EVOLUTION OF THE BRITISH TELECOM SWITCHED-STAR CABLE TV SYSTEM

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ABSTRACT

After briefly reviewing cable TV progress in the UK, the more advanced developments will be described, focussing on the British Telecom switched-star network, deployed already in Westminster and now with a second generation design coming to fruition. The evolution of the switched-star concept towards a multi-service network is discussed, and an implementation aimed at a small field trial in 1990 is described.

INTRODUCTION

Cable TV has never been widespread in the UK. Nevertheless a significant industry started in the 1950s, using mostly HF provision on twisted pairs, to cover areas of poor off-air reception. This peaked at around 3.5 million homes in the early 1970s, but was dampened as the comprehensive programme of installing UHF transmitters round the country came to completion.

By the late 1970s cable TV was in need of a major boost, and attention turned to the twin thrusts of service improvement (including more channels) and modern technology. British Telecom (BT), who had always been allowed to compete for cable TV franchises, had at that time a few conventional coaxial cable systems. The largest was at the new town of Milton Keynes, which was chosen as the site of a small all-fibre trial to the home using the switched-star concept [1]. Implemented in 1982, it coincided with an upsurge of interest in the potential of cable TV and the advent of subscription film channels.

From its experience with this trial, BT moved to a design for a switched-star network (SSN) that was more practical for large-scale deployment; this was chosen for installation in Westminster, one of 11 large franchises awarded in November 1983 as part of a major initiative on cable TV in the UK. This network and its capabilities are described in the next section in more detail.

The combination used in Westminster of fibre to a street-located switch point and coaxial cable to the home is still seen as the most cost-effective solution, and remains the basis of a second generation design that is nearing completion. The experience gained allied to improved technology has enabled significant improvements to be made, which are described later in the paper.

There is worldwide interest in future broadband multi-service networks, and so effort has been applied to extending the switched-star concept towards this aim, essentially by marrying up the cable TV and remote telecomms multiplexer ideas. These evolutionary developments will be described to indicate the potential that the switched-star concept has to meet future service demands.

EXPERIENCE WITH THE WESTMINSTER SSN

The Westminster system started service in mid-1985, and will shortly reach its initial target of 200 Wideband Switch Points (WSPs) (each WSP being capable of serving up to 300 customers). The network has been described in detail in several papers [2], [3], but Figure 1 shows the topology used, and a brief outline of its operation follows.

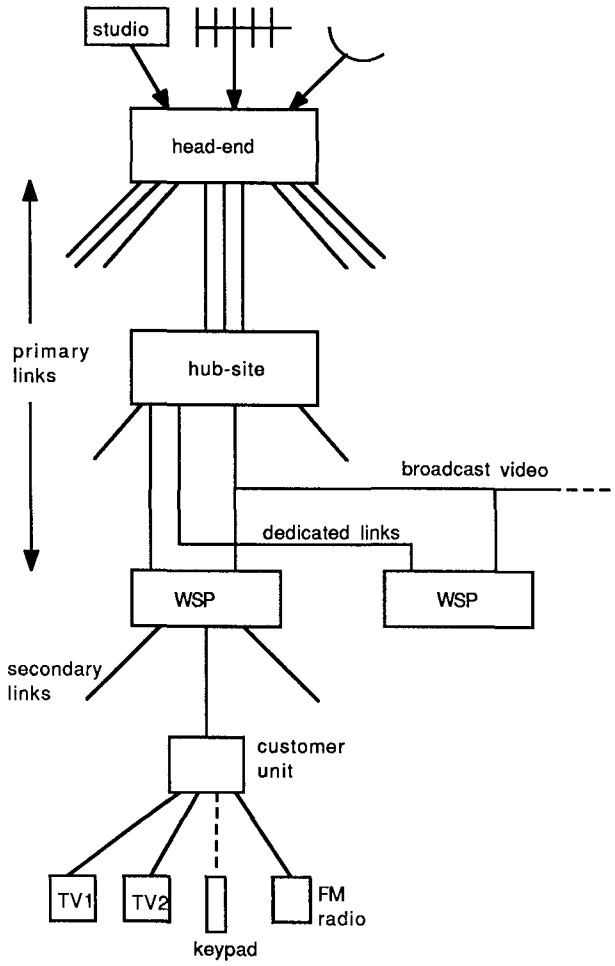

FIGURE 1 - Westminster switched-star network topology

Multimode fibre optics is used to carry multiplexes of 4 frequency modulated (FM) video channels per fibre from head-end to WSP via an intermediate repeatering and fan-out point, the hub-site. This is the primary network which saw one of the earliest uses of large numbers of optical splitters, taking advantage of the spare optical budget to distribute the broadcast TV channels more economically.

