ELECTRONIC TRACK CIRCUITS

Much interest has been shown by American signal engineers in track circuits using other than the low voltage DC, particularly because of the extensive use of welded rail. Audio frequency circuits are used in the U.S. and Canada for release of electric locks and for highway crossing protection installations. To bring readers of Railway Signaling and Communications news of what is being done with electronic track circuits overseas, herewith are three reports, two from France and one from Japan.

The first is by J. Jutier, an engineer with Etablissements Saxby, Paris, France. The second report is by Hajime Kawanabe, chief, signal laboratory, Railway Technical Research Institute of the Japanese National Railways. Mr. Kawanabe's paper deals with electronic track circuits for the new Tokaido line between Tokyo and Osaka. The third report is by J. G. Walter, chief signal engineer, French National Railways. The material presented herewith is an abstract of a paper presented by Mr. Walter before The Institution of Railway Signal Engineers, Nov. 15, 1961. Our thanks are extended to IRSE for permission to use this material.

During the past dozen years the track circuit techniques of the French railroads have been considerably developed. Whereas the signaling equipment on DC 1,500-volt electrified lines was realized by means of the usual AC 50-cps track circuits, which system has not changed much in nearly 40 years, the success of the French electrification methods in single-phase current, 50 cps, enabled the research engineers to find entirely new solutions. The track circuits on the first lines thus equipped in about 1950 were derived from already existing devices: (1) DC single-rail track circuits; (2) AC 83⅓-cps track circuits, analogous to the 50-cps circuits of DC electrified tracks, which gave satisfaction and which are still in operation.

The DC circuits are sensitive to stray currents. As far as the AC circuits are concerned, which are in use where stray currents are to be feared, they necessitate a special two-phase power supply with a rotary converter, and are therefore expensive. In order to avoid the resulting disadvantages, the use of electronic track circuits has been generalized and several thousand are now in operation on the French railroads.

The first type of electronic track circuit to be put in operation is the audio frequency track circuit with conventional tubes. Four frequencies were adopted, in such a way that adjacent track circuits are not working at the same frequency. Consequently, they will not influence each other. They are mainly comprised of a power supply and receiver.

(a) On the power supply side: An emitter group with three-grid tube acting as an oscillator, emitting a current at the selected frequency, hatched at the rate of 13 to 20 per second (interrupted 13-20 times per second), which favors good shunting. An impedance bond of smaller dimensions than those of the 83⅓-cps track circuits, in view of the much higher value of the frequency.

(b) On receiver side: A receiver group with the same three-grid tube as the one of the emitter, but which acts as an amplifier; an impedance bond identical to the one of the power supply; a DC track relay.

The track circuits have a length up to 3,608 ft. They are fed under 50-cps voltage. Their power consumption is very low and, in general, they do not require a special feeder, as emergency power can be supplied by means of small converters working on accumulator batteries.

The perfecting of diodes and transistors of satisfactory quality permitted track circuits identical to the former, but without the conventional tubes and of lower power consumption. The length of these track circuits can be up to 4,920 ft.

The use of welded rails, long ba approximately 2,264 ft in length, h been generalized on the French ra roads. For tracks equipped with th kind of long rails, a special audio fr quency track circuit has been develop which does not require the sectioni of rails, and therefore does not ha any impedance bonds. These track ci cuits are limited at both ends by stopper circuit, mainly constituted b a rail a few meters long (1 met = 3.28 ft) with the suitable impe ance, limited by a connecting cab short circuiting the two rails, and condenser whose plates are connecte to each of the two rails. The adopte frequency permits these circuits have a length of 3,280 ft. Their co sumption is extremely low, a few wat only, and they are working on an volt accumulator battery.

It is well known that vehicles suc as light engines do not shunt well track circuits. The sanding of the rai by the locomotives for the start heavy trains also occasions shunt fai ures. This can have very serious co sequences for power signaling wi "flexible transit" (a single-powere passenger car or a power car hauli non-powered passenger cars), the num ber of which is increasing more an more on the French railroads. In orde to elucidate the reasons for the shunting failures the French railroad and the Organization for Research an Testing of the International Union the Railways undertook systematic i vestigations which showed that in o der to obtain short circuiting of th rail-wheel contacts it is imperative tha (1) the voltage to be applied is seve al dozen volts, and (2) the contac must be fed by a current of sever amperes.

The investigations resulted in th design of a new track circuit, of whic several thousand are already in oper ation on the French railroads. It wa out of the question to feed the trac by 100 volts DC, such consumptio ıg prohibitive. This high voltage is ıg applied in impulses of very short ation, emanating from a thyratron rate of three per second.

his kind of track circuit therefore ıprises: (1) an emitter of thyratron ulses feeding the track by the in-nediary of the impedance bond; a receiver equally connected to track by the intermediary of the er impedance bond; and (3) a sed DC track circuit.

Due to the improvements realized semi-conductor techniques, a new ice has been developed in which thyratron is replaced by a con-led rectifier whose consumption is ch lower.

