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OPTICAL WIDEBAND SUBSCRIBER LOOPS AND LOCAL AREA NETWORKS IN THE UK

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Optical technology for Cable TV systems and Local Area Networks is discussed with emphasis on equipment intended for use in the BT Switched Star system. FM optical links, planned for the latter, are described but experience on alternative modulation methods is also presented together with a discussion of multiplexing options. Future developments in Optical Wideband Network design are considered in relation to trends in optical technology. Potential opportunities offered in the long term by monomode based networks are discussed.

INTRODUCTION

In the past two or three years the future for Wideband Subscriber Loops in the UK has been the subject of an intense debate leading finally to the establishment of a British Government policy which will largely deregulate cable TV systems. The intention in the first instance is to install 11 cable TV systems as pilot projects, each serving up to 100,000 homes. These prospects for wideband services to the home have created great interest in the role of optical fibre systems in this area and it is the purpose of this paper to review recent activities in the UK on the development of relevant optical technology. Wider aspects of broadband networks, including overall system planning, non-optical technology, customer services etc, are dealt with in a companion paper to this conference[1]. In addition to Wideband Subscriber Loops there is also great interest in optical technology for Local Area, or Metropolitan Area Networks (LANs and MANs), intended to supply data, computer and video communications to the business customer, and this topic is also briefly reviewed.

OPTICAL TECHNOLOGY FOR WIDEBAND SUBSCRIBER LOOPS

The general system layout currently envisaged for optical wideband local networks in the UK is the Switched Star topology, illustrated in figure 1, and technology is currently being developed for large scale deployment. In this type of network the electrical (baseband) wideband switch points (WSPs) are mounted at street cabinets each of which serve around 300 subscribers. The wideband switches are fed with programme material and other services from a hub site by a primary link which is typically less than 3km but can be up to 5km in length. Secondary links connect the wideband switch point to individual subscribers and these are typically around 200m, but can be up to 1km in length. Superprimary links are also required to link hub sites to a Main Head End and these can be as long as 30km in some locations.

Essentially the Switched Star topology has evolved due consideration of the properties and costs of optical fibres and optoelectronic devices together with the general objectives of providing large numbers of TV channels and advance interactive facilities to each subscriber. Thus, in order to exploit the advantages of the new technology in an economically viable manner, some means had to be found of sharing transmission medium costs between subscribers and this has been achieved by the use of remote concentrator switches (WSPs) placed relatively close to small groups of subscribers. In the longer term, new trends in optical technology could well lead to the emergence of radically different network topologies and system design concepts and some speculative possibilities in this area are discussed in section 4. For some time to come, however, the Switched Star Topology can be expected to dominate practical, engineered systems and relevant optical technology developments underway in the UK are now described below.

A number of technical options have been examined for the transmission of video over the primary optical fibre links (fig 1) and some comparative studies have been made[2]. Amplitude modulation (VSB), although economic on required baseband bandwidth, has been rejected on grounds of inadequate section length, and source linearity and modal noise problems. Digital encoding (into 70Mbit/s streams) has also been considered and, although likely to be the preferred format in the longer term, has for the moment been rejected on grounds of video codec cost and the fact that electrical multiplexes of more than one TV channel would lead to very high bitrates. Various Pulse Time Modulation schemes have been considered[2] and PFM transmission, in particular, has proved to be a reliable technique with excellent section length performance and was successfully used in an early British Telecom Wideband Trial[1]. Various forms of this equipment have been produced, including a duplex option featuring the use of wavelength multiplexing at 850nm and 1300nm[7]. The major difficulty with PFM, however, is that multi-channel operation by electrical multiplexing is not a practicable proposition. This solution has therefore also been rejected in favour of an FM approach in which up to 4 (or in principle more) frequency modulated video channels are multiplexed onto a

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single optical carrier. This technique combines acceptable video performance and bandwidth requirements with the key advantage in a local network context of a multichannel transmission capability. The latter is crucial to system economics in that the fibre provision required for a given network is minimised together with the numbers of fibres per cable, thus keeping splicing and cabling problems within bounds. Work is now under way to develop viable optical transmitters and receivers for multi-channel FM operation and an 850nm laser based version, with 5km range on 3dB/km, 600MHz.km graded index fibre, has been developed by STL[3] to BT requirements for deployment in the primary links of the first BT switched Star systems[1]. Prototype FM optical fibre equipment has also been reported by Plessey[4] for primary link application using a 1300nm edge emitting LED and hybrid PIN/FET receiver with similar performance being achieved.

The final link of the wideband system into the home - the secondary link - is the most cost sensitive part of the system and for this reason a coaxial cable solution with conventional circuitry is planned for initial BT systems[1]. For fibre links to be competitive further major cost reductions are necessary in fibre, cable, and equipment. For the latter, both cheap devices and investment in LSI will be required. Prototype FM optical links, operating at 850nm and capable of carrying 2 TV channels (+ 3 FM radio channels) over 700m of fibre, have been demonstrated by Plessey[4].

