THE BRITISH TELECOM SWITCHED STAR SYSTEM IN WESTMINSTER (LONDON) UK
PART 1: AN ADVANCED SYSTEM

Kevin Shergold
Director of Local Line Services

BRITISH TELECOMMUNICATIONS PLC

INTRODUCTION

During the last three or four years, Cable Television Operators in the USA have been quite justifiably cynical about the prospects for advanced Cable TV Systems which offer a sophisticated range of interactive services using optical fibre technology and off-premises switched electronics:

- There is still little evidence in the USA of a significant market place for interactive services.

- Coaxial technology is a safe and secure technology that is now well understood by the Industry.

- Above all, the cost of coaxial plant is still significantly cheaper than systems which employ optical fibre and switched technology.

In the UK however, the political, regulatory and commercial climate is very different to that of the USA and this has directed the British Communications Industry down a path which has resulted in the painful birth of a somewhat fragile Cable Television Industry.

In spite of all the difficulties and setbacks, most of which were out of British Telecom's control, the Switched Star System is now operational in Central London and is proving to be a strategically important element in the introduction of optical fibre into the Local Communications Network.

The commitment towards the use of fibre in the local network by many of the Telephone Operating Companies throughout the world will bring down the cost of fibre and optoelectronic devices and challenge MSOs on the use of these new technologies. During the next decade, the telecommunications industry will be moving towards the provision of integrated broadband local networks capable of delivering not only entertainment television and information services but also general telecommunication services including telephony.

The Switched Star System has been developed in British Telecom's Research Laboratories with particular focus on the entertainment television and information services aspects BUT with the clear intent to evolve towards all digital, all fibre integrated services.

This paper (Part 1), together with Part 2 by my colleague John Powter will outline the political/regulatory background in the UK, describe the Switched Star System and its construction in the densely populated urban community in Central London and briefly discuss the economics and marketing prospects.

BACKGROUND

Most observers of the European Cable TV scene are agreed that there has been a dramatic turnaround over the last few years and this has been particularly visible in the UK. The early enthusiasm generated by the publication of the Information Technology Advisory Panel Report (ITAP) in February 1982 which made initial proposals for the creation of a national electronic infrastructure, has faded considerably as the new emerging Cable TV industry faced up to the harsh commercial realities.

In the initial Franchise Round advertised in August 1983, the Department of Trade & Industry was eager to see applications that promised the use of advanced technology and offered a range of interactive services. It was hoped that these new networks would provide alternative local telecommunication systems that would compete with the existing British Telecom local network. Amongst the initial applications were Consortia who proposed to offer, not only a TV distribution system with videotex possibilities, but also business data and telephony services. In a few cases, there were proposals for the use of optical fibre in certain parts of the network. It was assumed (and is still assumed) that all these local networks would be financed from the private sector and not from any public funds.

In November 1983, it was announced that the Department of Trade and Industry had awarded the first eleven franchises. British Telecom was involved in five of these schemes as a partner in the Operating Consortia and as a provider of the networks in each case.

(A dual approach had been taken by British Telecom to develop both Multi-channel conventional VHF Coaxial System with final star distribution and an advanced Switched Star System.)

The Operating Companies were dealt an unexpected blow however when the Chancellor of the Exchequer announced the phasing out of capital allowances in his 1984 Budget and this damaged the already precarious economics of Cable TV. The Operators had to re-examine their financial models very carefully to find approaches that would justify them to proceed. It was soon apparent also that expectations by the Government of an early demand for non-entertainment TV services was not to be realised.

The new National Cable Authority who have the responsibility for awarding Cable TV franchises is now established and have advertised additional "rounds" and awarded further franchises. It is important however to note that the UK Cable Authority is in a position to provide a powerful incentive to Operators to offer advanced systems as the legislation allows for a longer franchise period of 23 years to be awarded for a Switched System as compared to a 15 year franchise for a more conventional coaxial tree network.

Currently, British Telecom is constructing three major systems passing a total of over 300,000 homes: the Switched Star System in Westminster London and VHF Coaxial Systems in Aberdeen and Coventry. All three systems are operational.

