level subcarrier. There is no extensive test data available as yet, but it is known that both the amplitude the phase of these high frequency components and must be preserved if the decoder is to be able to recover the HDTV signal accurately.

Unfortunately, with the coder being in Mannheim right up until the last moment, it was not possible to laboratory test the terrestrial TVOB link with HDMAC signals. However a brief test using off-air HDMAC signals (after IBC 90 in Brighton) had indicated that

TVOB link equipment would probably be suitable.

A direct link between Kingswood Warren and Silwood Park proved to be impractical but a good link was established using a double hop, via the permanent link site at Crystal Palace.

There are subtle differences between frequency modulators for PAL and MAC, so a suitable modulator (provided by CCETT) was used at Kingswood to provide the correct i.f. signal which was carried on 'non-demod' links to Silwood Park.

Alan Lafferty, E.I.D.

The Olympus up-link terminal at Silwood Park

Specialised Services experiment

Although the Specialised Services transponder was not used during the Olympus transmissions, we did have the opportunity at an earlier date to test this link, for future reference.

The uplink to the Specialised Services package from Kingswood was by means of the BBC Scotland mobile earth station. This was installed at Kingswood, and using the same 1.9m dish for both transmit and receive, HDMAC signals were beamed to the Specialised Services package of the satellite, received and decoded again at Kingswood.

Whilst the decoder successfully reproduced the HDTV signal, the link introduced a little too much noise to be considered as contribution quality. However if a larger receive dish had been available, a significant improvement in noise performance would have been achieved and it may have been possible to use the link. Nevertheless, this link would always be marginal and, under severe conditions, may not prove satisfactory.

Conclusions

The equipment has highlighted a number of factors which must be taken into account in the planning of a full-time broadcast service of HDMAC. These include:

1. The need for synchronous switching, both between picture sources and between HDMAC and MAC sources.
2. The need for good quality feeder links for the satellite earthstation.
3. The need to optimise resources for the economic provision of standby sources of recorded HDTV programme material.
4. The problems of scanning film with incompatible format.
5. The identification of the dominant field for scanning film.

The transmission side worked well, although the experiment to use the Specialised Services package confirmed that this link would be marginal for (high quality) contribution use.

Many thanks are due to the large number of people — both from within the BBC and from various organisations around Europe — without whose help this project would never have got off the ground.

Andrew Lyner & Chris Nokes
RF Systems Section
Research Department

Research Department

Nick Tanton at the technical monitoring area at Kingswood Warren

LOCAL RADIO

Programme Share and Contribution network

A new system has been developed to provide automatic routeing of programmes and contributions between Local Radio stations within an English region.

Martin Harper describes the network as installed in Midlands Region.

Fig 1 shows how the Local Radio audio network has been configured in Midlands Region. It consists of two main hubs — at Birmingham (West Midlands) and Nottingham (East Midlands) — and interconnecting links with the region's Local Radio stations. The main matrices are at the two hubs, but each station has a smaller matrix to allow access to its own local sources.

The network also allows access to common sources — such as London Distribution Service 2 (LDS2) — of which there are about three hundred available in the Midlands. At present, the network is mono but is capable of being upgraded to stereo.

Control and Management

Fig 2 shows how the hardware has been configured. A schedule of routeing events — derived from 'bookings' — is created on the Sun 386i workstation, which manages the whole system. These events are then downloaded to a matrix (real time) controller that executes the switching action anywhere on the network. The capacity of the controller at present is about a thousand switches, which equates to around twenty-four hours of bookings in the region. The switching can take place instantly or at a predetermined time, depending on audio network availability.

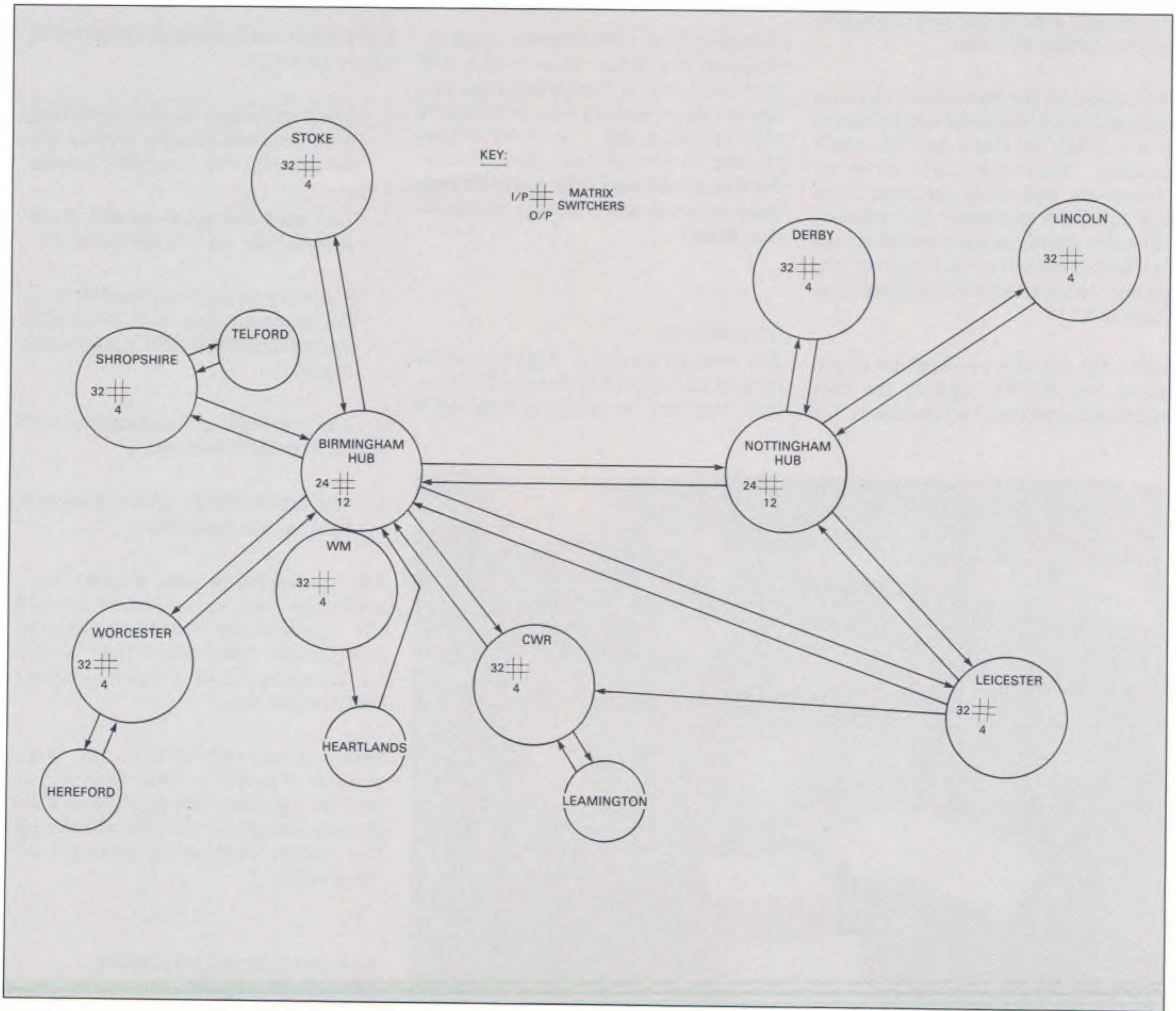


Fig. 1: the Midlands audio network

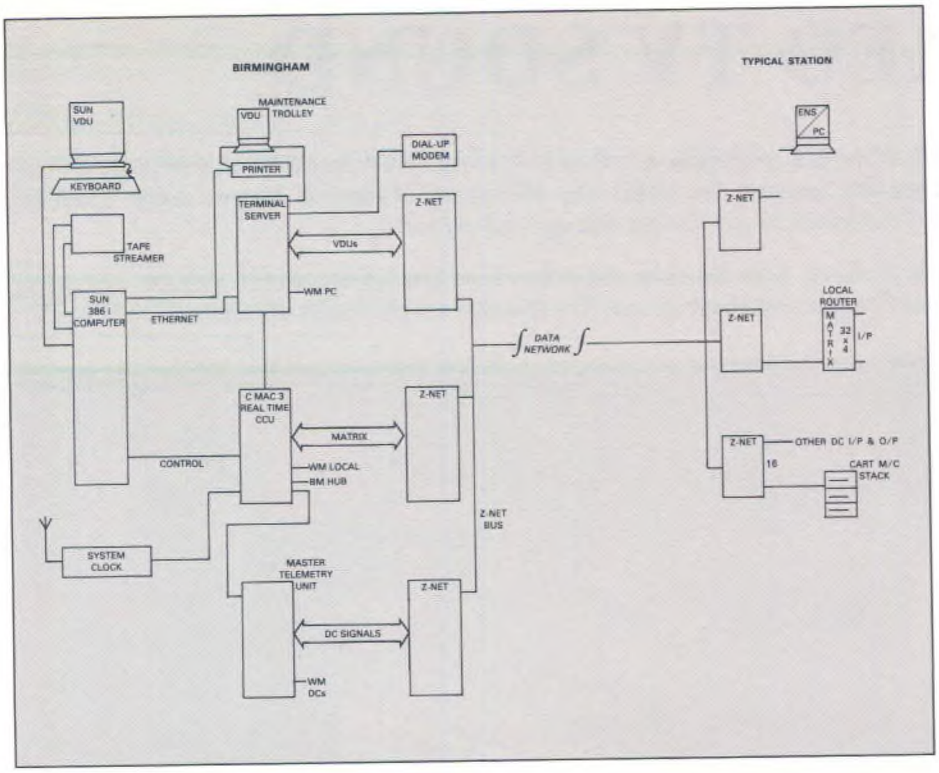


Fig. 2: the Midlands hardware configuration

to the requested mode. Typical fields include: the name of the booking: the contact name and telephone number; the source required (which can be selected from option lists), and the associated dates and times.

Next, the selection details are confirmed by the computer which gives it a reference number and enters it into the 'schedule' — unless the booking clashes with another in which case it will be rejected. To prevent clashes, there are a number of ways to view the existing schedule in advance of making a selection.

Users will gain access to the system via a unique terminal at each local radio station, with the ability (at a future date) to access the system from their ENS (Electronic News Service) terminals.

Credits

The system software was developed by Venturon, who also provided the hardware.

The software contract was supervised for the BBC by Tony Moore, the Broadcast Computer Engineer in Radio Projects, while the overall project control and installation engineering was undertaken by Roger Denning, also of Radio Projects. Large credit must go to Mike Wells, EiC Radio York, for it was his original work on specifying the operation and potential of such a system that set us on this course.

Martin Harper
Project Manager
Radio Projects (Regions)

The network uses the Zeta multiplexing system to carry RS232 control signals — via kilostream circuits — from the station VDU to the control computer and from the control computer to the Hub and Local matrices. In addition a channel is allocated to carrying telemetry signals to and from the stations and Birmingham.

Software

The system software has been modularised as much as possible with the use of standard packages where appropriate. An example of this is the bookings database which has been designed around a proprietary database, 'Empress'. The prime language used in compiling the functional programmes, which interact with the database, is 'C'.

The system is menu-driven to enable user navigation through the different levels. It offers help facilities, confidence messages and option lists if required.

Operation

A prime requirement was that anyone within a Region who has access to the system could readily select a source to themselves — either booked or instantly. To this end the design team devised modes of operation and a hierarchy of access, as shown in Fig 3. The hierarchy defines which modes can be implemented by particular classes of user.

So that some semblance of order can be maintained the modes have a priority arrangement imposed, ie Mode 1 has precedence over Mode 2 and so on, with the Instant mode having least priority. Any route made on the network through any of the modes will remain until overridden.

Bookings

To create a connection via the system, a user will be asked to select a mode — dependent on the class of user — and then will be shown a booking form. This form has simple fields to fill in, tailored

User Class	Mode	Function
Regional Controller	1,2,3,4,Inst	Regional programme bookings. Overall editorial control.
Station Manager	2,3,4,Inst	Station programme bookings. Local editorial control.
Station Operator	3,4,Inst	Contribution bookings for own Station.
Maintenance Operator	1,2,3,4,Inst	Response to system failure. Monitoring traffic. Emergency re-routeing.

Description of Modes:

Mode 1:	Normally used for repetitive longterm bookings of shared programmes, covering the output of all stations or a cluster of stations within a Region.
Mode 2:	Normally used for occasional bookings of programmes which are shared between two or more stations. They may be repetitive but not continuous.
Mode 3:	Normally used for interstation contributions which are set up in advance and booked.
Mode 4:	Normally used for pre-booking access to sources required during a programme on an instant basis. Several sources can be set up and the presenter could then flip between them during the booked period.
Inst:	Allows free access to any source that the network allows.

Fig. 3: the various classes of user and the modes of operation

STEREO TV SOUND

From the autumn of this year, about 73% of the UK population will be able to receive Nicam stereo sound with their BBC television programmes. In this special feature, we chart the efforts by Research Department, D&ED, Transmission, P&ID Tel and Network Television to get the service up and running.

To start the feature, RD's new Research Author, Alec Booker, describes how the Nicam stereo system – or more correctly NICAM 728 – was developed at Kingswood Warren and, for the more technically-minded, how it works.

RESEARCH DEPARTMENT

The foundations for the development of **NICAM** (Near-Instantaneously Companded Audio Multiplex) were laid in the early 1970s, when Research Department carried out fundamental work on digital sound coding and, separately, on digital modulation techniques. However, the search for the UK system to broadcast stereo tv sound did not begin in earnest until March 1982.

The following objectives were agreed:

1) **Compatibility with existing television receivers.** The new signals needed for stereo should not interfere with reception of the picture or the mono sound on existing receivers.

2) **Compatibility with the existing uhf transmission network.** The new system should be capable of being broadcast via the existing network of uhf transmitters and relay stations.

3) **Compatibility with the existing uhf frequency plan.** There should be no increase in interference to or from other broadcasts in the same or the adjacent channels.

4) **Ruggedness.** The new signals should be rugged enough to provide reliable delivery throughout the existing service areas.

5) **High-quality stereo sound.** A particular problem for analogue television sound systems is crosstalk between the picture and sound signals — 'buzz-on-sound' and 'sound-on-picture'. An additional requirement for stereo is good separation between the left and right sound channels; at least 20-30 dB in the mid-frequency range for stereo and at least 55dB if the system is to be used for dual-language broadcasts.