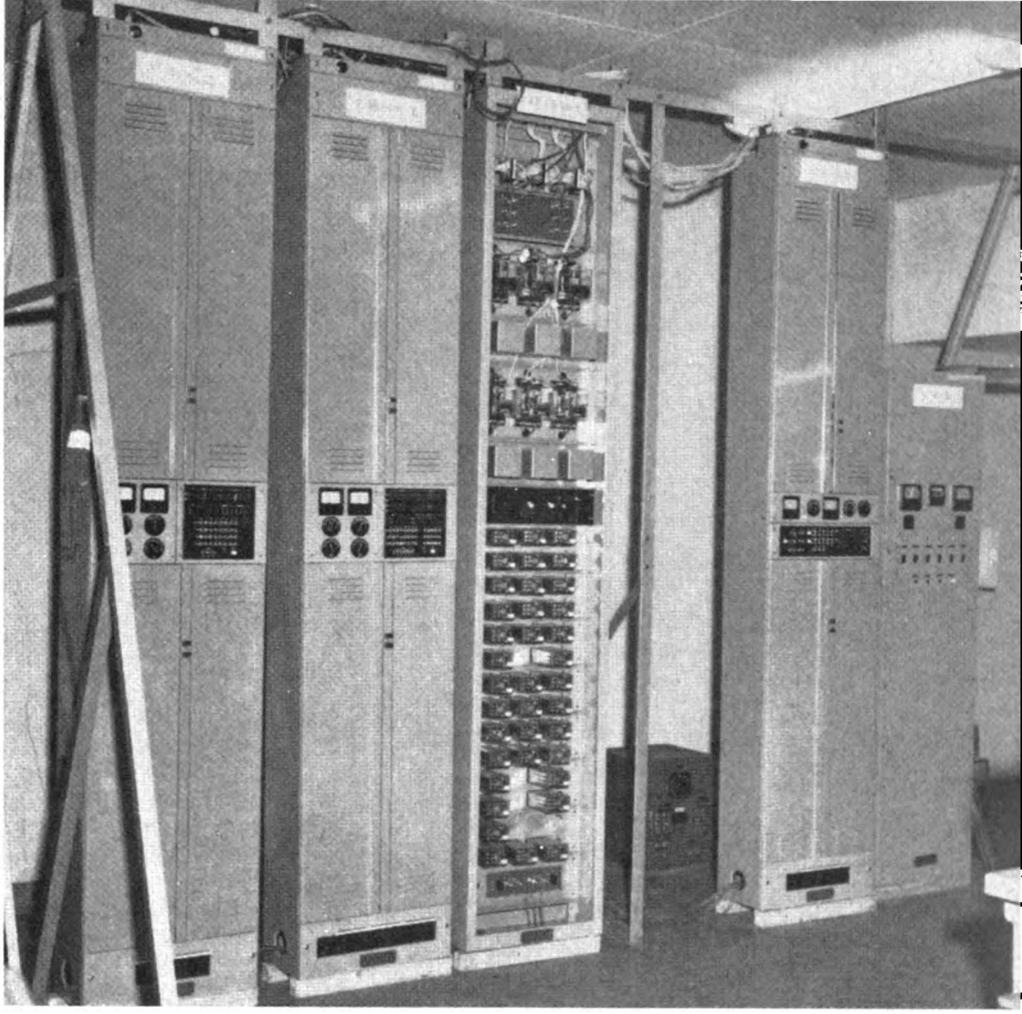
he above described devices apply electrified tracks; it is obvious that se equipments can also be adapted steam or diesel traction. In this e they are very much simplified. **RSC**

panese Line Has SSB Circuits

he new Tokaido trunk line now under construction is a high-speed, h-density line unprecedented in world, in that it will be able to trains with a minimum interval of minutes, at a maximum speed of 4 mph over a distance of 500 km 0 miles, 1 km = .62 mile) between kyo and Osaka.

The new Tokaido line is to be AC ctrified at 60 cps, 25,000 volts, and maximum of 1,000 amp of traction rent will be flowing through the ls. If it is to be considered that un-lanced current accounts for 10% of total traction current, it means that 0 amp of unbalanced current will flowing through the track circuit. erefore, the track circuit to be util-d on the new Tokaido line must of a system which will not be af-ted by such an interfering current. rthermore, in view of the fact that train operation system requires sev- kinds of signal indications, the track cuit system must be capable of lti-indication. As a system which fills the conditions mentioned above, more highly developed electronic ck circuit than the one which has eady been in service several years the existing AC electrified sections, s been decided upon as the most itable.

While the electronic track circuit eady in use is the double sideband, e system to be adopted for the new kaido line will be the single side-nd. Moreover, the carrier wave is ade by the source synchronizing sys-m, which multiplies the frequency 0 cps) of the trolley wire voltage. This is necessary because it has een found that the interfering volt-ge on the new Tokaido line will be greater than that on existing lines, leading to the danger of faulty action in the relay if the double sideband system is utilized. As a countermeasure, it was seen best to use a system which can make the carrier frequency completely correspond to one of the higher harmonics of the interfering voltage. Theoretically, there will be absolutely no effects from any interfering voltage if this system is adopted. As the result of actual measurement, it was found that there is absolutely no effect, even though interfering voltage amounting to 20 times the voltage of the signal may appear at the output end of the receiver's bandpass filter.



Electronic track circuit equipment racks for Japan's Tokaido line: (left to right) transmitter; carrier-wave and intermediate modulating oscillators; safety devices and relays; receivers; and power supply rack.

As to the signal frequency, the track circuit of the up-bound track will have an upper sideband of alternate 720 cps and 900 cps frequencies, while the track circuit of the down-bound track will have a lower sideband of alternate 840 cps and 1,020 cps frequencies.

The modulation frequencies will be 10, 15, 22, 29, and 36 cps, with respective corresponding restrictive speeds of 130, 99, 68, 43 and 19 mph. For Stop signals (0 mph), a non-modulated wave of 840 cps for the up-bound track and one of 900 cps for the down-bound track will be used. However, the current to be used for the Stop signal will not flow through the rails, but through a loop line which will be established for 164 ft beyond the Stop point. Moreover, by flowing a sufficiently large current, there is no effect from any interfering current.

