CHAPTER XI

UNION SWITCH & SIGNAL COMPANY

Coded Track Circuits Developed

Coded track circuits have made possible the modern signal systems which safeguard today's high speed trains, and they represent one of the most important advances in the history of railway signaling.

The coded track circuit was developed and introduced by the Union Switch & Signal Company. The first installation was placed in service in electrified territory in March, 1933, and in steam service territory in October of that same year. The original or steady-energy track circuit, invented in 1872 and applied to the practical needs of railway signaling by the Union Switch & Signal Company since its organization in 1881, constitutes a safe and reliable medium through which a train may automatically control a signal or other device provided for its protection.

This steady-energy track circuit operated what we know as the automatic block signal. In this system the electric current from a track battery feeds over the rails, energizing a relay at the base of the signal mast and holding the semaphore arm at "clear." When any part of a train is present in the section, or "block," the shunting action of the wheels and axles deprives the track relay of the current and releases the relay. Through this release the signal light or arm is placed at "stop."

When the train leaves the section, or block, the shunt is removed and pick-up energy is restored to the track relay, causing the signal to show "clear," indicating that the section is again vacant.

Signal systems employing track circuits of this steady-energy type have been extensively used by many railroads all over the world, and still are. These systems perform faithfully and well the task assigned to them. Coded track circuits, however, go further, performing magically many functions in train signaling beyond the range of the steady-energy track circuit.

We shall make no attempt to cover all the highly technical aspects of the coded track circuit and its applications, but rather indicate in as simple language as possible what it is and what it accomplishes.

The basis of the coded track circuit is the same combination of elements used in the steady-energy track circuit. It differs from the steady-energy circuit in that the rail current is broken up into recurring pulses to form a code. By using codes of different characters the current in the track rails can be employed not only to detect the presence of a train and protect against broken rails, but also to perform a great variety of other functions which higher train speeds, more powerful locomotives, longer trains, increased traffic density, and other factors demand.

The coded track circuit is a circuit in which the rail current is broken up into recurring pulses to form a code. This is done by a code transmitter, which is a continuously operating electric mechanism installed between the source of current and the track rails and produces in the track circuit a code made up of "on" period energy pulses, separated by "off" period intervals. This system employs a code-following track relay, which picks up during each "on" period of the code and releases during each "off" period; a track-circuit detector relay, which is held picked up continuously during the code-following operations, but which releases if the code-following track relay ceases to follow the code due to the shunting action of a train.

The older steady-energy track circuit and the modern coded track circuit perform the same functions, viz., that of detecting the presence of a train in the track-circuited section. Notwithstanding the similarity of the function, the coded track circuit has certain marked advantages over the steady-energy circuit, and these include: greatly improved sensitivity to train shunting; greater immunity to false operations by foreign currents; and extension of the length of the track circuit which may be reliably operated without the necessity of using cut sections.

Train-detecting operation is only one of the many functions which coded track circuits are designed to perform. When applied to systems of automatic block signaling they are capable of additionally controlling three or more aspects, either or both wayside signals and train-carried cab signals, and of doing this solely through the medium of rail-transmitted energy and without the aid of line wires.

Let us consider the control of a wayside signal in which the signal-code track circuit is amplified to include: (1) continuously-operating coders for supplying the rails with a "clear" (180 pulses per minute) or with an "approach" code (75 pulses per minute); (2) a relay which selects the clear 180 code when the block next in advance is vacant and the approach 75 code when that advance block is occupied; (3) decoding apparatus for distinguishing between 180 pulses per minute and 75 pulses per minute operation by the code-following track relay; and (4) means for controlling the signal in accordance with that distinction.

Such a two-code track circuit thus performs the independent functions of: (1) detecting the presence of a train in a particular block and (2) selecting between the "proceed" and "approach" indications of the wayside signal for that block.

If four indications are desired instead of the three which are available with two different code frequencies, a third code of intermediate frequency, such as 120 pulses per minute, may be employed, and a still greater number of indications may be obtained by the use of additional frequencies.