6) **Receivers should be inexpensive.**

A preliminary step towards fulfilling these objectives was to review the stereo television sound systems already in use or proposed in various parts of the world (see Table 1).

George Pope, Newcastle

Simon Forrester at the stereo sound control desk in Newcastle BC

Japan had started stereo broacasts in 1978, West Germany in 1981, and some US broadcasters were beginning experiments with a modified version of the Zenith/General Electric pilot-tone system, as used on stereo FM radio broadcasts throughout the world. However, preliminary BBC tests indicated that none of these analogue systems met our objectives and so work was begun to develop a system based on digital techniques.

Which digital system?

The decision to develop a digital stereo tv sound system was (in 1982) a bold one. Although the BBC had been using digital audio techniques for sound-signal distribution and contribution since the early 1970s, the size and cost of digital audio equipment had seemed to rule it out for mass-market consumer applications. However, in 1982, the launch of the digital Compact Disc was just one year away and with it came the promise of low-cost VLSI components for digital audio, including low-cost 16-bit digital-to-analogue convertors.

Several hurdles had yet to be overcome. The first of these was to show that a digitally-modulated carrier could be added to the spectrum of the UK System I television broadcasts — in such a way that it did not interfere with the existing picture and mono sound signals, and yet could be received reliably even in areas of poor reception.

Laboratory tests indicated that it might be possible to accommodate a digitally-modulated signal of up to about 700 kHz bandwidth — centred on a frequency around 6.55MHz above the frequency of the associated vision carrier.

Crucially, with a digital system, the level of this new signal could be as much as 20dB below the level of the associated vision carrier, whilst still maintaining adequate immunity to noise. This is significantly lower than the minimum level which would have been needed for an additional analogue FM carrier (as used in Germany) and so could provide a much greater margin between compatibility problems (new carrier too large) and ruggedness problems (new carrier too small).

The digital modulation system adopted for the new carrier was ***Differentially-encoded Quadrature Phase Shift Keying*** (DQPSK), which is described on page 13. This is a simple but efficient digital modulation system which easily allows up to about 700kbit/s to be broadcast in the 700kHz bandwidth available for the new digitally-modulated carrier.

SYSTEM	DESCRIPTION	WHERE USED
Pilot-Tone	AM sub-carrier modulating the existing mono FM carrier. (As in VHF/FM radio broadcasting.)	Used in the USA (with noise reduction on the difference signal). BTSC/MTS system.
FM/FM	FM sub-carrier modulating the existing mono FM carrier.	Used in Japan since 1978.
Two-Carrier	Additional FM sound carrier.	Used in W. Germany, Holland and Australia.

Table 1: the analogue multichannel terrestrial tv sound systems which were considered by the BBC prior to the development of the NICAM 728 system

Field trials

Experience with teletext, and earlier tests of digital broadcasting using DQPSK in the vhf bands, had shown that multipath — caused by reflections from hills or tall buildings — might be a serious problem for a digital system.

Therefore an early priority was to test the ruggedness of the prototype NICAM 728 system in the presence of multipath. These out-of-hours over-air tests were conducted — via Wenvoe and its relays — in the mountains and valleys of South Wales, during October 1983, and successfully proved that the new digital system was at least as rugged against multipath as the picture signal. Furthermore, the new signals were found to pass transparently through the existing relay stations without major modifications to the equipment (some of Wenvoe's relays are fourth or fifth generation).

To confirm the compatibility of the digital system with the wide range of televisions and VCRs used in the UK, over-air tests were conducted from Crystal Palace in the spring of 1984. Over two hundred BBC staff volunteered to sit up into the small hours of the morning and critically assess picture and sound signals for evidence of interference: no significant increase in interference was noted when the new digital signal was added.

Digital Coding

Having thus established that a reliable digital communications channel at about 700kbit/s could be provided, the next step was to design a suitable method of digitally coding the stereo sound signals within that bit-rate.

For broadcast and telecommunications purposes, a sampling-frequency of 32kHz has long been established as the standard for high-quality sound signals. This affords an audio bandwidth of about 15kHz and in practice this is not, for most listeners, significantly inferior to the 20kHz audio bandwidth provided by CDs (where a 44.1kHz sampling-frequency is used).

Furthermore, with good control of sound-signal levels, 14-bit resolution (rather than 16-bit as used for CDs) was found to be sufficient. Thus a raw bit-rate of about 900kbit/s (32,000 x 14 x 2) could deliver the required quality in a stereo or dual-channel system. However, this bit-rate was still too great to be accommodated within the 700kbit/s we had available.

Bit-rate reduction

With a linear coding system, reducing the number of bits-per-sample from fourteen down to ten would produce unacceptable quantisation noise and distortion, which would be especially noticeable on quiet signals. However, BBC Research Department had already developed a means of reducing the transmitted bit-rate to only 10 bits-per-sample, while maintaining an effective resolution equivalent to nearly 14 bits-per-sample. The principles of operation of the ***Near Instantaneous Companding*** used to achieve this are explained on page 14.

Audio multiplexing

For transmission via a digitally-modulated carrier, it is necessary to form the data — comprising the digitised and compressed sound samples of the left and right channel audio signals, together with their associated parity bits — into a single serial datastream. This process, known as ***Audio Multiplexing***

DQPSK

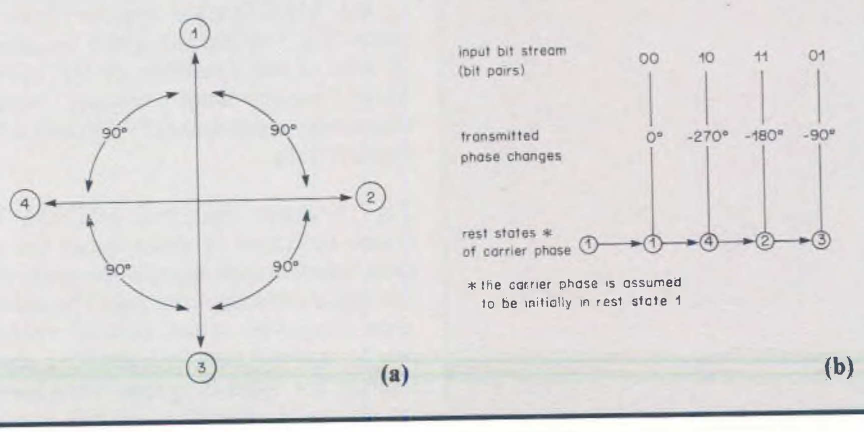
The serial datastream comprising the 728kbit/s NICAM 728 multiplex is conveyed by Differentially-encoded Quadrature Phase Shift Keying (DQPSK) of the new carrier. This is a four-state phase modulation in which each change of state conveys two data bits (or symbols)

The datastream at the input to the DQPSK modulator is differentially-encoded by the following processes:

1. Serial to two-bit parallel conversion
2. Coding of the transmitted phase-changes

The changes in carrier phase which correspond to the four possible values of the input bit-pairs are shown below. Thus, the carrier phase can dwell in one of four rest-states which are spaced at intervals of 90° apart, as illustrated in (a). An input bit-pair will shift the carrier phase into a different rest-state by the amount of phase-change assigned to that particular value of bit-pair. The transmitted phase-changes and subsequent carrier rest-states for the input bit-pair sequence 00, 10, 11, and 01 are illustrated in (b).

In the receiver the transmitted datastream can be recovered unambiguously by determining the phase-changes between one bit-pair and the next.



Near-Instantaneous Companding

Analogue COMPression and ExpANDING (Companding) systems such as Dolby B are well-known as a means of reducing the effects of noise in a recording or transmission.

All companding systems rely on psycho-acoustic masking effects to produce their results: a simple example of this is that loud noises tend to mask quiet ones. In a digital system with a restricted data-rate capacity (eg, NICAM), the simple approach of reducing the coding accuracy to meet the data-rate restriction would result in a lot of quantisation noise. Digital companding allows the data-rate to be reduced whilst the noise is masked as in an analogue companding system.

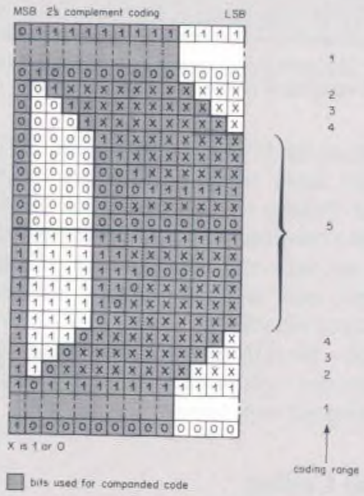
Unlike an analogue companding system, however, in a digital system the process of compression at the coder is exactly reversible in every decoder and hence no distortion occurs. (In an analogue companding system, the expansion in the decoder may not exactly track the compression in the coder, due to normal component tolerances, and so the expanded signal is distorted).

Digital companding is performed by removing the most significant bits (MSBs) or least significant bits (LSBs) of the original linearly-coded sound signal, depending upon the amplitude of the signal being quantised. Thus for low-level signals, the redundant MSBs are removed and the signal is quantised with the full 14-bit resolution; for large signals, the LSBs are removed and the signal is more coarsely quantised but the increased quantisation noise is masked by the loud programme signal.

In the simplest form of digital companding, the decisions about which bits to remove are made on a sample-by-sample basis. This is ***Instantaneous Companding*** as used in the well-known 'A-Law' compander. Unfortunately, with instantaneous companding, the quantisation noise increases very rapidly with increasing programme signal-level and this results in a relatively high level of programme-modulated noise.

Near Instantaneous (NI) Companding is an improved digital companding system for high-quality audio signals, devised by Research Department in 1972. In this, the decisions about which bits to remove are taken on blocks of samples rather than sample-by-sample; each block comprises 1 millisecond of one sound-channel (32 samples-per-block with 32kHz sampling). The resolution used to convey each block is determined by the largest sample in that block.

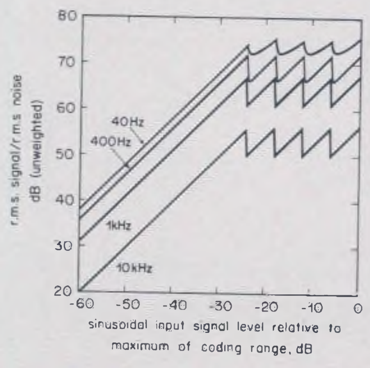
The overhead needed to convey the ***range-code*** (also termed 'scale-factor') information is much lower than for instantaneous companding where the range-code information must be sent with every sample. Thus, with NI companding, more bits are effectively available for coding each sample, and the level of the programme-modulated quantisation noise is therefore lower.



The diagram above shows the look-up table used in NICAM 728 to determine which 10-bit section of every 14-bit sample (within a given sound-coding block of thirty-two samples) will be transmitted. Note that three bits-per-block of thirty-two samples are needed to convey the range-code information to the decoders; in NICAM 728 these are conveyed using ***Signalling-in-Parity*** which is explained on page 17.

CCITT J-17 pre-emphasis in the coder (and de-emphasis in the decoder) is used to reduce further the audibility of programme-modulated quantising noise.

The resulting signal-to-quantisation noise for various input signal levels is illustrated below. Note the four 'gear-changes' in signal-to-noise ratio as the system moves through the five companding ranges.



(see page 16) adds the 'AM' tag to the NICAM acronym. As well as forming the sound/data samples into a single datastream, multiplexing also involves performing various 'housekeeping functions' such as ***framing***.

In the early 1980s, a Near Instantaneous Companding multiplex format — known as NICAM-3 — was entering service on BBC contribution and distribution links. NICAM-3 equipment, developed by the then Designs Department, accommodates two high-quality sound signals within a bit-rate of 676kbit/s. It would thus have been quite feasible to adopt the NICAM-3 multiplex for the digital stereo sound with television system. Indeed, many of the early tests were done with NICAM-3. However, NICAM-3 existed only in an expensive professional implementation and, with an uncertain market for stereo televisions, integrated circuit manufacturers were reluctant to commit themselves to produce special VLSI components for this particular multiplex.

Thus, what was needed ideally was a multiplex which was common with some other planned consumer product, in order to help kick-start the market for the necessary VLSI chips. That commonality was found in the then-emerging MAC/packet standard for Direct Broadcasting Satellites (DBS). One of the sound coding options in the MAC/packet system is a version of NICAM, and chip manufacturers strongly urged us to make our terrestrial digital stereo sound system as close as possible to that of the MAC/packet system.

Fig 1a illustrates how the frame structure of NICAM 728 was developed from that of the MAC/packet system: the core 704 bits — comprising 64 samples of the digitised sound signals — are identical in both cases. However, the 23-bit 'packet-header' needed for the multiple unsynchronised sound signals of the MAC/packet system could be discarded. Furthermore, the remaining 24 bits of the preamble of the 751-bit MAC/packet were replaced with a frame alignment word (FAW) and other control data.

Fig 1b shows the final NICAM 728 frame structure in more detail for the case where stereo signals are conveyed. As well as this stereo mode, the system also supports other coding options (eg to convey two independent mono signals for dual-language broadcasts) as shown at the foot of the section on *Audio Multiplexing* (page 16). Note that with 728-bit frame transmitted every millisecond, the overall data-rate of NICAM 728 is 728kbit/s — hence the '728' suffix on the acronym.

