The first thousand transmitters

Britain's u.h.f. colour television reaches 98.7% coverage

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On the seventh of November, 1980, Mike Neville, star of 'Look North', opened a small television transmitting station at Hedleyhope in the Deerness Valley, County Durham. The Hedleyhope relay contains the one thousandth u.h.f. television transmitter to be brought into service by the BBC.

In less than 17 years, 51 main stations and more than 450 relay stations have come into service. With the exception of two stations which do not carry BBC2 (Sandale provides BBC1 Scotland for Dumfries and Galloway, and Wrexham-Rhos offers BBC Cymru/Wales) all the stations have transmitters for BBC2 and BBC1 (or BBC Cymru/Wales).

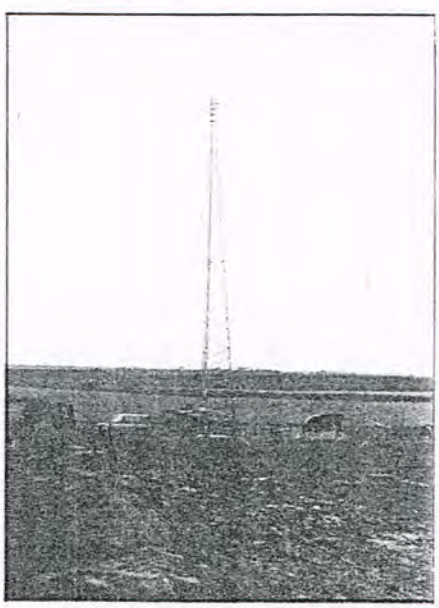
Hedleyhope is a long way from Crystal Palace, where the United Kingdom's u.h.f. television service began in 1964, carrying the brand-new service, BBC2. Like its predecessors (the original BBC television service in 1936 and ITV in 1955) BBC2 was pioneering a new broadcasting band of higher frequency than any used before in the UK. But it was also using a new line standard destined to be the vehicle for colour transmissions.

The BBC's u.h.f. transmitter network is a major engineering achievement which stretches the length and breadth of the country, from Baltasound to St Helier, from Dover to Fermanagh and from the Scillies to Peterhead. The problem compared with v.h.f. is that more than 500 stations have been needed to reach the present 98.7 per cent coverage of the 55 million people in the UK. By comparison, the BBC's 405-line v.h.f. network needed only 110 stations to give 99 per cent coverage.

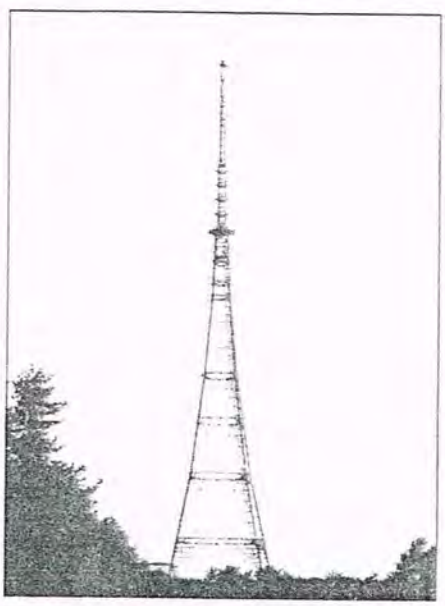
The u.h.f. network represents a great deal of co-operation between BBC and IBA engineers. The service has been planned using the computer at the BBC's research department in Kingswood, Surrey, where the transmitting parameters of all the u.h.f. stations in the UK plus those of the main stations in nearby countries in Europe, are held in memory. The Stockholm plan of 1961 allocated all main station channels and maximum powers, but the detailed planning of the relays is done with the computer. The proposed parameters are fed in to check for possible interference. Even though u.h.f. transmissions do not normally propagate over great distances, some 500 stations, each using 4 channels out of a possible 44, mean that finding useful channels for new relays is getting difficult.

Where possible, existing v.h.f. sites doubled as u.h.f. transmitting stations although more main stations were needed and have been built, with the BBC responsible for site acquisition of half the sites and the IBA responsible for the other half. At each station one organisation is the tenant of the other. The landlord is responsible for the building, tower or mast, aerials and transmitters for its own services: the tenant organisation looks after its own transmitters.

