

VEHICLE PROTECTION SYSTEM

5 This invention relates to a vehicle protection
system. It is particularly useful in connection with
automatic protection of railway vehicles, especially
those with which communication is maintained through
the transmission, for example, of track circuit
10 signals.

In a system of the type referred to the vehicle is
provided with a safety system, such as an emergency
brake, which is brought into operation automatically
15 when an unsafe situation is detected by control means
carried on the vehicle. This may happen, for example,
if the control means ceases to receive a track circuit
signal, or receives more than one signal in
circumstances which may cause ambiguity.

20 Problems can also arise in such arrangements due
to "cross-talk" and leakage between adjacent tracks
which may lead to a signal being carried by a "wrong"
road or track and its possible misinterpretation by a
25 vehicle as a valid signal.

According to the invention there is provided a
vehicle protection system, comprising:-

- 30 a) a vehicle confined to move within the system
via pathways, which pathways comprise:-
b) first and second pathways each of which is
sub-divided into sections, there being means
whereby communication between the vehicle and each
of the said sections is established by
35 transmission from the section of a signal having a
predetermined frequency, which frequency changes
from one section to the next according to a
predetermined sequence of frequencies in each of
the first and second pathways; and

- 5 c) a further pathway, intermediate the said first and second pathways, whereby the vehicle may pass from one of the first and second pathways to the other, the further pathway comprising a further section and there being means whereby
- 10 communication with the vehicle and the further section is established by transmission of a signal which has a further frequency, wherein:-
- 15 d) the predetermined sequence of frequencies of the first pathway comprises a first sequence of frequencies, the predetermined sequence of frequencies of the second pathway comprises a second sequence of frequencies, each of the frequencies of the first sequence of frequencies being different from each of the frequencies of the second sequence of frequencies, and the said further frequency being yet a different frequency; and
- 20 e) the vehicle is provided with a signal receiver and control means responsive to the sequence of frequencies of received signals to perform a
- 25 safety function in the event that this sequence is not a valid sequence.

30 The invention will now be described by way of example only, with reference to the accompanying drawings, in which:

35 Fig 1 illustrates one scheme for allocating five railway track circuit carrier frequencies;

Fig 2 illustrates the layout of signal loops in the vicinity of the cross-over of Fig 1;

Fig 3 (a), (b) and (c) show a flow chart outlining

5 the logical decision paths of a vehicle borne receiver for use in the scheme illustrated in Figs 1 and 2; and

Fig 4 shows a block diagram of an ATP system
10 employing the present invention.

Referring now to Figs 1 and 2 of the drawings there are shown two parallel railway tracks, labelled "up line" and "down line" in which the normal
15 direction of travel of a railway vehicle is indicated in each case by an arrow. These two tracks are electrically divided into track circuits using jointless track sections by conventional means, except
20 in the vicinity of a cross-over where special arrangements are employed as will be described below.

The track circuits are distinguished one from its adjacent neighbours by the use of different carrier frequencies upon which may be superimposed an
25 automatic train protection signal (hereinafter referred to as an ATP signal). Five carrier frequencies are employed, as follows:

30 $f_1 = 4080\text{Hz}$
 $f_2 = 4560\text{Hz}$
 $f_3 = 5050\text{Hz}$
 $f_4 = 5520\text{Hz}$
 $f_5 = 6000\text{Hz}$

35 On the "up line", frequencies f_1 and f_4 are used in an alternating sequence, whilst on the "down line" frequencies f_2 and f_5 are used in a similar alternating sequence, and the fifth frequency f_3 is reserved for use as a transfer frequency at the cross-over. This allocation of different frequencies

5 to each of the tracks reduces electrical interference
between the tracks and also increases the overall
system safety.

10 In the ATP system being described, and to which
the invention has been applied, the carriers are
frequency shift keyed by $\pm$ 40Hz and the rate at which
the frequency is shift keyed is a modulation rate
comprising a coded representation of a safe maximum
speed limit for the particular section of track.
15 There are up to nineteen ATP code modulation rates
available in all sections, plus one track circuit code
generator modulation rate, which may lie within the
frequency range of 28Hz to 80Hz, but the latter is not
directly concerned with the present invention.

20 Referring now to Fig 2 there is shown a track
circuit arrangement of the ATP system in which each
track circuit (TC) has an associated transmitter (Tx),
in the example being described located in a remote
25 relay room, a tuning unit mounted in the "four foot"
near the exit end of the section, a tuning unit also
mounted in the "four foot" near the entrance end of
the section and a track circuit receiver (Rx) again
located remotely in the relay room. The tuning units
30 at the exit and entrance ends of the section match the
output of the transmitter and the input of the
receiver respectively to the impedance of the running
rails of the section.

