Radio Based Signaling
System Description
Integrated Radio-based Signalling from Siemens SIMIS RETB

In the face of increasing traffic problems, many projects in recent years have concentrated on major routes of the railways having a very high traffic density, e.g. trans-European networks. It therefore seems appropriate now to point out that the so-called 'branch lines' or lines with medium or low train frequencies constitute a major part of the line network for which investments such as ETCS Level II or a Radio Block Centre based on GSM-R would not be worthwhile. In this presentation a system shall therefore be discussed which was designed with precisely these lines in mind and still does not go against the idea of a standardized European signalling system. One of the conditions when developing the system was that an up-to-date solution should be created using the benefits of modern technologies.

A sufficient demand for a low-cost system permitting train operation with full signalling evidently does exist in this market segment.

The volume or density of traffic on branch lines is typically from a few odd trains up to some ten or twenty a day. Although there are several trains on the line at a time, making signalling necessary, between two stations - or, in signalling terms, block posts- there is never more than one train. In the station area, crossing and passing moves need to be implemented; beyond this, however, operations such as the formation of new trains generally do not occur. Thus, the signalling equipment must be "fail-safe", and matched to the actual operational needs.

The optimization of the equipment with respect to the demands of the volume of traffic and the implementation of simple methods of train protection are the principal challenges facing the developers of signalling and safety systems. These are precisely the areas targeted by the system described here. Hence it is also of interest particularly to small railway authorities, especially due to privatization and the demand for increased economic efficiency.

The use of modern information and telecommunications systems permits the implementation of a wide functionality with fail-safe operation and comparatively low acquisition and operating costs. The most important operating parameters of rail transport are markedly enhanced: increased transport safety, shorter headways, improved user convenience and a better supply of information about the service status of peripheral equipment thanks to integrated maintenance and diagnosis support, enabling life cycle costs to be reduced considerably.

Advantages for the customer result particularly when attention is focused on producing a comprehensive, integrated system that is able to ensure a uniform level of transport safety and automation across the entire system of rail transport. Provided a decision was made in favor of a fail-safe system, the development of a compact and consistent overall system has a synergistic effect if the necessary investment in a signalling system is to provide a maximum degree of technical support and safety responsibility.

It goes almost without saying that any new signalling and control system is bound to be based on modern radio transmission. The SIMIS Radio-Operated System ROS comprises the following existing system units from conventional signalling in the form of an integrated and well-coordinated system:
- centralized traffic control (CTC)
- interlocking functions for route protection
- train control with cab signalling, with or without automatic running and brake control (automatic train control, ATC)

**ROS Variants**

There are several different types of radio-based system solutions for branch lines from Siemens; the two product variants currently being implemented are: SIMIS FFB and SIMIS RETB.

SIMIS FFB is a radio-based system that dispenses entirely with lineside signals, track vacancy detection and classical interlockings. The on-board unit performs important interlocking functions such as the setting and detection of routes. To a large extent, the system uses the interface specifications and standards of ETCS. It also makes use of telecommunications options rising from new technologies such as decentralized data transmission from train to field elements using GSM (GSM-R). German Railways, DB AG, is planning to switch over to FFB operation throughout its regional network. A first-time application of SIMIS FFB will be implemented for EXPO 2000.

The second variant of radio-based signalling is SIMIS RETB (Radio Electronic Token Block). It is built on the same hardware platform of SIMIS computers; however, the system's central orientation makes it more like a conventional solution. This means that changes to the operating rules and regulations are kept to a minimum, and the current distribution of functions and safety responsibilities remain largely unaffected, facilitating the introduction of a new system. This variant will now be discussed in greater detail.

SIMIS RETB, as already hinted, is founded on certain "conventional" concepts:
- The line is entirely controlled and supervised by a central interlocking.
- All train movements are carried out on the basis of locked routes. Locked routes and the central management of running orders instead of fixed signals prevent conflicting train movements.
- In many applications a lineside track vacancy detection system is desirable because this not only permits the current train positions to be ascertained but it also allows divisions of a train to be technically and safely detected. Therefore, an integrity check by the train is not required.
- The central signalling to the trains is performed using the well-known "token system" taken over from the British. The running order and permission to proceed are transmitted directly to the train in the form of electronic telegrams.
- A major advantage of the system results from the consistent use of state-of-the-art telecommunications and computer systems, without special signalling safety-related demands being placed on the transmission system.

**Description of Mode of Operation of Token-based Signalling Systems**

The two most important tasks of the signalling system are the exclusion of conflicting train movements and the avoidance of excessive speeds. This is achieved by signalling various proceed aspects: proceed, slow running etc. The generation of the correct proceed aspects must be ensured by the appropriate interlocking conditions in the block and interlocking equipment.

