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TUNNEL RADIO COMMUNICATIONS SYSTEM AT STANFORD LINEAR ACCELERATOR CENTER *

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SUMMARY

A unique single frequency, dual daisy chain tunnel radio communication system has been developed for use in our new Positron-Electron Storage Ring. Communications are possible between portables in the underground ring and between a portable in the ring and all control rooms on the site. The system is designed as a wide band facility and therefore can carry many simplex and duplex transmissions. This system utilizes TV twinlead as a distributed antenna and repeater amplifiers to cover more than 7000 feet of underground tunnel. The design philosophy, tests and initial design will be discussed and contrasted with the final implementation of the system. Future uses of the system will be discussed.

With the completion of the new 8000 foot Positron-Electron Storage Ring at Stanford Linear Accelerator Center (SLAC), radio communications to and from the ring and the various support buildings and the control room must be established (Fig. 1).

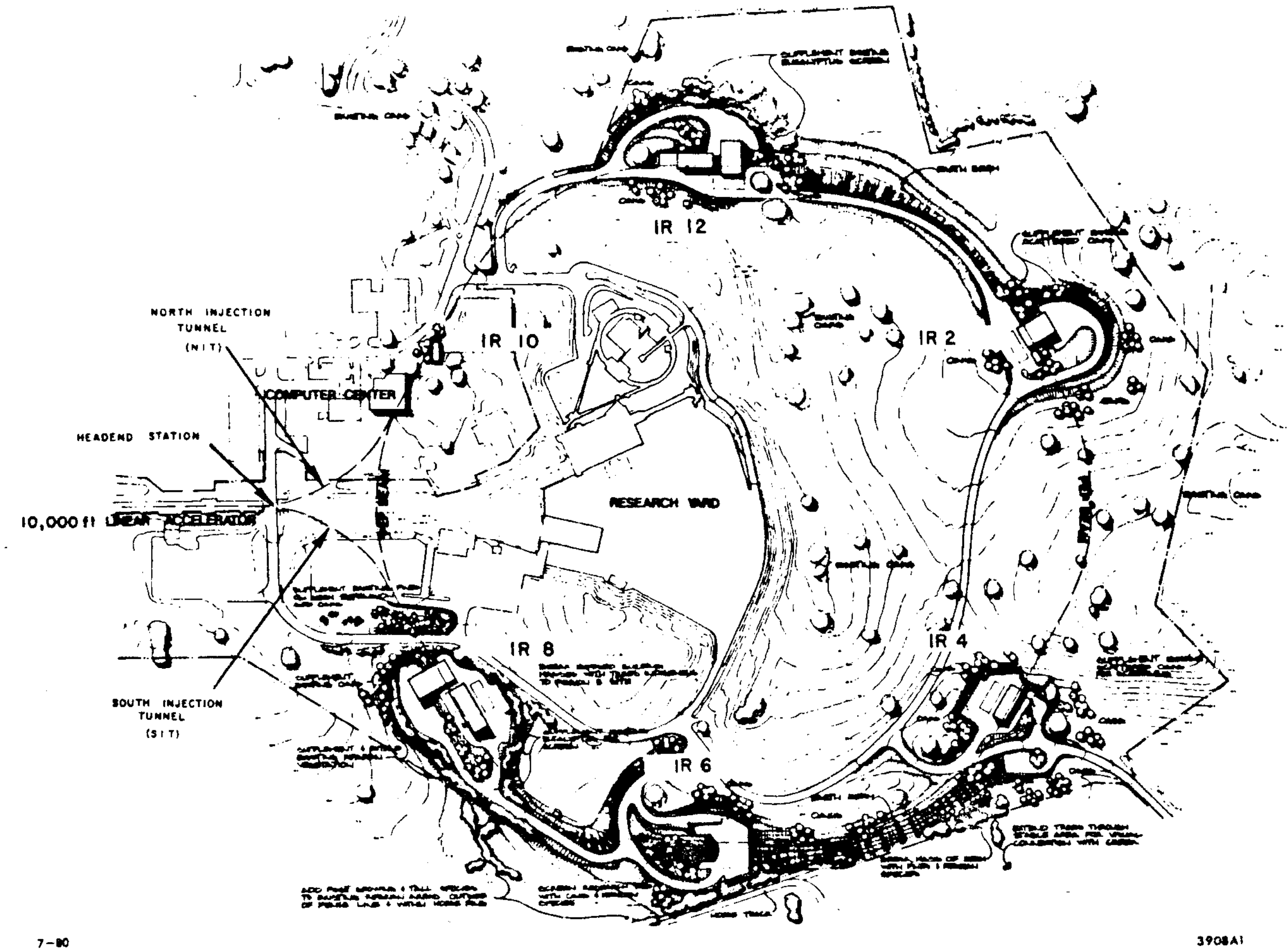

Figure 1.

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All of the usual facilities including telephones and wire line audio intercoms as well as paging are available, but for safety and maintenance requirements, good reliable radio communications must be available throughout the ring. The storage ring is one of several experiments which use the two-mile linear accelerator as an injector. Site radio communications have been in operation for many years, but VHF radio communications into and out-of underground tunnels had been a difficult problem until we installed passive antenna systems. These passive systems