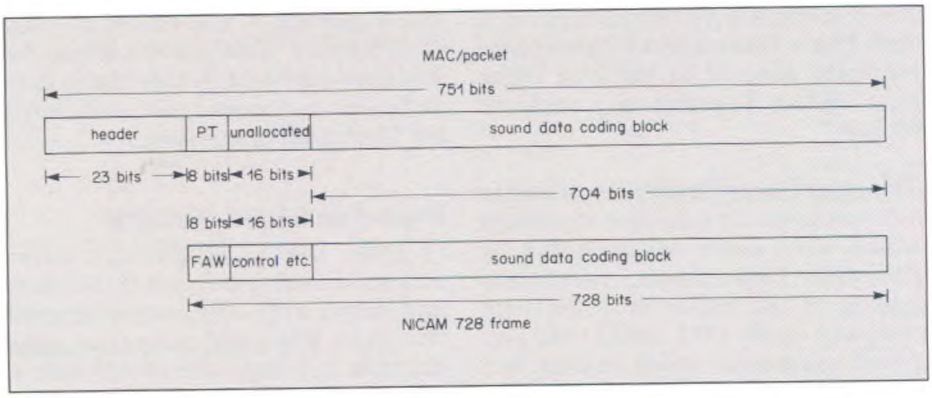


Fig. 1a: the frame structures of the MAC/packet and NICAM 728 systems

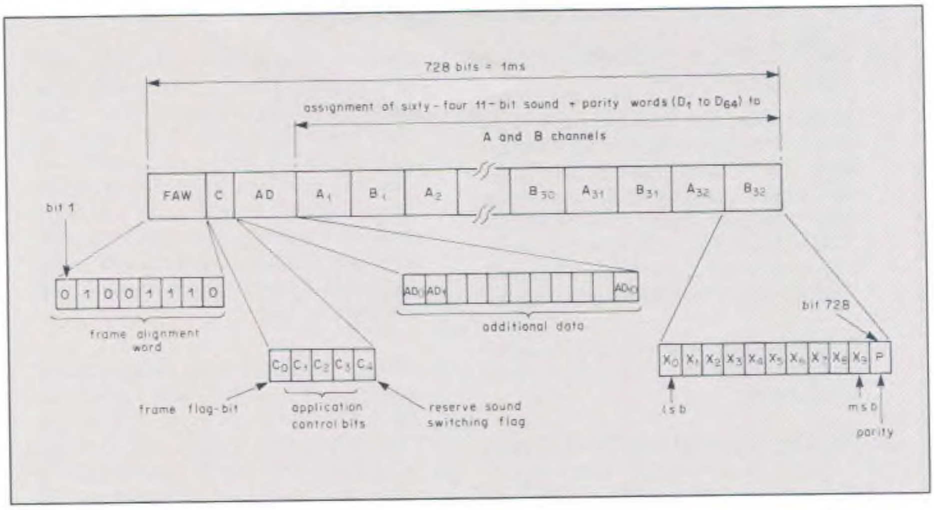


Fig. 1b: the NICAM 728 frame structure in more detail (stereo case)

International standardisation

The basic specification of NICAM 728 was completed in 1985 and agreement reached with the IBA and industry over its adoption and general form. Discussions with industry, and further intensive testing, led to some detailed improvements in the specification. In September 1986, the Department of Trade and Industry gave the system the seal of approval as the UK standard for two-channel digital sound with terrestrial television broadcasts.

Although the establishment of NICAM 728 as a UK standard was a major step forward, many receiver manufacturers perceived the UK market on its own as too small to make it worth their while developing Nicam receivers. Thus it was important to win support for the system from other countries. Apart from the UK, only Ireland, Hong Kong and some countries in Africa broadcast using System I PAL. Thus it was important to adapt Nicam for use with Systems B and G which are used in the rest of Europe (apart from France which uses System L SECAM).

Adaptation for use in System B posed a particular challenge since that system operates in 7MHz channels rather than the 8MHz channels available for Systems I and G. Thus the spectrum space available for the Nicam signals in System B is even more constrained than in System I. However, by moving the digital carrier closer to the mono fm sound carrier, and squeezing the bandwidth of the DQPSK signal down to about 500kHz (by tighter filtering), it was found possible to accommodate NICAM 728 even in System B.

The success of this adaptation was confirmed by field-tests — conducted with assistance from Research Department — in Sweden and Finland during the cold, cold winter of 1987. With temperatures in Helsinki down to -30°C, the only problem that the Research Department team reported was that their eyelashes froze to their eyes whilst making the measurements!

With support now from all the Nordic countries, NICAM 728 was adopted by the EBU (European Broadcasting Union) in January 1987 as the basis for a recommendation on the standard for digital multichannel sound transmission television Systems B, G, H and I. Industry was now quick to develop receivers, and the first Nicam-equipped VCRs went on sale in the UK and Sweden in the autumn of 1987.

NICAM 728 has already been adopted in at least seven countries, as well as the UK; it now forms part of a CCIR Recommendation (Rec 707) and is expected to become the first European Telecommunications Standard on a broadcasting system.

A summary of the NICAM 728 specification for various television systems is given in Table 2, (page 17) while a brief specification of the UK standard, published by EID, can be obtained by telephoning White City (07) 25040 during office hours.

Objectives achieved

Since July 1986, about three thousand scheduled BBC programmes have been transmitted with Nicam stereo sound — on an experimental basis — from Crystal Palace and its relays. Also, a limited Nicam service has been provided by some ITV and Channel 4 transmitters since 1989. These broadcasts have confirmed that the objectives we set ourselves back in 1982 have been amply met with NICAM 728.

The public has enthusiastically supported the system — even in advance of a service — by buying over a million Nicam-equipped TVs and VCRs. In many parts of the country, viewers can now look forward to a stereo tv sound service which is capable of reliably delivering very high-quality digital sound signals into their homes.

Alec Booker
Research Author

(The author acknowledges the valuable assistance provided by Dr Bob Ely, Dr Andy Bower, Neil Gilchrist, Adrian Robinson and others in the preparation of this article.)

DESIGN AND EQUIPMENT DEPARTMENT

D&ED's involvement with NICAM started in the early 1970s, shortly after the introduction of the 13-channel linear pulse code modulation (pcm) system. The department built experimental equipment to allow six full-bandwidth audio channels to be carried in a 2048 kbit/s bitstream, which was then becoming adopted by the Post Office (now British Telecom) as a standard bit-rate.

This experimental hardware was used to test various bitrate reduction algorithms which were under investigation by Research Department, eventually leading to the choice of 14-to-10-bit companding. By 1977, D&ED had produced equipment which carried two audio channels in a bitstream at a rate of 676 kbit/s. This was developed for Radio to distribute further channels of audio over and above those available on the 13-channel pcm system.

Dual-channel SIS (DCSIS)

In 1986, D&ED produced a stereo version of Sound-in-Syncs (SIS) which used the same NICAM processing as the version for Radio and carried two audio channels at a data rate of 676 kbit/s. This equipment used four-level coding in the sync pulses, rather than the two levels which had been used on the mono version. The design also used a custom gate array (specially developed by D&ED) to perform many of the companding functions of NICAM, thus saving space. A complete DCSIS coder or decoder (including the video processing) uses 3U of rack space, rather than the 4U needed by the original sound-only version used for Radio.

It was originally envisaged that some form of the 676 kbit/s data stream would be used to provide a stereo tv sound service to the public. However, a different version of the NICAM bitstream at 728 kbit/s was eventually chosen.

This different bitrate is used because it allows lower delays in the NICAM coder and decoder (due to the different framing structure) and provides better error detection capabilities (more parity check bits). The bit-rate is also an exact sub-multiple of the rate chosen for MAC satellite broadcasting, so allowing simple mapping between the systems.

The 728 kbit/s version of DCSIS was not developed 'in-house' but by Pye Varian Limited (now Harris TVT) and is based on the original 676 kbit/s design. Another version of dual channel SIS equipment working at 728 kbit/s is in use by NTL (formerly the IBA). Produced by R.E.Communications, it uses a different coding structure for the data bits in the sync pulses, and is not directly compatible with the BBC's version.

Transmission designs

Since the adoption of NICAM 728 as the transmission standard for stereo tv sound, D&ED has carried out work to ensure the signals can be carried through the transmission chain. In particular, the department has developed a ***uhf 4-tone tester*** which enables fast and accurate measurement of the linearity of television transposers and amplifiers, carrying both conventional and digital sound carriers.

The format for this test — which involves four generated signals representing vision carrier, colour sub-carrier, FM sound carrier and Nicam sound carrier — was agreed between Research Department, D&ED and TED, following a series of subjective and objective tests. These led to the adoption of limits for the additional intermodulation products (IPs) intro-

Audio Multiplexing

In NICAM 728, multiplexing involves the following processes:

1. ***Serialisation***: the formation of a serial datastream from the bits which comprise the left and right audio signals and/or data, together with the range-code information and control bits. In NICAM 728, the range-code information is conveyed using 'Signalling-in-Parity', which is described on page 17.

2. ***Error-protection***: a single-bit parity check is provided on the six MSBs of each sample.

3. ***Framing***: in serial data transmission systems, it is usually necessary to partition the data into 'frames' or blocks which are delimited by special 'Frame Alignment Words' (FAWs) which tell the decoder where each frame starts and ends in the continuous serial datastream. In NICAM 728, this framing information is achieved by a fixed 8-bit header word (the FAW in Fig 2b) together with the five application control bits which tell the decoder how to interpret the contents of the 74-bit sound/data coding block (see the table below).

4. ***Bit interleaving***: this is applied to the 704-bit sound/data coding block only and its purpose is to reduce the effects of bursts of errors in the transmission path, by changing the order in which the bits of the sound-coding block are transmitted. Thus the first transmitted bit of the sound/data block is bit 25 of the frame, the next bit 69, then bit 113 and so on. When the decoder reassembles the bits in the correct order, burst errors are spread amongst several sound samples and so can be detected (and then concealed) using the single-error detection capability of the parity check.

5. ***Energy dispersal scrambling***: this is applied to the whole frame apart from the FAW and its purpose is to ensure that, even when the data conveyed in the sound/data block is constant (eg when silence is being transmitted), the pattern of bits in the broadcast datastream is continually changing. This both helps minimise the effects of interference, if any, from the Nicam signal to the picture and/or mono sound (by making the interference more noise-like), and helps carrier and clock-recovery in the Nicam decoder.

   This energy dispersal scrambling is achieved by adding, modulo-two, a pseudo-random binary sequence to the transmitted serial datastream. The signal is unscrambled at the decoder by a complementary process of subtraction. The FAW is left unscrambled so that the decoder can keep in step with the scrambling at the coder.

Application Control Information			Contents of 704-bit sound/data block
C_1	C_2	C_3 *	
0	0	0	Stereo signal
0	1	0	Two independent mono sound signals
1	0	0	One mono signal and one 352 kbits/s transparent data channel
1	1	0	One 704 kbit/s transparent data channel

* C_3 = 1 provides for signalling additional sound or data coding options

duced by the digital sound carrier (F_{SC2}). These IPs are centred on Vision carrier ±0.552 MHz and, due to the relatively wideband QPSK modulation used for the Nicam sound carrier, they appear as low-frequency noise (as opposed to patterning) on the demodulated picture.

Following this work, D&ED then developed ***linearity correctors*** for the Blue and Silver Streak ranges of transposers, to allow intermodulation-free Nicam to reach all parts of the country. The department has also equipped the rebroadcast receivers and transmitter check demodulators with ***NICAM 728 decoders*** to allow monitoring.

Signalling-in-Parity

As noted in the section on Near-Instantaneous Companding, the decoder must be told which compression range to use — for each 32-sample block.

This range-code information could be conveyed as a separate bitstream, for which 3 bits-per-millisecond (for five ranges) would need to be sent for each audio channel. This could be done with dedicated bits in the multiplex, as it is in NICAM-3, but these range-code bits must be well-protected against errors, because corrupt ranging would produce very severe disturbances in the reproduced audio signal. This could even result in the listeners' loudspeaker cones being delivered into his or her lap!

An ingenious solution to the need to convey range-code information very reliably was devised by John Chambers of Research Department in 1974 and is the subject of GB Patent 2 116 403B. This system, known as ***Signalling-in-Parity*** is fully described in Research Department Report 1985/15, but the principle of its operation in this context may be summarised as follows:

Each 10-bit sample in a group of nine samples from within a NICAM sound-coding block is protected by a single-bit parity-check which can be used to detect single bit-errors. If a group of nine samples were received with the parity-check wrong on every sample, then either there have been nine single-bit errors (highly unlikely) or else there is a systematic error somewhere in the system. Thus a single bit of information can be conveyed by systematically modifying (or not) the parity on all the samples any one such group of samples.

In practice, three groups of nine samples each 32-sample coding block are modified in this way, to convey the three bits of range-code information associated with that block. In the decoder, a majority logic decision is taken on each 9-sample group to determine if the parity is modified or not. Since it takes five or more errors for this majority logic system to be induced to fail, the system is very robust. The only penalty paid for using Signalling-in-Parity is to weaken very slightly the error-protection provided for the sound samples. However, in practice, this weakening is not significant until the frequency of errors has passed the point where the sound-samples are so corrupted, even without Signalling-in-Parity, as to be unusable.

Studio designs

Now that the BBC has decided to use D3-format videotape machines in the future, high quality digital sound is available with the programme video. This is produced at a sampling rate of 48 kHz — the studio standard — and so must be converted in some way before it can be sent out by NICAM 728 (which uses a 32 kHz sampling rate). This could, of course, be done by using a digital-to-analogue converter followed by an analogue-to-digital converter working at the different sampling rate, but this loses quality. It is quite straightforward to convert between these two sample rates digitally, especially if the ratio between them is simple (in this case, 3:2).

As the decision has been taken to equip the new Network Transmission Area (NTA) with digital sound mixing and routeing facilities, it becomes possible to remove all analogue parts of the programme chain. D&ED is currently producing equipment to allow the digital sound output of a video tape recorder to be fed directly into the DCSIS distribution system, thus preserving the audio quality.

In addition, the department is producing designs to allow the incoming sound from an outside broadcast (carried on a DCSIS link) to be converted digitally to the studio standard so that it can be mixed in the NTA.

This will shortly enable the BBC to transmit sound from a live television OB direct to the viewer's home — ***entirely in the digital domain***.

Nick Cutmore
Audio Section

1.	**Specification of the digitally modulated carrier:**	
	i) Carrier frequency:	System I: 6.552 MHz above the vision carrier. Systems B, G and H: 5.85 MHz above the vision carrier.
	ii) Carrier level:	—20 dB with respect to peak vision carrier level.
	iii) Modulation:	Differentially encoded Quadrature Phase Shift Keying.
2.	**Overall bit-rate:**	728 kbits/s
3.	**Sound coding characteristics:**	
	i) Pre-emphasis:	CCITT Recommendation J.17.
	ii) Audio overload level:	System I: +14.8 dBμ0 at 2.0 kHz. Systems B, G and H: +22.0 dBμ0 at 400 Hz.
	iii) Sampling frequency:	32 kHz
	iv) Initial resolution:	14 bits/sample
	v) Companding characteristics:	Near instantaneous (NI), with compression to 10 bits per sample in 32-sample (1 ms) blocks.
	vi) Coding for compressed samples:	2's complement.