At the WSP the incoming channels were demodulated, switched at baseband (0 to 6 MHz for PAL) by DMOS-FET semiconductor devices, and then amplitude modulated (AM) onto a coaxial cable to go over the secondary network into the home. This secondary link carried 2 TV channels on 40 and 56 MHz carriers plus the FM radio band (88 to 108 MHz); signalling placed at the bottom of the spectrum carried customer requests back to the WSP where they controlled the switch directly or, for the more sophisticated services, were relayed back to the head-end. The low total bandwidth on the link allowed a reach of up to 500 metres.

The Services

Broadcast TV was of course the core service, but the network was aimed at providing much more. Text generators housed at the WSP feed into the switch. They provide standard captions and user guidance, but are also the vehicle for information services using data fed down the primary link. A user is allocated a text generator, whilst his requests are relayed back to the head-end to access information either stored in databases there or in external databases accessed via a gateway.

Video library service was also built in from the start, with a limited number of dedicated video links to each WSP to carry channels from the library at the head-end via the switch down to customers. Signals from the customer are relayed up the network to fully control an allocated video disc player, thus enabling flexible access to the contents of a disc.

A carefully designed control structure was built into the network with a hierarchy of processors in the customer equipment, the WSP, the hub-site, and the head-end linked together by a messaging system. At the head-end there is a particularly comprehensive network management and systems administration software package, as well as packages for the information and video library services.

Experience

Technically there have been few problems, the worst being early failures of the 0.85μ lasers, now fortunately overcome. Concern over how the WSP equipment would fare housed in a street-sited cabinet proved unnecessary; the environmental control provided by fans and a heat exchanger has proved very successful. The only real disappointment has been the slow build up of cable TV in the UK; there are signs that this

may change and that the switched-star scheme will then get a chance to be exploited to the full.

MARK 2 SSN

The system for Westminster had been designed within a tight timescale to meet an urgent operational demand. It had performed remarkably well, but experience and improving technology were showing where gains could be made; it is often in the move from the first to the second generation design where the greatest degree of benefit can be realised. Hence virtually from the moment that Westminster became operational there was work proceeding on a Mark 2 SSN design.

The Switch Point

The heart of the system is the WSP and this became the first focus of attention for improvement. To reduce size and cost a new more integrated switching chip was developed based again on the successful DMOS-FET crosspoint. At the same time it was decided to change the switch unit construction from a special shelf module to a conventional card based system, allowing standard shelving and racking to be used. The new switch card is shown in schematic form in Figure 2 . It has 48 inputs buffered such that each can go to one or all of 16 outputs. The transmitter units sit as daughter boards on it, taking as standard 2 outputs to each customer. Thus this compact card of 220 x 230 mm serves 8 customers. It can be controlled from customer signalling incoming from the coaxial link or centrally by parallel or serial lines. The opportunity was taken to incorporate some additional return switching capability for video services and monitoring purposes.

