IRSE
Institution of Railway Signal Engineers

Train detection – the basics

BACK TO BASICS


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This, second of a series of articles on 'back to basics' themes, looks at the essentials of train detection (or more accurately, as we shall see, train absence detection). One of the main safety requirements of a train control systems is the need to know it is safe to establish a route and provide movement authority for a train. In particular, before points or other moveable infrastructure has its position changed or a train is given permission to proceed, the relevant part of the line has to be proved to be clear of other trains. Thus, the ability to detect the presence of a train on a particular stretch of track is a key requirement for modern train control. The principles of train detection will be very familiar to experienced signalling engineers, and so this article is intended for members new to the industry.

"There are two main types of technology generally used for train detection"

There are currently two main types of train detection system, namely the track circuit and the axle counter. Both of them use track-based technology, and although other track-based solutions have been trialled over the years (including mass detectors, infrared and optical detectors), none of these have been widely adopted. We will look at both track circuits and axle counters in some detail in this article.

An alternative approach is to use train-based technology, whereby the train determines its location and communicates this information to the interlocking and control centre on a regular basis using a reliable secure communication link. Various technical options exist, including:

- Satellite positioning (Global Navigation Satellite Systems – GNSS).
- Odometry (counting wheel revolutions).
- Video (by recognition of infrastructure features).
- Proprietary systems offered, in particular, by Communication-Based Train Control (CBTC) suppliers.

These solutions are sometimes used in combination to achieve the required degree of positional accuracy, and they may also be supplemented by equipment such as track-based balises or RFID (radio frequency identification) tags to periodically correct incremental positioning errors. Train-borne positioning systems are a standard feature of modern CBTC systems (which often use moving block technology) and will be for ERTMS Level 3 as well. We will explore this subject further later in this article.

All train-borne positioning systems rely upon some form of train to track communication system so that the interlocking is regularly provided with up-to-date information about the train location. This may be a radio system, or a short-range communication system such as inductive loops in the track, Wi-Fi, or leaky feeder technology.

Despite the growth of train-based technologies, for the majority of railways around the world that use train detection systems, the track circuit and the axle counter continue to be the favoured solutions. There are, of course, also many railways which use little or no train detection technology and rely instead on 'absolute block' methods of working or 'train orders' (verbal communication between the control centre and the train drivers).

Track circuits

The track circuit was originally used simply to remind signallers that a train was present on a particular section of track, not as an integral part of the locking of points and signals. It was the development of the track circuit that enabled the full potential of 'space interval' signalling based on track circuit block principles (continuous train detection between signal boxes). It also enabled signals to be provided that worked automatically with the passage of trains.

The track circuit continuously proves the absence of a train from a given section of track in a fail-safe manner. It cannot prove the presence of a