Table 2: summary of characteristics of the NICAM 728 system for digital two-channel sound with terrestrial television

TRANSMISSION ENGINEERING DEPARTMENT

Transmission's involvement in the Nicam project can best be described under three headings, namely: Programme Feeds, Main stations and Relay stations.

Our task has been to provide the necessary programme feeds to the ten chosen transmitter sites, and to modify these stations along with their 380 or so relay stations, as appropriate.

Programme feeds

In 1986, the then Designs Department developed a dual-channel version of Sounds-in-Syncs (DCSIS), using a data-rate of 676 kbit/s. The subsequent adoption of NICAM 728 as the stereo transmission standard presented a problem in that data-rate conversion equipment would be required at every main transmitting station. Consequently, work on the 676 kbit/s system was discontinued in favour of a 728 kbit/s DCSIS system.

TED invited tenders for the replacement of all mono SIS equipment with 728 kbit/s DCSIS equipment in November 1988. The contract was awarded to Varian TVT (now Harris TVT) who had previously carried out work on the 676 kbit/s DCSIS system (which uses much the same circuitry, thus reducing the product development time).

Operational trials of the dual channel 728 kbit/s system began in the early part of 1990. It highlighted the need to design an effective data re-framer to buffer the audio from network glitches such as those caused by the regional studios opting-out. This was completed by the end of 1990, in time for regional installations to commence in early 1991.

The installation work has required a transcoder to be positioned in London Switching Centre — to convert the outgoing DCSIS back to mono SIS for onward distribution to Norwich, Southampton, Bristol and Birmingham. This has allowed each 'leg' of the distribution chain to be tackled separately and in isolation. Further transcoding facilities have been deployed temporarily in Cardiff, Bristol, Birmingham, Manchester and Glasgow, as the DCSIS border expanded. Dual-channel SIS will have reached Black Hill in Central Scotland — the furthest transmitter to carry stereo tv sound — in time for test transmissions to commence in the summer of 1991.

Main stations

In order to radiate Nicam stereo sound from a main tv transmitting station, the following modifications would be needed:

- The provision of a suitable path to carry the Nicam signal through the transmitter drive system
- The provision of a high power amplifier to take the drive signal and boost it to the required level
- The provision of a combining system for the vision, mono FM sound and Nicam stereo signals
- Provision of a monitoring system for the additional service.

The cost of implementing these modifications at existing stations would be very high, so it was decided that only stations which had been (or were in the process of being) re-engineered would carry the new stereo service.

At sites about to be re-engineered, the specification was modified and contractors were asked to submit tenders for transmitter systems which were fully stereo-equipped. The new transmitters at Belmont, Sandy Heath and Mendip have already been installed to this specification.

At sites already re-engineered, the following modifications were specified:

1) The Nicam-modulated carrier would be fed from the TIE (transmitter input equipment) bay to the transmitter drive at 6.552 MHz.

Sound-in-Syncs

Television sound has been distributed internally within the BBC since 1968 using mono Sound-in-Syncs (SIS). This is essentially a time-division-multiplex system in which an audio signal is digitally encoded and inserted into the line-synchronising period of the television waveform. At transmitter sites, the audio signal is retrieved from the composite SIS signal and transmitted using the normal frequency-modulated sound carrier.

The SIS system samples the audio signal at a frequency equal to twice the video line frequency (ie, 2x15,625 = 31.25kHz) and each sample is converted — without digital compression — into a 10-bit binary code. Two samples are interleaved to form a 20-bit word, a marker pulse is added (making 21 bits total) and the complete message inserted into the following line-synchronising pulse at a peak-peak amplitude of 0.7V.

The individual pulses are shaped into sine-squared form with a half-amplitude duration of 182ns, and spacing of 182ns. During the field-blanking interval, alternate equalising pulses are widened to accommodate the digital SIS signal and, at the decoder, the sync pulses are blanked and a standard regenerated sync signal gated in.

In order to achieve an acceptable noise performance, the SIS system utilises an analogue compander along with pre- and de-emphasis. The audio signal at the coder is pre-emphasised (CCITT Rec J-17) and then compressed along with a line-rate pilot tone. At the decoder, the pilot tone is extracted and used to control an expander to restore the dynamic range of the signal.

With the introduction of stereo sound for television, it became necessary to develop a dual-channel version of the Sound-in-Syncs system. The original dual-channel system (DCSIS) utilised a 676kbit/s datastream, based on the digital system which was developed for the distribution of Radio programmes (NICAM-3). Here, the audio signals are sampled at 32kHz and initially encoded to an accuracy of 14 bits/sample. Digital compression to 10 bits/sample is then employed, using the NICAM-3 near-instantaneous companding system.

The data is inserted into each line-synchronising pulse using a quaternary (four level) code and, since the data is non-synchronous with the television line frequency, a slightly higher gross data capacity of 687.5 kbit/s is necessary. Most lines contain a marker pulse followed by 22 quaternary symbols and justification is achieved by using a marker pulse with only 20 symbols, every fifth or sixth line. Like the mono SIS system, the symbol-rate within the sync pulse is 182ns.

Following the standardisation of NICAM 728 for stereo sound with television, the 676 kbit/s DCSIS system was further developed for compatibility reasons. The design of DCSIS-728 is similar to the original system but with an increase in the number of bits required in each line sync pulse. This necessitates the slightly higher symbol-rate of 167ms, allowing each sync pulse to accommodate a marker pulse followed by 24 quaternary symbols. Justification is achieved by sending only 22 symbols plus a marker every second or third line. The resulting instantaneous data-rate is 382 x line frequency, ie 5.96875 Mbit/s.

In the DCSIS decoder, the quaternary digits (sometimes referred to as 'quits') are sampled and corrections made to the sampling levels, in order to compensate for gain or loss in the transmission path. The 728kbit/s bitstream is regenerated and a check made on its frame structure to block any discontinuities or glitches. Audio decoding is performed by an integrated circuit developed for use in television receivers, while the digital oversampling filter and digital-to-analogue convertor uses ICs developed for compact disc players.

Colin Spicer
D&ED

Paul Eaton
TED

Here, it would be mixed with a local oscillator to give an i.f. signal at 32.348 MHz. This signal would be added to the existing sound i.f. signal (32.9 MHz), linearity pre-correction would be applied, and the combined sound i.f. signals would then be mixed up to the appropriate uhf channel and amplified to a level of around 1 Watt.

2) The existing sound klystron amplifier (normally set for saturated output power) would be retuned to a bandwidth of around 2MHz and the beam current increased to give more linear operation. The FM sound and Nicam signals could then be amplified together.

3) The two sound signals would be combined with the vision signal in the existing sound/vision combiner, after modifications as appropriate.

4) The existing drive monitoring system would be extended to cover the Nicam signal, and the transmitter metering and power indication circuits would be modified to take account of the extra carrier.

It was decided that Winter Hill would be equipped with new drives which are suitable for 'pulsed' operation — to increase the transmitter efficiency. This would give the added benefit of better processing for the Nicam signal. The main problem then was due to the lack of bandwidth in the sound/vision combiner; there was no room to add an additional resonator since the combining equipment was installed inside the transmitter.

It was established that the combiner had a 3dB slope across the bandwidth of the digital signal. There were two possible solutions:

a) Tune the resonator higher in frequency and with a flatter response

b) Apply an equal and opposite slope to the digital signal

The former solution would be a compromise and would affect the existing FM sound signal. The latter, on the other hand, would require an accurate network to be designed to provide the necessary amplitude correction, and it was not known how group delay distortion would manifest itself. Thus, it was decided to test both solutions. The combiners were modified at Sutton Coldfield whilst the slope corrector (provided by D&ED) was employed at Winter Hill. Subsequent measurements revealed that both systems work satisfactorily.

The drive system at Sutton Coldfield has an early-generation pre-corrector and work is still progressing to meet the specification for intermodulation products (IPs) at the transmitter output.

At the other chosen main stations, up-converters have been added. These convert the 6.552 MHz Nicam signal from the TIE up to the i.f. frequency (32.348 MHz) for injecting into the drive. Also, modifications to the control and monitoring systems have been carried out, without any major problems.

The efficiency of the sound klystrons at all these stations has been reduced from a typical 30% to around 13% — to give sufficient linearity for the dual sound carriers.

Relay stations

Relay stations use transposers which in most cases amplify the vision and sound signal together in a common amplifier. To accommodate the Nicam carrier, it has been necessary to address problems on transposers associated with a whole range of powers and from different manufacturers.

The introduction of the second sound carrier gives rise to additional IPs which can cause patterning on the received picture. The most significant IPs appear at V + 0.553 MHz and V + 5.447 MHz. In order to reduce these to an acceptable level, and to provide a margin for maintenance, some form of linearity corrector is required.

The majority of relay sites use BBC-designed transposers — either the 'Blue Streak' (EP16/501,2) or the 'Silver Streak' (TM4M/503). (These transposers together number some 680 units.) D&ED has designed a pre-corrector, for use with these transposers, which will be installed by maintenance staff during routine visits — concentrating on the relays within the areas served by the initial ten main stations.

Another linearity corrector has been developed by engineers at the Wenvoe transmitting station, for use with a German-made transposer which is also used in fairly large numbers.

An investigation is currently underway to establish maintenance limits for the stereo service. On some relay chains there can be as many as five stations in series — each contributing to degrade the signal.

George Pope, Newcastle

Fred Gelder (ATM Pontop Pike) at the stereo decoder on the TIE bay

Future work

The work described above is expected to continue for many years because main stations are currently re-engineered at the rate of only one a year.

It is not possible to foresee all the problems which may occur when the stereo service comes on air. However, experience gained with test transmissions from Crystal Palace and Wenvoe suggests that the problems will be minimal. We're all keeping our fingers tightly crossed!

Fred Lyons, Phil Osborne,
Paul Eaton and Ian Jefferson

PLANNING AND INSTALLATION DEPARTMENT, TELEVISION

P&ID Tel's involvement with Nicam covers two main areas:

1) The provision, with TED, of DCSIS equipment in the contribution and distribution chains.

2) The installation of the systems required to route stereo signals through regional centres, including the equipment needed to enable them to record and replay network programmes in stereo.

Dual-channel SIS

The routes by which television programmes get from an OB to the studio centre and from the Network Control Room to the transmitter are not constant or consistent. For example, OBs may contribute via satellite, radio links or a variety of land lines, while the network distribution chain has regional optouts which break the London feed.

Because of the multiplicity of routes available, it was fairly easy to set up field trials of the DCSIS equipment on the contribution network. These tests — involving staff from D&ED, NCA, Tel OBs, Tel Network and Technical Investigations & Evaluations (TIE) — showed a number of problems, both in the DCSIS equipment and in the surrounding systems. The main lesson we learned was that if you code the stereo sound onto a 'grotty' video signal, or at a point which is not the same as where the insertion test signal (ITS) is inserted, then the result may be undecodable.

P&ID Tel set up a complete opt-out chain at Woodlands, using a small Pro-bel router as the SB matrix/opt-out switch, a Grass Valley Master 21 mixer, (which is the basis of the new regional presentation desks), together with all the usual infrastructure of sync-pulse generators, synchronisers, proc amps, equalisers and ITS generators.

The output of this setup was modulated along with Nicam sound onto the Woodlands rf ring main — to be received on both domestic and professional equipment. This was as close as we could get to hijacking the Crystal Palace transmitter!

There were a number of problems with the system, mainly centred on the way in which the DCSIS decoder responded to cuts in the vision bearer. These were similar to the effects being reported by OBs and so the heart of the opt-out chain was retained to enable these effects to be investigated.

The Varian DCSIS equipment at that time did not have a reframer and, although the manufacturer had agreed to design one, we were certain that there was something more fundamentally wrong in the way the bitstream was recovered from the DCSIS. After investigation and demonstrations to TED, D&ED, TIE and Varian, the dynamics of the bitstream regenerator were changed.

The requirements for the reframer were easily defined:

1) It should maintain the Nicam sequence from the transmitters at all times — so that there is no muting in domestic receivers — albeit at the penalty of a delay of up to 32ms in the audio.

2) It should introduce a minimum delay of only 2ms on the contribution network (where reframing should not be needed and several codecs may be cascaded).

Adding the reframers has caused late delivery of satisfactory DCSIS equipment. However, at the time of writing (14th June), the DCSIS networks to all regions, except Leeds, are complete for both distribution and contribution. By the end of June, all studio centres should be passing DCSIS.

Peter Weitzel

Regional Studio Conversions

P&ID Tel has additionally been responsible for converting regional centres to stereo operation. This work features a number of new equipment designs, manufactured externally to P&ID Tel specifications.

Some regional studios were easy to convert to stereo — Southampton's new RBC and Plymouth, for example, which were specified as stereo. However, others — such as those in the national regions and at Manchester — are predominantly mono and are not yet old enough to require replacement on grounds of unreliability. Nevertheless, their inability to opt in and out of network locally, without loss of the stereo image, was unacceptable.

A compromise was therefore devised whereby the mono studio output would be split to give a 'pseudo stereo' signal which could be mixed with the true stereo network. A specification was prepared for a unit which would perform this operation, together with monitoring and line-up tone insertion. Known as a ***network combiner***, it has been designed and built to P&ID Tel's specification by Glensound Electronics.

Regional VT areas have also required conversion to enable stereo network programmes to be recorded and replayed. This work has ranged from the very easily accomplished changes to Pebble Mill (which was built as a stereo system, but not quite the same as was finally decided), to the almost impossible modifications required on the simpler mono installations at island sites such as Leeds and Norwich.

An additional requirement in VT has been the ability to record a dual-channel mono signal onto one of the two audio tracks and to replay it into a stereo environment. This has been accomplished by installing switchable stereo/mono and mono/stereo converters (SMS units) in the programme chain of each and every network videotape machine. An SMS card has been manufactured by Audio and Design — about 110 of these cards have been installed in regional VT areas and a further 105 in central areas at regional sites.

In the Central Technical Areas (CTAs), all regions have required precious space to be found for DCSIS equipment, stereo tone distribution facilities and the aforementioned SMS units. Also, the local router has invariably needed a second audio level to be fitted.

For CTA monitoring purposes, a professional (balanced-output) Nicam off-air receiver has been designed by Arcam, of Cambridge, based on their domestic Delta 150 receiver.