In the short term, cascaded primary link equipment will probably be used over graded index fibres to fulfill requirements for superprimary links. This will, however, in most situations, involve repeatered transmission and extra system impairments. Monomode fibre transmission at 1300/1550nm is likely to provide the solution to this problem. Results have been reported for the unrepeatered transmission of PFM video signals over 102km of monomode fibre using a specially developed 1550nm, narrow linewidth laser[8]. More recently, Dakin et al[4] have reported 4 channel FM video transmission at 1300nm over 27km of monomode fibre without the use of repeaters, and over 108km using 3 repeaters.

OPTICAL LAN TECHNOLOGY

Current development activities in the UK span two generations of LAN. Work concerned with the application of optical technology to present day LANs has included an optical Cambridge Ring experiment where a optical fibre section was used to provide a 600m section through a hostile electrical environment to link two portions of a working ring[9]. Recoding of the data allowed the two twisted wire pairs to be replaced by a single optical fibre. A parallel area of activity, which has been underway at Plessey[10], with support from British Telecom, is the development of low cost, high performance, modular data links with a transmission capacity of up to 50Mbit/s. This development is now nearing completion and widespread application of these modules is anticipated leading to lower cost optical LANs. Research into second generation LANs, with bitrates in the region of 100Mbit/s, has centred to date on analysis of possible protocols and topologies. A 100Mbit/s register insertion ring is in an advanced stage of construction and preliminary results have been reported[5]. Two interesting topics under investigation are arbitrarily connected networks[6] and asynchronous code division multiplexing[11].

FUTURE TRENDS

Medium term developments in optical technology for Wideband Local Networks could include the use of wavelength multiplexing to minimise initial network installation cost and allow subsequent uprating in line with demand. This possibility for minimising the amount of fibre needed in a given network could be of major importance in enabling economic solutions to be found to splicing, installation and general cable handling problems in the subscriber's loop context. Another important development could be the development of the "blown" fibre approach to cable installation[12] which may prove of major benefit in reducing installation costs and providing the ability to increase fibre provision in line with service demand.

The prospects for using monomode optical fibre in the superprimary links of Wideband Local Networks have already been discussed. In the long term, however, it seems possible that monomode technology will penetrate further down towards the subscriber thus allowing a network to emerge that does not suffer from the engineering compromises dictated by the graded index fibre. Although the prospects for such an all-monomode network are clearly speculative at this stage, the speed with which monomode technology has moved into the UK trunk network has highlighted the fact that many of the anticipated problems have not materialised. A monomode based network, once installed, would in principle be capable of meeting any conceivable bandwidth demand for future new services and would also allow planar lithographic technologies to be used for any necessary junction devices (power splitters, taps etc) with consequent potential for significant cost reductions in the future. For typical local network distances below the superprimary level (up to, say, 5km), monomode fibre losses would amount to only 2-3dB at 1300nm and even less at 1550nm. Substantial portions of the power budget would therefore be available for exploitation in other ways as illustrated in the Monomode Power Budget in below:

Table 1

Wideband Local Network Monomode Power Budget

Launch power	0dBm
Cable loss (5km, 0.6dB/km including splices)	3dB
Connectors	3dB
System Margin	5dB
Receiver Sensitivity (140Mbit/s)	-46dBm
Remaining power margin	35dB

(13,14)

This remaining margin, for example, could allow the extensive use of optical power splitters and wavelength multiplexing to produce a "tree and branch" or "passive star" network where the optical spectrum is used in the same way as the VHF or UHF spectrum is used at present in coaxial or radio systems. Attractive possibilities exist for this - and other networks - for both direct detection and coherent monomode optical systems. A possible topology is indicated in fig 2 where the amount of splitting is, in principle, consistent with the direct detection power budget of Table 1 and where the numbers of wavelengths required on a single monomode fibre are achievable with "classical" wavelength multiplexing technology. A network of this type could make possible a huge reduction in the total amount of fibre needed for a given system and would moreover eliminate the need for an electrical switch at street cabinet level. In the longer term, the potential offered by the extended power budgets and greatly enhanced multiplexing possibilities of coherent optical systems could be enormous[15] The provision of subscriber return path communication on such a network might be achieved in a number of ways, including, for example, return transmission over the same fibres but with different transmission wavelengths being allocated to each subscriber (perhaps on a switched, traffic basis). Alternatively, subscribers on a cabinet might communicate with the hub via a common wavelength but at a lower bitrate than for downward transmission and using some contention or poling protocol. Other ideas for monomode network design can be expected to emerge for both this and other application areas as optical technology continues to develop and compete successfully with electronics to perform more complex network functions such as switching, routing and multiplexing.