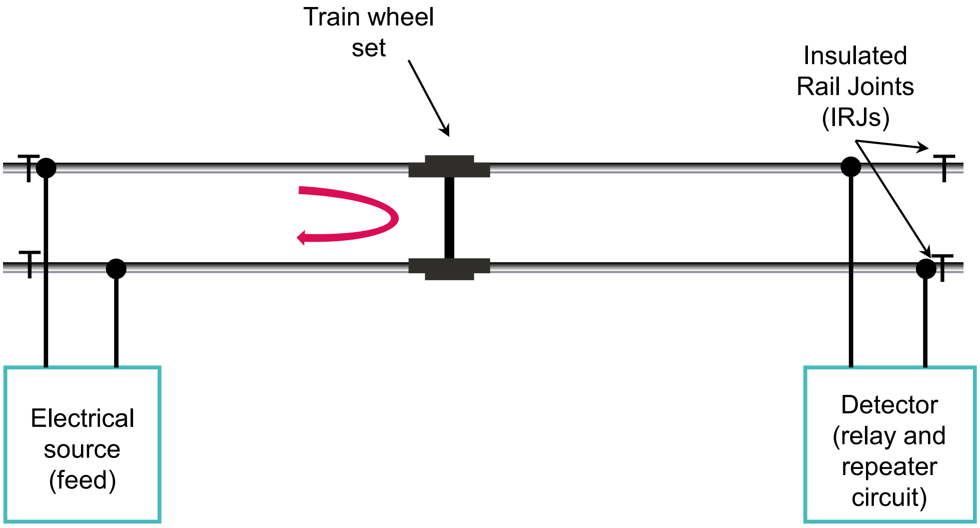


Figure 1 – The fundamental principles of the track circuit are simple. A train travelling between an electrical source and detector shorts out the current flowing between them, and the loss of current at the detector indicates that the absence of trains can no longer be assured. More modern devices use coded, typical shift-keyed, signals to offer more immunity to complex traction systems.

train, since almost any failure mode will give the same indication as if a train is present. By positively proving the absence of a train, a track circuit can be used to confirm that it is safe to set a route and permit a train to proceed. The track circuit should not be confused with a 'rail circuit', which is used for non-fail-safe applications to positively prove the presence of a train.

Fundamental design principles of track circuits

The most basic track circuit consists of a source of electrical energy (a direct current – DC), fed through an impedance and along the rails to a boundary which is defined by a pair of Insulated Rail Joints (IRJs are provided at both ends of the track circuit to define the detection limits of the track circuit). At the boundary a detection device, typically a relay, is connected across the rails and is energised by the direct current provided there is no train present (see Figure 1).

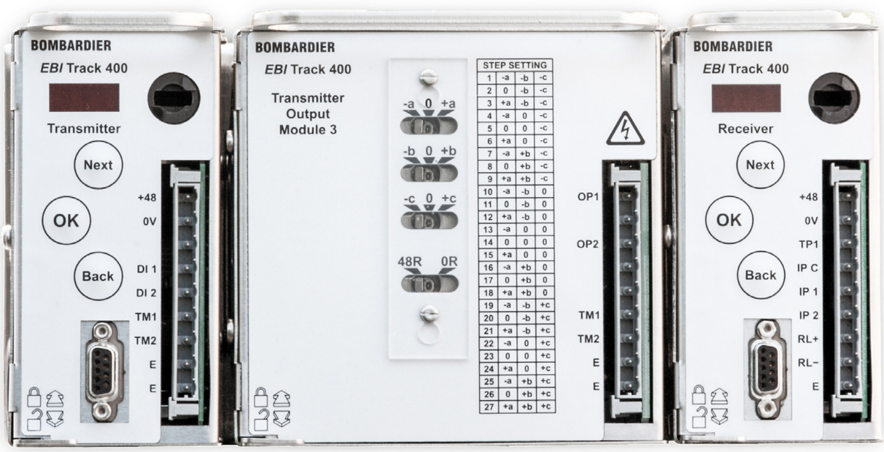
Thus, the track circuit confirms the absence of a train to the signalling system (track circuit clear). The presence of metal wheels and axles of a train within the track circuit boundaries will cause the rails to be 'short circuited.' The increased current flow results in a greater volt drop through the feed impedance which, together with the shunting effect of the short circuit, means the detector no longer sees sufficient electrical energy to remain energised, and so it changes to the 'de-energised' state. This state change informs the signalling system that the track is 'occupied'.

Any electrical short-circuit between the rails, whether caused by a train or not, or any disconnection within the circuit (for example a cable being cut or falling off the rail), or a loss of supply current, will cause the track circuit to inform the signalling system it is occupied. This means that virtually any equipment fault will cause the system to 'fail safe' and thereby maintain signals at red. Although safe, this behaviour can result in unreliability, especially if the track circuit is not set up or maintained correctly. A track circuit operating device (e.g. 'clips') can also be used to protect a train in an emergency. Correct operation of a track circuit also depends upon good electrical contact between a train's wheels and the rails, together with a continuous low-impedance path between each wheel via the connecting axle on the train. This will be discussed later.