35 The selected carrier frequency for a track circuit
is generated in the transmitter and is frequency shift
keyed by a selected modulation code generator. This
signal is then transmitted via the running rails of
the section to the receiver, which is arranged to
filter and check the carrier and sideband frequencies

5 of a received signal and, assuming these checks are correct, then energise the track circuit relay. The track circuit relays of all the track circuit sections are therefore normally continuously energised and "picked-up" providing that a train is not present in
10 any section, in which case the signal in that section is shorted by the leading vehicle, and thus prevented from reaching the receiver, which releases the track circuit relay to indicate presence of the train.

15 When there are no trains, either in or approaching a track section, the corresponding track circuit carries a signal which contains no coded information for the train's ATP system, but merely carries the basic track circuit signal to energise the track
20 circuit relay. Since the ATP signal contains at least maximum speed limit information intended for one particular train only, the ATP signal is injected into the track circuit in the immediate vicinity of the location of a train. As a train approaches a track
25 section the track circuit signal is changed to one carrying the required ATP coded signal.

When a train enters a track section it receives the ATP signal via signal pick-up means located ahead
30 of the leading axle which, as is well known, shorts out the signal between the track circuit transmitter and receiver leading to the track circuit relay being de-energised to indicate the presence of the train.

35 In sections where trains may cross from one track or road to another, as at cross-overs, steps are taken to avoid putting an ATP signal onto the "wrong road". As shown in Fig 2 for example individual loops 10, 12 are laid in each of straight ahead route directions and a separate, third loop 14 is laid in the

5 cross-over itself. The cross-over loop 14 overlaps the straight ahead loops 10 and 12 in those parts at either end of the cross-over section which are shared with the straight ahead routes.

10 The presence of a train in the track sections is detected conventionally by de-energisation of track circuit relays normally picked-up by track circuit signals conducted by the rails between track circuit transmitters and receivers as is well known. The
15 rails of the cross-over, lying between the two straight ahead routes, are insulated from the rails of the other sections by insulating block joints 16, 18 which effectively prevent cross-injection of signals from one road to the other via the running rails.

20 When a straight ahead route is set, the straight ahead loop 10 or 12 only is energised and carries the corresponding ATP signal in the correct carrier sequence allocation for the line. The cross-over loop
25 14 is not energised and carries no signal at all.

However, when a cross-over route is set, the cross-over loop 14 is energised and transmits the ATP coded signal superimposed on the carrier frequency
30 allocated for cross-overs, that is frequency f3, and the straight ahead loops 10 and 12 are switched off and carry no signals at all.

The ATP equipment carried by the train includes
35 signal pick-up means positioned at the front of the leading vehicle ahead of the foremost wheels, the output of which feeds the received signal into a receiver and then into a decoder. This decoder extracts the maximum speed signal and compares it with the measured speed of the train. If the actual speed

5 is greater than the permitted maximum the emergency
brake is brought into operation. The emergency brake
may also be actuated in other circumstances detected
as being potentially dangerous to the safety of the
train and its passengers, such as when no ATP signal
10 is detected, or if two or more signals are received
with sufficient amplitudes to prevent certain
detection of the correct signal. With the arrangement
of the system being described, in which an ATP signal
is transmitted only in the vicinity of a train, the
15 situation should not arise in which a train may
receive two conflicting ATP signals but, should this
arise, the train equipment may be arranged to permit
the train to proceed at the lower of the detected
maximum permitted speed limits.

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The output of the decoder is connected to control
operation of an emergency brake circuit, for example,
by normally holding an emergency brake control relay
in an energised state for as long as an ATP signal is
25 received and is not exceeded by the measured train
speed. If no such signal is received or is exceeded,
the control relay is immediately de-energised and the
emergency brake accordingly actuated.

30 The decoder carried by the train includes means
for identifying the carrier frequency and its
modulation rate. As the train proceeds from section
to section a sequence of carrier frequencies will be
formed, and the decoder is provided with a temporary
35 memory means in which is temporarily stored the
detected sequence of carrier signals encountered by a
moving train. There is also provided a permanent
record of all possible such sequences, or at least
those which may be encountered on a particular route
to be travelled by the train, and means for comparing

5 the contents of the temporary memory with the contents of the permanent memory to determine if the received sequence is a valid sequence.

10 It is preferred, in order to permit re-routing of a train, for example to accommodate conflicting train movements, that the decoder is not prearranged to expect a particular sequence of carrier frequencies but to have a reset capability, which upon being
15 activated operates to clear the temporary memory thus enabling a fresh sequence of carrier signals to be received and checked without either the train's progress being impeded or the emergency brake being brought into operation. The decoder includes means
20 responsive to reception of the transfer frequency f3 to perform the reset function whenever a train runs over the loop 14 at a cross-over.