Fortunately, the replacement of the regional presentation desk was brought forward to tie in with the stereo conversion programme. The new stereo desks are based on Grass Valley Master 21 mixer electronics, with the control system and surface supplied by Plasmec.

Nigel Thompson, Terry Lindfield and Peter Weitzel

NETWORK TELEVISION

When the Nicam service begins on the 31st of August, it will be over five years since transmissions actually began. Crystal Palace has been carrying an experimental service which started on the 18th of July, 1986, and since then about three thousand programmes have been made and transmitted.

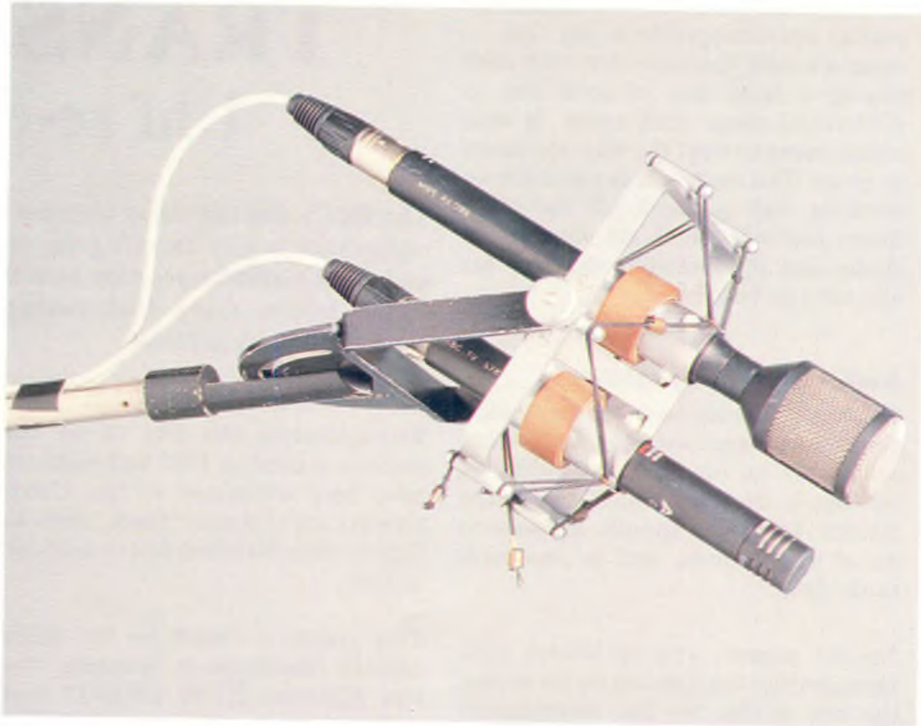
Frustrating as it has been for producers and sound staff to have the audience restricted in this way, it has nevertheless been extremely valuable to have this long learning period — valuable in two ways:

1) It has allowed sound staff in particular to be bold and experimental and to make their mistakes in relative privacy, but knowing all the time that the programme was actually going to be transmitted. Whilst it has been important that the stereo should preferably make sense, it has been vital that the compatible mono was not impaired.

2) The availability of stereo programmes and the pressure from

operators to get them on the air has exercised the fledgling system which one day would be responsible for putting two entire networks out in stereo. I hope it will offend no-one when I say that stereo line-ups, at one time mysterious and difficult (what level should this tone be at?) are now handled smoothly and quickly throughout communications, central areas and post production's recording areas.

Every conceivable kind of programme has been made with stereo sound. Many people ask why this or that programme is in stereo — what does it gain? Surely stereo should be reserved for those programmes which can obviously be enhanced? The answer we give is that any programme can be improved by stereo. It is simply better, more natural. When colour television was just beginning, the same sort of voices queried 'talking heads' in colour. Why waste colour on the news? I don't suppose those questions would even be asked today.



BBC Television

Double microphone mount carrying M-S mics as used on booms

So why the fuss? Surely stereo radio has shown the way — the techniques are all known. As for stereo with pictures, hasn't the cinema been doing it for years? Well, yes and no. Radio has one enormous advantage when arranging microphones for pick-up of sound, both in mono and more particularly in stereo. By and large, the microphones stay put and the performers come to them. In stereo, they may move around in a way calculated to produce the desired stereo image — it can be anything you like.

Unfortunately, in the picture business, someone else gets first crack at the images and the sound must support and enhance but never argue. Now, the grammar of television includes some very effective but tricky visual devices — rapid cutting between parts of a scene, wide shots to close-ups, and full 360° 'four wall' shooting. Even the complete 'reverse cut' may be used for effect. So how does the cinema cope with these problems?

The cinema copes, by and large, by not getting into these difficulties. The cinema doesn't do stereo. It's a fact of life that most cinemas are too large to make conventional stereo work, and certainly the majority of the audience could not possibly be in the right place to perceive positional stereo. Dialogue recorded in mono stays firmly in the centre, avoiding conflict with the pictures, whilst music and effects are spread around in a larger-than-life sort of way. Played at the kind of level you couldn't possibly allow at home, it makes for very effective entertainment.

Television viewing, by contrast, is a much more intimate experience. Small groups of people sit in a room of modest proportions and see the pictures on a small screen. They can, and usually will, be in a position to appreciate sound images in a continuous array between the loudspeakers and, because of the near-field position they occupy with respect to the loudspeakers, will be in a position to observe the local acoustic in which dialogue takes place.

Real stereo can therefore be appreciated.

Microphone configuration

It was a bold idea to put a stereo microphone pair in a boom, when it was first attempted some years ago during a live studio opera; but the movement was gentle, the scenes well rehearsed and the whole event recorded multi-track for later mix-down. Its considerable success encouraged Sound Supervisors to experiment on other styles of programme — anything, in fact, in which booms are used.

The mic configuration chosen is M-S and not A-B. This means that, instead of the conventional left and right microphones mounted in a near-coincident position, a central or 'M' (mono) forward-facing microphone is mounted vertically above or below a figure-of-eight microphone with the two pick-up lobes looking left and right. It is a feature of these microphones that the outputs of the two sides are in opposite phase; simply summing the M and S microphone outputs twice — with the S signal in 0° phase in one case and 180° in the other — produces left and right looking pick-up. There are several advantages to this apparently cumbersome method of achieving what you could have got from A-B microphones in the first place:

1) You can choose your 'M' microphone to suit the circumstances. Cardioid, hypercardioid and short rifles are most popular, the short rifles being especially useful on location.

2) The M-S technique guarantees a compatible mono signal, since it came from one microphone in the first place. The main axis of one microphone is usually better than the sum of the side lobes of two.

3) When recording for later post production, the signal can also be recorded in the M-S format. This may make life much more straightforward for the videotape editor, who will find that minor discrepancies between takes — when edited together — produce only small changes in image width (generally difficult to observe) rather than the much more obvious sideways twitches of incorrect A-B matching. The M-S signals are commonly carried through to Sypher (audio post-production) where the immediate control of image width is valuable.

Of course the M-S and A-B signals are readily interchangeable at any time — using a simple matrix — but with each change a small risk of error due to differential phase shift exists. It thus makes sense to start the way you mean to go on. This technique is particular to working with pictures; all the other stereo methods which are common in Radio and the recording industry are also used in Television.

Audio-visual compatibility

So what of the old chestnuts about small pictures and large sound images? What do you do on reverse cuts? Surely all on-screen dialogue must be in the centre? There are specific answers to all of these points, and in particular to the first.

No-one expects you to believe that, because there is a close-up on the screen, the rest of the cast has disappeared! Thus, the sound image can continue to portray those parts of the scene not at the moment in vision. Equally, stereo pick-up of two people speaking close together is not the same as mono; there will be a small but valuable difference in image position but, more importantly, the local acoustic surrounding them and the many natural small sounds of movement will have a correct sense of space and perspective. It simply feels more solid, more real.

But the overriding rule, the answer to all of the vision-versus-stereo image questions is this; if the sound and pictures disagree, then the sound is wrong.

We are still discovering what makes good television stereo. Music is obvious enough, as are sound effects in science fiction and the like. However, the real surprise stars are people — especially crowds of them. Sports events come alive when the full wrap-around effect of the spectator is added, and the partisan groups can be heard in their relative positions. The crack of a golf club on the ball might ricochet around the trees before a small group of appreciative spectators applauds it on its way ... the cacophonous interior of a swimming pool could completely envelope the viewer at home ...

It's really all about greater involvement — and we're sure the viewers will agree.

Larry Goodson
H Tel Sound

TRANSMISSION
Uhf re-engineering

The BBC's uhf television transmitter network opened in the 1960s and the equipment is now reaching the end of its useful life. Here, Ian Jefferson and Alan Griffiths describe how the main stations are being re-engineered while, below, Gary Mainwaring outlines the 200W relay transmitter replacement programme.

MAIN STATIONS

Re-engineering the fifty or so main stations started in 1985 and eight sites have been completed so far. Current projects are at Sandy Heath, Divis and Durris, with Waltham due to start early in 1992.

This article is based on the project recently completed at Belmont, where two Marconi 25kW UHF/77 transmitters were replaced with four Varian-TVT parallel-operated pulsed 15kW transmitters.

Containerised transmitters

Clearly the service must be maintained during re-engineering and this is achieved using 'portable' containerised tetrode transmitters (similar in idea to the FM containers described in the previous issue of ***Eng Inf***). In the case of Belmont, separate 20kW and 10kW uhf containers were positioned on site in late 1988, having carried the service at Pontop Pike during re-engineering at that station. These operate in a 20kW/10kW passive-reserve configuration.

Each container houses a Rohde & Schwarz low-power drive transmitter, intermediate power amplifiers (IPAs) and three valve cavities — two for vision and one for sound. The 20kW transmitter is water cooled while the 10kW version is air cooled. The drive is fed with baseband video and audio signals — derived from the station's existing transmitter input equipment (TIE) — and produces an IF-modulated vision signal at 38.9MHz and a sound signal at 32.9MHz. These are then mixed with a local oscillator, derived from an 'Adret' synthesiser. The resultant uhf carriers are amplified to around 1W and fed to the solid-state IPAs.

The main amplifiers are coaxial cavities equipped with tetrodes having approximately 16dB gain. Thus the vision driver cavity requires 12W from the IPA to produce the 500W which is needed to drive the output stage to the final peak-sync output power of 20kW, in the case of the main transmitter. Typical operating conditions at average picture level for the 20kW output stage are 6.6kV and 3.8amps anode current. Although this is a high efficiency, little linearity pre-correction is required.

The sound chain has no driver cavity and the IPA output is fed directly to the output stage at a level of around 50W, thereby producing a final transmitter power of 2kW. The vision-to-sound power ratio is therefore 10:1, ie 10dB.

The reserve 10kW transmitter operates similarly and each container has its own sound/vision combining unit. Neither is capable of carrying Nicam digital stereo sound, without modification.

The 20kW container has a high-power r.f. switch under the control of an automatic changeover system. Thus, if the 20kW system fails, the 10kW containerised transmitter is brought into service.

The containers were set up at Belmont during the autumn of 1989, cleaned and overhauled, and retuned to channel 22 (Vision = 479.25MHz, Sound = 485.25MHz). This involved changing the anode primary sliders, the grid tuning and matching rods, the decoupling capacitors and the output elbows, before the cavities would operate correctly. Much of this information could be found in the handbooks but there were times when a knowledge of German was required. At one stage it became necessary to dismantle a cavity from the container being prepared for use at Sandy Heath to see how it was different from the one at Belmont!

On-site preparations

Contractors provided temporary electrical wiring to maintain the existing services and to provide lighting and power in areas where work was being carried out. Apertures were formed in the walls for the new transmitters, the floor was refurbished, and a completely new electrical installation was provided.

The low voltage switchboard was overhauled and brought up to current standards, and the station's automatic voltage regulator controls were replaced with modern units to give the 2% regulation required for the new transmitters.

Early in March 1990, the cooling plant and new BBC2 transmitters were installed by the manufacturer. Alignment and commissioning took place over the following two months.

System outline

The new transmitter system comprises dual IF-modulated drives, two 15kW pulsed klystron amplifiers, sound/vision combining units, and a feeder switching frame for each service.

Although there are completely separate drives for each transmitter of the parallel pair, the outputs of some modules are shared: the mono sound (S1) modulator, Nicam sound (S2) upconvertor, vision i.f. oscillator and master oscillator. One set of these is used to feed both pairs as frequencies need to be identical.

The use of individual drives allows separate pre-correction and gain adjustment to be applied to each amplifier as required, and also prevents loss of service from a single drive fault. A monitoring system operates on the modules common to both drives and, in the event of failure, the equivalent module in the other drive will be automatically selected. As separate sound and vision amplification is performed throughout the transmitter, their drive chains are largely independent.

Vision drive

The input impedance of the vision drive is 75 ohms and video is fed from the TIE at 1 Volt (see diagram). It first passes to the video processor which separates the picture information from the sync pulses (these are used for timing purposes and to trigger the klystron pulsing operation).

The resulting video has no sync pulses and is applied to the modulator and pre-correction units. Phase corrections are applied to the vision i.f. signal in accordance with picture content, and the modulator also provides VSB (vestigial sideband) filtering using a surface acoustic wave (SAW) filter. From this point, signals are at i.f. frequency (38.9MHz) and generally at a level of 0dBm.