In addition to the arrangement thus far mentioned in which a number of controls may be communicated from the exit to the entrance end of the block the coded track circuit may also be arranged to perform other functions usually requiring separate line wires with the steady-energy track circuit. These additional functions ordinarily require communication from the entrance to the exit end of the block and may include approach lighting of the signals, approach application of cab signal energy, approach locking and the like. These controls are accomplished with the coded track circuit by means of reverse codes which are automatically supplied to the rails so that the reverse-code pulses occur during the "off" energy intervals of the normal code supplied at the exit end of the block.

Coded track circuits, as we have pointed out, may be used to perform a great variety of functions as compared with the distinctly limited capacity of the steady-energy track circuit. With requisite apparatus, the basic form of the coded track circuit may be expanded to accomplish all elements of control required by certain signal systems, and, when so used for system operation, the term "coded track circuit control" is applicable. This flexibility is an important factor, not only in automatic block signaling but also in connection with installations of centralized traffic control, remote control, interlocking and other systems of signaling.

Thus far mention has been made only of coded track circuits employing the well-known frequency code system. Because the frequency code system as well as the apparatus required for its operation are relatively simple it has been highly developed and widely installed. In the frequency code the distinction between the different codes is based upon the rate or frequency at which the "on" pulses recur and discrimination between different codes is accomplished by apparatus which is selectively responsive to these frequencies.

Other types of codes are usually known as the "time code," the "polar code," and the "count code." The time code is characterized by "on" and "off" code periods of varying lengths, and discrimination is accomplished by suitable timing apparatus. Polar codes are made up of recurring energy pulses of distinctive polarity which responds selectively to the polarity of the pulses. Count codes are characterized by the number of pulses, separated by cycle-defining intervals. Suitable counting apparatus distinguishes between codes.

Aside from the frequency code, these three types, or some combination of them, appear to be the only practical ones suitable for use with direct-current track circuits. It is claimed by many signal authorities that the time, polar, and count codes, are less desirable than the frequency code, which is installed extensively on a great many railroads in this country as well as abroad.

Coded track circuits are adaptable for use in steam territory using either direct-current or alternating-current track circuits, or in direct-current or alternating-current electric propulsion territory where alternating-current track circuits must be used. They can be employed for single-direction running on multiple tracks or for either-direction running on one or more of these tracks. They may be effectively combined with remote control and centralized traffic control systems, and for use with automatic block signaling on single track.

The coded track circuit may, further, be used for wayside signals alone, for cab signals where there are no automatic wayside signals, or where a combination of wayside and cab signals are used. They are also utilized for special purposes, such as securing improved shunting sensitivity in interlocking, and in isolated locations in automatic block signal installations where difficulty has been experienced in the operation of steady-energy track circuits.

In a steady-energy track circuit a train shunt must reduce the rail potential below the track relay's release value in order to effect track release. In a coded track circuit, however, the shunt need only reduce the rail potential below the relay's pick-up value to stop the track relay from following code. As the latter value is considerably above the former, coded track circuits inherently have a shunting sensitivity which is much higher than that of steady-energy circuits under equivalent conditions. In addition to this basic improvement, the coded track circuit lends itself to use with impulse codes of comparatively high voltage, which still further improve the shunting sensitivity where required by unfavorable conditions caused by various kinds of rail film.

It sometimes happens that foreign currents are present in the track circuit and it is highly important that these foreign currents shall not cause improper energization of the track relay. The track relay in the coded track circuit follows the code and such relay cannot set up an improper signal indication because it is inconceivable that any foreign current present would have the code pattern of a regular trackway code. Every stoppage of the code-following track relay operation, either with the relay picked up or released, immediately causes the code-controlled relay to release and consequently puts the signal to "stop."

So many factors combine to determine the maximum operable length of a track circuit that no rigid limits for either the steady-energy or the coded type can be stated. However, since the coded track circuit shunts against the pick-up rather than the release value of the track relay, and for other reasons established by engineering analysis, laboratory test, and field experience, it can be operated with complete satisfaction and without sacrifice of "broken rail" or other essential forms of protection, over a greater length of track than a steady-energy track circuit. Track circuits using coded direct current are, in fact, regularly operated over 11,000-foot track lengths. Because of this extended operating range, cut sections are seldom necessary and additional insulated joints plus energy-repeating devices and housing facilities for these are eliminated.

An important factor of the coded track circuits is the reduction, or complete elimination, of line wires for signal control and thus affords a high degree of immunity against interruption by storms.