THE SWITCHED STAR SYSTEM

The technical arguments for off-premises switching on Cable TV Systems are well rehearsed and understood. However, the cost implications and the practical implementations of such systems have in the past overshadowed the technical advantages. In Europe however, where there are national interest considerations and incentives that go far beyond technical elegance, a switched topology has become more preferred than in North America:-

- In the UK, teletext services delivered by the Broadcasters are well established. 18% of new domestic television sets that are purchased are equipped to receive and decode teletext services.

- Home computer penetration in the UK is currently at 20%.

- The fully interactive videotex service PRESTEL run by British Telecom is now profitable and is currently offering home banking and home shopping too. Prestel has more than 60,000 customers of which about half are business customers. Currently, a million pages of information are summoned to those screens each day and over 100,000 electronic mail messages are exchanged every week.

  Telecard, a company in Central London has just opened up a home shopping service offering home delivery of 3,500 supermarket lines (at below store prices) to 8,000 existing Prestel users in London.

- The technology and software for photo videotex services are already available and will be shortly introduced on British Telecom's coaxial system in Milton Keynes.

- The penetration of VCRs in the UK is 38% and is an indication of the demand for greater viewing choice and evidence that discretionary income is out there to be tapped.

These features, together with the current political climate, have encouraged the industry to design systems capable of supporting a range of services that go beyond downstream television entertainment. British Telecom therefore decided to develop and install an advanced system that is capable of offering a sophisticated range of services:-

a. Downstream television capable of providing basic channels, subscription channels and pay-per-view channels.

b. FM Radio - 16 Stereo channels.

c. Interactive videotex - alphanumeric and photographic.

d. Individual on demand access to a video library.

e. An advanced network management system offering a customer database plus a range of customer service facilities including a billing and accounting system.

f. Provision is also made for both low speed telemetry services and high speed data, although this is not currently being offered in Westminster.

Although a coaxial tree structured network is the most economic way of delivering downstream entertainment services, when it comes to coping with the large number of individually routed signals that is demanded by such a comprehensive range of services, the problems of congestion, delay, addressability, security and noise become awesome. A single star network would overcome most of these problems but, of course, the cost of providing dedicated broadband paths from a headend to each customer would be prohibitive.

The BT Switched Star System locates a switch in the network near the customer so that communication from the headend to that switch is provided on shared primary circuits. The switch also acts as a common access point and message concentrator and provides an ideal network-node for the provision of additional intelligence, and concentration and primary transmission-bearers as traffic growth demands.

In the Westminster System where multimode fibre is used, there is, in fact, a "tree element" in the system as optical taps are used on some of the fibres that are carrying the downstream channels.

THE SYSTEM ARCHITECTURE (Figure 1)

The system uses optical fibre transmission in the super primary links to the Hub Sites and also utilises fibre in the primary link from the Hub Sites to the Wideband Switch Points (WSP). Each Switch Point is served by 5 optically tapped fibres for providing downstream channels plus 5 dedicated fibres. One of the dedicated fibres is used for upstream video and for control signals so the 9 remaining downstream fibres terminate on optical receivers. The incoming TV channels are demodulated down to baseband where the channels are switched using DMOS FET devices.

The digitally encoded Radio Channels transmitted on one of the fibres are converted back to analogue form, reconstituted as a conventional FM Radio band, and distributed to the Secondary Link launch module.

The Secondary Link from the Switch to the customer is currently engineered to use discrete small bore coaxial cables (2.9 mm diameter) to each customer. The switch unit can initially provide two switched simultaneous channels to each customer assembled onto carriers at 40 MHz and 56 MHz. FM radio and a pilot signal at 120 MHz are added. The overall loss of the coaxial cable is about 10 dB per 100 metres and the system design allows a span of 500 metres from the switch to the customer.

The current switch is designed to have a maximum capacity of 300 customers, although a smaller switch serving 150 customers is also available. The coaxial launch modules have been physically designed in a modular form to allow for the introduction of fibres into the secondary network when this becomes economic. This would allow a longer reach so it is expected that a larger number of customers could be served from a single Switch Point. It is also expected that by then, the physical size of the WSP will be reduced as a result of an increased level of integration in the switch circuitry.

The equipment at the customers premises consists of 4 units: the Customer termination unit (CTU), a small adaptor which plugs into the UHF input to the TV receiver, a remote infra-red receiver and a hand-held IR key-pad. The equipment converts the incoming VHF channels to UHF and processes the control signals.