have been found usable, but better communication is desired. When the storage ring tunnel was near completion, tests established the fact that portable-to-portable operation was only possible around the tunnel for a distance of approximately 100 feet. Passive antennas were tried, but due to the tunnel size (approximately 10 feet in diameter) and construction (sprayed-on cement) the tunnel was found to be a very poor waveguide. Some better way of propagating VHF signal had to be found.

The author found references to "leaky feeder"[1] distributed antenna systems which had been developed in England and had been used in the British coal mines and in tunnels and mines on the continent (Fig. 2). These systems were operated as duplex (two frequency) systems using a "leaky" coaxial

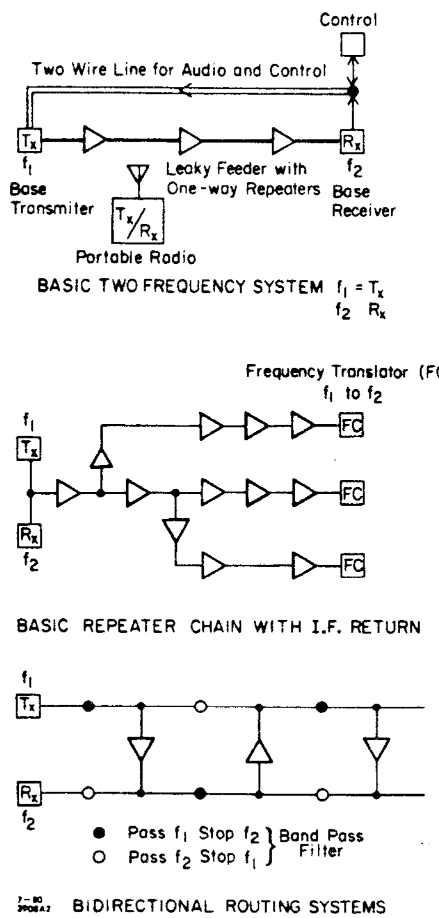

Fig. 2. Some typical two frequency systems.

cable as a distributed antenna. The radio system at SLAC had been established as one frequency simplex systems on four VHF channels. Our fire service, which is provided to us by a nearby city uses a two-frequency repeater VHF system.

The cost of leaky coax (slotted coaxial cable)[2] is over $2/foot (not including installation) and we need about 16,000 feet to cover our ring. We decided to investigate ordinary TV twinlead as an alternate. By definition, a parallel line feeder does not radiate, but experience had proven that it does. Since twinlead, in principle, does not radiate, no "leakage" data could be found. In fact, data on attenuation when the cable was supported near a concrete (lossy) wall was not available either, nor was coupling between two adjacent cables known, so we installed two runs of 300 ohm twinlead[3] with adjustable spacing in one of our unused tunnels and proceeded to measure these parameters.