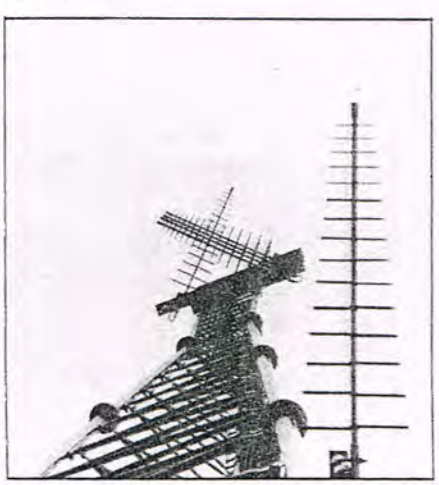
The relay network also used existing v.h.f. sites where possible but many more sites have been obtained on the same landlord/tenant relationship. The obstruction caused by terrain is much greater at u.h.f. than at v.h.f. and the relay stations fill in the gaps left by the main stations. The flat lands of eastern England need very few relays but the heavily-populated valleys of South Wales and industrial Yorkshire and Lancashire need very many. On the whole the relays serving larger populations have been built, and the number of people served by each new relay has fallen from half-a-million (Sheffield) down to between 500 and 1000 for most



Hedleyhope, the BBC's 500th u.h.f. station, with modular, 3-legged tower, log-periodic aerials and prefabricated building, all of BBC design.



The Crystal Palace tower where the country's u.h.f. services began in 1964. The u.h.f. aerials are in the white cylinder at the top.

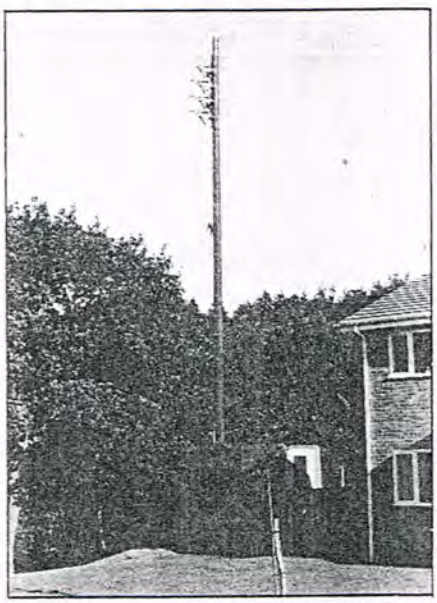


Looking up at the mast at Hedleyhope. Log-periodics abound. That on the right is the receiving aerial. The transmitting aerial puts most power in the direction of the stack of four with a little at right angles to serve an odd few houses in that direction. Note the simple tower construction.

current stations. Hedleyhope serves 1000 people.

Deficiencies in coverage are measured during detailed surveys by the service planning section of the research department. Possible transmitting sites are investigated using the computer and ground profiles drawn from ordnance survey maps. Site tests are carried out with mobile test transmitters and aerials and to check for good received signals. These methods ensure that optimum coverage can be achieved in any area where deficiencies exist.

At this stage, either the BBC's site acquisition section or its IBA counterpart takes over. There has to be main power available within a convenient distance, and reasonable access. Then the landlord has to purchase the freehold or negotiate a lease on the site and obtain planning permission and air navigation obstruction clearance. In some areas there can be objections to even a small pole on environmental grounds but the broadcasters are at pains to erect the most discrete structure consistent with performing the necessary service. They have no power of compulsory purchase, and planning consent has to be obtained in the usual way.



Totley Rise, Sheffield. One of the BBC's tiny, unobtrusive installations with wooden pole, log-periodics and prefabricated building.

Providing the stations

The BBC's transmitter capital projects and architectural and civil engineering departments are responsible for turning the research department's specification for each station into reality. The specification includes transmitted power, channels, aerial radiation patterns and height. The most appropriate equipment, aerial support structure and building are all carefully selected to fulfil these requirements.

Most components are ordered in quantity and parts are allocated to each station while it awaits its turn to be built. At present the broadcasters are opening 70 new stations each year and it is vital to maintain a steady flow of materials to meet this target.