DC, AC and coded track circuits

Simple as the track circuit may seem, there are various ways of powering the system and detecting the state of the track circuit (occupied or clear), and all have their benefits and weaknesses.

The source of electrical energy may be any of DC, AC at power frequencies (typically 50Hz), AC at audio frequencies (a few thousand Hz),



Bombardier's EBI Track 400 is typical of modern, microprocessor-based track circuits that use coded waveforms to provide traction immunity and can operate without insulated rail joints. *Photo Bombardier.*

In many temperate climates autumn leaf fall can cause contamination on the rail head, and unreliable shunting of track circuits.

"Tread-braked trains can sometimes give a better track circuit shunt than modern disc-braked trains"

a series of impulses or complex waveforms including digital codes. Similarly, the detector may be a simple relay, an AC 'vane' relay or a more complex receiver tuned to a particular frequency or pattern of signals. It should be noted that the high volume of conductive metal in a rail results in a high inductance and thus track circuits with a high frequency component tend to be short in length. Some track circuits can also act as a carrier for coded signals that are passed to the train. These are usually associated with ATP and early ATO systems, and examples include TVM430, the original ATP system used on French High-Speed lines, and the original implementation of ATP with ATO on the London Underground Victoria line.

The two rails on a railway are in practice not perfectly insulated from each other. There is always a leakage path between the two through the rail fixings, the sleepers, the ballast and the ground itself. This is known as the ballast resistance. Its value is dependent upon the condition of any rail insulation, the cleanliness of the ballast, and the prevailing weather conditions. It is inversely proportional to track circuit length. High ballast resistance values are ideal for a track circuit and may be obtained in dry/clean conditions or during frosty weather, but wet conditions may reduce the value significantly, especially where there is bad drainage and/or contamination from conductive materials in the track-bed. So, if for instance the track is flooded, the track circuit will show occupied and the signal controlling the track section will remain at red. Wet tunnels, sea walls and similar locations can be a particular problem, as the conditions can vary significantly on a frequent basis, which means that the track circuits need to be repeatedly adjusted to keep them working reliably and safely.

One difficulty with adjusting track circuits is knowing the prevailing value of ballast resistance. If a track circuit fails due to wet weather, it may be possible to remedy the situation by reducing the feed impedance. However, a too low feed impedance can lead to trains not being detected (a 'wrong side failure'). This will occur when a low feed impedance allows enough energy to reach the detector despite a train standing on the track. Some track circuits with highly variable ballast conditions may need frequent, often seasonal, adjustment to avoid this risk. This adjustment and testing currently has to be carried out manually, putting staff out on the railway and therefore placing them at risk, as well as being an expensive and time-consuming use of resources.

Rust films and contaminants

The resistance through the train's wheels and axles is also an important factor, as it is the train which shorts out the track circuit. There are several ways in which the resistance of this short circuit may increase, with detrimental effect on operation.

One way is the presence of a rust film on the rail head or wheel. The mechanical strength of light rust films is much reduced by the presence of moisture, when the contaminant tends to be squeezed out from the wheel/rail contact patch. Therefore, lightly rusted rails will only be a problem when dry. Very heavy rust, from prolonged disuse of the track, or after re-railing with new rail, can result in track circuits being incapable of detecting trains, especially lightweight trains as they are not heavy enough to penetrate the layer of rust. Therefore, care needs to be taken after track relaying, when track circuits should not be restored to full operation until a good electrically conductive surface has been created. One positive result from today's crowded railway on some routes is that busy lines have little chance to rust, reducing the problem. However, seldom-used branch lines, particularly in coastal regions where rust formation is exacerbated by salt, are at risk.