The smaller size of the switching circuitry allows the WSP cabinet to reduce to two-thirds of its previous size; there is just one switching bay instead of two, with still the common services bay. With the new switch card, standard 19 inch racking and eurocard shelving could be used throughout; Figure 3 shows the full layout. Since cabinets were often against a wall or fence, it was decided to avoid the necessity for rear access by having only shelf backplanes (no rack backplanes)

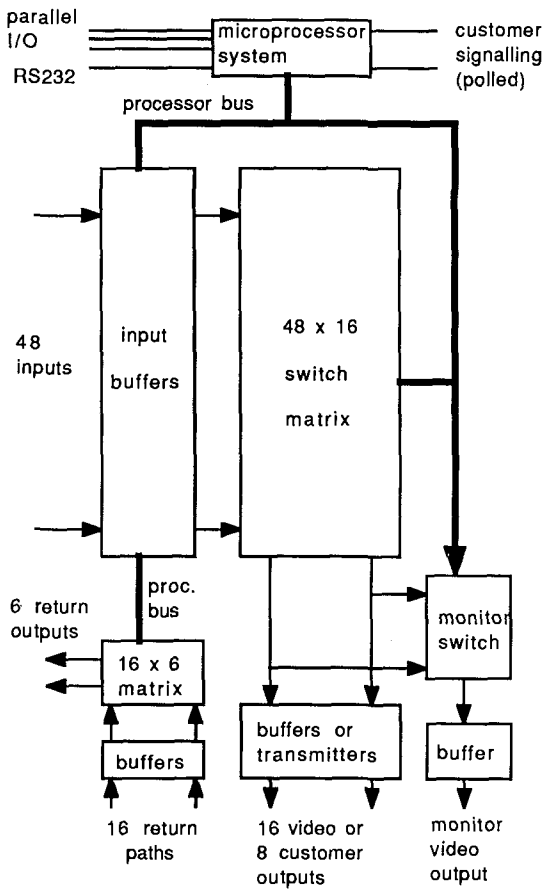

FIGURE 2 - Schematic of the second generation switch card

and all shelf input/output ports brought to the front by interconnect cards.

With the circuitry now more compact an improved heat exchanger arrangement was devised, with all environmental aspects (temperature, humidity etc.) alarmed back to the head-end. Both glass reinforced plastic and stainless steel cabinets can be used, as in Westminster, with the latter having the edge in terms of ease of handling and RF screening.

Customer Service

A new, but compatible customer link was designed so that existing customer equipment could still be used. Plans have been made for an improved set-top unit, somewhat cheaper and with additional display facilities (e.g. message waiting). Greater integration of the coaxial transmitter unit was possible using

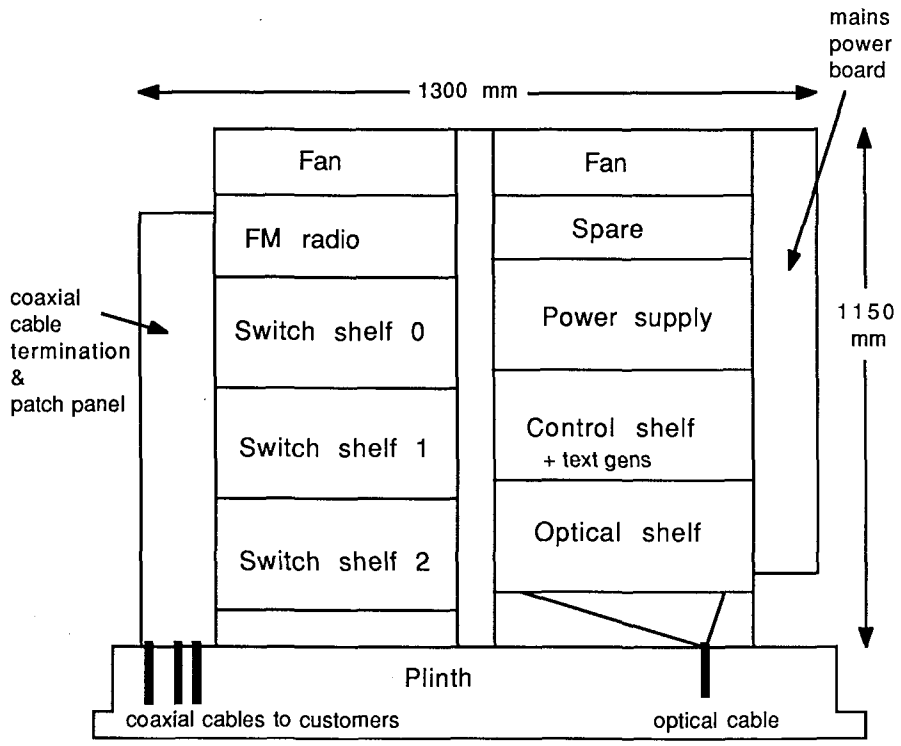

FIGURE 3 - Mark 2 WSP Layout

surface mount technology; one of the above mentioned switch unit daughter boards served 2 customers where the standard option was two separate feeds of 2 TV channels plus the FM radio band. There is flexibility over this arrangement however.