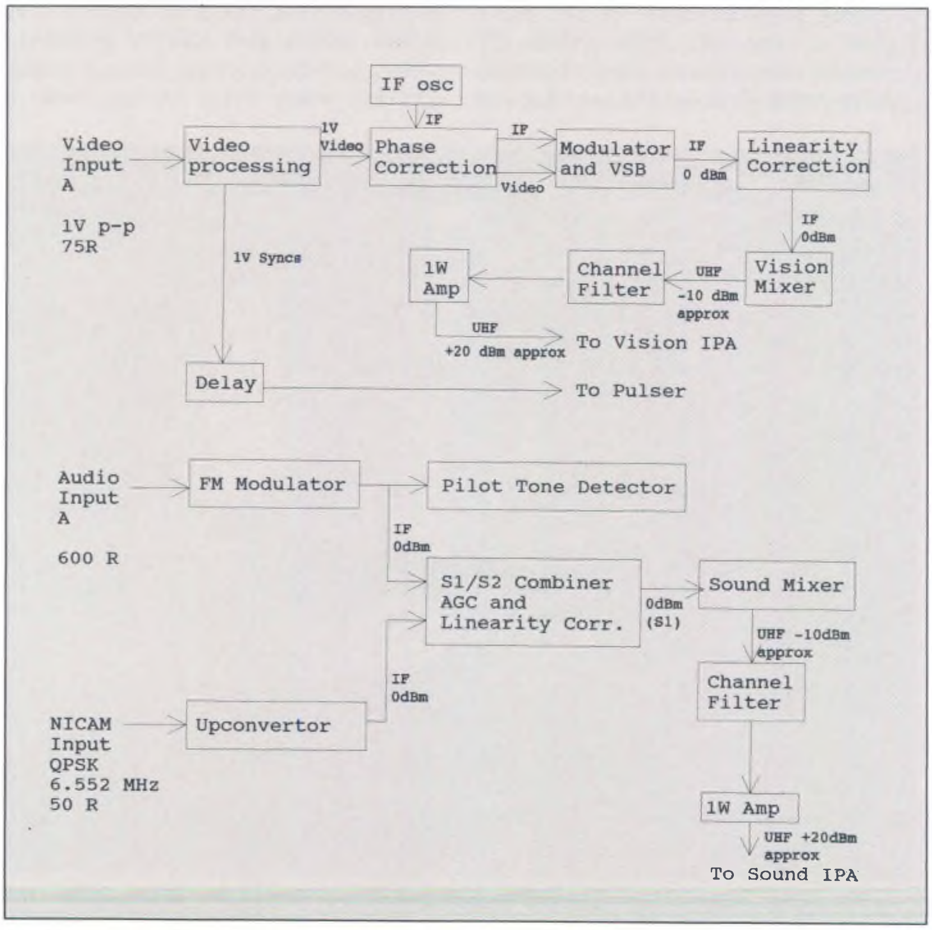
Group delay and linearity pre-correction are applied, followed by sync phase-correction which is necessary to overcome the large phase changes occurring in the klystron as it is pulsed. Finally the vision i.f. signal is mixed to the uhf carrier frequency, filtered and amplified before being presented to the intermediate power amplifier. An automatic gain control (AGC) signal is derived from the power level at the input to the klystron, and is fed back to the linearity corrector to stabilise the drive level. There is no AGC around the klystron itself and so the peak-sync power is dependent upon the absolute level of the EHT supply (14kV at Belmont).

Sync pulses derived from the video processor are taken via an optical fibre interface to the 'pulser' — an FET switch which applies a bias signal to the beam-control electrode of the klystron, giving a pulsed-back beam current of 1.6 amps in the case of Belmont. The rise-time and amplitude of the pulses can be adjusted to give correct sync shape, although the peak-sync power level is adjusted by changing the modulating anode bias for saturated output. The output sync pulses are therefore generated in the klystron itself and are only related to the video by their timings.

Sound Drive

Mono audio is fed to the sound drive on a conventional 600 ohm balanced pair where it enters the modulator directly. Modulation is FM with a deviation of 42.5kHz for +8dB input, and 50 μS pre-emphasis. A 19kHz pilot-tone detector is provided for monitoring. Stereo sound is modulated externally to the drive and enters as a 6.552MHz QPSK carrier. This signal is then upconverted to i.f. (32.348MHz) and combined with S1 in the linearity corrector/AGC module. The S1/S2 power ratio is set here to 10dB. Mixing to final frequency is similar to the vision chain.

The sound klystron is fed via a small solid-state amplifier and operates with 3dB headroom (0.6 amps beam current) to give sufficient linearity to handle the combined S1/S2 signal. Any intermodulation products (IPs) in the vision passband would manifest themselves as a high frequency luminance signal or a low frequency chrominance signal, depending upon the receiver.



Block diagram of the new uhf transmitter system

Klystron beam-current pulsing

Conventional klystron amplifiers are inefficient since they operate with a large standing beam current and, as negative modulation is used, the video sync pulses correspond to maximum carrier power. The standing beam current must be sufficient to give enough headroom to produce the required peak-sync power, but this is in excess of that required for the picture period.

Since sync pulses occupy only 4.7 μS of the line time (64μS), a system was devised which reduces the standing beam current during the picture period to a level sufficient to give an output power around 0.5dB greater than black level (58% of peak-sync power). It is not possible to operate with less than this 0.5dB headroom, since it would be impossible to correct for the non-linearity of the klystron so produced. Using this technique, peak-sync efficiencies (defined as the ratio of peak-sync power to dc input power) of 60-65% can be achieved for average picture levels, compared with 30-40% for an unpulsed amplifier.

There is a penalty to pay in the guise of increased non-linearity and therefore complex pre-correction of the drive signal is required. Sync pulses are generated directly in the klystron, which is driven with black-level power and has increased gain during the sync period as the beam-limiting pulses are removed. However, large phase changes are produced which have to be corrected by the sync-phase corrector in the drive. This leads to characteristic pulsed-transmitter sync overshoots.

Klystron cooling

Despite the increased efficiency provided by the pulsing technique, there is still around 40kW of heat per service to remove from the collectors of the two pairs of vision and sound klystrons.

Each klystron is fitted with a boiler containing about ten litres of de-ionised water and this is allowed to boil at atmospheric pressure, taking energy away from the collector. This is a superior method to cooling by flowing water, since the latent heat of vaporisation of water is much greater than its specific heat capacity, so a smaller amount of water is required to remove the heat.

The steam produced by the boilers is condensed in a forced-air-cooled heat exchanger and the condensate flows back into the boilers under gravity. There are no pumps on the klystron cooling circuit, but there is a test load circuit which also utilises de-ionised water, and this does use a single pump. The hot water from the test loads is cooled in a heat exchanger mounted alongside the main unit.

In addition, the steam flows through an auxiliary shell-and-tube heat exchanger, which forms the primary circuit for the station central heating system. Thus the building is heated utilising waste transmitter heat at low cost.

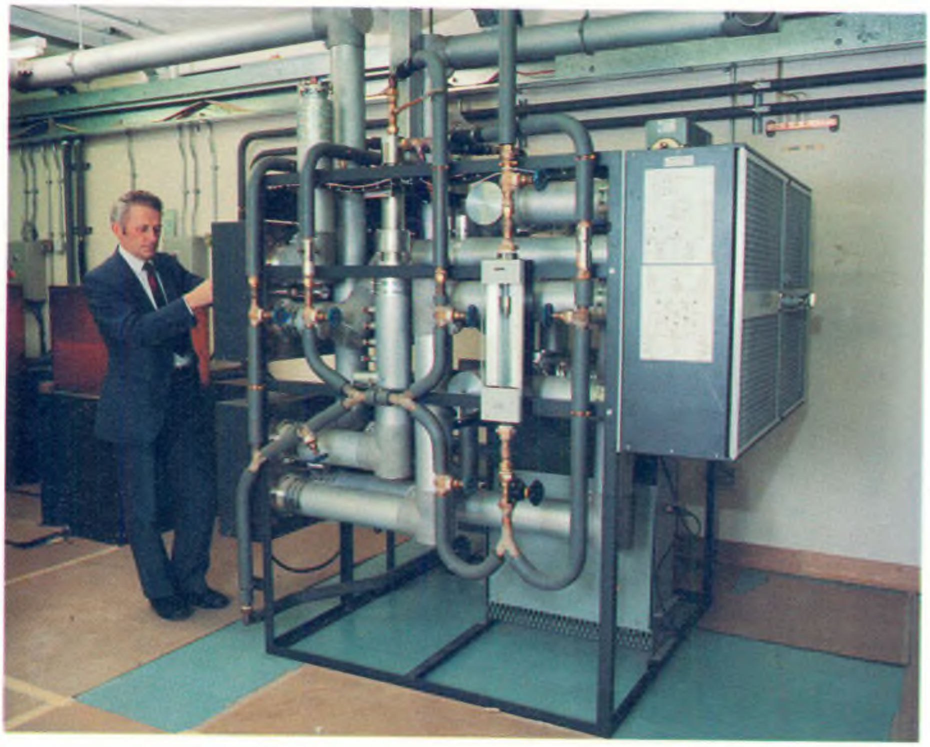
Output stages

The high power r.f. signals from the sound and vision klystrons are combined in a ring composed of 3dB couplers and sound resonators. The ring has a low loss (typically less than 0.1dB) and wideband response to the vision signal, and a narrow band response to the two sound signals, with a loss of around 0.5dB.

The combined signal is fed to the feeder switching unit (FSU) where it is diplexed with the signal from the other transmitter of the parallel pair, and then split to feed the two halves of the transmitting antenna. The FSU has high-power switches and U-links which enable various test or operating conditions to be implemented (eg, one transmitter into test load, the other to service).

The new BBC2 transmitter at Belmont went into service in July 1990 and the old transmitter could then be removed — to leave room for the installation of the new BBC1 transmitter. Building and electrical work was completed by November 1990 and the new BBC1 transmitter was commissioned and put into service at the beginning of February 1991.

Ian Jefferson and Alan Griffiths
Transmitter Section
TED



T.E.D.

Eric Mitchell operating the high power uhf "feeder switching unit" at Belmont during commissioning. The two large aluminium pipes leaving from the top of the unit are the 50 ohm output feeders, each carrying 15 kW.

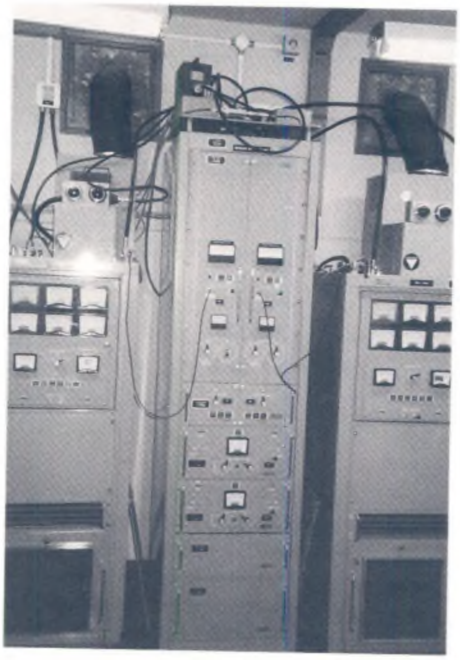
200 WATT RELAYS

The uhf network includes forty-nine 200W relay stations. The sites are as diverse as Fenham which serves part of Newcastle, and Rothesay serving areas of the Isle of Bute. In the context of uhf television transmitters, these relays rank as medium power — between a main station such as Crystal Palace (serving 13 million people with a transmitter power of 80 kW) and low power stations such as Llanfach (serving 300 people with a power of 0.5 W).

The stations date typically from the early 1970s and consist of separate areas for the BBC and NTL (formerly IBA) equipment. The combiner and antenna facilities are however shared. The original transmitting equipment consisted of Plessey 200W transposers, the final stage of amplification being carried out by a travelling wave tube (TWT). Subsequently, 40W solid-state reserve amplifiers were provided.

The primary objectives of the re-engineering are as follows:

- higher efficiency — typically £4,000 annual saving on electricity costs per station
- elimination of the routine replacement of TWTs, also giving an annual saving of around £4,000 per station
- the opportunity to update power wiring and ventilation
- reduction of maintenance visits



T.E.D.

BBC1 and BBC2 TWT transmitters at Barskeoch Hill (before re-engineering)

T.E.D.

BBC1 and BBC2 solid-state transmitters at Newton (after re-engineering)

Thomson-LGT transposers

When writing the specification for the replacement equipment, solid-state technology had advanced to the stage where fully-transistorised transmitters were becoming an attractive proposition at 200W. TED further took the view that the final vision amplifier stages should operate in class AB, in the interests of efficiency.

Equipment manufactured by Thomson-LGT was selected. A single bay contains the complete transposer for one service. While this in itself is not a great reduction in size compared to the existing equipment, bulky ancillary equipment such as automatic voltage regulators are not required. The overall saving in space permits the addition of national FM services at a number of these tv sites.

Each bay contains two low power transposers configured as main and reserve. The amplification stages are in multiple-transistor configurations such that the service will be maintained at reduced power when a transistor fails. Output power levels are monitored, and fault conditions are automatically reported to the local Monitoring and Information Centre (MIC).

Sound and vision are split and follow separate i.f. and amplification chains through the equipment, thereby greatly reducing problems of intermodulation between sound and vision carriers.

Composite Contract

The first twenty-five sites were re-engineered by TED staff. Transmitter Section engineers and installation technicians worked with power contractors organised by Power Systems Section and builders organised by ACED.

The final twenty-four sites were put out to tender with the object of signing a composite contract which would embrace all aspects of the re-engineering. The successful tender was submitted by Rohde & Schwarz Services Ltd.

The composite contract covers the following main areas:-

- Transporting to site and setting up a caravan equipped with temporary 50W transposers which maintain the services during re-engineering
- The 'strip-out' — removal and disposal of redundant equipment
- Building work and decorating of the BBC-exclusive area, and the common areas on BBC-landlord sites.
- Power and ventilation work.
- Transporting to site and setting up the Thomson-LGT transposer.

The contract started in early September 1990 and is due to run for over two years. To date, the work is running ahead of schedule.

Gary Mainwaring
Transmitter Section
TED

D.E. MOVES TO WHITE CITY

Senior Engineering Management moved to new accommodation at White City on 11th August. The following new addresses at White City should be noted:

Bill Dennay (D.E.)	Room 2114	Ext 25000
Bernard Buist (C.A. Eng)	Room 2118	Ext 25150
Bert Gallon (C.E.T. & P.S.)	Room 2102	Ext 24088
Phil Laven (C.E.R. & D.)	Room 2124	Ext 25442
Charlie Sandbank (Asst. to D.E.)	Room 2672	Ext 25353

Also moving to White City that weekend were: Engineering Finance, Energy Management Section, Engineering Safety and the Telecom Section of Transmission.

NETWORK TELEVISION

Remote control of London SWC

Since the early days of Television, there has been a Switching Centre (SWC) at Broadcasting House in London. Keith Sudel describes how the facility is now remotely-controlled from Television Centre.

Originally, SWC switched the British Telecom — formerly Post Office — lines to Alexandra Palace and later to Lime Grove Studios and Television Centre. Video circuits were checked and equalised at the Switching Centre before being handed over to Central Apparatus Room (CAR) at TC for Network Television, or Spur Central Apparatus Room (SCAR) in the case of News & Current Affairs.