In operation of the described arrangement,
25 consider a train travelling in the direction of the arrow on the "up line" in Fig 1. In approaching the cross-over it will have encountered a sequence of frequencies in which f1 and f4 alternate. The "down line" will carry a sequence of alternating frequencies
30 f2 and f5. On approaching the cross-over section and leaving the last section carrying frequency f4 the train encounters the cross-over section in which loop 14 carries a signal having frequency f3. Up to this time the train ATP decoder will have expected to
35 continue encountering the sequence f1, f4 and would interpret any other received frequency not in that sequence as a potentially dangerous situation.

However, upon encountering frequency f3 the decoder is "reset" and the temporary memory containing

5 the sequence f1 and f4 is erased, and prepared to
receive a fresh sequence. Upon reaching the "down
line" the train first encounters the frequency f2 and
then f5, establishing a fresh sequence to which the
decoder will now continue to respond until such time
10 as it may encounter a further transfer frequency f3.

Whilst the system described is fail-safe in
operation, the present invention makes it possible to
interpret accurately situations which arise through
15 less than perfect operating conditions but which are
not inherently unsafe, and so a train may be permitted
to continue running in situations where otherwise it
would be necessary to fail to safety.

20 The ATP equipment carried on the train continually
seeks to prove a predetermined set of safe conditions
and only if successful in this does it hold-off the
emergency brake. Firstly, it is safe for a train to
operate if ATP signals are received in a valid
25 sequence for the route being travelled.

Second, the train may continue if a mixture of two
ATP signals is received provided both are members of a
valid sequence; if one of those received signals
30 belongs to the valid sequence but the other does not
the train may still continue but an alarm is raised.
However, if both received signals do not belong to an
already established valid sequence then the emergency
brake is applied and the alarm warning issued.

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Generally, any situation giving rise to more than
two signals received simultaneously cannot be resolved
safely. In such circumstances the train must be
halted and the emergency brake is applied.

5 When the transfer frequency f3 is received
the ATP equipment is "reset" and subsequently will
respond normally to a fresh, or the same, valid
sequence. However, if the equipment receives mixed
frequencies from different sequences the emergency
10 brake is brought into operation and an alarm
initiated. Also, if the train has not previously
received any ATP signal, for example because it has
just emerged from a marshalling yard or depot, then it
is receptive to the first encountered signal frequency
15 to establish a new valid sequence. If two signals
from the same sequence are detected, a mixed code
alarm may be raised, but operation of the train is
permitted. On the other hand if mixed signals from
different sequences are encountered an unresolvable
20 and unsafe condition is determined to be present and
the emergency brake is operated.

In one embodiment of the invention the decisions
outlined above are determined by a microprocessor with
25 reference to the permitted and non-permitted
combinations of signals stored in a memory in the
equipment. The analysis of the received signals may be
carried out by several alternative arrangements, one
such suitable arrangement is described in the
30 applicants' published Patent Application No.
2,114,342A in which there is disclosed a suitable
railway signalling receiver incorporating a Fast
Fourier Transform frequency spectrum analyser.

35 Referring now to Fig 4 of the drawings there is
shown, in schematic representation, an ATP system.
The track is shown diagrammatically at 41 and the
direction of motion of a train is indicated by arrow
42. The portion of track shown consists mainly of a
track section carrying a track circuit signal at
frequency f4, with further track sections on either

5 side carrying a signal of frequency f_1 . The track circuit transmitters and receivers are indicated by blocks Tx and Rx respectively, suffixed by the frequency of the track circuit signal as appropriate.

10 The train (not shown) is provided with a pair of pick-up coils 43a, 43b mounted low down at the front of the leading vehicle, ahead of the front axle, one immediately above each of the track rails and in signal receiving relationship therewith. The coils
15 43a, 43b are connected to amplifying means generally indicated at 44. The construction of this amplifying means and of the equipment thus far described may be as well known and used in the prior art.

20 The output of amplifying means 44 is connected to the signal input of an analogue to digital sampling means 45 operated at a suitable sampling rate for accumulating real time series data samples which are supplied to a fast Fourier transform processor 46, of
25 the type described in Patent Application No. 2,114,342A. The output of processor 46 is connected to frequency spectrum analysing means 47 operatively responsive to the frequency domain output of processor 46 to execute the code analysing function described
30 above. The processor output comprises a digital read-out of the amount of power calculated in each frequency element or frequency bin of the signal spectrum, calculated from the real time series data samples of the received signal provided by the
35 sampling means 45. Analysing means 47 comprises means responsive to the identification of the appropriate bins of the track circuit signal frequencies which it is possible for the train to encounter during its progress. At the moment depicted in the drawing the output of analysing means 47 will indicate, assuming correct operation and no interference etc, that signal

5 frequency f4 is present, it will previously have identified signal frequency f1, as it will do so again as the train moves leftwards in the drawing, followed by f4 again and then f1 and so on.

