THE PROVISION OF TELECOMMUNICATIONS LINKS FOR THE LEP COLLIDER

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Abstract

The relatively large physical size of the LEP collider complex has resulted in a radically different approach to the provision of the telecommunications links for LEP compared with earlier accelerators. In previous accelerators, telecommunications links in the widest sense (links for voice, data, TV images, special signals, etc.) have generally been provided by using one transmission medium, such as copper cable or optical fibre, for each link. In the LEP approach, many different signals, of widely different types and bandwidths, are multiplexed on to one high-bandwidth transmission medium. Microwave radio, copper cable and optical cable are all used as transmission media in LEP. This paper describes the system which is being installed for LEP, and examines the economic and other advantages which have resulted from the adoption of this approach. Finally, some future trends in telecommunications are examined which have particular relevance for physically large installations such as the newer particle accelerators.

Special Features for LEP

There are several special features of LEP which differentiate it from all previous accelerators, and influence the way in which telecommunications and signal transmission facilities are provided around the collider.

The first is the much greater physical size of the LEP collider. This means a proportionate increase in the length of cables. Also, in some cases it will be necessary to install higher quality cables and more regenerators than have been required for a particular application in the past. Considering that the costs of installed cables are generally increasing, this would lead to a very significant expense if LEP were to be cabled in the traditional way. The large distances in LEP also mean that any new applications which require the installation of extra cables cannot be implemented quickly.

The second difference between LEP and previous accelerators is that there is, in general, no way of routing cables round LEP except in the machine tunnel itself. There are no general-purpose surface trenches or service tunnels for cables. Space for cables in the LEP tunnel is very limited, especially as space has to be left for a possible second accelerator.

Both of these problems - distance and space limitations - could be resolved, to a certain extent, by the use of optical fibre cables. These have very much higher bandwidth than copper cables, and are far less bulky. Unfortunately however, they are susceptible to radiation. The use of present-day optical cables in the LEP ring tunnel is therefore excluded.

The solution which has been adopted for LEP is to multiplex many different signals, for many different applications, on to one cable. This is possible because, with a few exceptions, the available bandwidth of a cable is much in excess of the user's requirement. The cost of the multiplexing equipment is far outweighed by the cost saving due to the reduction in the number of cables.

Multiplexing

Multiplexing is general done in the frequency or in the time domain.

Frequency-division multiplexing (FDM) uses different frequency bands for different signals; filters are used to extract the required signal at an access point. FDM is widely used for cable television distribution systems. Whilst it is particularly suited for that purpose, modems and modulators are available to permit data and voice communication over an FDM system. An FDM system has been successfully used to provide communications facilities for SLAC[1].

FDM is also the basis for older long-distance transmission systems used by PTTs for telephone traffic.

FDM systems require tuned circuits which do not lend themselves readily to large scale integration, which require careful setting-up, and which are prone to drift. This, together with the general trend towards digital transmission, led to a proposal[2] to use time-division multiplexing (TDM) for LEP. The TDM network supports links mainly, but by no means exclusively, for the LEP control system[3].

The principal services carried by the LEP TDM network are:

a) the LEP machine network (token ring)
b) the LEP services network (token ring)
c) the general CERN network (Ethernet)
d) links for the digital PABX telephone exchange
e) the SPS/LEP general machine timing system
f) the LEP beam synchronous timing system

The only important systems not carried by the TDM network are a dedicated link for RF synchronization, and the the TV distribution system which, for the moment, uses FDM.

Time-Division Multiplexing

The time-division multiplexing technique has been widely adopted by PTTs and telephone administrations around the world, in order to multiplex many pulse code modulated (PCM) voice channels on to one high-speed digital link.

In time-division multiplexing, a number of bits is taken sequentially from each of the input ports (known as tributaries) and applied at a higher rate to the output port. The converse operation takes place at the demultiplexor. This is illustrated in Fig. 1.

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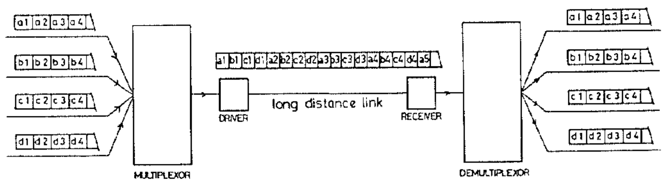

Fig. 1 Simplified TDM System

In a real system, the situation is far more complex. Extra bits are required in the output stream for various purposes, such as to allow for synchronization and for deviations from the nominal bit rate of the tributaries (these deviations must be transmitted across the link if data are to be reproduced transparently at the destination). This means that the bit rate at each level of the hierarchy is slightly higher than the sum of the tributary bit rates.