C.T.C. and Coded Carrier Control

We have examined the application of the coded carrier impulses in connection with the rail, and now we will examine the functions of the coded carrier as applied to line wires, where it performs further miracles for the railroads of today.

Coded carrier control, as developed by the Union Switch & Signal Company, has increased enormously the capacity of centralized traffic control systems for any number of sections may be operated simultaneously over a two-wire line.

Centralized traffic control is a system of train dispatching whereby the dispatcher seated at his C.T.C. control machine has at his finger-tips complete control of switches and signals over his district or division. Coded carrier control is employed principally for large C.T.C. installations where it is desirable to divide the territory into two or more sections. Ordinarily this would require the use of a separate pair of wires for each section.

However, with coded carrier control all sections can be controlled independently from the same control point over one pair of wires. Coded carrier control is a carrier system designed for the purpose of remotely controlling "time code control" systems, and it consists of carrier equipment that is used to transmit codes in both directions between the control points and the remotely located control apparatus.

In general, the coded carrier equipment generates—transmits directly to—and receives directly from the line an individual carrier frequency for each carrier-operated control and indication code. Frequencies in the 10-30 kc. range are usually employed. In some instances, frequencies as low as 4 kc. and as high as 56 kc. have been utilized, while for special applications carrier equipment operating in the voice range can be used for modulating communication carriers.

With coded carrier control the section adjacent to the office is usually controlled directly by means of a conventional D.C. code line circuit. The second section, which is installed as an independent D.C. code line circuit, is controlled by coded carrier frequencies transmitted over the first section. A third section can be readily controlled by means of a different pair of carrier frequencies transmitted over the first and second sections. It is thus apparent that additional sections, if required, can be controlled in a similar manner to extend the territory to any desired practicable length, or to handle any number of functions in a particular territory.

Coded carrier control can be readily coordinated with other communication facilities and may be superimposed on the same wires with other facilities. This very important application affords great latitude in locating the control point of the control installation. For example, the desired control point may be so far from the actual C.T.C. territory that it may not be considered practicable to extend the wires of the line circuit to that point.

In such an instance it is usually possible to transmit coded carrier currents over an existing communication line and thus permit the control point for the C.T.C. territory to be at the preferred location. This flexibility in choosing the control point has resulted in an increasing tendency to centralize the control of C.T.C. territories by locating the control machines at Division Headquarters.

Where the C.T.C. territory includes a large number of controlled switches and signals, the entire territory can be divided into sections and all sections can be operated over the same two line wires extending from the office. Let us say that the territory is 180 miles long. Three sections controlled by conventional equipment would involve 720 miles of code line wire, with sections evenly divided. With coded carrier control only 360 miles of line wire would be required.

Another important advantage of coded carrier control is its use in territory where code delay makes it desirable to divide the territory into groups which can be operated independently.

In general, the carrier frequencies for the coded carrier system are selected above the voice frequency range so that the two wires for the C.T.C. system may be used also for a physical telephone circuit. Furthermore, if necessary, the frequencies are selected in a way that other carrier communication systems may be operated on the same pair of wires. If a new line is installed for the time code control system, particularly if it is on a Western Union pole line or railroad communication line, the new line should be transposed so that it will be suitable for frequencies up to 30 kc. This provides for the coordination between the coded carrier control system and other carrier frequency systems, such as carrier telephone and telegraph.

It is standard practice to install duplicate sets of carrier equipment in the office and at the field carrier locations, one set serving for stand-by purposes. Stand-by equipment is essential to a C.T.C. installation for the following reasons:

(1) A complete section of C.T.C. is dependent on the proper operation of the carrier equipment. Stand-by equipment guards the section against being inoperative through a fault in the carrier circuits.

(2) With stand-by carrier equipment in use, it is not necessary for a maintainer to be sufficiently well acquainted with the details of the apparatus to be able to repair it.

(3) Since it is advisable to have spare equipment, it is most logical to have it wired in place ready for service.

Change-over circuits are provided for shifting from the normal to the stand-by equipment. The change-over is under control of the operator, enabling him to place either set in service as desired.

The standard carrier equipment is usually adjusted to deliver a higher voltage to the line than the normal units and to respond to a lower received voltage. Thus the stand-by equipment may be able to operate under emergency conditions, such as a broken line wire, when the normal units, adjusted for a lower power level, could not operate. For this reason, the field changeover relay is usually so controlled that the field stand-by equipment will be placed in service automatically in case of a line fault in the carrier circuit.