The circuits were either plugged by hand at SWC or, for regularly used routes, switched by a Pro-bel video matrix. It was possible to remotely control some of these circuits from TC but, about two years ago, it was decided to extend this remote control facility to cover all the functions of SWC. The alternative plan of rerouteing all video circuits direct to TC was considered too expensive.

The existing Pro-bel matrix has now been expanded to cover the previously manual functions. However, additional matrices were required to provide: video feeds to the London offices of various foreign and commercial broadcasters, and facilities houses; as well as feeds to Radio at LBH and Bush House. The Radio matrices are controlled from the Engineering Operations Centre at Broadcasting House.

A number of video circuits which terminated at SWC were capable of being manually reversed in signal direction. These have now been equipped with relays and a system of remote control which works over data highways used by the Pro-bel control system. This was an economical alternative to having an entirely separate system using an additional control circuit.

The equalising equipment at SWC has been transferred to CAR and SCAR. Additionally, new equipment has been installed in the OB receiving points at Swains Lane and Crystal Palace, to enable OB engineers to equalise the incoming circuits for London or Regional contributions — work formerly done at SWC.

A line-up area has been formed in CAR — away from the main desk — for checking and equalising video circuits. Equipment includes the bode equalisers transferred from SWC, and a Tektronix 1781R oscilloscope with matrix selection. A Tektronix VM700A waveform monitor and dot matrix printer are also available for more accurate measurements on incoming video circuits. These measurements and diagrams of the video waveforms can be recorded on the printer for future reference.

LOCO

The London Coaxial Circuits (LOCO) also terminate in SWC. These are permanent circuits from places of interest in London — such as Buckingham Palace and Downing Street — which are often used for OBs. These circuits require a separate control system to operate remote relay switches at various BT premises around London. Due to the long unequipped circuits involved, remotely-controlled Path Length Equalisers were required at SWC — controlled from CAR and SCAR. These have been designed and manufactured by Design and Equipment Department.

The installation work in Broadcasting House was supervised for Radio by Simon Isles Buck of Radio Projects, while the work in CAR, SCAR, SWC and at Swains Lane was overseen for Television by Neil Studley, Peter Horne and Joanna James of P&ID Tel.

Keith Sudul, Project Leader
Central Systems Group
P&ID Tel

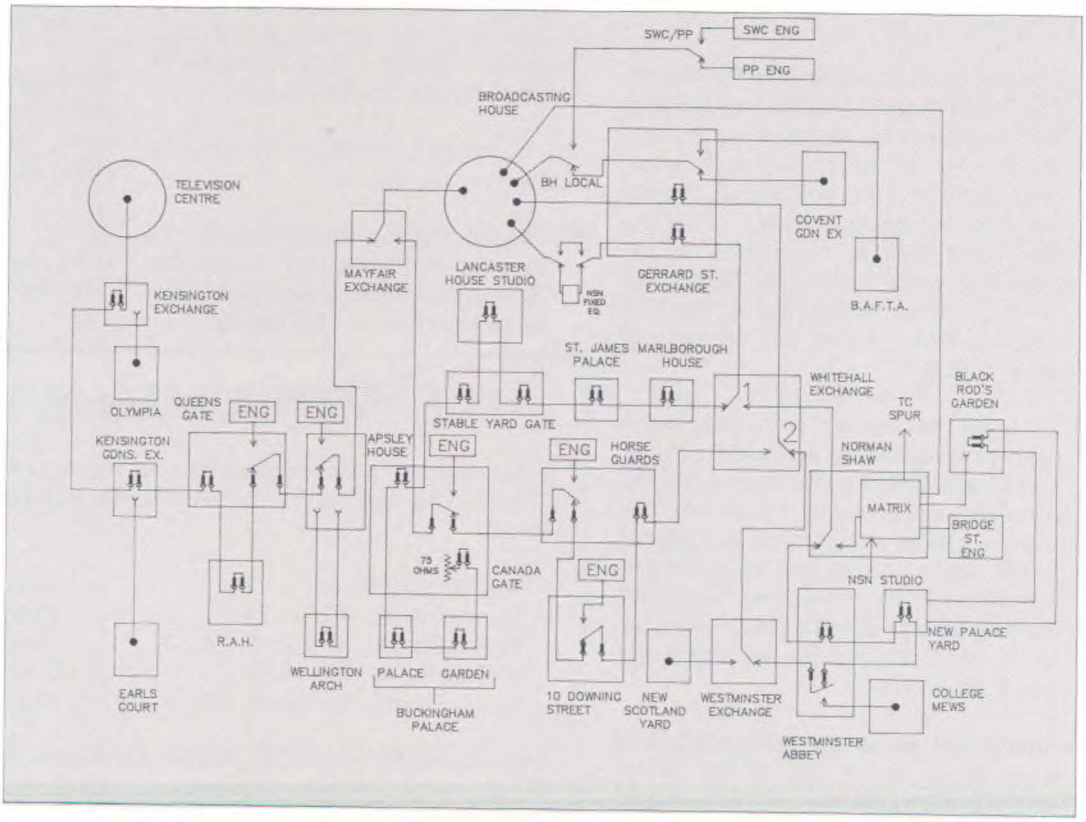


Diagram of LOCO showing the points of access

SOUTH & WEST
Plymouth's new TV facilities

Earlier this year, new television facilities at Plymouth were officially opened by Ronald Neil (M.D.R.B). They are described here by Gaeron Davies.

The project's main objective was the provision of reliable up-to-date production facilities, replacing an installation which dated back to the early seventies. Allied to this was the construction of a new block to house a newsroom, into which an electronic newsroom system could be installed. This block would also provide a restaurant, club facilities and conference rooms on its ground floor.

At the same time, the opportunity would be taken to introduce new BT facilities, a new network logo and Dual Channel Sound-in-Syncs equipment (with the future Nicam stereo service in mind).

Production facilities

Remotely-controlled Ikegami 355P lightweight CCD cameras have been provided in both the main and presentation studios — four normally allocated to the studio and one to presentation. All are equipped with autocue, a 7-inch viewfinder, a 14:1 lightweight standard zoom lens and comprehensive talkback facilities. The five cameras are mounted on Teal pedestals, enabling full remote control of pan, tilt, zoom and focus; one also has remote control of elevation.

Permanent wallboxes, connected via a Triax routeing panel, allow cameras to be used in other parts of the building. It is also possible to deploy them in a portable mode using Betacam SP recorder backs; a selection of tripods, waterproof covers, etc, is available for use on the road, or on site.

Studio lighting is on spring pantographs and up to ninety lamps can be used. A new design of Strand dimmer has been installed. These store individual lighting settings for up to four news presenters: the required setting can readily be called back by the presenter when in the 'self op' mode.

The **Production Control Room** has desk positions for up to six production personnel. Control panels for a Grass Valley 200-2/20-channel vision mixer and an Ampex ADO 100 digital video effects unit are arranged with sufficient flexibility to allow the director to operate both if required. Each position has comprehensive talkback and vision monitoring facilities.


Roy Melhuish, Plymouth

The Production Control Room

The heart of the **Sound Control Room** is a Calrec Compact 28-channel, 4-group stereo mixing desk. This area also has ¼-inch Studer tape machines, cassette desks, compact disc players and a selection of audio effects equipment.

The **Technical Control Room** is arranged to provided maximum visual contact with the other control rooms whilst minimising aural disturbances. There are two operational positions where staff can control production lighting, camera movements, camera exposure and balance. The lighting desk is a Rank Strand Gemini-2 and this controls the dimmers for the main studio, the presentation studio and the newsroom.

The control room complex is completed by a **Measurements and Apparatus Room**.

Newsroom

The large newsroom has been designed around a Basys electronic newsroom system which services not only regional television in Plymouth but also local radio in Devon, Cornwall and the Channel Islands. The Plymouth newsroom has around thirty terminals with up to ten in each of the radio stations.

Comprehensive monitoring facilities are provided in the newsroom. Most TV and radio services in the Plymouth area can be monitored along with many in-house functions. The audio is carried on a 24-channel ringmain with most listening carried out on headphones.

The vision system uses videoplex which enables a polyphoto of 16 sources to be displayed simultaneously. Key positions in the newsroom can then select any one of these sources to be displayed full frame.

At one end of the newsroom is an 'in-vision position' with basic production lighting and simple sound facilities for short news bulletins.

Other facilities

Other facilities were revamped using existing equipment. They include a graphics and design area — containing Paint Box, Slide File, Wallet, Caption and a Rostrum Camera — and a three machine vt suite with its own mixers and connections to the graphics area. Transmission and recording is possible from both this area and from a new dedicated transmission suite.

Accommodation changes tied in with these has allowed the functionality of the site to be enhanced. For example, the psc library is now adjacent to the edit suites and the graphics control next to the design office.

Coincident with this work, the psc format has been upgraded to BetacamSP. Thus, pictures are now leaving Plymouth with 1990s technology, having made the jump from the seventies in one go.

Gaeron Davies
Project Manager, Plymouth
P&ID Tel


Roy Melhuish, Plymouth

The Newsroom

ROYAL ALBERT HALL
BBC Control Room refurbished

BBC Radio's control room at the Royal Albert Hall in London has just been completely refurbished – in good time for the start of the Proms season in July. Mark Edgar and Nick Sharwood-Smith describe the updated facilities.

Over a hectic nine week period, the Proms bring more than two hundred hours of programmes to the radio listener. At the centre of much of this output lies the Albert Hall control room, which is situated at balcony level in the revered old building. Last refurbished in 1973, the area was badly in need of redecoration as well as a technical refit.


Mark Edgar, Radio Projects

The Calrec M series desk

Microphone circuits

There are eighty-eight microphone points situated inside the hall. Some of these are arranged around the balcony while the remainder are concealed under the stage. Each point is permanently wired to a four-way splitting amplifier, located either understage (for the stage points) or in the control room bays (for the balcony points).

Two isolated (transformer-balanced) feeds of every microphone are available to external contractors (eg PA or recording), which simplifies operations during complex broadcasts. The other two feeds (which are electronically balanced) are reserved for BBC use, either in the control room itself or via the OB truck interface at the hall's Door No 11.

In addition to these analogue lines, fibre optic circuits have been installed from Door 11 to both the understage mic amps and to the control room. These will cater for the use of the Digital Control Vehicle (DCV) and its associated stage boxes at this venue, as well as allowing for future expansion in the digital domain.

Ventilation and acoustics

In the control room, an inspection above the old ceiling level revealed a space of almost the same volume as the usable space below. This has now been put to excellent use by converting it into an area housing ventilation plant. This will improve the situation from last year when hotter summer evenings meant that the operators had to bear the noise of a window ventilation fan running at full speed, or have the broadcast equipment give up through heat exhaustion.

With the removal of the above-mentioned fan and the false ceiling, a real improvement to the room acoustics has been made possible. A solid woodwool slab ceiling has been built to provide isolation between the ventilation plant and the operational area. This, plus double-glazing and extensive acoustic treatment, have achieved a suitable environment for the balancing of serious music.

Main mixing desk

In the control room, a new Calrec M series desk has been installed. This has been supplied with thirty-two channels, eight of which are stereo. The desk has been configured to allow the control of echo send in parallel with the selected audio group. This is a feature from the old Calrec equipment which was strongly desired in this area but which does not regularly feature on modern desks.

The audio chain at the Albert Hall is unusual in that the main desk does not normally provide the main output from the hall, but instead creates a clean feed of the musical performance for the later addition of commentary. The use of three separate mixers for commentary means that the hall can simultaneously generate multiple outputs for other national and international broadcasters.

Commentary mixing system

In order to avoid sending the audio programme on a circuitous route to have the various feeds of commentary inserted, a remotely-controlled mixing system, provided by Glensound Electronics, has now been installed.

The hub of this system comprises three microprocessor-controlled VCA (voltage-controlled amplifier) mixer racks in the control room bays. These are linked via fibre optic cable to three mixer control surfaces, located in the commentary positions. Here, VCA amplifiers raise local microphone sources to line level before they are directly routed up to the control room equipment. The only locally-controlled audio signals are for monitoring purposes. The remote control is effected by a series of constantly-updated serial codes which are sent on the optical fibres, giving precise information on fader, equalisation and switch positions.

Digital programme link

A NICAM 676 digital link direct to Crystal Palace has been installed. It is now possible to have the programme coded by NICAM equipment in the Albert Hall control room and then routed up into a small bay at the very top of the dome of the hall. From there, the signal is modulated onto a 1.5GHz bearer and radiated from a directional antenna which has been mounted discretely above the dome, in a position from which there is a clear line-of-sight to Crystal Palace.

During the project, the building and ventilation work was co-ordinated by Bob Corn of Corn Tarrant Partnership. The technical installation was carried out by Elliott Brothers (Audio) Ltd. Being a listed building, alterations and rewiring had to be carried out with extreme care, paying close attention to the architectural detail in the hall.

Mark Edgar, Engineer
Nick Sharwood-Smith, Project Engineer
Radio Projects

NETWORK TELEVISION
185 kW UPS system

A 185 kW Uninterruptible Power Supply (UPS) system has been installed at TVC to protect Network output against supply problems.

Peter Barlow and Richard Barratt describe the background to the project and the subsequent plant installation.

At 2117 hours on Sunday 13th May, 1990, most of the Shepherds Bush area — which includes Television Centre and the nearby Hammersmith Hospital — experienced a loss of the public electricity supply for approximately 7½ hours.

This was due to the ingress of water into an 11kV cable which fed Woodlands, White City, Wormwood Scrubs and Hammersmith Hospital. However as the protection circuits at the Electricity Board's 66kV substation at Bulwer Street failed to operate — due to an incorrectly fitted resistor — it led to the tripping of the circuit breaker which feeds most of the area including Television Centre.

This incident was the culmination of several supply failures which have occurred over the previous few years. These can, in part, be attributed to the large number of developments taking place in the White City area, thereby placing additional demands on the Bulwer Street substation. It is unlikely that this situation will improve in the near future, although it is also highly unlikely that any interruption will last as long.

Backup Diesel

Until recently the transmission of BBC1 and BBC2 has been supported only by a 750kVA diesel alternator. This allows the restoration of the networks to a certain level. It also powers those building services which are necessary for transmission to be maintained, thereby preventing the requirement to vacate the building on the grounds of safety.