Firstly a version of the board could supply one customer with 4 channels, since there is plenty of spectrum available. A second option is again to use 4 channels on a feed but to share it between two customers, splitting and filtering just outside the home. This gives small savings on the daughter board (shared FM radio and surge protection circuitry) and significant cable and duct savings. This flexibility in customer options needs to be matched by capability in the local control and central administrative software to cater for the alternatives.

Optical Links

One of the clearest changes to consider was to move from multimode fibre working at 0.85μ to single mode fibre at 1.3μ for the primary links. It extends reach without repeatering to 15 km or more and allows greater splitting. The latter means that even with higher laser cost, greater sharing can improve the final link cost. The price differential has in fact now decreased; further 1.3μ devices offer improved performance (noise, linearity) and better reliability.

Frequency modulation is still the chosen transmission technique though this needs constant reviewing. On the one hand digital operation is being examined; PCM devices are getting cheaper and one-bit coding offers a very simple decoder [4]. On the other hand AM operation on fibre is receiving great attention[5]. If this proves viable and the signal can be passed through the switch in its AM form (so it is ready to go straight onto the coaxial cable), then it should lead to lower cost.

In considering the modulation technique to use, it is as well to bear in mind the different TV formats [6] that may have to be carried. NTSC, PAL, and SECAM are still dominant worldwide, but the move to higher definition has started. In Europe the newest format is MAC (Multiplexed Analogue

Components), where each TV picture line is sent as a sequence of :- a burst of data (digital sound), the compressed chrominance signal, and the compressed luminance signal. It offers higher quality by separating the components in this way (so avoiding mutual interaction), and has the facility also to allow a wider screen format. There are several versions of MAC including one termed HD-MAC which is compatible with true high definition TV (HDTV). A 30 MHz bandwidth FM slot or a 140 Mbit/s digital channel will both act as a "universal channel" carrying any of the standard formats or MAC. AM is less robust but requires lower bandwidths; a 16 MHz channel is probably needed for HD-MAC whereas the reduced form D2-MAC can fit in the same 8 MHz channel as the standard formats.

It may seem attractive to put as many channels in a multiplex as practical to share the optical device costs. Dedicated links for video library can sensibly take advantage of recent developments [7] which promise 50 channels or more within a wavelength, using existing GHz microwave technology with broadband lasers. However the higher bandwidths mean lower receiver sensitivity. For a broadcast link it may be just as well to retain optical budget for splitting, and so a multiplex of 16 FM channels per fibre seems appropriate at present, avoiding "putting too many eggs in one basket".

EVOLUTION OF THE SWITCHED-STAR CONCEPT

The Mark 2 SSN represents a good viable cable TV system for deployment now, but it is important to keep in mind potential improvements. Alternative transmission options have already been mentioned above, and there are similarly alternatives in other areas, most obviously for switching. The present card switches baseband signals, the most flexible format if the transmission means is going to be different on either side of the switch. There is however benefit in eliminating signal processing (modulation, demodulation) within the network and having transparent operation, with the one transmission format for primary link, switch, and secondary link (e.g. one of the "universal channels" mentioned earlier).

The FET switching devices have a wide bandwidth, which is however reduced by crosstalk on the card itself. By increasing the bandwidth of the input buffering circuitry the present design has been shown as also able to pass FM signals centred on 25 MHz with good quality. The FM format into the home may become a viable option, since this is used by the Direct Broadcast Satellites and so cheap set-top FM decoders are now on sale.

A different switching technique worth revisiting for fibre based systems is that based on the frequency agile tuner. Now that large multiplexes of channels can be carried on a fibre down to the cabinet, it may be sensible, at least in part, to use frequency translation to put a channel into the required slot on the customer link.