Two track circuits, each with a standard length of 4,920 ft, will make up one block. Moreover, in order to increase the reliability of the various devices and to make maintenance easier, the transmitters and receivers for every 12 miles will be collected at one place and connection with the impedance bond of the track circuit will be made with cables.

When the leakage conductance is 0.7 mho/km (0.7 mho per 3,280 ft), the attenuation over the 4,920-ft track circuit is 26 db. If 9.9 miles of cables are connected separately to the sending end and receiving end, the attenuation at the connection point and in the cable will be 24 db in all. Thus, if the transmitter output is 40 dbm and the receiver sensibility −10 dbm, the track circuit can be fully controlled.

Block diagrams of the transmitter and receiver are shown in Fig. 1 and Fig. 2. As the devices are collectively

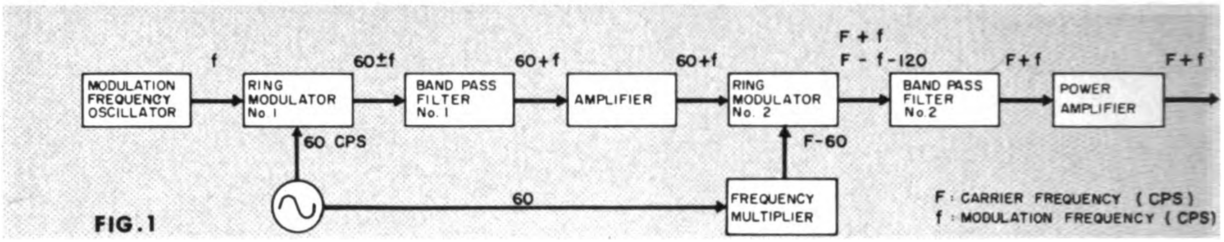


FIG.1

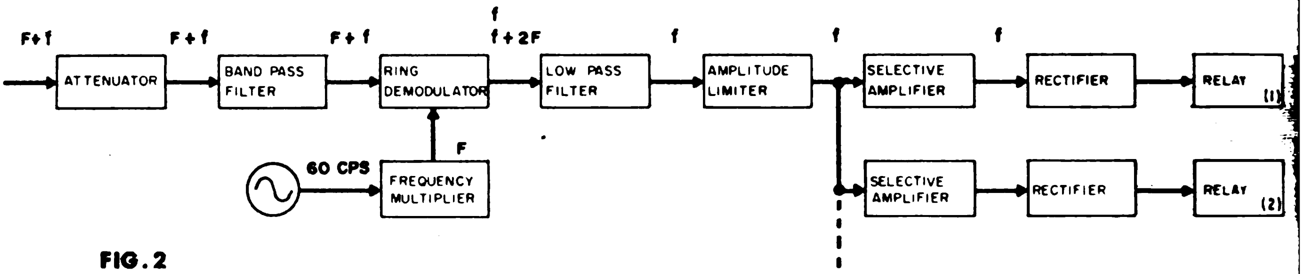


FIG.2

Block diagram of electronic track circuit transmitters and receivers used on Japan's high-speed Tokyo-Osaka line.

installed actually, they are divided up into a number of blocks according to function. Common devices are used together in the equipment room. All of the devices are mounted respectively in the carrier-wave oscillator rack, intermediate modulating-wave oscillator rack, transmitter rack, receiver rack, repeater rack, relay rack, electric source rack and safety device rack. In addition, mobile measuring instrument racks for maintenance are also attached.

As for the electronic circuit, in particular, all complicated devices are made up by combining a small number of standardized basic circuits (units). In event of a failure, a warning is given to the maintenance personnel, and replacements can be made in units.

The transmitter consists of two equipments, the No. 1 transmitter and the No. 2 transmitter. The No. 1 transmitter is constantly connected to the track circuit, but when there is a failure, the connection changes over automatically to the No. 2 transmitter. The receiver also has the No. 1 and No. 2 receivers. In addition, it possesses a check receiver. These three receivers are connected in parallel with the track circuit. When one of the three shows action diversified from the other two, a failure is recognized and a warning is given.

The general appearance of the equipments manufactured in prototype for the collective system is shown on the preceding page.

The frequency multiplier is supplied with electric power at 60 cps from the trolley wire and creates a rectangular wave. This is made into a pulse wave by a differential circuit. The higher harmonics are taken from the pulse wave through a filter. Also, the modulation wave is created by the LC fixed oscillator.

The impedance bond is made resonant by four kinds of frequencies through a change-over of the condenser. The impedance value is able to be changed into four kinds. The current capacity is 500 amp at one arm.

Generally speaking, the relay circuit is so made that the modulated current sent by transmitter through the rail is at 36 cps in the section next to the one occupied by a train, at 15 cps in the following section, and at 10 cps in all following sections. Consequently, upon receiving the transmission in the cab, as the following train approaches the section occupied by the preceding train, the speed can be lowered from 130 mph to 99 and 19 mph, in that order.

If equipment is to be used for signaling it must, first of all, fulfill all the requirements in regard to being fail-safe. This means that it must be fail-safe *(a) as a system, (b) against failures outside the equipment, and (c) against failures inside the equipment.*

(a) As a system: As this is a source-synchronizing system which completely matches the carrier frequency with one of the higher harmonics of the interfering voltage, there is no danger of a frequency arising which corresponds to one of the modulation frequencies of the low frequency, caused by the slight difference between the interfering frequency and the signal frequency, although the frequencies of the interfering wave's higher harmonics may fluctuate. Consequently, there is also no danger of the relay showing faulty action due to any interfering wave. It is in asynchronous cases that the danger is present.