We found that the attenuation at 160 MHz was about 10% higher than the free space value when spaced about two feet away from the tunnel wall and properly matched and terminated (Fig. 3). We also

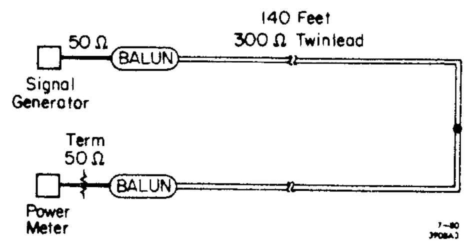

Fig. 3. Attenuation measurement setup adjacent to cement tunnel walls.

found that the coupling loss (as measured about 5 feet away from the above cable) using a VHF portable 1W transceiver was about 60 dB (Fig. 4).

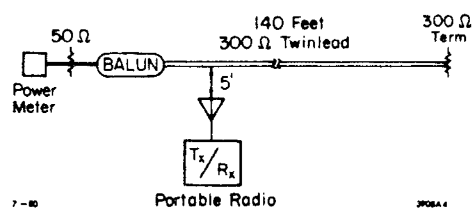

Fig. 4. Coupling loss measurement from portable to twinlead.

We also discovered that two 140 foot runs of twinlead spaced 3 feet apart had a coupling loss of about 45 dB (Fig. 5).

In order to further verify the last measurement, we set up a bidirectional amplifier test (Fig. 6) and found that if the amplifier gain was made less than the coupling values found, that a stable system would result. Terminating and

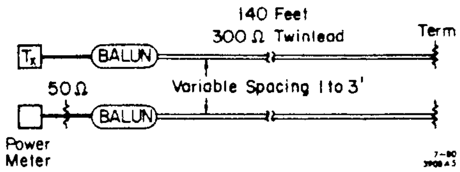

Fig. 5. Coupling measurements between two twinlead lines.

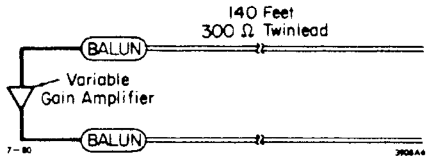

Fig. 6. Measurement to verify twinlead-twinlead coupling.

unterminating the line proved to make negligible differences in these test results.

In parallel with this work, we proceeded with amplifier tests based on the TRW CA2800 series of wide band amplifiers. Amplifiers with gains of 17 and 33 dB were tried, as well as multiple combinations of these units. These amplifiers have input and output impedances of 50 ohms so a suitable coaxial balun was used to transform the impedance up to 200 ohms which resulted in a reasonable match to the 300 ohm twinlead.

The coax balun was adequate for our limited frequency range of 150 to 170 MHz. Since attenuation of the twinlead increases with frequency and we wished to maintain a unity gain system, we utilized inexpensive TV hi-pass filters at the input to each amplifier to provide some equalization. The 150 to 170 MHz bandpass at the "head end" was determined by a suitable multipole coaxial filter.

We now had all of the measurements and test results so we proceeded to design a workable system. Since we were limited to simplex single frequency operation, we felt that a dual repeater-chain repeater system would be suitable for our requirements (Fig. 7). This figure shows the layout of the initial system as installed in our storage ring. The system was composed of about 4000 feet of twinlead. two 16dB repeater amplifier at the midpoint and the "head end" filters, amplifiers and receivers. The amplifier spacing was determined by calculating the loss of the twinlead and placing the amplifiers at a point which would just offset this loss. In our case, a convenient mounting area was found about 800 feet from the "head end" so the amplifier gain was padded to match the cable loss. This was found to be non-critical.

Since the temperature differential in the ring from day to night and from winter to summer is small, temperature-gain compensation was not included in the repeater amplifiers.