OPTICAL TRANSMISSION IN THE PRIMARY PATHS

Digital transmission to provide four TV channels on multimode fibre is, of course, quite feasible but it is also still too expensive to be appropriate for the architecture described above.

The digital transmission costs and the common costs of the receive equipment and codecs located in a switch serving a maximum of 300 customers would not be economic. On the BT system, 4 TV channels are frequency modulated onto a carrier of 345 MHz and then down-converted and placed within an intermediate multiplex extending up to 200 MHz. The IF multiplex intensity-modulates an 850 nm laser and the output is launched into a graded-index fibre of 50 μm core with an attenuation of less than 3.5 dB/km and a bandwidth product of more than 600 MHz km.

Normally the maximum reach of the super primary link without repeaters is 5 km but with the use of a better quality fibre, the span can be increased to 8 km. The receiver is an avalanche photodiode which converts the incoming light back to the IF multiplex and a demodulator, employing a phase locked loop, brings each channel down to baseband. This transmission in concept is deployed on both the super primary and primary routes, although allowances must be made in the power budget for the use of optical splitters in the primary path.

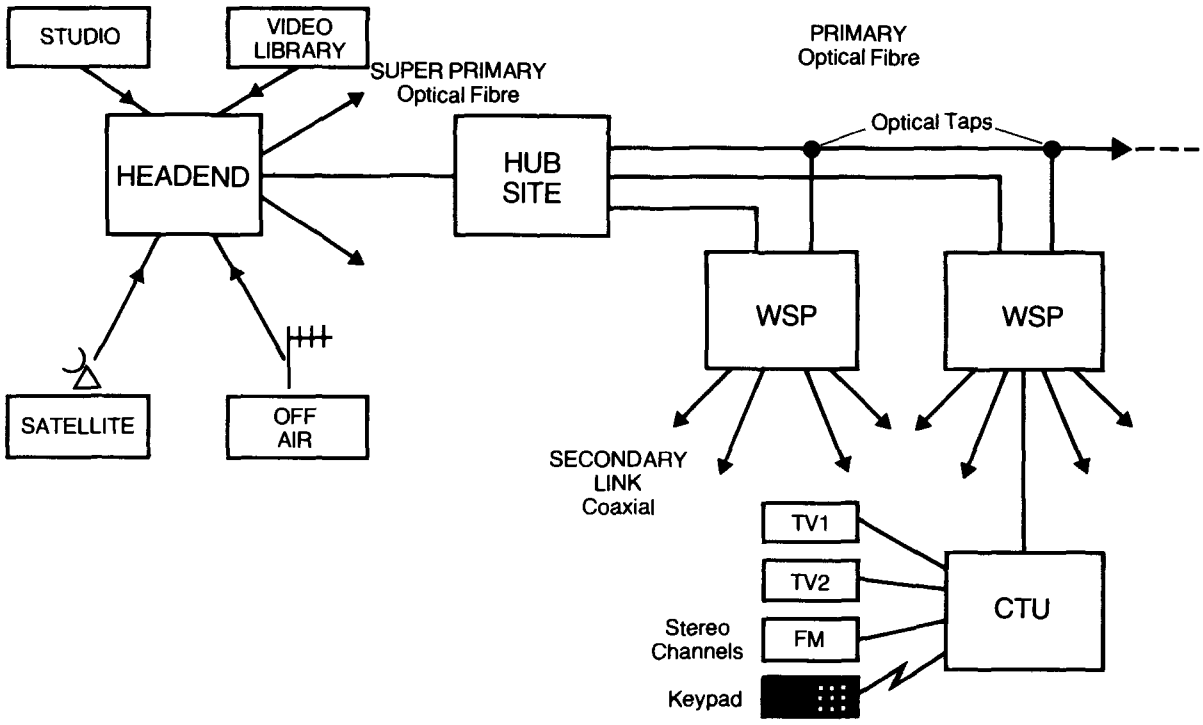
In the Westminster scheme alone, there will eventually be a total of 4,000 fibre kms and this will provide British Telecom with some very valuable experience in the deployment of fibre on such a concentrated scale.

Cables with up to 160 fibres have been specially designed and this has required the development of compact joint organisers to house both fusion joints between fibres and the optical taps on the primary links.