The signal aspects are normally indicated by means of lineside signals. These are, however, a major cost factor in infrastructure investments and maintenance—particularly for the semaphore signals. They
offer a big potential for rationalisation. Without these signals the corresponding information or running order needs to be indicated by other facilities, i.e. ultimately by a type of cab signalling.

A proven technique that manages without any lineside signals is the signalling of a permission to proceed using so-called “tokens”. These represent the permission to proceed into a particular track section. Such installations are used as section block systems, with the usually simple stations lacking any separate protection. The electronic token block system described here, however, also includes the station tracks in the detection.

Fig. 1 shows the general procedure. The entire line (incl. station tracks) is divided into track sections because the trains run with a space interval. For each track section there is exactly one individual permission to proceed (token). In order to enter a new section, a train must be in possession of the appropriate token. Only with this on board, is the train authorized to enter. Train A in the figure is thus permitted to proceed from section 3 to section 4, whereas train B may not leave section 5.

A fresh output of a token is not possible until the relevant train has cleared the section and the permission granted (token issued) for the section is available again on the track.

For the signalling of different speeds, the signal information represented by the token should have more than two states. This is not a problem in principle but does constitute a considerable extension over the original idea.

Originally, token systems were mechanical or electromechanical. The very first type, known from Scotland, has exactly one wooden or metal staff available for each block or line section that is assigned to the train when it enters the section. The exclusion of conflicting moves is ensured by the existence of only one staff. This extremely simple, but also effective, variant manages without any linc
communication. The disadvantage of the system is that train runs must take place alternately from one and then the other direction. The token moves to and fro with the trains between the two block posts.

In order to allow a number of train runs in succession in the same direction, mechanical 'staff token' systems were introduced. For each section there are a number of these staff tokens inside two block instruments situated at either end of the block section. Once a token has been removed from one of the two instruments, a second one can only be removed when the first one has been locked again in one of the two instruments. Because all the staffs can be removed train by train from one instrument and locked again in the other one, the number of succeeding moves without any opposing move is the same as the number of staffs which can be locked in one instrument.

These staff token systems resemble in many respects the block systems commonly found in Germany. They require the technical implementation of an exchange of information along the line because two block instruments always need to be interrogated for entry into the track section.

The two systems described administer the permission to proceed locally. The control of the block equipment thus requires personnel at the block posts.

**Systems with electronic tokens**

A number of other systems use modern telecommunications and information systems. The running orders (tokens) are no longer transmitted to the train physically, but as information instead. The principle of operation described above is, however, adopted by and large. The term “electronic token” is generally used in this connection. The basic characteristics of such systems and differences between the systems will now be outlined, without going into the specific product profiles in detail.

A simple variant is the provision of support for the operator in the administration of the tokens by means of a standard PC. The tokens are transmitted to the train by radio telephony and entered in a journey log in the locomotive. As a safety procedure, the journey log entry is repeated by the engine driver.

As an extension of such a system, the running orders can be transmitted to the train for indication across a data connection. The running orders are indicated or printed out on a special device in the locomotive. These systems do not provide any technical safety, but merely provide support for the operator and driver.

A first step towards technical protection of the system is the connection of the trackside equipment to an interlocking. This enables a consistent issuing of running orders by the system.

A further step is to interface the train-borne equipment with a train control system. This allows the reception of running orders to also be monitored automatically. In this way, the tokens issued can be used on the train to release the brake, for example, rendering the train unable to proceed without the token.

The different systems have been designed in their architecture for particular safety integrity levels. The system architecture alone, however, is not sufficient to ensure the operational safety. Operating procedures, therefore, need to be observed as well. Because these operational safety procedures are largely determined by the "human factor," one objective will be to make the equipment itself fail-safe and so relieve the staff of this responsibility as far as possible.

The various system variants can now be logically extended to incorporate architectures that are safe in signal engineering terms. This means specifically that the lineside administration of the tokens is performed on a fail-safe platform that monitors the observance of the running orders issued by means of fail-safe train control and protects the data transmission.
Common to these systems is the fact that both the lineside block information and the train-borne signal information are associated with the token. Owing to their simple operating principle, these systems have important operational and technical advantages. The operating rules are simple and at the same time relatively easy to implement in a technical system.

Now that the benefits of such systems have been mentioned, the limits shall also be pointed out. On lines with a high traffic volume, the issuing and withdrawal of the many tokens becomes complex and processing-intensive, making conventional cab signalling (e.g. by means of destination distance and target speed indication) appear preferable.

When a token system is introduced, in most cases the existing service instructions for operators and drivers need to be modified.

Electronic token systems offer many advantages provided only a few unequipped trains use the line since these need to be handled separately for signalling safety purposes.