On many small BBC sites the concrete tower base (which includes the building base) is laid by BBC staff. A BBC-designed pre-fabricated building is equipped at the Brookmans Park workshops. Building, tower components and aerials are taken by lorry to the site, where the rigging team puts the pieces together. The aerial engineer pays a brief visit to check that the transmitting aerial (which he assembled at the workshops) is a good impedance match when installed with its feeders. He checks the received signal and installs the combining and splitting filters. The relay engineer installs the transposers to complete the installation. The tenant's representatives install their transposer(s) and finally the manager of the transmitter maintenance team accepts the BBC equipment on behalf of the transmitter group, who will operate it. The station is now ready for switch-on and appropriate publicity is arranged through local papers, the 'Service Information' programme and the trade, a week ahead of the opening date. An engineer from the BBC's engineering information department visits the service area with a survey vehicle in the first week or two of operation to check the performance of the station. He advises both dealers and members of the public on the spot about reception conditions as he finds them.

So far only the planning and provision of the stations have been considered, but the expansion of the networks has made huge demands on the ingenuity of our engineers. At several stages in the programme when there was no suitable commercial device, the equipment has been designed within the BBC. The Hedleyhope relay, for instance, has aerials, tower, transposers, amplifiers and channel-selection and combining equipment all of BBC design.

The programme has been a continuing story of smaller and smaller stations serving fewer and fewer people. Inevitably the cost per person served increased and the BBC has made considerable efforts to reduce complexity and expense. The Hedleyhope station has cost some £50 per viewer whereas a high-power station for a densely-populated area would cost 30 or 40p.

Transmitters

Crystal Palace was a test-bed for u.h.f. equipment for several years before it went into programme service in 1964 and the

The main stations in the BBC's u.h.f. transmitter network.

BBC also benefited from the experience of the West Germans who had already begun a u.h.f. service. We aimed to make all u.h.f. stations unattended, requiring maintenance rather than operational staff. So klystrons were used for the main station power amplifiers because of their reliability and long life. Recently the amplifier drives at these stations have been replaced and klystron amplifier efficiency has been improved by 50 per cent although we are still experimenting to obtain even higher efficiencies. Initially, parallel transmitters were used, with separate sound and vision amplifiers (i.e. four amplifiers) so that one half of the system could fail or be maintained whilst the other continued in service. Later, we used one klystron each for vision and sound with a 'cut-back' condition whereby one could carry both signals with a loss of 7dB in power output.

Transposers at the early relays used valves with klystron or travelling-wave-tube final amplifiers. Solid-state transposers came in early and were used initially with output valves or travelling-wave tubes but the most powerful amplifiers using solid-state techniques were 50W units. For most of the smaller stations, 2W and the occasional 10W amplifiers have been adequate. For that, out of the BBC designs department was rolled the 'Blue Streak' – not a rocket as the name suggests, but a transposer/amplifier unit with a very good specification and designed for ease of maintenance. Interconnections are the most likely source of problems in r.f. equipment, so all of the Blue Streak's interconnecting leads are visible and replaceable from the front.

Although this makes it an ugly duckling, the equipment has proved extremely reliable in service. For the future, the designs department has developed a new transposer, already nicknamed 'Silver Streak' which out-performs its predecessor at lower cost. In a very small space, four 2-watt units can be installed side-by-side and only one spare is necessary because the operating frequencies are determined in a separate unit.

Inside Hedleyhope. Gordon Bowhay, of the BBC's transmitter capital projects department, is putting the finishing touches to his 'Blue Streak' installation. The instruments at bottom left are test gear, not station equipment.

Shatton Edge. The 'slimline' tower was originally developed for use in the Peak District National Park. The 'trough' receiving aerials are just above the special stone building. The cantilevered cylinder contains a 'cardioid' transmitting aerial.

Aerials

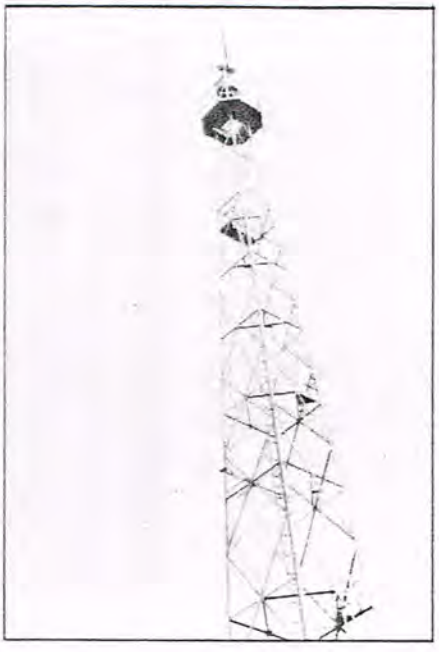
The most obvious feature of a u.h.f. main station is the white glass-reinforced plastic radome which appears as a cigarette-like cantilever on the masts and towers. The transmitting aerials consist mostly of panels, normally four wavelengths high, arranged in stacks on three or four sides of the central spine. The aerials are in two halves, fed by independent feeders and phasing is arranged to give an overall downward tilt to the main beam. At most stations one aerial carries all four services but there are a few where one is used for the BBC and one for the IBA services.