Text generators have been a key element in the SSN. They have made it "user friendly" and enabled extensive information services to be provided at marginal cost. Greater integration with 8 units per card has been achieved for the Mark 2 design, and no doubt this may increase. The question is whether they are now cheap enough to provide on a per customer basis either within the WSP or the set-top unit. There may still remain a role for some centralised text generators feeding into the switch to provide special displays.

Multi-service Networks

The SSN has some restricted ability to provide data, telephony, and even videophone. As standard this is limited to 12 customers per cabinet. However the modularity of the system is such that a switch shelf could be removed (reducing cable TV capacity by one third) and replaced by a "Special Services" shelf. There is spectrum for these to be multiplexed in with the TV channels or of course sent on their own.

The full multi-service provision is being addressed by the BIDS (Broadband Integrated Distributed-Star) development. This is a combination of the switched-star design with a third bay to house a remote telecomms multiplexer. The whole is now termed a Broadband Access Point (BAP), the layout of which is shown in Figure 4. As the network

diagram of Figure 5 shows separate fibre links carry the telecomms multiplex and the video channels on the primary side, there being little value in integrating the two. There is though definite benefit in a single feed to the customer. For the present the cost-effective solution is certainly a coaxial link as used for the Mark 2 SSN. However there is a desire at

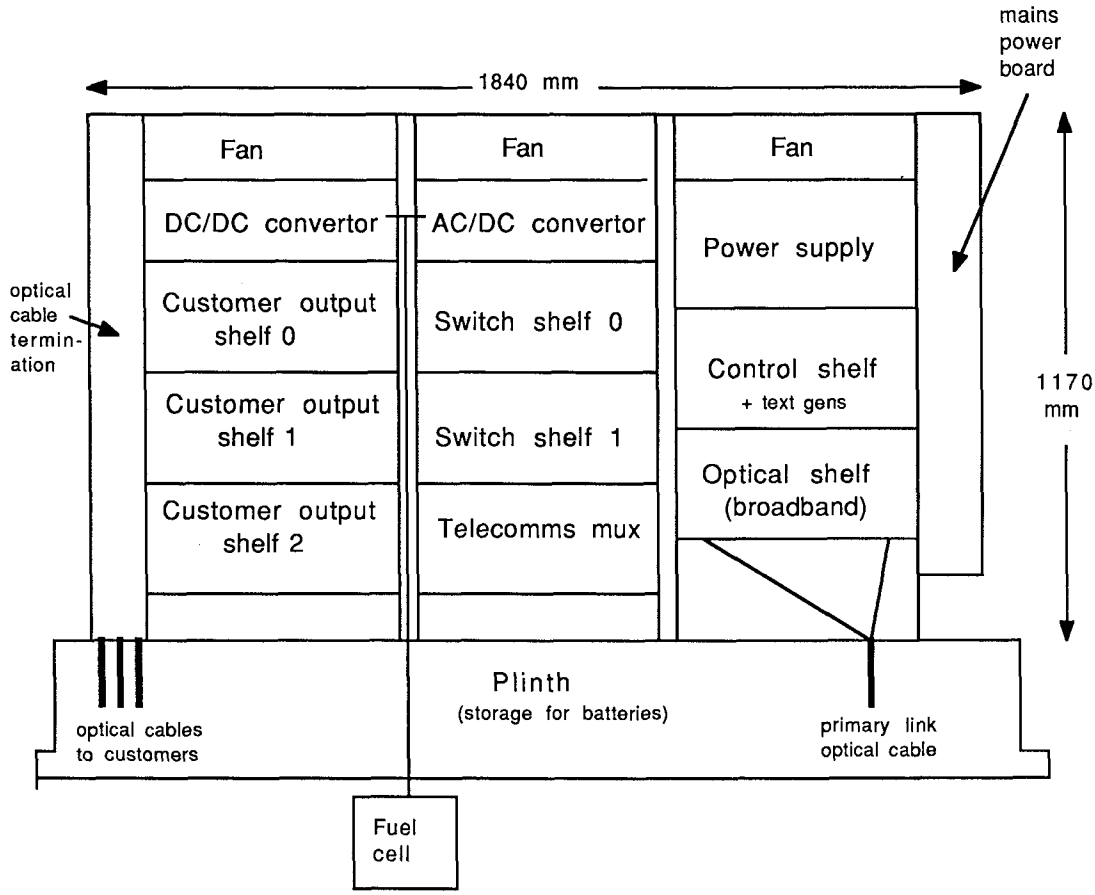

FIGURE 4 - Layout of the Broadband Access Point (BAP)