In most systems available on the market part of the responsibility for safety remains in the hands of the staff, whether it be the reception of the running orders issued or ensuring that the train has completely left the section upon returning the token. In the design of the Siemens Radio Electronic Token System both these features were incorporated right from the start as fail-safe system functions. Hence the automatic train protection (ATP) system permits fully protected rail traffic.
**Principle of Operation of RETB from Siemens**

The running orders are transmitted to the train by radio in the form of tokens. A fail-safe token processor prevents multiple issuing, i.e. the signalling of conflicting train movements. In the system described here, not only is the open line protected but also the entire station area. (In Fig. 1 this system feature is taken into account: train A may proceed from section 3 to section 4 because it is in possession of the relevant token.)

In order to be able to grant the trains entry into certain station tracks, the tokens represent not only the destination station, but also the destination track. Thus, with the issuing of token 6 to train A in Fig. 2, this train would be granted permission to enter the main track of station Y.

In order to protect train runs from one station to another, the position of the points along the route needs to be managed by the safety equipment. Thus, a generally simple route logic is included as part of the lineside system functions. In addition, seamless track vacancy detection (either by the train or trackside) is implemented, enabling the system to check that the track sections have been completely cleared before it returns the tokens.

All the section limits are identified by means of balises. The system's integral intermittent ATC function can thus monitor the observance of the running orders issued. The data necessary for the detection of the route and speed supervision are ascertained by the self-locating function of the train and the combination of tokens in the train's on-board computer. Thus the train control system monitors on the one hand the end of the permission to proceed and on the other hand the observance of the maximum permissible speed in accordance with the route, distance from the destination, train class and other safety-relevant criteria.

Unlike many other token-based systems, the system described here protects the traffic fully by the integration of the token processor into the interlocking and the supervision of train movements by means of automatic train control. Thus, the system enables hazardous situations to be eliminated in accordance with fail-safe signalling principles.

**Bahariya Line Project, SIMIS RETB Reference Installation**

An initial system variant of SIMIS RETB was developed for the 350 km long ore railway at the Egyptian oasis Bahariya. Here a minimum of lineside installation was called for. On the one hand the points at the stations were to be operated manually (cf. below) and on the other hand axle counters needed to be used for track vacancy detection. The energy requirements of the local equipment were so modest that solar power could be used.

Fig: 3 shows the system architecture for the SIMIS RETB pilot application. The entire line is controlled and monitored by a central interlocking with an integral token processor. Here the entire interlocking logic is concentrated.
In the stations along the line there are element control computers for indicating the current state of the outdoor equipment to the control center and for issuing commands to the field elements and the pointsman's display board at the site. The vehicles are fitted with an intermittent ATC system and the track is equipped with the necessary balises for train locating. Voice and data are transmitted by a microwave system for the lineside communication with a train radio system on top of it. Together they provide the medium for communication between the central interlocking and the element control computers, and the link to the trains. The data both from the interlocking and to the train are protected at both ends of the transmission path by means of suitable procedures.

In the control center an electronic interlocking in proven SIMIS® 3216 technology is configured as a fail-safe 2-out-of-3 system with redundancy. In the stations along the line, element control computers are used to control the field elements. Due to the temperature range required and the limited power supply, the element control computers are implemented in SIMIS® 3116 technology. They ensure the activation of the field elements and control & display unit.

Each route is set in the interlocking for a particular train by the operator. The associated permission to proceed (token) is then transferred to the locomotive via the radio system using a special safety procedure. It becomes effective once it has been checked and accepted by the driver.

The particular location of the line – in the Sahara Desert – requires special point machines. Before almost every reversal, the points need to be freed from drifting sand and tested for functional integrity,
making the conditions unfavorable for electric point machines. In addition, the equipment along the line is solar-powered. The power consumption of electric machines is a further argument for the use of manual equipment. The points are secured with mechanical locks; the keys are locked locally in electric key release instruments. After the appropriate keys have been released by the central interlocking, the points can be operated manually by the pointsmen at the crossing stations. The position of the points and their locking by means of point locks are communicated to the central interlocking via the status indication from the key release instrument.

The ZUB/RET B radio-based train control system used is based on the Siemens ZUB train control system family. This system constructed in modular SIMIS 3116 technology is an extension of the ZUB 111 system introduced in Egypt. As already described, a cab signalling system takes the place of the lineside signals. This includes, in addition to the conventional ZUB 111 Indication Unit, an RETB-specific indication module (Fig. 3).