Again, in regard to the restricted speed corresponding to the modulating wave, the higher the frequency is, the lower is the corresponding restricted speed. Because of this, there is a danger of failure, even though the relay corresponding to the higher frequencies may show a mistaken pickup caused by the higher harmonics of the lower frequencies. The higher frequencies naturally are selected in a way to avoid the higher harmonics of the lower frequencies with adequate selective characteristics against the various modulation waves.

Through the back-check of the contact in the relay circuit, double protection is offered against any faulty action such as described above.

With entirely separate carrier frequencies allocated to the up-bound track and down-bound track, there is no danger of faulty action from any induced current caused by mutual induction on either the up-bound track or down-bound track.

The up-bound track and down-bound track each have two carrier waves which are arranged alternately on the track circuits. For this reason there is no danger of faulty action arising from any short circuit of the insulated rail joint between adjacent track circuits, which may result in an output of another track circuit entering the receiver. In addition to the above full study is now being made of the relations between level fluctuations in leakage conductance and short circuit sensibility.

(b) Against failures outside the equipment: In order that there will be no effects from circulating current

aused by rail breakage and one arm isconnection of impedance bond, pro- isions have been made in respect to e selection of the signal level and thers.

In regard to the cable between the ollective equipment and the track cir- uit, separate cables have been pro- ided for transmitting and receiving. this manner, the conductors inside e transmitting cable cannot come in- direct contact with the conductors side the receiving cable. Moreover, hen conductors inside the same cable ive rise to a contact, a warning is iven through the use of the contact etector.

When there is a suspension of the urrent for the Stop signal flowing hrough the loop line, a warning is lso given.

(c) Against failures inside the equip- ent: The oscillating part inside the ransmitter which emits the carrier and nodulation wave is so made that when failure occurs, it will not emit fre- uencies which are equal with other arriers or modulation waves. In addi- ion, the oscillating part is designed o prevent any extra large output going ut, caused by failure in the equip- nent.

The resistance attenuator for the nput of the receiver is of the ladder ype. As a result, in event of a dis- onnection in the circuit of parallel lements, there will be no sudden harp rise of sensibility. In the same nanner, a transformer coupling is pro- ided for the parallel elements of the andpass filter. Moreover, by using he super pass condenser, the input of ll the frequencies is made to be cut ff whenever there is any disconnec- ion of the circuit of parallel elements f the bandpass filter. Steps have also een taken to ascertain that no interferences are caused by failure in other elements.

For the transistor circuit of the output part of the receiver, a transformer coupling is adopted. Through diodes, the current is rectified to excite the DC relay. No dangerous switching circuit is utilized.

In order to prevent circulating current due to an unbalance of the ring demodulator, a high resistor is inserted. Great care has been taken in the designing not to cause any oscillation phenomenon in the amplification circuit after demodulation.

Considering various failures possible, experiments have been carried out to make certain there will be no dangerous faulty actions.

Although metallic contacts are used for the track relay, melting and gluing of the contact is prevented by giving sufficient dissociation force to the contact. In addition, the circuit can be fused when an over-current flows through the contact.

The track circuit described above was developed by the author and others for the new Tokaido line. This track circuit will be put into actual use in 1964, when it will be completely installed over the 310 miles from Tokyo to Osaka. When the new Tokaido line is further extended to the west or to the east, the new track circuit naturally will be extended as well. However, in the other lines such a high level system is not required, and consequently there are no plans for its utilization elsewhere. **RSC**

French Track Circuit Practices

The AC, 25,000-volt, 50-cps electrification has resulted in a considerable number of experiments and achievements in connection with track circuits and important developments in electronic track circuits have resulted from these studies.

From the outset DC fed track circuits have been used on double-track lines, insulated in one rail only. This provides a cheap and simple installation. But we have not gone on with its use since it has some rather important drawbacks. From the signaling point of view, it does not automatically detect the breaking of a rail unless it is the insulated one. Consequently the rail used for the return current may be broken at one point—or even two—and the relay will remain energized. There is also another reason why such a track circuit is not favored. Being insulated in one rail, only half the section of the rails is available for the passage of return currents.

AC electrification generates induced voltages in the conductors running alongside the line and the reduction of that induced voltage is a permanent preoccupation of all electrification railwaymen and of all signaling engineers. The use of both rails is far more favorable for that reduction, this being more effective since it works directly at the point of origin and on the cause of the phenomenon. These two considerations govern the reasons why preference must be given to track circuits with both rails insulated, where the return current runs symmetrically and by halves through one and the other. Indeed, these reasons are in the interest of signaling and telecommunication engineers themselves. If the induced voltages encountered are not reduced as much as possible by appropriate arrangement of the signaling, difficulties will be met with their own telecommunications devices and they will run the risk of having to face the necessity of finding complicated and costly ways of countering the effects of the induced voltage on circuits adjoining the railway line.

From a general point of view, the advantages of using alternating currents of various frequenies for the work of signaling devices, as well as for the telecommunication system must be stressed. When using DC it is necessary to bring the circuits of the cable without discontinuity to the apparatus, to relays for instance. This disposition compels the induced voltage to be limited to 60 volts, according to CCITT, or to a value not much higher than 60 volts. When using AC, however, a transformer can be placed before the connection to the apparatus and it is then possible, according to CCITT rules to raise the induced potential to 60% of the disruptive voltage. This advantage is so important that in many cases it is worth replacing conventional equipments by quite new devices and the numerous possibilities offered by electronics offer a wide choice of solutions for such a replacement.

The first attempt to solve the question of interference in AC track circuits on 25,000-volt electrified lines was to use a current in the rails sufficiently different from 50 cps to prevent interference, but not too different from it, in order to retain the benefits of long experience in the field of track circuits.

