The T1 Carrier System

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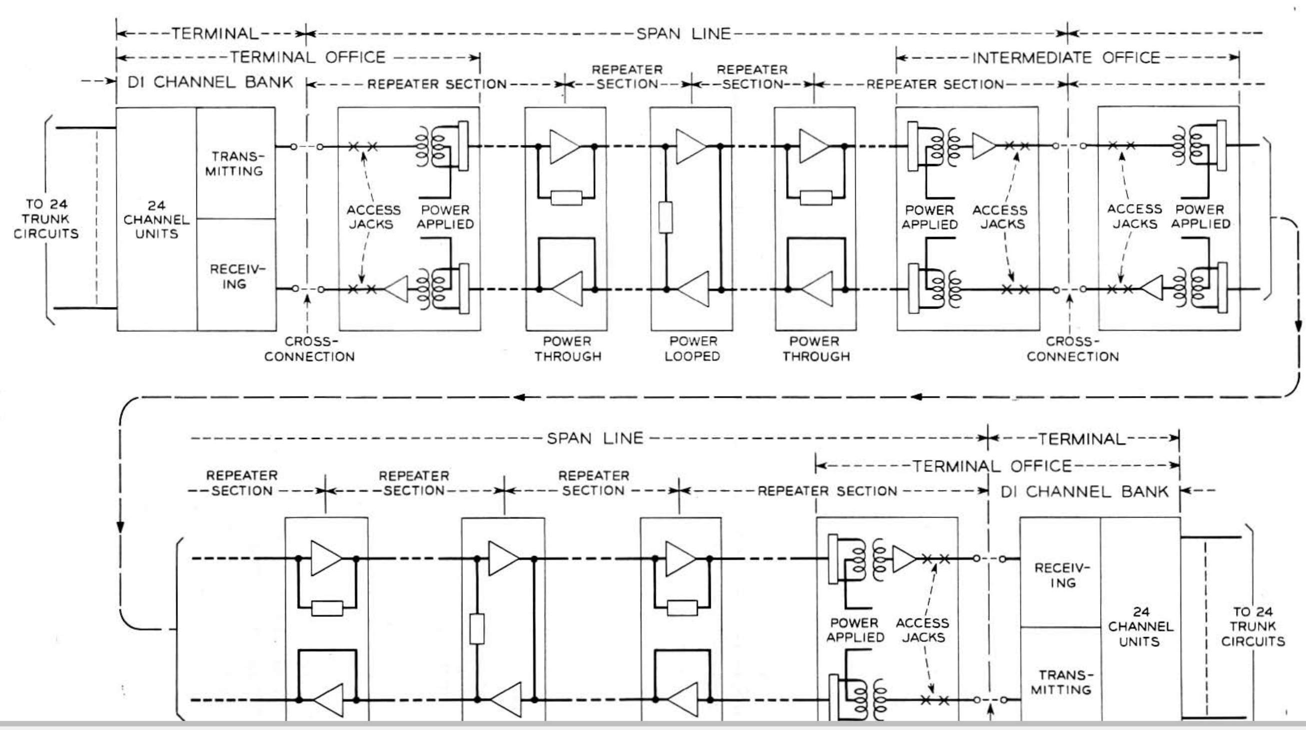
T1 carrier provides 24 voice channels by time division multiplexing and pulse code modulation (PCM). Each voice channel is sampled 8000 times a second and each sample is coded into a 7-digit binary word. Provision for signaling and synchronization raises the pulse repetition rate on the repeatered line to 1.544×10^6 pulse positions per second. The bipolar pulse train out of the terminals is transmitted over pulp, paper or plastic insulated paired cables by the use of regenerative repeaters. For 22-gauge cable pairs, repeaters are normally located at 6000-foot intervals.

The system has been designed for low cost and is being widely applied on many trunks interconnecting switching units within metropolitan areas. Western Electric Company manufacture of T1 began in 1962 and about 100,000 channels are now in service throughout the Bell System.

I. INTRODUCTION

The rapid expansion in the telephone network that has occurred since 1950 has stimulated a thorough investigation of methods for reducing the cost of additional trunk facilities. The desire to improve the quality of telephone service has given additional emphasis to studies of improved trunking arrangements. One way to obtain additional trunks for growth is to increase the utilization of existing conductors by using them to transmit more than one voice signal. For such an arrangement to be economical, the savings from the more efficient use of the transmission line must more than offset the cost of the terminal equipment required to multiplex a number of voice channels. On trunks between cities, carrier systems (systems transmitting a number of voice channels) have been economical for many years. The lower terminal costs achieved in the T1 carrier system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have made carrier systems economically attractive for the longer trunks between local offices within a city. In a large number of situations the T1 carrier system will prove-in over voice frequency circuits for distances longer than 10 to 12 miles. Satisfactory performance is achieved over lengths up to 50 miles, and the performance over longer lengths is being evaluated.

A major contributor to the low terminal costs in T1 is the economy with which the signaling information required to control the switching equipment can be transmitted in a digital system. In most carrier systems the digital signaling information is converted into analog tones for transmission. In a digital system the signaling information can be added directly to the coded speech samples with the saving in digital-to-analog conversion of the signaling information. Additional economies are achieved by an instantaneous compandor shared by a number of channels rather than individual channel syllabic compandors as used in some carrier systems.

The T1 carrier system now being manufactured by the Western Electric Company is a refinement of the experimental PCM system described in the January, 1962, issue of this Journal.[1-5] The basic system plan and the fundamental circuit approaches remain unchanged.