Future effort on optical LANs, beyond that for circa 100Mbit/s systems mentioned above, is now turning to more speculative research on a third generation integrated services LAN. This new type of LAN will be designed from the outset to handle a wide range of different services; voice, video, videotex, etc as well as basic data transmission and switching capability. Target speed for this network is likely to be around 1Gbit/s and ultra fast circuitry will be required (Si or GaAs integrated circuits) to perform access protocol functions. In addition to this trend towards ultra-high speeds, wider developments in optical technology of the kind discussed above for domestic CATV type networks, may well lead in the future to radically different concepts in LAN design.

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REFERENCES

1 Powter, E.J., "Broadband Networks and CATV in the UK", this conference.
2 Heatley, D., IEE Colloq. on Opt. Fibre Local Networks, 2 June 1983.
3 Fuller, D. and Powell, W., ibid
4 Dakin, J. et al, ibid
5 Ghani, F., Davies, P.A., ibid
6 Pung, H., Davies, P.A., ibid
7 Heatley, D., Sympos. on Trans and Comms Techniques for Control and Instrum., Middlesborough, Sept 1982
8 Heatley, D., Electron. Lett., 1982 18, pp 66-67
9 Litchfield, G.W., Hensel, P., Hunkin, D.J., Proc. of the 6th Intern. Conf. on Computer Commun., Sept 1982.
10 Sumerling, G.W., Morgan, P.J., ibid.
11 Davies, P.A., Shaar, A.A., IEE Colloq. on Channel Coding Techniques, London, Feb 1983
12 Reeve, M.H., et al, 9ECOC, Geneva, Oct '83. "The design and fabrication of Monomode optical fibre".
13 Ainslie, B.J., et al, IEEE J Quantum Electronics, Vol QE-18, No 4, pp 514-523, April 1982.
14 "Field Installation of a 31.5 km monomode fibre system operated at 140 Mbit/s and 650 Mbit/s". Stern, J.R., et al, Electronics Letters, Vol 18, No 14, pp 631-632, 8 July 1982.
15 "A review of techniques for long wave length coherent optical fibre systems" Stanley, I.W. and Midwinter, J.E., IEEE Globecom 83, paper 21.1.1, San Diego USA 1983.

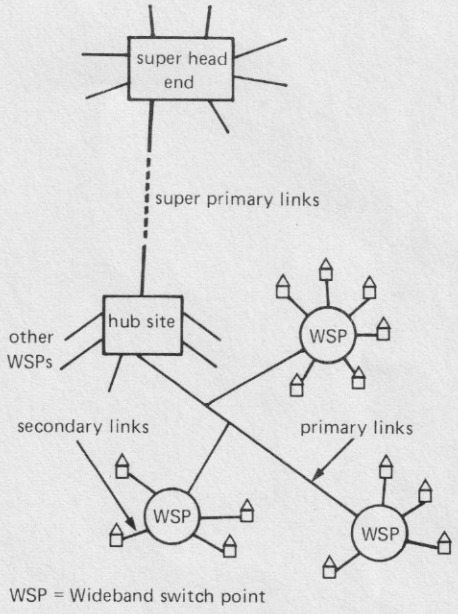


Figure 1 - Switched Star Network Topology

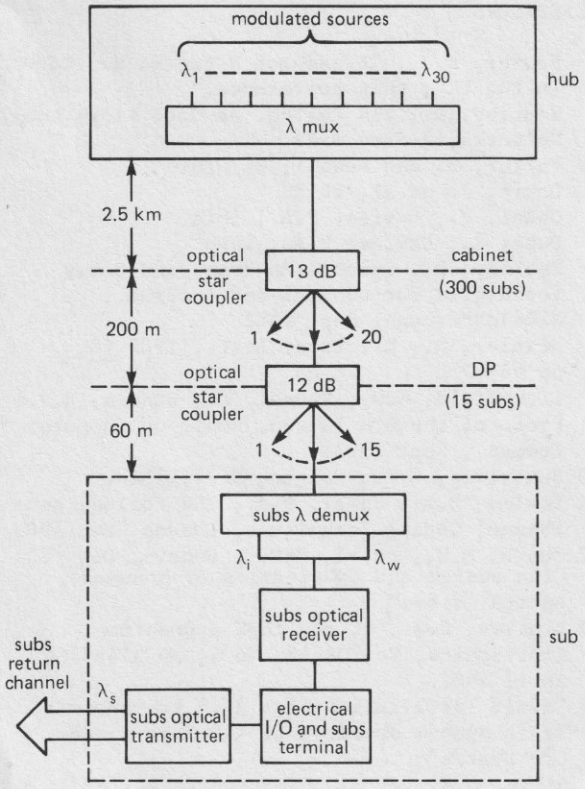


Figure 2 - A Possible Monomode Wideband Local Network Topology