The 83⅓ cps frequency was the nearest solution to conventional equipments. It provides very reliable installations, the service from which is quite satisfactory. But in many cases such a solution is costly. Numerous signaling substations are necessary for the generation of this current, while its distribution along the wayside requires special cables. If electrification at industrial frequencies simplifies the substations and their feeding cables, it would seem desirable also to find a cheaper system for signaling.

It is this kind of preoccupation that gave birth to a great variety of electronic track circuits, which have multiplied on the French 25,000-volt lines.

All these track circuits have the following point in common: electronic devices, using either tubes or transsistors, receive the 50-cps current, either from the catenary, or from the general grid, or from an emergency supply, and then generate *in situ* the special currents to be sent to the track.

At the beginning of our AC electrification, the semi-conductors were not at that time sufficiently perfect and reliable to be used for track circuit work. That is why electronic tubes were generally employed until recently. These electronic tubes had to be manufactured with special care for the service they had to give, but this result was achieved and the performances of our 3,200 track circuits equipped with these tubes are quite acceptable and give satisfaction. These investigations were carried out by the Compagnie de Signaux et d'Entreprises Electriques in close cooperation with the SNCF.

The number of distinct frequencies to be used arises from the following condition. Insulated joints placed at both ends of a track circuit may fail and become short circuited; in that case, it could happen that the receiver of one track circuit comes into contact with the transmitter of the adjoining circuit. It is then necessary that the said receiver should not pick up or, even better, that it should de-energize when the current of the next track circuit reaches it. These requirements meant that it was impossible to use a single frequency for all cases and finally four types were adopted; 300 cps and 850 cps for long track circuits and 1,500 cps and 2,000 cps for the shorter ones in the stations. The frequencies of the first two are not transmitted continuously, but are interrupted at 14 or 20 times per second. On the other hand, there is no interruption to the frequencies transmitted at 1,500 and 2,000 cps (Fig. 1). A single electronic tube is included in each transmitter, working as an oscillator, while the same tube plays the part of an amplifier at the receiver for the 300 and 850-cps units. (No amplifier is needed for the receiver of the short track circuits working at 1,500 and 2,000 cps.) The track relay is of a conventional type, being energized by the decoded and rectified current of the receiver. The equipment for these track circuits is not costly and their current consumption is remarkably low.

Modern developments have made it possible to transistorize the audio frequency track circuit. This achievement has been made possible after a certain number of experiments and adaptations in our laboratory by the TRT firm (Telecommunications Radioelectriques et Telephoniques). The transistorized track circuit is not quite similar to the previous one that works with tubes. In the TRT installation, the frequency is transmitted without discontinuity or modulation and the effective band is limited to a few cycles. All other frequencies are weakened, the more so as they are further away from the nominal value of the track circuit frequency. This results in very effective protection against all sorts of interference. The chosen values are 110, 180, 210, 275, 315 cps. The first three are able to operate track circuits whose length is 6,560 ft as a minimum, and the last two, track circuits of 4,920 ft length. Each track circuit is fed from the 8-volts battery supply at the signal, and the consumption of the transmitter is about 20 watts, that for the receiver being 2½ watts. The transmitter (Fig. 2) is composed of an oscillator having an excellent stability, followed by three symmetrical amplifiers. The last of these is coupled with the impedance bond, this coupling being made with an impedance sufficiently low to prevent any induction with the connecting cables. The receiver (Fig. 3) has four parts: a filter working at the specified frequency with a bandpass range of only a few cycles; a sensitivity limit for the voltage of the signal received, this limit resulting in the voltage above which the track relay is energized and below which the relay does not pick up; a non-linear filter which passes the required frequency and stops all other frequencies or any other irrelevant signal; and an amplifier which feeds the track relay through a detecting device.

The five specified frequencies provide a solution to all track circuit problems even in the most complicated stations.

Other types of track circuits, of quite new design, have been used or installed experimentally during the last few years and seem to offer very interesting possibilities. They are track circuits that require no insulated rail joints and therefore can be installed in areas equipped with long welded rails without requiring the rails to be cut.

They have been developed according to two different formulae that apply to two kinds of problems.

The first sort of track circuit without insulated joints was invented several years ago for use at level crossings equipped with automatic signaling (red flashing lights and automatic gates). There is no need for the length of the track circuit to be longer than the width of the level crossing, since its only role is to check the presence of a train at that point. The solution has been found with the use of a frequency of about 10 kc. Considering the characteristic impedance of the track and the longitudinal resistance