Other contaminants that increase the electrical resistance between the rails and the train's wheels can cause the same problems. Those associated with falling leaves are generally limited to the autumn, and are usually confined to known locations, which may include built-up areas. Leaves are drawn into the wheel–rail interface by the passage of a train where they are squashed into a pulp. This contaminates both the rail and wheel, causing wheel-slip problems when wet, and significantly increasing the electrical resistance when dry.

Reasonably dry weather with little wind will cause the leaves to fall gradually over a longer period, and they will be reasonably sap-free when they do fall. But high wind conditions will lead to a sudden fall of sap-laden leaves, giving rise to the worst conditions.

"Direct metallic connection between the rails will cause the track circuit to show as occupied"

Problems with coal dust and other similar contaminants on the rail head tend to be confined to collieries and other loading/unloading areas. Sand contamination can also be a problem, although not so much due to seaside locations, but with slow-moving locomotives using excessive amounts of sand for adhesion purposes. In each of these cases, the effect is similar to heavy rust. Problems can also occur with ballast condition issues associated with carbon-based contaminants, and of course heavy rain causing puddles and floods can short out the track circuits.

Train issues

Where a thin film of contaminant insulates the wheel from the rail, this can often be pierced if there is a rough surface on the running face of the wheel. The older style of tread brakes caused the wheel tyres to be cleaned and roughened at each brake application, whereas more modern disc-braked trains do not, and the tyres may be rolled into a very smooth surface condition. Therefore older tread-braked trains generally provided better track circuit operation than modern disc-braked trains.

"Insulated rail joints are expensive, both to install and to maintain"

Similarly, the axle weight has an effect, as a heavy load will pierce a film more easily. Again, modern lightweight trains, which are designed to minimise track wear, cause more track circuit problems than old-style heavy locomotive hauled trains.

To assist vehicles to shunt track circuits, a device known as the 'Track Circuit Assister' (TCA) is sometimes fitted to modern trains in Britain to induce an electrical potential between the wheelset and the rail head and thereby break down any insulating film. Typically, a TCA consists of a control unit and aerial with associated tuning unit, mounted between a pair of wheelsets close to the rails. These devices tend to be fitted to the end bogies of the train because it is important, especially around point work, that the extremities of the train are detected so that the points cannot be inadvertently moved at the wrong time.

Insulation

As has been described, any direct metallic connection between the two rails will be interpreted by the track circuit as a train and will cause the track circuit to show occupied. Therefore, apart from the insulated rail joints or block joints used to electrically separate sections of line, the reliable operation of track circuits also requires the provision of insulators to stop other track components shorting out the track circuit.

At a set of points, for example, there are many cross-rail connections – stretcher bars, point motors and heating elements – all of which need to be insulated, giving rise to quite complex insulating and bonding arrangements. In addition, the actual running rails cross at the 'frog' or 'heel' of the points, requiring insulated rail joints and bonding in the switch rails to transfer the polarity of the circuit to the other rail. Designing track circuits to work reliably and safely through complex switches and crossings can be quite a challenge!

Concrete sleepers incorporate a rubber pad under the rail foot and moulded insulations where the fixings bear on the top of the foot. These increase ballast resistance to levels significantly higher than can be obtained with timber sleepers. However, the insulations can erode due to the vibration of passing traffic and, consequently, require inspection and periodical replacement – another maintenance overhead. Steel sleepers are even more of a problem. They are also insulated, of course, but any degradation of that insulation will result in severe problems.

Ultimately the maximum length of a track circuit will be limited by the achievable ballast resistance, its variability with prevailing environmental conditions, and the level of reliability required. It will also be influenced by interference from electric traction, which is discussed below. In the UK it would be reasonable to assume that these factors limit a track circuit to a maximum of about 1500m, although isolated examples of longer ones can be found.