Included in the stand-by equipment we usually find a "coded carrier repeater," which is not normally used in the circuit, but is there to amplify coded carrier frequencies under emergency conditions. This coded carrier repeater is an electron tube device for amplifying carrier frequencies. It has two particular applications in coded carrier control. Its most extensive application is to overcome emergency conditions, such as severe sleet storms or a broken line wire which produce a large amount of attenuation or thinning out of the carrier current. In this application, the coded carrier repeater is cut in to amplify the coded carrier frequencies under the existing emergency conditions. The second application of the repeater is employed to extend the distance over which it is practicable to transmit coded carrier frequencies.

On a carrier system, a disturbance on the line, such as a severe lightning surge, may stall or blank out a step of an indication code and cause the office and field units to get out of step. In such a situation synchronizing circuit relays are employed to reset the field and office units.

Unusual Installation

A coded track circuit control system of unusual interest was installed between Norfolk and Forest, Virginia, by the Norfolk & Western. The territory included over 400 track-miles, with several stretches of preferential grade single-track making up part of the double-track line. Coded track circuits are employed exclusively.

On double-track, the coded track circuits effect conventional signal control and, through interlocking, they provide detection. On single-track stretches, either C.T.C. or A.P.B. signaling is used. For these locations, several adaptations of the coded track circuit control system were employed with interesting results and important advantages.

In general, the installation employs the well-known two-block, three-indication system with signals spaced about 9,000 feet. Sections of three-block, four-indication signaling were installed on both single- and double-track where local conditions made it necessary. The signals in approach to interlocking were usually equipped with a fourth ("approach-medium") indication. The installation was planned to permit future cab signaling operation without change to wayside installation, simply by the addition of the necessary locomotive equipment.

In double-track territory where the signaling is required to accommodate traffic movements in only one direction, the coded A.C. track circuits are comparatively simple. The necessary controls are provided by the selection of the code frequencies applied to the rails and this selection is governed by traffic conditions. Basic circuits of the type used for this purpose were discussed earlier in this chapter.

Most of the single-track sections which intervene between extensive stretches of double-track are equipped with absolute permissive block signaling, using coded track circuit control. The great flexibility of this arrangement made it possible to operate the system with a smaller number of line wires than would be required with steady-energy track circuits. All "approach" signal indications are exclusively controlled by coded track circuits, as well as many "proceed" indications.

The operation of the system is accomplished over two line wires used for centralized traffic control of the switches and signals and also for telephone purposes. Because coded track circuits were used, no signal control line wires were required in the C.T.C. territory.

C.T.C. Motor Car Indicators

The Santa Fe's new type motor car signals, built by the Union Switch and Signal Company, are an exceptionally fine addition to their C.T.C. installation on the Plains Division.

In sections where sighting distances are short motor-car indicators are provided, by means of which men on motor cars can be warned of the approach of trains. Where A.C. power is available the indicators are of the electric lamp type, each indicator consisting of an electric lamp previously used on the old semaphore signals. These indicators are mounted on signal cases, the lamps being directed at an angle across the track so that, as a man approaches on a motor car, the indicator he sees applies to the territory into which he is going to proceed.

Each indicator has a 3.5-watt, 13.5-volt lamp which is normally lighted. The relay which controls each indicator is normally energized by a line circuit which breaks through front contacts of the track or line relays for the limits of the control of the indicator. The indicator line circuits are taken through contacts in the directional-stick relays so that the indicators will clear for a man on a motor car to follow a train.

At locations where A.C. is not available to feed a lamp, the indicators are semaphore type with 500-ohm coils which are normally energized by the line circuit. In most instances the line circuits are fed from the D.C. side of the rectifiers. When the A.C. power fails, the line circuit is de-energized but this is of no consequence because with the A.C. off, the lamp in the indicator would not be lighted.

These motor-car circuits are entirely independent from the signal circuits, so that any grounds or crosses will not interfere with the signaling. An important part of the improvements was a motor-car set-off, built of old ties, provided at every power switch and every intermediate signal as well as at others placed not more than an average of one-quarter mile apart.