Most early relay stations used cardioid-pattern transmitting aerials built to a BBC specification. Enclosed in a structural gap cylinder, they consisted of a pole with dipoles on one side. Later aerial systems were built using components designed by a team at the BBC's research department. The trough aerial (resembling a pig-trough) was used occasionally for transmitting and more often for receiving. The panel aerial, essentially two slots etched into a printed circuit board and panel and protected by a plastic cover, became the common building block of the Phase 1 stations serving populations down to 1000. The log-periodic aerial has since taken over and is the common component for both reception and transmission at Phase II relays serving groups of people down to 500.

The early heavy-duty towers were not acceptable to the environment conscious planners for the Peak District National Park. A new, more elegant, tower was commissioned. Named the 'slimline', it appeared in the Peak Park and in every other part of the country from St Just in Cornwall to Fodderty in Easter Ross. Even this was too big for the smaller stations which use either simple poles or a lightweight, modular tower designed by the BBC's architectural and civil engineering department at a fifth of its predecessor's price. The tower was designed to be put up by the BBC teams who previously had only erected the aerial systems after contractors had erected the actual tower.

Distributing the signals

A number of main transmitters receive their feed by Post Office (British Telecom) link. This applies to at least one station in each region as there are regional opt-outs on BBC1. The remaining main stations take their picture by off-air reception using BBC-designed rebroadcast-quality receivers. Relay stations almost all use transposers to avoid the need for demodulation to baseband. In a number of cases the Post Office was unable to provide the necessary links and the BBC planned its own link systems to do the job. The three most obvious examples are in Scotland where the feeds to the Inner and Outer Hebrides and to the Shetland Islands are all carried by microwave links installed by the broadcasters. The relay at Torosay (Mull) receives its signal by link from the relay station at South Knapdale, above Loch Fyne in Argyllshire. The main station at Eitshal (Lewis) is fed by a 6-hop link from Rosemarkie on the Black Isle near Inverness. This network, which straddles northern Scotland, was planned and installed by staff in the communications and links unit of the BBC's transmit-



St Just. Another 'slimline' tower but with 'panel' transmitting aerials.

ter capital projects department. The country that the route crosses is so rugged that two sites without electrical power are used for passive deflectors. The chain of links carries the v.h.f. radio, as well as the television channels, to the Melvaig transmitter on the Wester Ross coast. The feasibility of a link to Shetland via Fair Isle was investigated by the BBC and the eventual installation was the responsibility of IBA staff. Both Torosay and Bressay (Shetland) are classed as relays but actually use klystron amplifiers for the BBC services and, of course, cannot employ transposers.

The way ahead

The current phase of the relay programme is taking in stations for as few as 500 people and last May the Home Secretary authorised a third phase for populations as low as 200, where practicable. The broadcasters are now looking towards even simpler and cheaper equipment, 'Silver Streak' being the first of this.

The Home Secretary has also given permission for people in communities of less than 200 to install their own cable systems or transmitters but, of necessity in collaboration with the broadcasters. Already more than 60 applications have been received by the BBC.

The 405-line transmissions in Bands I and III are to be phased out between the beginning of 1982 and the end of 1986. Not all of Band I will be available for broadcasting after that, but the remainder and Band III are under consideration for 625-line area television or another near-national network.

So it would seem that we have exploited all the possibilities for terrestrial television broadcasting in the United Kingdom. It remains now to use the next group of broadcasting bands with satellites as discussed by my colleague Dr G. J. Phillips in his articles in this journal of October and November 1980.