Bonding

Bonding is the means by which the individual components of the railway track are connected together electrically for track circuit purposes. The term also includes the additional electrical connections necessary for the proper operation

The black art of bonding in areas with track circuits and third-rail traction is very visible in this view of Clapham Junction in South London, UK. Look out for impedance bonds, traction cross-bonds, and track circuit bonding in this photo. *Photo Shutterstock/ Ian Stewart.*

of electric traction. For a track circuit to fail safe (show occupied) in the event of a bonding disconnection, it is necessary to bond all elements of the track circuit in series, so that any one failure breaks the circuit. In practice, in switches and crossings it may not be physically possible to arrange series bonding of every part of every rail.

Later in the article we will deal with single rail traction bonding (which only provides series bonding for the track circuit signal rail as the traction return is usually bonded in parallel with other traction return paths); and 'double rail traction bonding' (providing total series bonding for a track circuit as well as both rails for the traction return path). In the majority of cases traction bonding through switches and crossings is single rail traction where track circuits are provided.

"Audio-frequency track circuits can be unsuitable unless the point work is very simple"

Insulated rail joints

IRJs are expensive, both to install and to maintain, especially on tracks subjected to high speed, high axle-weight traffic or where there is an intensive service. A rail joint also presents an increased risk of rail fracture, although now with factory made six-hole glued joints this is less of a risk than with older styles of IRJ. As mentioned above, they are also required in areas of points and crossings, which makes the railway less physically robust than track engineers would wish.

It is also possible for the insulation in the IRJ to be compromised, either by failure or by burring of the top of the rail such that it bridges the insulating element. This could cause a wrong side failure because one track circuit supplies power to the detection element of the next track circuit, across the failed IRJ. For this reason, most simple DC and low frequency AC track circuits connect to the rails with opposite polarities either side of the IRJ to ensure that, should the insulation fail, both track circuits will show occupied.

One solution for avoiding IRJs is the use of audio frequency AC track circuits which permit the physical limits of an individual track circuit to be defined by 'tuned' zone, rather than by insulators in the rails. Adjacent and parallel track circuits operate at different audio frequencies and each one is designed to detect its own track frequency but no other. It is possible, with careful design, to arrange a short overlap in the centre of the tuned zone where both track circuits are effectively shunted.

The use of audio frequency track circuits is not always a practicable solution for complex switch and crossing layouts, not least because of the complication of significant rail impedances associated with parallel bonding.

Broken rails

By their very nature of operation track circuits are sometimes regarded as a means of detecting broken rails. However, track circuits will only detect a broken rail that is fractured all the way through and is not bridged by any form of bonding or other electrical connection. So, a damaged rail head or foot will not be detected but could be equally problematic. On an electrified railway the need to maintain a traction current return path through one of the rails and other paralleled conductive infrastructure means that in many cases breaks can only be detected in the other rail. Hence broken rail detection is, at least in the UK, now managed by the routine monitoring of the rail condition including ultrasound scanning, not by dependence upon track circuits. And of course, as we shall see, axle counters are of no help at all with broken rail detection.

Electric traction

On electrified railways, track circuits must operate despite large traction return currents passing along the same rails. The disparity is substantial, with AC traction currents of 300A or more and DC traction operating at up to 7000A. These values exclude traction fault conditions and are far larger than the track circuit currents which are a few amps at most. This gives rise to the concept of AC immune and DC immune track circuits. There are also some areas that have both forms of traction current supply which therefore require dual immunity.

The initial way of providing immunity was to use DC track circuits in AC territory and AC phase sensitive vane relay track circuits in DC traction territory. Where both types of traction were in use it was not unusual to use a locally generated special frequency to power AC track circuits, such

Below left: Rail breaks are rarely as clear-cut as this example, and not all rail breaks will be detected by track circuits – but no rail breaks will be detected by axle counters. *Photo Shutterstock/ Michael715.*

Below right: The introduction of any new or different rolling stock on areas where train detection is a significant part of the signalling system requires detailed analysis of the susceptibility of the trackside equipment to large traction currents. *Photo Hitachi.*

Axle counters are increasingly preferred as a less intrusive means of train detection. *Photo Thales*.

as 83.33Hz using rotary converters. This enabled the track circuits to detect and respond to the 83.33Hz frequency but not DC or 50Hz AC.