The system was initially set up to retransmit a portable located in the ring. The audio was recovered at the "head end" and applied to the wireline which keyed the base transmitter. We found that base transmitter was held in the transmit mode when the portable was unkeyed. Sufficient signal from the base transmitter was coupled, in the tunnel, to the outgoing receiver line to lock up the system. With the ingoing signal line disconnected, the same situation occurred. There was enough leakage into the ring from passive antennas, i.e., cables, water pipes and vacuum pipes, to cause lockup. The problem was solved by not retransmitting the portables from the tunnel, but instead, feeding audio via the wire line to the control rooms. Retransmission would have been useful, in that a portable in the tunnel could communicate directly with a portable adjacent to, but outside of, the tunnel. To solve this problem, we intend to couple some signal from the ring cable system to a passive antenna located just outside each experimental area.

The initial system also contains a receiver antenna relay which opens whenever a control room transmits. This disables the second source of audio on the transmit pair which tends to distort the transmitted audio from the control room.

The final system to be installed in the ring is shown in Fig. 8. Two receivers will be included to drive each of two base networks (one for operations and one for security). A link is also shown so that communication with the local fire department will be possible.

The final system will carry six frequencies simultaneously. We are receiving requests to transport other signals around the ring to control room for such systems as magnet over-temperature and other monitoring/control functions. The incremental cost of adding additional facilities is relatively small once the basic system of twinlead and repeater amplifiers has been installed. We feel that the system as planned will adequately serve our needs and hopefully may be applied in other similar situations in the commercial and industrial sector.

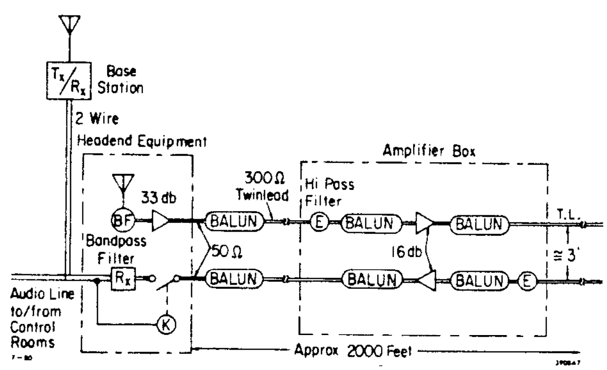

Fig. 7. System as installed in PEP tunnel for initial tests.

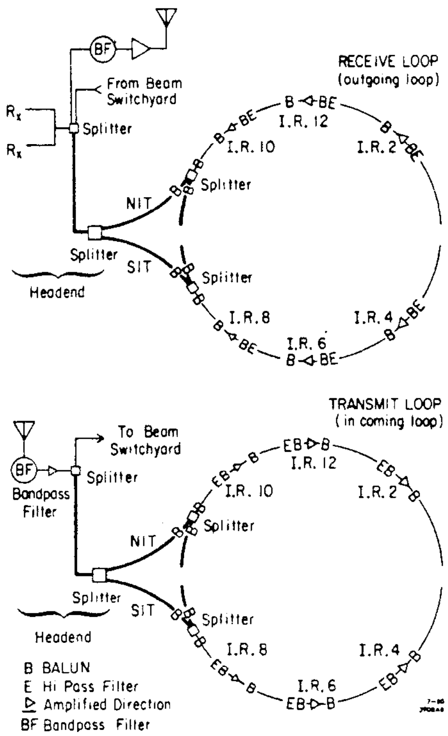

Fig. 8. Final system shown as two separate loops.

ACKNOWLEDGMENT

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REFERENCES

1. D. J. R. Martin, "A General Study of the Leaky Feeder Principle," Radio and Electronic Engineer, Vol. 45, p. 205, May 1975.

2. Andrew Radiax Cable, Andrew Corporation, Orland Park, Illinois 69462.

3. Belden #8275, 300 ohm twinlead.