I am indebted to the BBC's Director of Engineering for permission to publish this article. □

The author

Dr Trickett was educated at King Edward VII School Sheffield and University College Durham, gaining his doctorate under a BBC research scholarship. He began working for the Corporation in 1968. After a short time in the research department he joined the transmitter capital projects department. Three years ago he joined the engineering information department and is currently employed as a publicity engineer.

Smaller television cameras

There is a continuing pressure from broadcasters and industrial/commercial users to reduce the size and weight of television cameras. The broadcasters need them small for ENG (electronic news gathering) while the industrial users need them small to mount on machinery or to be unobtrusive for surveillance purposes. Soon, home video will be adding to this pressure (see News, December). Two recent responses from the electronics industry have been the c.c.d. (charge coupled device) image sensor and the single-gun photoconductive tube for producing colour pictures. New examples of these were presented at the International Broadcasting Convention, Brighton, in September, and also by Howard Steele, managing director of Sony Broadcast, in his October inaugural address as chairman of the IEE's Electronics Division.

The c.c.d. image sensor is claimed to be "the first commercially available sensor with the full 625-line tv capability." Developed by the GEC Hirst Research Centre, Wembley, it takes the form of a 14mm×10mm polycrystalline silicon chip mounted in a 30-pin package (type number MA357). The incident light image is converted from a pattern of photons to a corresponding pattern of electric charge by an 8.5mm×6.4mm image section on the chip, which contains 864 horizontal electrodes and 385 vertical charge transfer columns. This charge pattern is transferred, by a three-phase pulsing applied to the horizontal electrodes, line by line downwards into a storage section on the chip. The charge collection plus transfer time is equal to one field period (20ms in the 625-line standard) and the transfer takes place in the blanking interval.

At the bottom of the storage section each line is transferred in parallel into a line read-out section, from which it is read out sequentially in the time of an active tv line, 52μs. While each line is being read out a second pattern of charge is being collected in the image section. Although charge is collected from the whole image area in each field, the three-phase pulsing system causes the centres of charge collection to be shifted up and down between fields to give in effect a 2:1 interlace in the vertical direction. Thus the c.c.d. device is compatible with the 625-line tv standard, where 575 lines are displayed and the remaining 50 lines are used for field blanking periods.

Picture quality from the GEC device is not yet good enough for television broadcasting, but the present performance is claimed to be adequate for "a wide variety of industrial, professional and military applications."

The new single-gun colour tube, intended for ENG cameras and developed by the Sony Corporation, is only ⅔inch in diameter. It is called the Trinicon because of its similarity to the well-known vertical-stripe Trinitron cathode-ray tv display tube made by the same company. The light image, in fact, is focused onto a colour filter array consisting of red, green and blue vertical stripes, each only 9 microns wide, which are integral with the face-plate of the tube. An unusual feature of the tube is the colour coding principle, which uses a phase reference carrier onto which the red, green and blue signals are modulated. This phase reference carrier is generated within the tube by the electron beam scanning an inter-digital electrode structure (rather like two combs) behind the target, and is subsequently used in synchronous demodulators to obtain two quadrature modulated colour-difference signals.

In this system the incident light image is modulated by the striped colour filters to produce a three-channel pulse amplitude modulated signal containing the three colour components E_R, E_G and E_B. The base band and first harmonics are expressed as $E'=a_0\ (E_R+E_G+E_B)+(E_R-(E_G+E_B)/2)\ a_1 \cos(\omega t+\phi)+\sqrt{(3/2)}\ (E_G-E_B)\ a_1 \cos(\omega t+\phi-\pi/2)$.
In this equation the first term is the luminance signal while the remaining two are the quadrature modulated colour-difference signals which are subsequently recovered in the synchronous demodulators.

The inter-digital electrode structure which produces the phase reference carrier is related to the spatial pattern of the red, green, blue colour filter stripes in that a pair of the interleaved "fingers" or digits occupies the same horizontal distance (27 μm) as one red-green-blue triad of filter stripes (each 9μm). A small offset voltage is applied between the two comb-shaped elements forming this structure and is alternated at the television line rate, so producing the phase reference carrier onto which the red, green and blue signals are modulated. Outside the tube these phase-reference and colour-signal components are separated by a correlation system.

An ENG colour camera using this single new tube weighs 200g and occupies a volume of 80cc compared with the 1200g and 600cc of a corresponding three-tube ENG camera. The power consumption of the tube supplies (1.5W) is, as might be expected, about a third of the three-tube camera consumption.