A MULTIPLEX CARRIER SYSTEM FOR REMOTE CONTROL IN LARGE ACCELERATORS

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(Presented by G. BRIANTI)

The cable network for remote control in accelerators with energies in the range of $10^{11}$ eV and above has to be considered very carefully because of its economical and organisational implications. In fact, there is some fear that the total cable length and cost may increase even more quickly than in direct proportion with the radius due to the larger number of elements to be controlled in addition to the (linearly increasing) average distance to be covered.

There is some evidence that the overall cost may be reduced, the installation time shortened, and greater flexibility obtained by the introduction of multiplex techniques, namely the transmission of many signals (generally more than one hundred) along the same pair of wires. Restricting oneself to the cases of simple control and interlock functions (ON/OFF) and of slowly varying analogue signals, for which multicore cables are normally used, an economic comparison between the direct-wire and the multiplex techniques is shown in simplified form in Fig. 1.

For given types of installation and of transmission one can determine a critical distance $l_c$ above which multiplex is more economical than direct-wire. The same diagram suggests another interesting property of the multiplex solution, namely that the transmission cost is almost independent of the distance, or, in other words, the cost of the actual cable network is comparatively negligible.

This has a series of consequences, the most relevant of which are:

1. The bulk of the investment is in the form of transmission electronics, which can be moved from one place to another with very little effort, and for which only a centralised reserve is necessary.

2. The overall cable quantity being quite small, one can afford to install in the first place multiplex cables anywhere an exchange of signals is likely to occur, thus avoiding lengthy installations during the machine exploitation period. Obviously the transmission electronics, which represents the expensive part, can be installed (very quickly) only where and when necessary.

Many multiplex systems, using the time division or the frequency division principle, are available commercially. In general with these systems transmission and/or reception are «concentrated» in centres, from which normal direct wires go to the individual equipment. We think that, in order to be really useful, a multiplex system for accelerators and their experimental areas should be as «distributed» as possible, that is to say capable of accepting the insertion of information anywhere along the cable and its reception anywhere else. Since little has been done along these lines by commercial institutions, we have developed an experimental system of this kind at CERN.

SYSTEM DESCRIPTION

1. ON/OFF Functions, The signal to be transmitted, in the form of a closing contact, switches on a crystal-controlled transmitter of a given frequency (see Fig. 2). A selective crystal-controlled receiver, on the same frequency, detects the signal and operates a built-
Fig. 2. CERN multiplex system.
in output relay which remains energized for as long as the appropriate frequency is present on the line, an ordinary pair.

The minimum acceptable keying speed of 10 pulses/sec and the characteristics of available quartz crystals determine the operating frequency range (200—400 kHz). Up to 800 individual frequency channels can be accommodated in this band with conservative channel separation (250 Hz). The receiver selectivity is very sharply peaked on the appropriate frequency. Any receiver «sees» the neighbouring channels through the following attenuations:

- $f_0 - 250$ Hz ............... 60 db
- $f_0 + 250$ Hz ............... 100 db

Reliable bidirectional communication is possible at such frequencies for distances up to 3 km using normal plastic-insulated mains-type cable. Such a cable can at the same time supply the circuits with dc power (30 V). The transmitter takes 2 mA and the receiver, including the output relay, 30 mA, when ON.

Several power supplies can be connected to the line in parallel.

As is also indicated in Fig. 2, for maximum flexibility the cable should be laid as a trunk line passing near all equipment likely to require interchange of control information. The necessary number of self-contained transmitters and receivers are then installed in the equipment itself, and connected to the main line by means of a stub cable which should not, for correct functioning, be longer than 50 m. The main cable is fitted, at regular intervals, with junctions for the stub cables. It is possible to insert several tens of such junctions quite safely on the same trunk line.

The circuits are designed for high reliability and stability against important changes in environmental conditions, e. g. for a temperature excursion from $-20^\circ$C to $+50^\circ$C to take into account possible outdoor installations and the insertion of the transmission circuits directly inside working equipment. The choice of the crystal type thus becomes rather important:

![Diagram](image-url)
we have used so far the $DT$ cut which provides maximum stability against temperature variations. The crystal is contained in a standard can, small enough to be mounted on a printed board.

The receiver sensitivity is such as to give reliable operation at less than 5% of the transmitter output and no adjustment is needed for cable attenuation. Various tests have been carried out using an existing cable network around the CPS, and the system proved to be quite insensitive to noise especially of the pulse type so frequent in accelerators.

2. Analogue Functions. As schematically shown in Fig. 2, slowly varying dc signals can also be transmitted through the same cable. This is achieved by adding to a normal transmitter a voltage-to-pulse-period converter which turns on the transmitter for periods of 50 ms, spaced by an interval varying between 150 and 650 ms in direct proportion to the dc input voltage. The input voltage is 0 to $-10$ V. The receiver converts the signal back to dc voltage (0 to $-1$ V; 0 to $1$ mA). Fig. 3 shows the block diagram together with the principle of operation.

CONCLUSIONS

With the present prices of electronic components and control cables, the critical length $l_c$, above which the multiplex system described becomes competitive with direct-wiring, is about 800 m. The situation may well evolve in favour of the multiplex system, since the prices of electronic assemblies do not show as fast a rate of increase as those of cables and of installations labour. When rapid changes in the layout are required, such as in experimental areas, the proposed multiplex system is much superior to direct-wiring, effectively reducing the critical length $l_c$ on grounds of convenience. A full scale experimental set-up is being installed around the CPS for final testing. The trunk cable reaches all important control centres and experimental areas.

DISCUSSION

M. Plotkin

Would you rely on this system for interlocking information involved in personnel safety?

G. Brianti

I do not know. That is why we are building a full scale installation for life testing.

R. B. Neal

Will you comment on the relative advantages and disadvantages of the CFRN system in comparison with a time-division multiplex system?

G. Brianti

The time-division system is superior for «concentrated» systems (big. transmitting and receiving centres). This system is superior for «distributed» systems, since it does not need supervisory equipment for each channel.

S. M. Rubchinski

What percent of the cables on the accelerator may be replaced by the proposed system of multiple connections and what percentage of the total cost of the entire cable supply system will consist of replaceable cables? The latter figure is important because the most expensive cables of the proposed communication system are impossible to replace.

G. Brianti

1. About 60% of the cable cost in the CERN PS is represented by simple on off signals. This percentage might increase in large machines, because it will be difficult to transmit fast signals over kms. and one would use more than at present IN TOLERANCE/OUT OF TOLERANCE Techniques.

2. Price is 60 dollars/channel at present for an 100 channels experimental installation.