The ZUB 111 Indication Unit shows the maximum permissible speed (outer speedometer indication), actual speed (inner speedometer pointer), target speed (four-digit seven-segment display) and some additional operating states. The RETB indications include the number of the train addressed, its direction of travel (from/to Bahariya), the end of the permission to proceed (destination station) and the destination track. Here there are four possibilities: if the train needs to stop before the entry points of station "Y", the associated token is called "stop station Y". The entry into the through main track is signalled by the token "main station Y" and the move into the siding by the token "loop station Y". If a train is to pass the station without braking (this is desirable particularly for loaded trains), not the station immediately ahead but the station after that is signalled to it as the destination of the move. For shunting moves there is a special operating mode which is activated by the issuing of a shunting token called "shunt".

![ZUB 111 Indication Unit and RETB Indication Module](image)

**Fig. 3: Indication of signalling in the cab**

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The end of the track sections is signalled to the train in advance by balises (ZUB track coupling coils), enabling the ATC system to compute and supervise the braking curve in accordance with the tokens on the vehicle. Speed restrictions required on the line are signalled by additional balises.

Apart from the delivery of the signalling system, the project includes appropriate training courses for the technical and operating personnel, but also importantly a maintenance contract with a term of several years. This is to give the customer an assurance of optimal functional integrity despite the extreme environmental conditions.

Minor faults or failures are either tolerated by the redundant central interlocking or, if they occur in peripheral areas, do not seriously impede operation on account of their localized effects. Should a major incident occur nevertheless, operation can still be maintained by means of oral instructions via the radio telephone and train radio until the faults have been cleared by local maintenance staff. The typical mean time between repairs MTTR is in the region of a few minutes up to a few hours, with the upper limit determined by the long stretch of line in the desert and hence by the departure time.

**Outlook for the Future**

SIMIS RETB offers various upgrade levels or options, without affecting the basic concept regarding the operating principle and system architecture.

- The system is not bound to any particular configuration of lineside field elements. It can be used in conjunction with a large number of different - also existing - components; e.g. electric point machines, key release instruments, fixed- or variable-data balises, track relays, track circuits, axle counters, etc.

- An interesting exploitation of all the benefits is offered by equipping all the stations with automatic spring points and introducing general right-hand or left-hand running in the stations. With the functionality described above no further signalling safety equipment or personnel is required in the stations beyond radio base stations, balises and, where necessary, axle counters. Fully protected operation is thus possible with minimum outlay. In this upgrade level, ideally only one central CTC interlocking, fixed-data balises, on-board units and of course the telecommunications system are required.

- In the future, a gradual upgrading will also be possible while continuing to use existing systems. First the (in many cases mechanical or electromechanical) interlockings are connected to the new system. This can be done using additional indication contacts, lever locks or an extra connection of the existing relay interlockings. The control center interlockings are thus turned into remote interlockings that are controlled by the central interlocking. The existing lineside signals can thus still be used for trains not yet equipped with the system. During the upgrading, although fitted vehicles can be supervised, all other train runs need to be signalled from the track (the signal aspects between cab signalling and lineside signalling, however, must not differ to any considerable extent).

- To maintain compatibility/interoperability with existing systems of adjoining lines, either balises from existing systems can be integrated or the vehicles fitted with aerials and additional modules which can read and interpret both the RETB balise signals and conventional ATC aspects.

- In some cases it may not be possible to have only traffic with RETB-equipped train sets, i.e. on occasions non-equipped vehicles (e.g. maintenance machines) will have to be tolerated on the line. For such cases, portable units are available to supply the train/vehicle with the necessary signalling information. In this way, signalled traffic is possible despite the restricted availability of ATC functions.
Besides the actual signalling technology of the SIMIS RETB system, the transmission or telecommunications system available is of vital importance. In the past, transmission and signalling systems were assessed and implemented completely independently of each other. As it is, often quite different groups of staff are commissioned with the management of the two subsystems. For the efficiency of the overall installation, however, the efficient interoperation of these two subsystems particularly, i.e. the actual signalling system itself and the telecommunications system required among other things for the transmission of the signalling data, is a decisive factor.

In the SIMIS RETB system the interfaces between the telecom and signalling equipment have been kept as simple and compact as possible. For the lineside transmission between the central interlocking and element control computers by the track all that is needed are direct connections as per V24 (or RS232) standard. These can be provided by almost any kind of telecommunications system. Copper cable, as well as optical fibre, radio relay or other technologies can even be used. Similar conditions apply for the transmission to the train: for the transmission of running orders and maintenance data the frequently available "short data message facility" will generally be used.

Thus, the decisive synergistic effect for the SIMIS RETB system comes from the optimal use of the available system features of the telecommunications system.

Operating experience will demonstrate the trouble-free operation of the system. It will then be possible to further relieve the operator, enabling him to control and supervise a number of lines, e.g. from a regional control centre.

The combination of a simple operating concept and modern data processing and transmission systems are determining factors in the success of the system described. The work results thus far give us every reason to be optimistic.