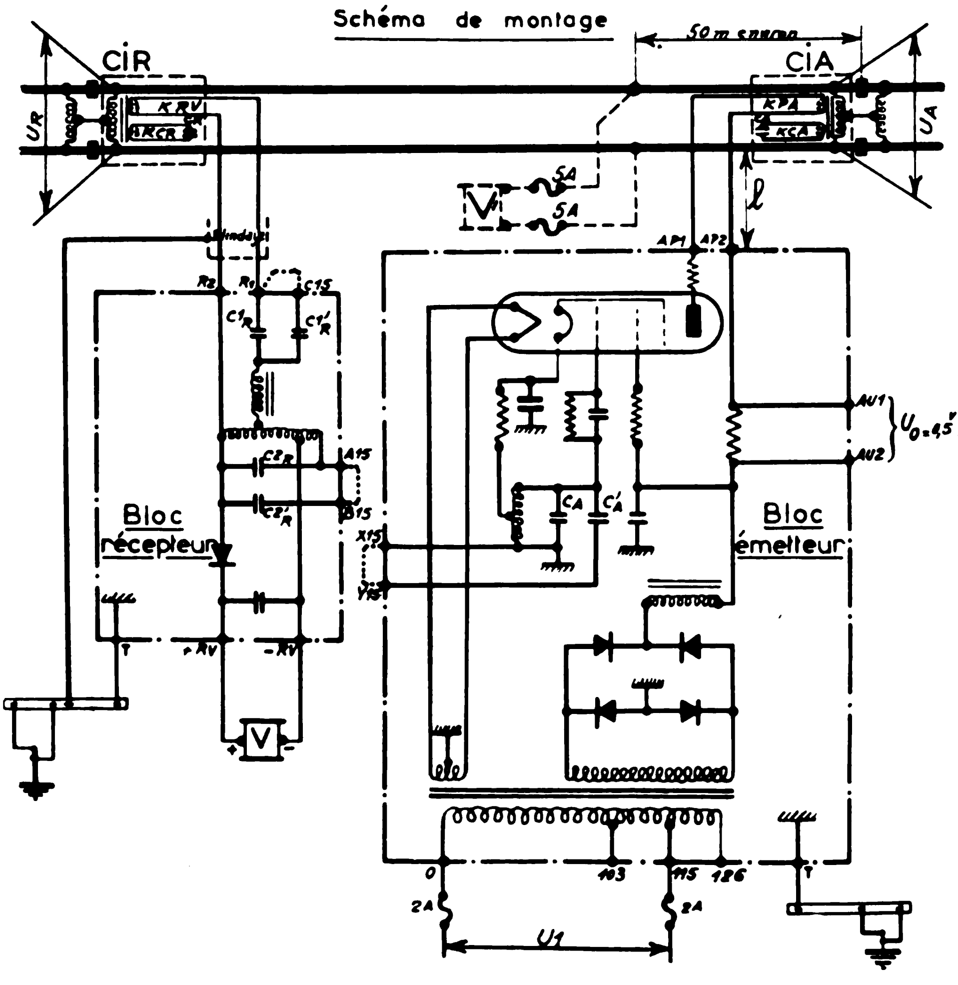


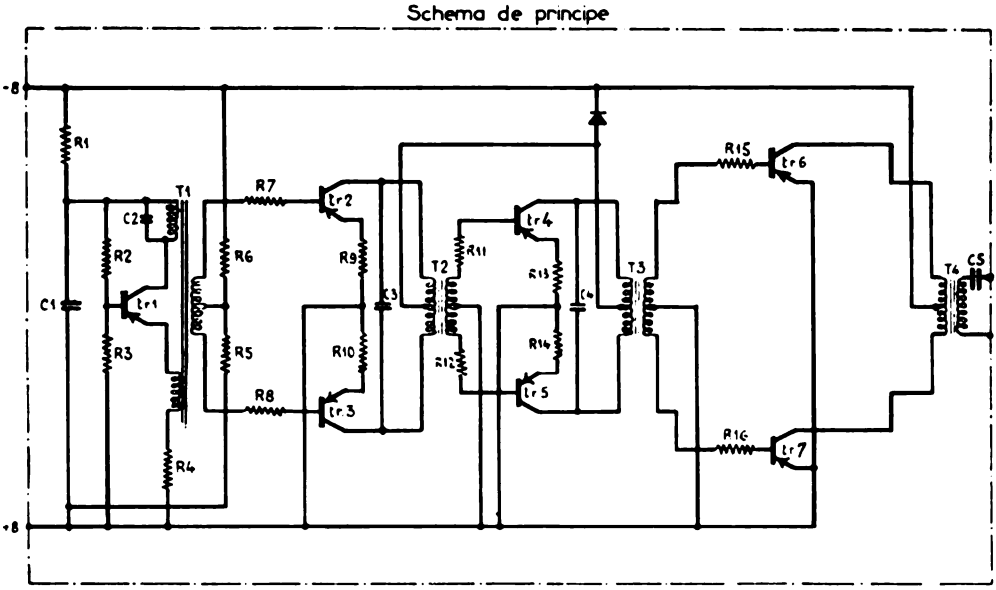
Fig. 1—Electrified line (single-phase, 50 cps AC) has electronic track circuit with 1,500 or 2,000 cps current. Schema de montage = circuit diagram; 50 m environ = about 50 meters (164 ft); bloc emetteur = transmitter; blocrecepteur = receiver; UA = voltage at feed end; UR = voltage at relay end; V = track relay.