Today, whilst these arrangements are still common, there is a steady increase in the use of modulated audio frequency track circuits selected for immunity. This move is partly the result of the application of three phase traction drives, which produce many harmonics some of which are present in the traction return currents. In practice the range of frequencies produced by modern three phase traction units makes it a challenge to find immune frequencies suitable for track circuits. This is also one of the reasons why there is a trend to use axle counters as the modern form of train detection.

"Coded track circuits can be used to transmit information to a moving train"

Track circuit arrangements in electrified areas are constrained by the need to ensure safe and reliable operation of both signalling and traction systems. This means that the track circuit must be immune to both false operation and to damage by the flow of traction currents through the rails. This also causes complications because, while the signalling track circuits are separated from each other by IRJs, the traction current needs a continuous electrical connection back to the substation.

This problem has led to the use of impedance bonds on double rail traction track circuits. These are devices that present a low impedance to traction current and a higher impedance to track circuit current. In simple terms, they allow traction current to pass along the rails and around the IRJs, but stop the track circuit currents in order to separate one track circuit from the next.

Although track circuits are designed to be immune to false operation (wrong side failure) from the presence of traction currents flowing in the rails, any significant imbalance in the amount of current flowing in the two rails may be misinterpreted by the track circuit detector as indicating that the track is unoccupied when it is not. In particular any fast change in the traction current may cause a short-term imbalance, which is why track circuits on electrified lines are normally designed to be slow to energise (i.e. slow to show track clear).

In DC electrified areas, the relatively low supply voltage results in high currents returning to the sub-stations via the running rails. In order to minimise voltage drop and consequential power losses in the DC-traction supply, all running rails are used for the return of traction currents wherever possible, and therefore double- rail track circuits are used. There is usually cross bonding between different tracks as well so that the current has as many feed and return paths as possible, again to minimise traction energy losses. As in AC areas, impedance bonds are used to ensure the traction current has a return path to the sub-station, whilst the adjacent train detection sections are kept separate from each other. In switches and crossings, however, it is not usually possible to bond the track in double-rail form, and therefore single-rail track circuits must be installed. It should be noted that 'single rail' track circuit really means single rail traction current return, as both rails are still used by the track circuit.

In AC overhead electrified areas, traction currents are generally lower than in DC systems and, in many cases, single rail traction return is sufficient for electrification purposes. However, increased traffic levels and alternative feeding arrangements may sometimes require that both running rails are used for traction return.

Coded track circuits

Coded track circuits can be used to transmit information to a moving train. The amount of information that can be communicated is limited to simple messages, for example transmitting one of a small number of modulations (14-20) to send maximum safe speed and target speed combination. Such systems can require extensive lineside equipment for each track circuit, especially on bi-directionally signalling lines. For the train to successfully detect the transmitted information before it is shorted out by the train wheels it must always run towards the transmitter end of the track circuit. Thus, on bidirectional lines it is necessary to switch the feed and detector (relay) ends of the track circuit depending on the direction of travel of the signalled train. This added complexity and the consequentially greater failure risk is one of the reasons that modern train supervision systems are generally moving away from coded track circuits to radio-based communication systems.

Axle counters

As its name suggests, an axle counter system used track-mounted equipment to count axles entering and leaving a track section. This information is evaluated to determine whether the track section is occupied or clear. They perhaps they should be more accurately called wheel counters, since the device attached to the rail uses a magnetic field to detect the passage of the rim and flange of a wheel. But because on most rail vehicles the wheel is connected to an axle with another wheel on the opposite side, they are called axle counters. Each axle counter head usually has two detectors on the rail, so the direction of travel can be identified. The head is connected to an evaluator which counts the number of wheels that pass. To make a train detection section two heads are connected to one evaluator, denoting the ends of the train detection section. One counts the wheels that enter the section and the other subtracts the wheels that have left the section. If the answer is zero the track section is deemed to be clear of trains. Note that because both heads can tell the direction of travel, both can either add or subtract from the total. Typically, one head can communicate with two evaluators, meaning one head is used both to count axles exiting from one section and entering the next.