It is convenient to consider a PCM system as being composed of two parts — a PCM terminal and a digital transmission line. For regular telephone trunks, the PCM terminal for the T1 system is the D1 channel bank. The D1 channel bank combines 24 voice channels in a time division multiplex and encodes them in a scale of 127 quantized amplitude levels (63 steps positive and 63 steps negative from zero) into a single pulse train. In the receiving direction, it reconstructs the analog speech signals from the incoming pulse stream. Other terminal arrangements are being provided which prepare wideband data signals for transmission over T1 repeatered lines. These terminals are discussed in a companion paper.[6]

The T1 repeatered line consists of cable pairs equipped with regenerative repeaters at appropriate spacings. At the end offices, and at intermediate offices along the route, each repeatered line passes through an office repeater which provides a regenerator for the incoming signal, powering circuits for the line repeaters, access jacks for patching, monitoring jacks, and cross-connection points for route flexibility. A block schematic of a typical T1 carrier system is shown in Fig. 1.

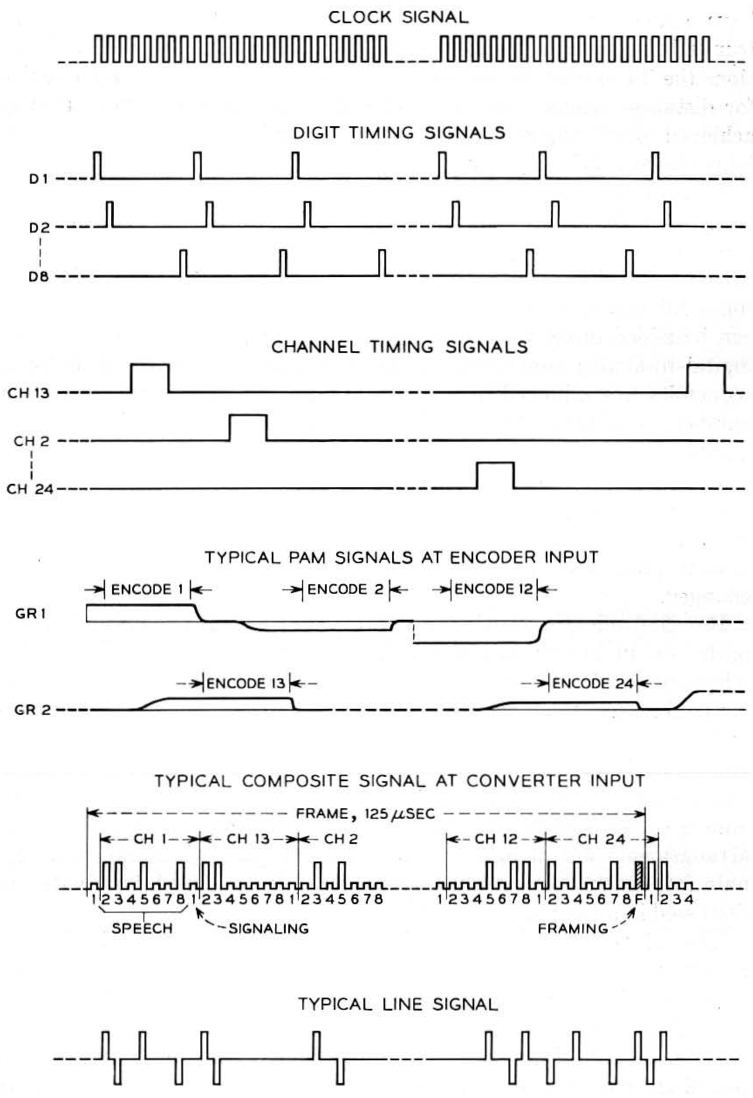

Fig. 2 — D1 bank pulse trains used in multiplexing and encoding.

II. D1 CHANNEL BANKS

2.1 *Group and Channel Circuits*

Most of the transmission functions in a D1 channel bank are performed in a block of circuits shared by a number of voice channels. These group circuits may be divided into two sections — transmitting and receiving. The transmitting group equipment samples the incoming voice signals for each channel, multiplexes the sample in time division, compresses and encodes the samples, combines the encoded sample with signaling information, and prepares the pulse train for transmission over the line. Fig. 2 shows the more important pulse trains involved in this process. The receiving group equipment accepts the incoming pulse stream, separates the signaling information from the coded samples, decodes and expands the speech samples, demultiplexes them, and reconstructs the voice signal. Thus, the group equipment provides 24 voice channels plus 24 signaling channels in each direction. Each signaling channel has a theoretical capacity of 8 kilobits/second. In some situations — revertive pulsing and foreign exchange lines — additional signaling capability is obtained by using the least significant* speech digit when speech would not usually be present.

The channel units shown in Fig. 1 are used to match the voice and signaling paths provided by the group equipment to the requirements of the individual switching circuits to which each channel is connected.

A block schematic of the group circuits is shown in Fig. 3. Consider first the transmitting direction shown in the upper half of the schematic. The transmission circuits in heavy lines come in at the left side from 24 plug-in channel units not shown. Six channels connect to each of four transmitting gate and filter plug-in units. Each gate and filter unit contains six low-pass filters and six sampling gates. The four gate and filter units are arranged in two pairs, a pair for each of two 12-channel groups. The sampling times of the two groups are interleaved so that group 1 channels are sampled at odd-numbered sampling times and group 2 channels at even-numbered times. Thus the channels appear in the PAM (pulse amplitude modulated) pulse train in the order: 1, 13, 2, 14, $\cdots$ 11, 23, 12, 24, 1, 13, 2, 14, $\cdots$.

The common output of each group of twelve gates connects to its own compressor, which reduces a wide range of input amplitudes to a

* The seventh digit of a seven-digit binary code is the least significant since it affects the coded amplitude by only 1 part in 128. The first digit affects the amplitude by 64 parts in 128, the second by 32 parts, etc.

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