The bit rates and electrical interfaces at multiplexor ports, as well as the multiplexing algorithms, have been defined by the CCITT[4] and by other standardization bodies.This enables multiplexors from different manufacturers to be connected together.

The systems used in various parts of the world differ in detail. Table 1 summarizes the hierarchy of bit rates recommended for use in Europe and in North America.

Table 1 Recommended Bit-rates

Europe:	2.048 Mbit +/- 50ppm
	8.448 Mbit +/- 30ppm
	34.368 Mbit +/- 20ppm
	139.264 Mbit +/- 15ppm
N. America:	1.544 Mbit +/- 50ppm
	6.312 Mbit +/- 30ppm
	32.064 Mbit +/- 10ppm
	44.736 Mbit +/- 25ppm
	97.728 Mbit +/- 10ppm

Time-division multiplex equipment following the CCITT Recommendations is now available from a large number of manufacturers. As a result of the very large quantity of this type of equipment required by PTTs and telephone administrations, and of the highly competitive telecommunications market worldwide, the cost of the equipment is relatively low. Also, the equipment, being built to PTT specifications, is extremely reliable. This is particularly true for second generation equipment which makes heavy use of custom LSI circuits and has very low power consumption.

Interface Equipment

The use of multiplexing and the adoption of standard interfaces (to CCITT Recommendation G.703 in the case of LEP) does imply that, in some cases, interface equipment will be required to convert from the standard interface to that required by the user.

Fortunately, the use of G.703 interfaces is becoming quite widespread, so interface conversion is not required in many cases. Equipment already available with G.703 interfaces includes digital telephone exchanges, television transmission equipment (although this is too expensive to be used for LEP at this time), and bridges for the IEEE 802.3 (Ethernet) local area network. Bridges and gateways for the IEEE 802.5 (Token Ring) local area network have recently become available with G.703 interfaces.

In several cases for LEP, CERN has subcontracted to industry for the design and production of special interface units. These enable signals for the LEP general machine timing[5] and beam synchronous timing systems to be transmitted across TDM links.

The LEP Communications Network

The Physical Links

No general-purpose cableways are available between LEP sites, other than the LEP tunnel itself. Synchrotron radiation levels during LEP operation preclude the use of optical fibre cable in the tunnel. However, various civil engineering projects in the area have provided the opportunity to install high-density polyethylene tubing over certain routes, permitting installation of optical fibre cables at a later date. These civil engineering projects included a road improvement scheme to construct a bypass road for the village of Prévessin, and the installation of underground high-voltage power distribution cables in the area. Optical cables, containing a mixture of multimode and single-mode fibre, have now been installed in these tubes, between the LEP control centre (PCR) and points 1, 2, 32, 6 and 8 of LEP. The optical links are generally operated at the 34 Mbit/sec rate, although two links will soon be upgraded to operate at 140 Mbit/sec. This network of optical fibre links has been supplemented by a number of short links on CERN's Meyrin and Prevessin sites. Approximately 50 km. of optical cable has now been installed, containing a total of nearly 1000 km. of fibre.

In order to provide a communications service to the remaining sites (points 33, 4, 5 and 7), to the two alcoves between each site, and to certain underground areas of LEP, a coaxial cable system has been installed in the LEP tunnel. This will provide alternative physical routing for security purposes. The coaxial cables conform to the CCITT Recommendation G.623, and are generally operated at the 34 Mbit/sc. data rate. The link from point 32 to point 4 will be operated at the 140 Mbit/sec. rate, to compensate in part for the lack of optical fibre cable to point 4.

A low speed (2 Mbit/sec) microwave link has also been installed, linking the Meyrin site with point 4 of LEP. This was done to provide a provisional telecommunications service to that site.

TDM Stations

TDM stations are or soon will be installed at each surface site of LEP and the SPS, in each alcove of LEP, and at various other locations. There are 45 stations in all.

Figure 2 shows how a simple TDM station might be laid out. Most of the TDM stations required for LEP will be considerably more complicated.