The distance of the track circuit in both directions is indicated on these signals. Thus, a trackman can tell at once how far he is protected. Where signal lamps are employed the lamps are only lighted when a train is in the circuit.

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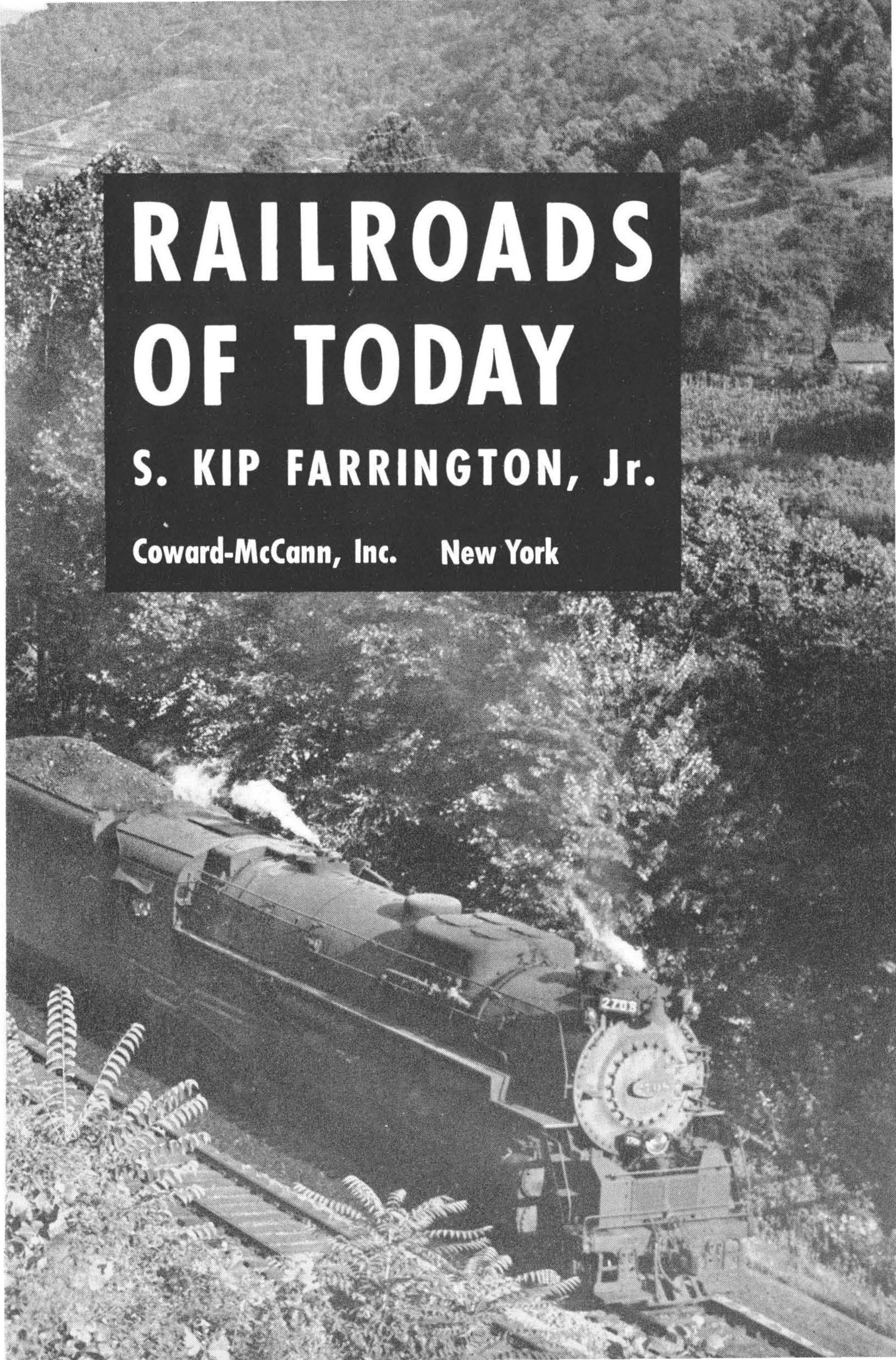

Published simultaneously in the Dominion of Canada by Longmans, Green & Company, Toronto

MANUFACTURED IN THE UNITED STATES