10 The sequence of identified frequencies f1, f4, f1 etc is digitally stored in a memory 48 for comparison with a record of valid frequency sequences stored in read-only-memory or ROM49. This comparison is performed by a comparator 50, and thus may achieved by
15 bit by bit comparison using suitable register means although, in practice it is found more convenient to employ a microprocessor for this decision making process using software incorporating the decision making rules described above and illustrated in Figs
20 3(a), (b) and (c).

The contents of memory 48 are therefore continuously added to and, the memory being of finite capacity, it can store only the most recent portion of
25 a frequency sequence and as each newly detected member is added to the existing sequence the oldest member is erased. The minimum number of stored frequencies required to positively identify a valid sequence in the described example is three, no more than this need
30 be stored, although a greater number may be desired for assurance.

The comparator 50 is required to provide no more than a Stop/Go output, in its simplest form, for
35 operating an Emergency Brake Relay (E.B.R.) Control circuit 51, to which it is connected. Control circuit 51 provides energising current for the emergency brake relay 52 (energised to hold open, de-energised to close) the contacts 53 of which are in series with the vehicle emergency brake circuit. If the relay 52 is de-energised the contacts 53 are released and close, "making" the emergency brake circuit and thereby

5 bringing about a full emergency application of the
train's brakes. As described above under certain
circumstances, i.e. when track circuit cross-talk
exists, it may be required to permit the train to
10 proceed at reduced speed, in which case the E.B.R.
control circuit 51 is conditional upon measured train
speed not exceeding a predetermined maximum speed. An
apparatus and technique for achieving this is already
known in the art in connection with railway vehicle
automatic train protection systems.

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The frequency spectrum analysing means 47 is also
responsive to detection of sufficient power in the
frequency bin containing frequency f3 to erase the
20 contents of memory 48 to permit a fresh frequency
sequence to be accepted without causing application of
the emergency brakes.

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**CLAIMS**

1. A vehicle protection system, comprising:-
- a) a vehicle confined to move within the system via pathways, which pathways comprise:-
 - 5 b) first and second pathways, each of which is subdivided into sections, there being means whereby communication between the vehicle and each of the said sections is established by transmission from the section of a signal having a predetermined
 - 10 frequency, which frequency changes from one section to the next according to a predetermined sequence of frequencies in each of the first and second pathways; and
 - c) a further pathway, intermediate the said first and second pathways, whereby the vehicle may pass
 - 15 from one of the first and second pathways to the other, the further pathway comprising a further section and there being means whereby communication with the vehicle and the further section is
 - 20 established by transmission of a signal which has a further frequency, wherein:-
 - d) the predetermined sequence of frequencies of the first pathway comprises a first sequence of frequencies, the predetermined sequence of
 - 25 frequencies of the second pathway comprises a second sequence of frequencies, each of the frequencies of the first sequence of frequencies being different from each of the frequencies of the second sequence of frequencies, and the said
 - 30 further frequency being yet a different frequency; and
 - e) the vehicle is provided with a signal receiver

(29)



and control means responsive to the sequence of frequencies of received signals to perform a safety function in the event that this sequence is not a valid sequence.

5 2. A system as claimed in Claim 1, wherein the said control means is further responsive to reception of a signal having the said further frequency to prepare the said control means to perform the said safety function in the event that the sequence of frequencies of
10 received signals is not another valid sequence.

3. A system as claimed in Claim 1 or 2, wherein the said pathways comprise railway tracks, the said sections comprise railway track circuit sections and the said frequencies comprise railway track circuit
15 carrier frequencies.

4. A system as claimed in any preceding Claim, wherein the said control includes: means for sampling a received signal to accumulate a series of data samples with respect to time; processor means which performs a
20 fast Fourier transform using the said data samples; and means responsive to an output of the said processor means to determine the frequencies of received signals.

5. A system as claimed in Claim 4, wherein the said means responsive to the output of the processor means
25 includes: a first memory, in which is stored a representation of the sequence of frequencies of



received signals; a second memory, in which is stored a representation of valid frequency sequences; and means for comparing the contents of the said first and second memories whereby to determine if the sequence of frequencies of received signals is a valid sequence.

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6. A system as claimed in Claims 2 and 5, wherein the said means connected to the output of the said processor means is responsive to reception of a signal having the said further frequency to clear the contents of the said first memory.

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7. A vehicle protection system, substantially as herein described with reference to the accompanying drawings.