Cost Analysis

The supply of multiplexing equipment, line terminals, interface equipment, and the supply and installation of optical and copper cable have largely

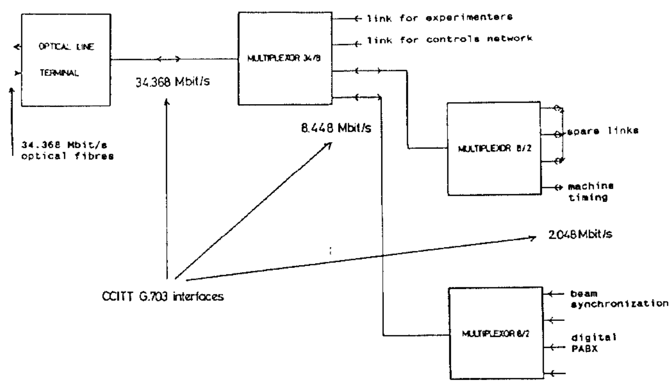

Fig. 2 Layout of a TDM Station

been completed. It has been confirmed that, for an installation as extensive as LEP, the cost saving obtained by the use of multiplexing techniques is quite substantial. It is clear that the economies depend on the length of the link and the number of signals transmitted across the link, as well as other factors. Figure 3 compares the costs, in this case over optical fibres over a distance of 10 km., the multiplexed link operating at the 34 Mbit/sec. rate.

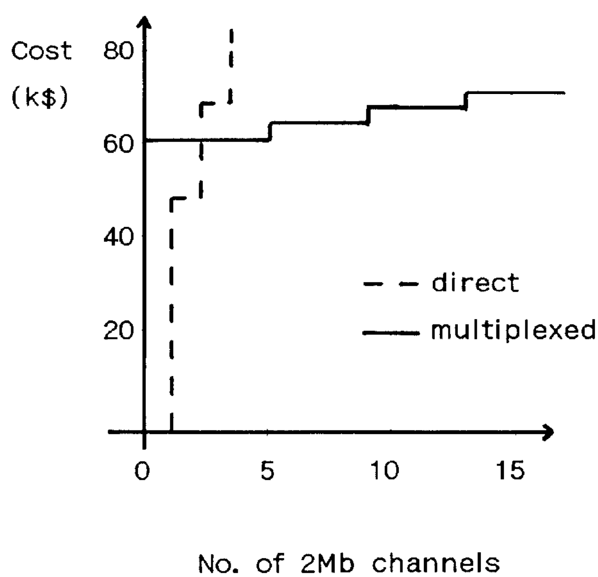

Fig. 3 Cost of Multiplexing vs. Direct Links

It is clear that more and more equipment will be produced with CCITT G.703 interfaces. One particular area which is of great interest is the development of equipment to transmit TV signals over TDM links. Studio quality equipment exists for 34 and 140 Mbit/sec., and codecs are available for 2 Mbit/sec. (these are used for long distance videoconference links). All of this equipment is currently prohibitively expensive, but prices are falling rapidly.

Another development with potentially important applications for physically large installations such as LEP is FDDI (Fiber Distributed Data Interface). This uses fibre optic technology, operating at 100 Mbit/sec., organized as a ring. It could in itself be used as a multiplexing system, but a more interesting topology would be where FDDI and TDM coexist. FDDI would be used as a "backbone" for the various data networks and, over short, low bandwidth routes, could carry G.703 services at 2 and 8 Mbit/sec. TDM links would be used over long or high bandwidth routes, and where optical fibre cables cannot be used because of radiation. In these cases, FDDI would be one of the services carried by the TDM links.

It remains to be seen, however, whether industry will ever produce FDDI equipment at prices low enough to compete with the purely TDM approach.

Conclusions

The use of time-division multiplexing for non-PTT applications is rapidly advancing throughout the world, and the choice of equipment available with standard CCITT interfaces is increasing equally rapidly. In the accelerator environment, the cost savings which can be achieved by multiplexing many signals on to one physical link are especially attractive when the distances involved are relatively large, as in LEP. Mass production of terminal equipment and of the multiplexors is bringing their price down, whereas the costs of installed cables are increasing. Thus the benefits to be gained by the use of multiplexing will increase in the foreseeable future.

Acknowledgements

Many people have made significant contributions to the design and implementation of the digital communications infrastructure. Particular mention must be made however of K. Kohler who has been responsible for much of the specification and planning of the network, and of B. Amacker who has been responsible in large part for the installation.

References

[1] W. Struven, "Mixed Video/Data Network using CATV Techniques", PEP-Note-354, SLAC, Stanford, California 1981.

[2] P. Wolstenholme, "An Integrated Digital Communications System for LEP", LEP Note 196, CERN, Geneva 1979.

[3] C.R.C.B. Parker and the SPS/LEP Accelerator Controls Group, "The Design Principle and Current Status of the LEP Control System", these Proceedings.

[4] CCITT "Red Book", Fascicle III.3, International Telecommunications Union, Geneva 1985.

[5] C.G. Beetham et al., "Overview of the SPS/LEP Fast Broadcast Message Timing System", 1987 Particle Accelerator Conference, Washington D.C.