WIDEBAND SWITCH POINTS

As has already been indicated, the switching is performed at baseband. The basic and subscription TV channels are bussed directly to the main switch units which is the heart of the Wideband Switch Point. Currently, each main switch unit serves 300 customers and can be installed on a modular basis as demand for services from each WSP increases. Each switch unit is self-contained with its own control functions responding to signals from the customer launch modules. These main switch units also have access to the video library channels via an auxillary switch so that in total each unit has 30 inputs which are bussed to all 60 outputs (2 outputs per customer).

Fig 1: BT SWITCHED STAR SYSTEM ARCHITECTURE



The Wideband Switch Point also provides local text generators which can be grabbed by any customer who requires access to videotex services and this means that customers can enjoy full videotex facilities - both text and photographic information - without requiring a special videotex terminal and without using the telephone line.

The WSP also provides a further level of control by providing local alarm and maintenance facilities.

The housing of the Switch Point has represented a major challenge as a large amount of sophisticated electronics must be densely packaged into a field-located cabinet. Equally a significant level of engineering has gone into the whole process of fibre splicing, coaxial jointing, joint enclosures and connectors as these are particularly critical at the WSP nodes.

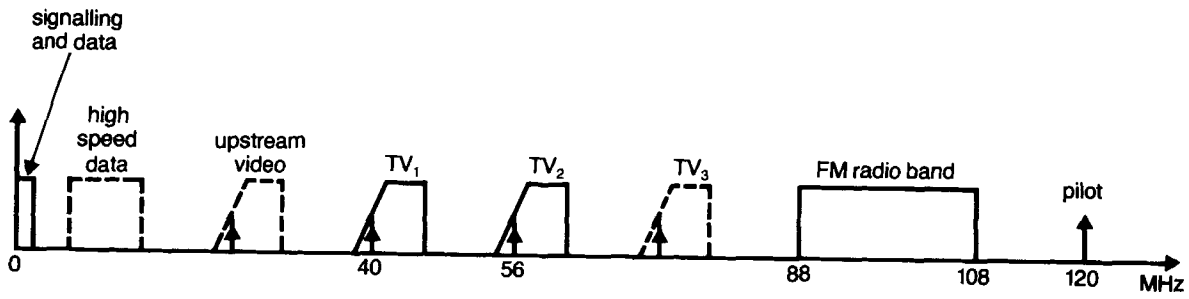
COAXIAL TRANSMISSION IN THE SECONDARY PATH

The launch module housed in the WSP takes two baseband video channels and amplitude modulates them onto carriers at 40 MHz and 56 MHz in standard vestigial sideband format (VSBAM). The launch module also accepts FM radio in its normal frequency band, along with a 120 MHz pilot tone.

These are presented to the launch module as high impedance inputs. The launch module's task is to adjust relative levels, combine the signals and drive them into the 75 ohm or coaxial cable at its output. The spectrum over the secondary link (Figure 2) includes a signalling channel at the baseband end which is routed through the launch module to the switch control.

The overall secondary link is composed of a number of cable sections: the patch cord within the WSP, the tail cable from the WSP to its associated joint box, the main run of multi-tube cable (up to 30 tubes per cable), the link cable at the distribution point, the overhead or underground feed to the customer, and finally the internal cable in the home. Overall the loss at 100 MHz is around 10 dB/100 m, which allows a reach of 500 m.

Fig 2: SECONDARY LINK SPECTRUM



CUSTOMERS EQUIPMENT

At the Customers Termination Unit the two TV channels are upconverted using a local oscillator set at either 495.25 or 503.25 MHz. This choice allows for the two switched channels to appear at the input of the customers television set at either the standard UHF channels 29 or 31 or at channels 30 and 32. The British Standard Institute has established stringent technical standards for Cable TV (BS6513) particularly for the UHF frequency stability of $\pm$ 20 KHz so the local signal is derived from a 4 MHz crystal by means of a frequency synthesizer.

The secondary link may have an attenuation of up to 50 dB at 100 MHz. At the carrier frequencies of 40 and 56 MHz, the corresponding maximum attenuations are about 32 and 37 dB. The customer equipment has an automatic gain control that compensates for this attenuation so that no installation adjustments are necessary. It works by detecting the level of the pilot signal at 120 MHz. In addition there is an equaliser that is automatically switched in or out to compensate for the attenuation slope introduced by the secondary link cable. The FM radio channel betwen 88 and 108 MHz also passes through the equaliser and a gain control element.