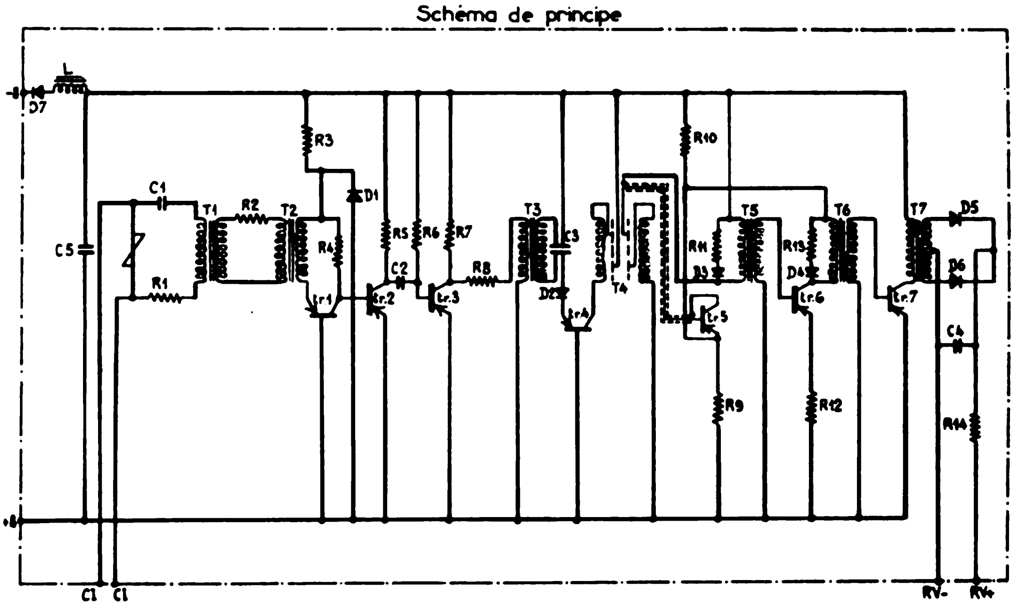
he rail at that frequency, the drop y of the track relay is achieved the shunting effect of the axles r a length of 131 or 164 ft. The eiver is connected to the rails at a y short distance from the transmit- When the wheels short circuit the s, they de-energize the track relay ittle before reaching the first of se connections and the track relay ks up again when the last wheel passed a little beyond the second nection. Such track circuits, now nsistorized, require only a small ount of energy, the total consump- n from the battery being only a y watts. It may be superimposed on ther track circuit working at a different frequency, for example, a sec- n of automatic block.

nother type of jointless track cir- t has been more recently designed the Aster firm, which can be in- led on mainlines and become part an automatic block installation. The gth of such a track circuit is of rse far greater than in the previ- case, being about half a mile. The quencies used lie between 1,600 l 2,800 cps. Each section of track limited by a stopper circuit, where is made of the inductance of a p extending over a certain length rail. Let us imagine a section of ck limited at its end by a cable rt-circuiting the rails (Fig. 4: AB A'B'), and including a condenser C C') connected between the rails a given distance from the origin (or A'B'). We have thus an oscil- ory circuit generating current at a tain frequency. At the other end the same track circuit a similar loop nstalled for the receiver.

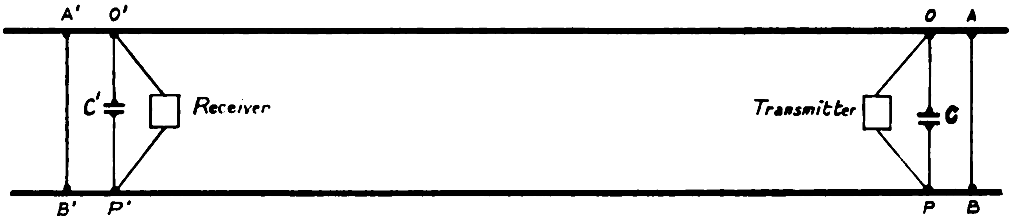
n actual practice a slight change st be made in this arrangement, ce a wheel standing on the connec- AB or A'B' does not short circuit installation and cannot de-energize track relay. A change has been de in the first diagram (see Fig. it consists of placing A and B at ne distance from each other. The ca- that joins A and B is then connect- at its middle to one rail through a ndenser to go to the receiver, and the other rail through another con- nser to go to the transmitter. The gths O to A and O to B are such t, in association with the condens- , the desired frequencies F2 and F3 generated in correspondence with h of the two track circuits. Al- ugh the voltage is not delivered ctly between both rails, the differ- e is very slight, owing to the values the impedances in the elements of loop.

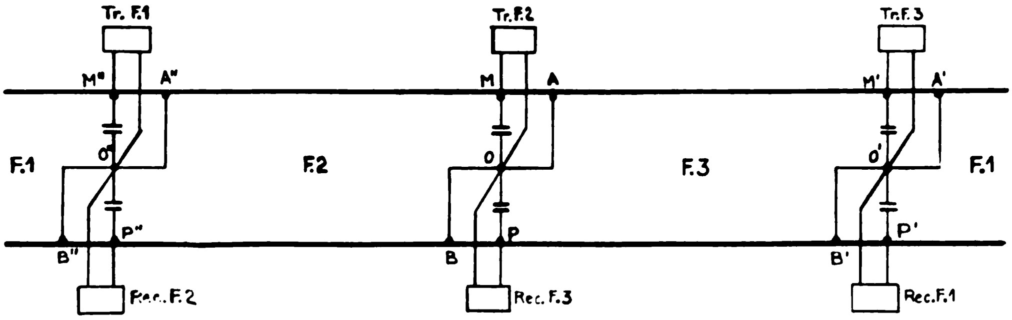
It is necessary to change frequency m one section to the next. In prac- e, three different frequencies are





Top pair of drawings show electronic track with codes of 110, 180, 210, 275 and 315 cps. **Fig. 2** (top) transmitter; **Fig. 3** (below) receiver. Bottom pair of drawings show electronic track circuit without insulated rail joints. **Fig. 4** (upper) basic principle; **Fig. 5** (lower) adopted in practice.





used, each loop being a short circuit for the next frequency. In addition, as a supplementary precaution, the groups of three frequencies are different on one road and the other.

The shunting action of the wheels is effective within a variation of only a few yards at the point where the track relay de-energizes. Thus, a short overlap appears, which is quite acceptable. Any rail break is detected by the dropping away of the track relay. Harmonics of traction current do not cause interference. Transmitters and receivers are fed by an 8-volt signaling battery and their consumption is 3 to 4 watts. The voltage on the track is 0.5 volt.

The maximum distance between a transmitter and its receiver being half a mile, it is necessary to equip longer sections by the use of two or more cut sections. The track relay is connected at the end of the last section and at the intermediate point no loop is necessary, since only a transformer associated with a condenser in series need be used. When no train is in its section, the receiver at the intermediate point receives a signal and the transmitter connected between the rails has its transistor biased and retransmits.