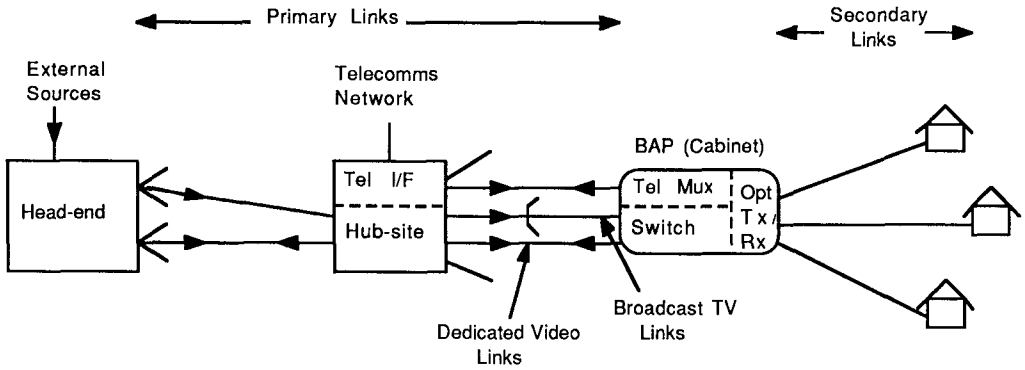

FIGURE 5 - The BIDS Network

some point to reach through to a fibre customer link to achieve a future-proofed network.

This all-fibre option has been chosen for field trial deployment in 1990 to around 100 customers in the town of Bishops Stortford, where the aim is to get practical experience with fibre methods. It will run alongside another local loop trial looking at the passive optical network (PON) technique [8], which is an alternative approach that BT is investigating in parallel.

The fibre based customer link is the subject of substantial development work in order to achieve a low cost solution. This is particularly pertinent to the telephony-only customer, who at least for the present would be in the majority in the UK. The link is short and the bandwidth or bit-rate low, so the task is in many ways very undemanding. However, since the circuitry involved in the copper alternative is minimal, the cost target is very tight. One option is to use a cheap LED/PIN combination packaged with a coupler to match onto a single fibre (bi-directional operation is desirable to keep fibre handling to a minimum). An alternative novel approach to keep costs low is to use a single device as both transmitter and receiver. A laser with the bias removed is a poor, but quite adequate receiver for this particular task. To time share the device in these two roles one can use a burst-mode technique, as developed for copper ISDN (Integrated Services Digital Network), i.e. a sequence of :- a burst of compressed transmitted data, a guard band to allow for transmission delays and devices to change roles, and a burst of compressed received data.

In a switched-star design the broadband services are also not that demanding on the customer link. Two video channels into the home are being provided for the trial, though there is potential for more. To give a simple upgrade to the above telephony link the broadband channels are being optically coupled in; they are transmitted at the same nominal wavelength but are effectively separated within the electrical spectrum (see Figure 6).

Once in the home the fibre terminates at a wall unit close to its entry point. This unit contains all the telephony circuitry which, in addition to local powering, requires battery back-up. The telephony signal is potentially available after the burst-mode circuitry in ISDN form, but for the present is converted to the standard analogue interface. The optical customer link means that some previously exchange-based functions (ringing, line current, etc.) must be provided by the unit in the home.