The customer termination unit can currently be located anywhere in the home and can then feed two televisions and an FM tuner. A remote infra-red receiver located on or near the TV set receives signals from the key-pad and delivers them to the termination unit via the same coaxial cable that carries the UHF signals to the television.

The customer signals are decoded in the termination unit where the message is processed and each control message is then delivered to the Wideband Switch Point when requested by a polling signal.

The infra-red signalling transmits 8-Bit codes when each button is pressed so that, in due course, an alphanumeric keyboard can be used in conjunction with the IR receiver for electronic mail and teletex.

ENHANCEMENTS AND COST REDUCTIONS

The System in Westminster has been developed, manufactured and installed over a remarkably short timescale with the initial objective of gaining early technical and marketing experience using an advanced system that offers new innovative services. The main thrust was therefore to engineer such a system in readiness for the pilot UK franchises but capable of evolving towards a fully integrated and viable telecommunication network. British Telecom has now embarked on a further programme of enhancements and cost reductions in preparation for future franchise applications:-

a. The re-engineering of the Wideband Switch Point Framework.

b. Significant integration of the switch circuit which will not only provide substantial reductions in cost but also in physical size.

c. Re-engineering of the Customer Equipment that will provide enhanced customer options and useful cost savings.

d. The introduction of single mode fibre in the primary links which will allow longer unrepeatered paths and more extensive use of optical splitting at the Hub Sites. This will bring further cost savings as well as offering much greater bandwidth with substantial evolutionary potential.

e. Further useful cost reductions can be achieved by multiplexing all the switched channels and services for two customers onto a single secondary cable and then splitting them at the final distribution point.

Over and above these immediate enhancements, British Telecom is continually evaluating three further potential enhancement/cost reduction opportunities:-

*An increase in the number of channels per fibre - particularly with the use of single mode fibre which will clearly bring cost savings in both fibre and in the reduction of optical devices.

*The development of optical fibre secondary links which will reduce duct-occupancy, give a longer transmission reach and minimise ingress problems.

*The introduction of digital techniques for the transmission of television pictures.

ECONOMIC FACTORS

The System under construction in Central London is substantially more expensive than conventional Cable TV networks not only because it is a new system using new technologies and offering new services but because it has been initially manufactured in relatively small quantities to serve just one franchise area. Throughout the development programme, there has been an underlying objective to produce a cost competitive system that will challenge the existing coaxial technology that currently has the great twin advantages of engineering maturity and large volume production. The initial enhancements listed above, when implemented on relatively small scale production, will bring the cost of the Switched Star System within 15 to 20% of the cost of a VHF Coaxial System that uses baseband scrambling constructed in a UK situation and meeting British Standard Institute Standards.

It is recognised, of course, that an incremental cost of 20% is very substantial in an industry that is keen to identify and exploit a saving of just 1%.

The Switched Star System is an advanced system that offers integrated services that are not available on conventional coaxial systems with a potential revenue from these additional features that goes beyond the income normally achieved by a successful MSO:-

*Impulse pay-per-view.

*Videotex and Photo videotex with gateways to Prestel and other information services with already established home shopping home banking services.

*Individual on-demand video library service.

*Video conferencing.

*High speed access to the national Packet Switched System.

FUTURE PROSPECTS

The use of single mode optical fibre and out-stationed flexibility points is compatible with the activities of most of the world's Post and Telecommunications Operators as they modernise their networks to provide the integrated services digital network (ISDN).

British Telecom, along with other European PTTs, is currently actively involved in establishing standards in preparation for Integrated Broadband Local Networks sometimes described as Broadband ISDN. These networks will be all digital networks capable of supporting a complex range of services including full broadcast quality television. (I leave it up to the reader to speculate on the implications that this will have to regulators, governments and broadcasters.) The Westminster Switched Star System, developed particularly with entertainment television in mind but with evolutionary potential, is one of the world's first steps towards the integrated broadband local networks of the future.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the contributions of Mr W K Ritchie, Mr E J Powter, Dr J R Fox and Dr R T Boyd.