"One particular advantage of axle counters over track circuits is that they can be overlaid on another detection system"

As can be seen from the above description axle counters depend on the equipment being able to count and store in memory the number of wheels that have passed. Such technology, as well as the communication between the three elements of the system, is much easier with modern computing systems and this explains the relatively recent increase in their use in some parts of the world. Other reasons for adoption are they are very largely (although not completely) immune to traction current interference; there is no limitation on section length, so especially on rural routes the volume of trackside equipment and associated power supplies becomes much smaller; and they are not influenced by rail head or ballast resistance conditions. In addition, the traction supply engineer is able to design the traction return system including all the cross bonding required, as well as the track earthing connections for AC traction, without the constraints of track circuit application rules. Finally, there is no requirement for an IRJ or block joint, which increases the integrity of the track system and reduces costs. Axle counters are now the preferred method of train detection for all new schemes in Great Britain and in many other countries throughout the world.

One particular advantage of axle counters over track circuits is that they can be overlaid on another detection system (whether track circuits or another axle counter system) during a re-signalling, thus enabling the new detection system to be tested and proved to be operational before it is required to control the railway. Compare this with track circuits where only one track circuit can be installed on a section of track at a time.

Axle counters are not without their problems, however. An axle-counter section cannot be made 'occupied' by the use of a track-circuit operating device to protect a train, nor will an axle-counter system detect a broken rail. However, the introduction of train radio for emergency communications has provided an acceptable alternative to the use of track circuit operating clips, and as referred to earlier, a track circuit is not regarded as a reliable means of detecting a broken rail.

More significantly, when an axle-counter system fails it loses track of how many axles have passed through it since the failure occurred. Therefore, for safety, it is designed so that when the failure is fixed, it shows the section of line as being occupied, unlike a track circuit. The section then needs to be proved clear of a train before the axle counters can be reset and restored to operational use, which can take some time.

Another problem with axle counters is that a right-side failure can occur when a wheel stops directly above the inductive sensor, known as 'wheel rock'. When the train leaves there is a high risk the section will remain occupied with no train present and the time-consuming process of reset and restore has to be carried out. That can cause difficulties at a busy station, especially if the platform is configured for multiple short trains stopped at various locations along the same platform. For these reasons, some sections of railway (e.g. Thameslink in the UK) have decided to retain track circuits where there are multiple split sections along the platforms.

Cab signalling systems

Modern signalling has a greater dependence on train-borne systems and communications, with CBTC becoming the dominant form for metro lines. These systems rely on the train regularly reporting its location and other information to the control centre, for which of course it requires a reliable communication link. Wi-Fi or data enabled radio (e.g. 4G/LTE) are used for the ground to train communications, with 4G/LTE now becoming favoured due to availability concerns with Wi-Fi. Together with the use of ATP and ATO, these are the key reasons why capacity can be increased on metro routes.

ETCS is the equivalent of CBTC for main line railways. However, enabling a main line train to define its position accurately is a greater challenge than is the case with metros (the latter invariably having fixed formation trains). Whilst the leading vehicle of a train may be able to inform the control centre of its location and movement, it is much more difficult to confirm the location

“For GNSS to work reliably there needs to be clear ‘line of sight’ from trains to satellites”

“Track circuits will still be used for many years to come”

of the rear of the train (unless the train is a fixed formation). In particular it is difficult to confirm that the train is still complete i.e. no vehicles have been left behind due to detachment (known as ‘train integrity’). The lost wagon or coach on a locomotive hauled train remains a significant challenge for main line railways. Thus, although ETCS level 2 can be operated without lineside signals, it still uses trackside train detection based on track circuits or axle counters.