Sufficient experiments have taken place in France with this jointless track circuit, either on DC or AC electrified lines, to prove that it works reliably and complies with the rules of signaling.

In the classification of track circuits must be included the high voltage impulse type track circuit, which has been developed to a high degree in France, since more than 2,000 are in service at present. The impulses of this track circuit are delivered at a voltage of about 100 volts on the rails and at a frequency of three per second. These impulses are used to energize the track relay; a condenser is connected to its winding, while a valve (or a diode) gives passage only to current of the right polarity.

In the original type, the impulses were generated through a thyratron, which required a DC supply of about 1,500 volts to work the tube. The most recent arrangement, however, uses a silicon controlled rectifier instead of a thyratron (Fig. 6). The whole transmitting unit requires no more room than a conventional relay and the maintenance is extremely simple.

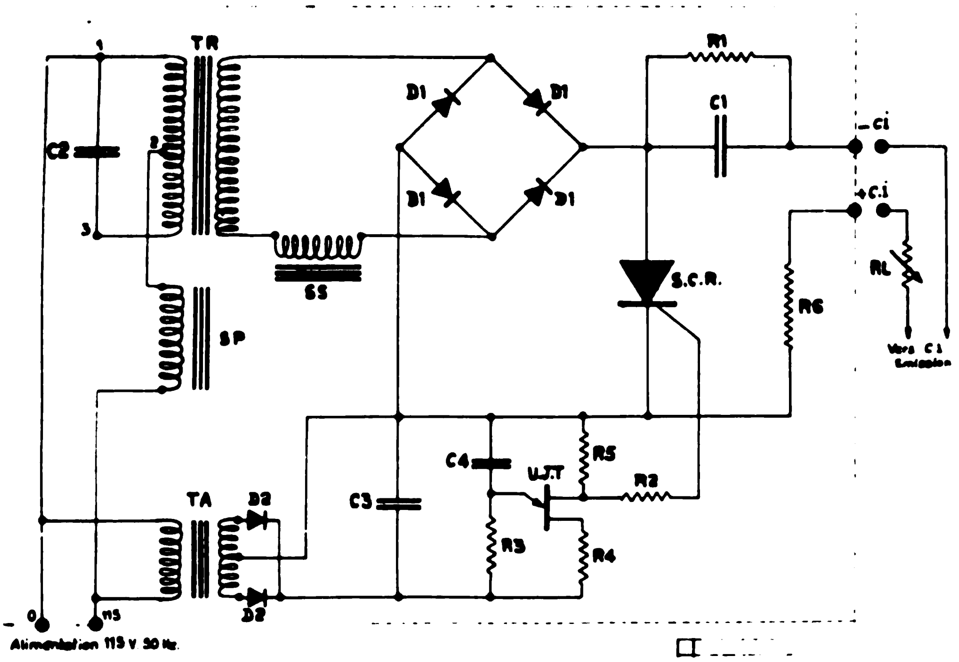


Fig. 6—High-voltage impulse-type track circuit transmitter has a silicon controlled rectifier (SCR). TA = transformer 115/2x20 volts; TR/SP = regulating transformer; C2 = 4 mf; SS = charging current limiter; D2 = two 100-volt silicon diodes; C3 = paper condenser, 10 mf; C4 = polystyrene condenser, 1 mf; R2 = 22 ohms; R3 = 500,000 ohms; R4 = 270 ohms; R5 = 33 ohms; D1 = four 500-volt silicon diodes; C1 = five 50 mf condensers in parallel; R1 = 150,000 ohms; R6 = 2 ohms; and RL = resistor adjustable in 1 ohm steps. Alimentation = supply of 115 volts, 50 cps, AC; Vers Ci emission = output current.

Such impulses have the great advantage of enforcing the short circuiting of the rails by the wheels of a vehicle, whereas some irregularity may occur with other types of track circuits. These irregularities may happen in the case of rusty or dirty rails, mostly when the train is composed of one or two light vehicles. The same thing may be observed on sanded track. A great deal of study and many experiments have been made in some of the Continental countries regarding the theory of track circuits in order to take these phenomena into account. It has been found that the conventional way of calculating track circuits, which does not take into account any isolating film that may cover the rail, does not give a complete explanation. The voltage necessary to break this thin coating on the rail has more importance than the shunting value, which is usually quoted as the only characteristic of quality for a track circuit. The contact between the wheel and the rail is either a semi-conductor, or it belongs to the disruptive type. In all cases where the surfaces of the wheel and of the rail are not perfectly clean, the increase in voltage is a great help towards short-circuiting the track relay. Besides, the very short duration of the impulses has two advantages: they ensure a low consumption for the track circuit and they are of no danger whatsoever to the men working on the track.

This new track circuit has also been employed to solve the problem of sanding. By themselves, in fact, these impulses are not able to exert their disruptive effect through a thick sanding on the rails. But a heavy sanding is more a habit than an actual need for the locomotive engineers. When sanding is necessary, as in the case of starting a very heavy train, a certain quantity of sand is required. Experiments have been carried out in France in order to find out if the minimum quantity of sand required by locomotive engineers in these conditions can be dealt with by improved track circuits of the high-voltage type. These experiments have shown that the possibility of a solution existed if the sanding from the engines was limited by the pipe and the delivery device, while at the same time the track circuit had the characteristics mentioned above. The French Railways have adopted these conclusions and whereas a great number of incidents have occurred in the past due to sanding on track circuits, these incidents have now disappeared, thanks to the precautions taken both by the traction and the signaling department. **RSC**