The incoming broadband signal to the home is decoded by its own optical receiver

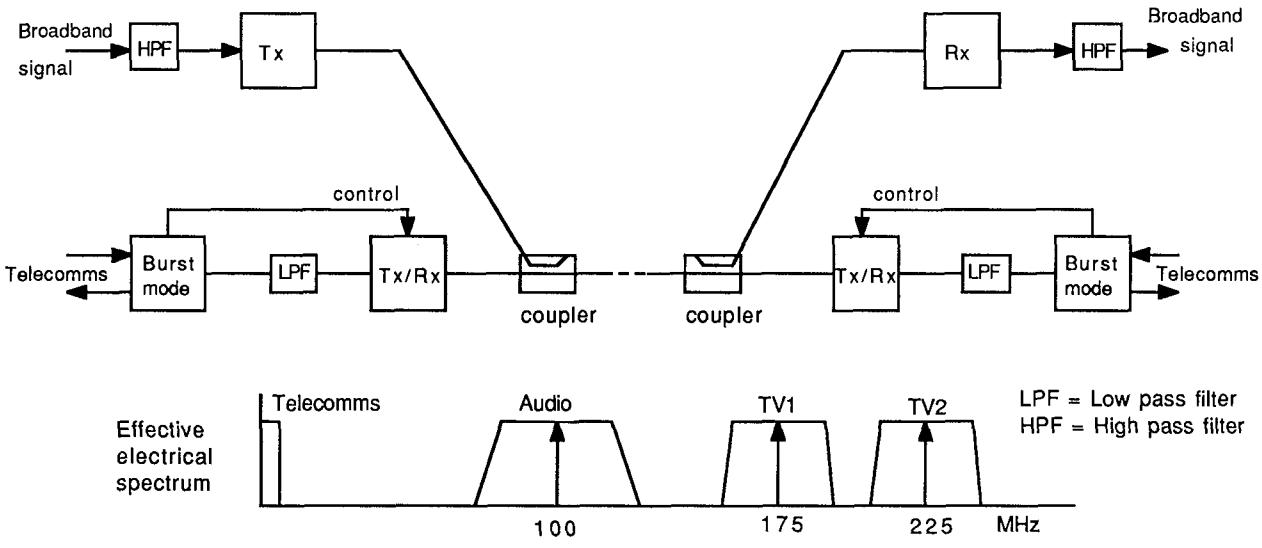

FIGURE 6 - The BIDS fibre customer link and spectrum

co-located with the telephony circuitry in the wall unit, and is then transmitted on by coaxial cable link to a set-top unit. This translates the link signals to the standard TV and audio input formats and receives the customer selections. The signalling associated with channel selection is sent back up the network via the telephony link, utilising the return path it already provides to the BAP.

Video transmission is in FM format all the way through, with the switch card modified to take FM signals. This gives the transparency described earlier, and hence some future-proofing by catering for MAC and HD-MAC. Full high definition TV will require additional measures. The customer link could be extended to add such a channel into its multiplex, but it may be an easier upgrade to add this in on as a separate optical wavelength. While demand is small and HDTV channels few, simple optical splitting in the BAP to broadcast it to a few customers is the simplest option; a switched system may be of value in years to come by which time technology advances will have eased handling the higher bandwidth/bit-rate of HDTV.

CONCLUSIONS

Switched-star has started to make an impact on a cable TV scene dominated worldwide by tree-and-branch. However the provision of additional services beyond entertainment TV by cable TV networks has been far smaller than anticipated in the early 1980s, and this in particular is where switched-star was expected to show benefit. There are signs that this area is taking off now, and it could be that the 1990s will usher in the era of the multi-service network. Certainly if cable TV penetration improves towards the 50% level, as is already the case in parts of the USA and some other countries, then the switched-star approach becomes increasingly attractive because of its simple customer equipment and its centralized resources becoming more effectively shared.

Competing directly with tree-and-branch on TV distribution has forced the switched-star concept to look for low-cost implementation rather than just a technical ideal. This then leaves it in good shape to move into a new era, whether it is as a predominantly cable TV network with strong capabilities for additional services, like the Mark 2 SSN described earlier, or whether it is a total multi-service scheme along the lines of the BIDS scheme.

ACKNOWLEDGEMENT

Acknowledgement is made to the Director of the Research and Technology Department for permission to publish this paper. The author also wishes to acknowledge the many colleagues throughout British Telecom who have been involved with the switched-star development.

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