ETCS level 3 is the conceptual system that will enable trackside train detection to finally be removed on main line railways, but when we will see it deployed extensively is an open question. The option of ETCS hybrid level 3 is one way of gaining some of the benefits of Level 3 whilst avoiding the train integrity problem. In hybrid level 3, fixed formation trains such as multiple units, which can easily be confirmed to be complete, are allowed to operate at level 3 whereas others (loco hauled freight and passenger trains) are operated in level 2. Thus, the infrastructure is equipped with train detection, but more than one level 3 train may occupy a given train detection section at a time. Furthermore, if the trains that are operating in level 2 in a hybrid level 3 area are sufficiently infrequent, it may be possible to have longer train detection sections and thus less trackside equipment on such lines.

ETCS standards currently specify that trains identify their location using a combination of balise reference points and tachometry, supplemented by Doppler radar. However, there is no fundamental reason why this information could not be generated from Global Navigation Satellite Systems (GNSS) such as GPS, or video tracking and position identification, provided it can be proven to meet the appropriate Safety Integrity Level (SIL).

Even in full level 3 areas, some track-based train detection is still usually considered essential in locations where moveable infrastructure, especially points, require locking. The provision of some track-based train detection may also help recovery to normal operations after an ETCS failure.

GNSS and Positive Train Control (PTC)

In the US, systems using GNSS are being introduced as part of the requirement to introduce Positive Train Control (PTC) over some 60 000 miles of railways. The challenge of installing PTC is further complicated by the fact that there are ten different systems in use across the US. Some systems use satellite links for train separation and were designed for areas of ‘dark territory’ where line-side signals and train detection are not provided and instead trains are controlled by train orders and track warrants.

As well as train location, GNSS based systems can also be used for passenger information both on trains and at stations. A further possible use of GNSS is to trigger the warning on the approach to a level crossing with a constant-time lapse regardless of the speed of the train. In a similar way, track workers could be alerted to the approach of a train within a known fixed time.

However, for GNSS to work reliably there needs to be clear ‘line of sight’ from trains to satellites, which may be prevented by bridges, tunnels, cuttings and on sub surface lines. GNSS also presents a potential problem in that neither the infrastructure manager nor the train operator will have any control over the availability of the GNSS signal.

Remote condition monitoring

Track circuits will still be used for many years to come, not least because of the massive task of replacing life-expired signalling some networks, so clever asset management and maintenance techniques will be required. One initiative that has helped reliability is remote condition monitoring (RCM). By monitoring the track circuit current, potential failure modes can be predicted and interventions planned before failure occurs. It is not something that is easy to automate, but there have been consequential improvements in track circuit reliability, with potentially more to come.

One recent innovation involving the use of RCM allows new jointless track circuits to be inspected in real time from remote locations, thus improving reliability. Prior to its implementation, track circuits had to be checked on site using digital multi-meters, which was a time-consuming task and not conducive to finding faults before they occurred. Axle-counter systems also have sophisticated built-in remote diagnostics, and this is one example of the digital railway delivering results today.

Conclusion

The development of train detection systems has been driven by need, accident and available technology. Increasingly we are seeing the use of train-based location systems, but track-based systems will continue to be important for many railways around the world.

Both of the major methods of track-based train detection, namely track circuits and axle counters, have their supporters and detractors. However, for now at least, axle counters are used more than track circuits for new signalling systems.

Have you got an idea for a future ‘back to basics’ article? Perhaps an area of command, control, signalling and telecoms engineering that you’d like to understand better.

Could you share your experience of these topics with the next generation? If you could contribute to a future article do let us know, email editor@irsenews.co.uk and we will be happy to consider your ideas.