When a complete interruption to the electricity supply occurs, the diesel generator starts automatically but the switching of all loads to this supply is carried out manually. The Networks are restored in about a minute and a half, and recommence with appropriate apologies.

UPS requirements

Following the incident of last May, MDN Tel requested a re-appraisal of the protection arrangements against loss of the public electricity supply.

It was decided that it was no longer acceptable for there to be a break in TC's output and that the Network Controls should always be in full control. An Uninterruptible Power Supply (UPS) would be installed with the aim of "*maintaining the continuity of output on BBC1 and BBC2 network distributions during interruptions to the electricity supply to Television Centre, without necessarily maintaining the published schedule*".

In addition, a separate UPS would be supplied to protect the News operation to a similar level. This is due for commissioning in August 1991 together with an additional diesel backup to support essential News facilities in TVC Spur. Furthermore, the areas provided with diesel volts will be augmented so that, for example, power is still available to the PABX if such a long outage recurs.

In order to achieve the stated objective, the Network UPS has been sized at 185kW and feeds the Network Controls and Continuities, Central Apparatus Room (CAR), a limited number of vt machines for transmission purposes only, and the main rf link to Crystal Palace.

Live programmes from studios are not protected, although OBs will still be available during a power cut. The only studios which will be available are News Studios N1 and N2 (via the News UPS) and Presentation Studios A and B which can be fed direct from the diesel and will be available three or four minutes after the loss of incoming supply.

Installation

The UPS main plant, switchgear, batteries and charger equipment occupy a space of approximately 60m² and have a combined weight in excess of 12 tonnes. Because of its weight, the plant had to be installed in the basement of the Scenery Block. A dedicated plant room and separate battery room were constructed from part of an 11kV transformer room and an adjacent store. Being next to the transformer room provided easy access to the main building cable duct system. Furthermore, the transformer room ventilation plant was able to be modified to extract the additional 18kW of waste heat produced by the UPS.

The UPS equipment was supplied by a German company, Anton Piller.

Operation

The UPS itself can be operated from three different supplies; a normal and reserve mains supply, and the site stand-by diesel alternator set.

Referring to Fig 1, the motor generator set is normally powered by the rectifier and inverter, in parallel with the

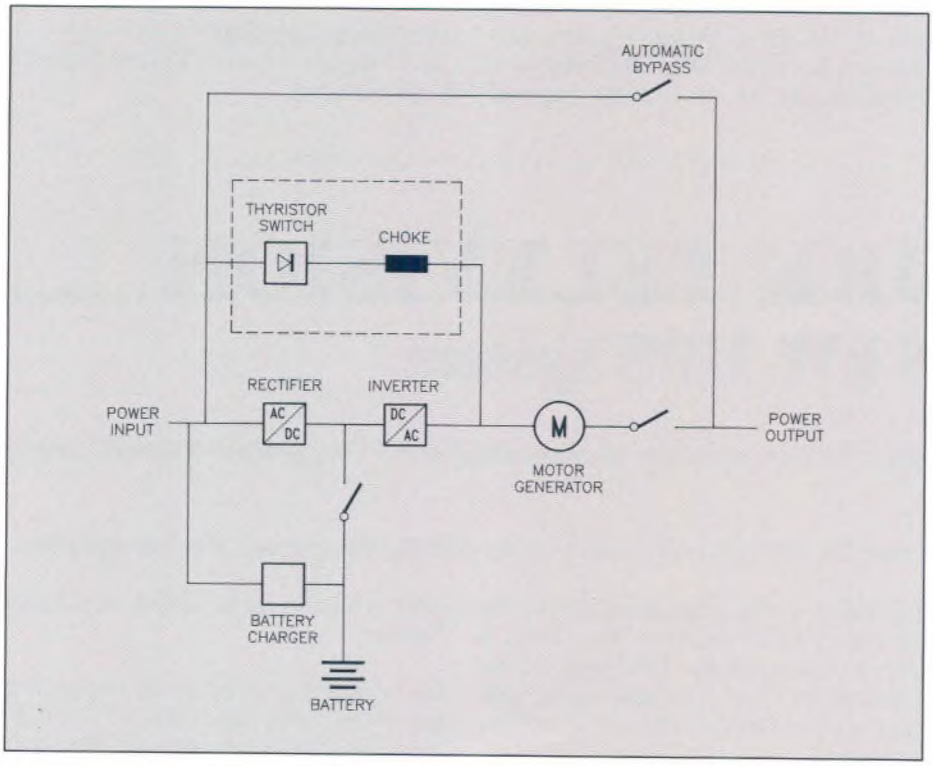


Fig. 1: the UPS system's block diagram

thyristor switch and choke. The addition of the latter improves the efficiency and reliability of the plant: the calculated MTBF (mean time between failures) is in excess of seventy years. Should a power failure occur, the motor generator set is supplied from the battery via the inverter. The 500V/1200A battery can power the UPS under mains failure conditions for up to 20 minutes.

When the UPS power input is restored from the standby diesel, the rectifier takes over from the battery and, after synchronising the UPS input and output, the thyristor switch closes. (Synchronism is achieved when the voltage, phase and frequency at the input match those at the output.) The UPS normally operates on line, that is with the motor generator set running, and with the input and output in synchronism. This allows the automatic bypass switch to close and maintain supplies should an internal fault occur.

For maintenance of the UPS, the auto-bypass switch is closed and then a manual key-interlocked external bypass switch is closed. (This external bypass switch is omitted from Fig 1 for clarity). Having transferred to manual bypass, the input, output and battery isolators are opened. However, due to the motor generator, voltages are still present in the equipment until the machine stops; it can take up to fifteen minutes to come to a complete standstill.

Output quality

In addition to providing an uninterrupted power output, the quality of the UPS output is very closely controlled to better than 1 volt and 0.5Hz for any load current up to the rated maximum. The load supported by the UPS comprises mainly electronic modules in equipment bays with either switched-mode or transformer-rectifier dc power supplies.

Characteristic of this type of non-linear load is the high level of harmonic currents produced as a result of the non-sinusoidal input current waveform. These harmonic currents cause distortion to the voltage waveform, which becomes flattened, and the absolute voltage level is thus depressed (Fig 2).

The degree of voltage distortion varies according to the impedence that the supply presents to its load. When supplied from the mains supply, distortion levels of up to 9% were measured at TC load centres — prior to the UPS installation. At the same load centres, distortion levels of up to 15% were measured when supplied by the standby diesel alternator set, which has a relatively high output impedence.

For the UPS, a target figure was therefore adopted such that the voltage distion at any load centre should be not more than 1% worse than the distortion when powered from the mains supply. In order to achieve this performance, the installed UPS is overrated by a factor of almost 2.

In-service testing

The system at Television Centre entered service in December 1990, since when there have been no mains failures and only one serious voltage dip. Thus, in order to maintain confidence in the UPS system, a regime of site testing has been adopted.

Once a month during normal broadcasting, the UPS is put to bypass (simulating a UPS fault). Once every three months, the system runs on battery for twenty minutes and is then selected to the standby diesel alternator set (simulating a mains failure). This second test is carried out at night when non-UPS-supported loads can also be switched to the diesel alternator supply.

Another UPS system entered service at Broadcasting House in late March. Also commissioned by TED's Power Systems Section and supplied by Anton Piller, as part of the 'Powerline' project, it offers similar facilities to the Network Television system but is rated at 400kW.

Richard Barratt, Project Engineer
Power Systems Section
Transmission Engineering Department

Peter Barlow
Senior Resource Planning Engineer
Network Television

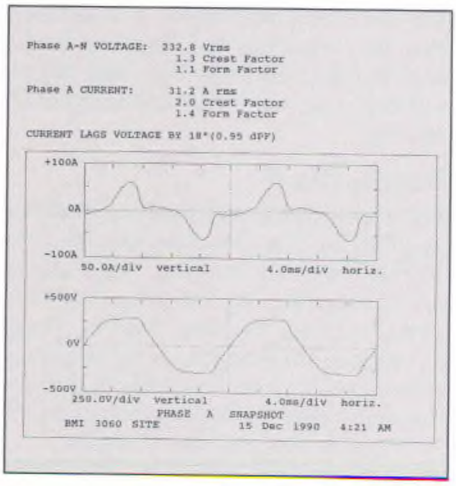


Fig. 2: current and voltage waveforms at a typical load centre

ENGINEERING RECRUITMENT

Transmission Direct Entry Engineers

In *Eng Inf* No 43, John Reymond introduced the new recruitment strategy pioneered by Engineering & Technical Operations Recruitment (Eng.T.O.R.), and its forthcoming application to the selection of Direct Entry Engineers for Transmission. The selection has now been completed successfully, as described here by Bob Forster.

One of the great advantages of the new procedure is that it enables candidates to be judged on their potential ability to do the job — rather than relying on their application form, the presentation of which may be highly dependent on many other factors unrelated to the job, eg social or cultural background, school and university attended, etc. The new method was used to consider all those on suitable courses who applied during the BBC's 1991 university and polytechnic recruitment tour.

All potentially qualified candidates who applied — expressing a preference for Transmission — were invited to an initial assessment. Candidates interested in joining other BBC engineering areas continued on the more traditional route of a preliminary interview followed by a selection board. As further objective job analyses are performed, it is expected that further groups of recruits will be selected using this strategy.

So, what of the potential Transmission engineers? The whole procedure to be followed was laid out clearly from the start. Information packs setting out examples of the assessments and providing a timetable for the whole selection procedure were sent out to candidates, who were then all invited to the initial written assessment. These were undertaken at many sites throughout the country — at colleges or our own regional centres — so that candidates did not have far to travel and their studies were minimally interrupted.

All the candidates also had a brief 'counselling session' with a Recruitment Officer to ensure a good understanding of the job and the selection process. This is purely an opportunity for information exchange and there is no element of selection or appraisal.

Initial assessment tests

The initial assessment tests explore the candidates' aptitude in several different areas, each of which have been determined by intensive research into the job of Transmission engineers. They are not tests of engineering knowledge, but of innate potential in the key areas identified by the job analysis. After careful design, the tests have been thoroughly validated on existing employees and target populations of students. This ensures that they are totally fair across gender, ethnic origin, disability and age, and accurately indicate which candidates have the capabilities to succeed as Transmission engineers.

Once all the candidates had been assessed, those with the highest overall score were invited to the final selection process. Candidates not invited to the final stage were contacted to explain that they were still eligible and were welcome to apply for vacancies in other BBC engineering areas; their test result is only relevant for the particular combination of attributes required by Transmission.

The initial assessment tests were carried out on approximately two hundred people and were designed to rank the applicants in order of potential suitability on the job-related attributes which were tested. The initial tests concentrated on candidates' key abilities; personality and other qualities which are more properly assessed in small groups or, individually, would be dealt with at the final assessment stage.

Final selection programme

The final selection programme covers a 24-hour period and, for convenience, is currently undertaken at Wood Norton although it could be carried out at any location offering suitable accommodation. Part of this time is spent providing information to candidates in order that they have a clearer idea of exactly what the job entails. This is achieved by a tour of the Sutton Coldfield transmitter, and also by an informal evening session when managers from Transmission (both Operations and Engineering) are present as well as Recruitment Officers. This aspect of the selection programme was particularly welcomed by the candidates, and spoken of enthusiastically in the feedback they provided.

The final assessments measure a further range of the applicants' abilities — both latent and developed — and fall into several different categories as follows:

1. A written report on the Sutton Coldfield tour from which we assess their literacy skills and technical comprehension of what was explained during their tour. (Here it was important to ensure that the 'tour' was accurately reproduced each time it was run.)

2. A group exercise to assess communication and interpersonal skills, a fine co-ordination test to assess manual dexterity, and a series of three practical tests designed to assess their approach to and ability in problem solving.

3. Finally there is the selection board where motivation, determination, and relevant experience (of all types, including hobbies and course projects, etc) are explored.

It was also very noticeable how much more relaxed and open the candidates were at the selection board, having met the Transmission Managers and Recruitment Officers 'socially' the previous evening. Being more relaxed and self-confident allowed the discussions with candidates, although structured in terms of what should be explored, to be much more open than would be the case at a normal selection board.

After all the candidates had completed the whole procedure (some fifty applicants being assessed during the two short weeks each side of Easter), a discussion involving all the board members was held. Each element of the whole assessment process was scored for each individual candidate. The board members therefore had available to them data on: the first objective assessment test; the group exercise (team-working ability and influence); the written report (style and content); the three practical tests (problem solving); manual dexterity, and from the selection board (determination, motivation and relevant experience).

Continued from previous page

All had been marked against predetermined criteria using agreed scales.

Scores were compared and different factors given slightly different weighting depending on the specific job within Transmission under consideration, for example Engineering or Operations. This meeting was noticeable for the objective and dispassionate way in which the selection decisions were made. 'Gut feelings' about candidates from the boards melted away when faced with a comprehensive table for scores built up from the whole array of assessments.

Outcome

The advantage of this new recruitment process is its objectivity. By assessing the individual against the criteria required to perform successfully in the job (derived from its job analysis), the problem of unrealistic recruitment qualifications and experience are removed. In turn, having minimised the subjective approach of the traditional purely-by-interview selection process, any elements of discrimination, of whatever form, are also minimised.

The Transmission selection procedure this year resulted in a high proportion of women being appointed. These candidates were of a high calibre at interview, but if this inherently subjective judgement had been the only basis for selection, then it perhaps would have been difficult to defend charges of positive sex discrimination!

The final result led to seven engineers (four male and three female) being offered appointments to join in September 1991. A further group was felt to be 'also suitable' and, in years when recruitment targets were higher, would have been offered appointments.

The next stage of the strategy is the long term feedback to track this group of recruits over the next few years — to confirm that they do indeed possess the abilities to become not just a Transmission engineer but an excellent Transmission engineer. This will doubtless form the basis for a report in years to come. We are now, however, busily working on the job analysis of engineers in Radio so that, for next year's university and polytechnic tour, a similar system can be operated which seeks the attributes required for an engineer in Radio areas.

Bob Forster
Senior Recruitment Officer
Eng.T.O.R.

Marconi Company Ltd

Transmission's containerised FM transmitter which was featured in the previous issue of ***Eng Inf***

Printed by BBC WOOD NORTON