D1.1 ATB system description

for the development of an STM ATB

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CONTENT

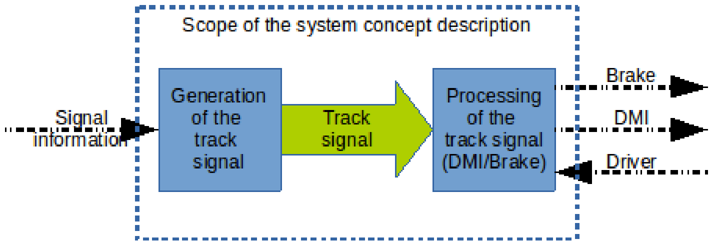
1 Preface

In this document a description of the concept of the ATBEG + ATBVv functions will be given. This description concerns the overall system concept and safety principles, thus infrastructure and on-board equipment. Specific equipment in use will not be described. The performance of currently used on-board systems is discussed in [D2.2].
In chapter 2 the general principle of ATB is discussed.
In chapter 3 the overall ATBEG functionality will be described, thus the function in relation to the current maximum speed at the next line side signal.
In chapter 4 the same is done for the ATBVv functionality.
In chapter 5 the “track to train information” to communicate the maximum speed at the next signal to the train, is described in detail. The reason to concentrate on this internal (between way-side and train-borne equipment) ATBEG interface is that the safety (fail-safe) concept of the system is included in the concept of the interface.
In chapter 6 a description of the ATBVv track to train communication is given. This communication is not fail-safe and simple in comparison to the ATBEG track to train communication.
System interface are described in figure STMA-25799 , and include:

- At the way side: interface to the interlocking for the signal aspect
- At the train borne: Brake and DMI

[STMA-25801 **]**

Definition, STMA-25799 - Figure “scope of the system concept description



1.1 References

Reference documents

All the documents references used in this document can be found in the document P6.1 Bibliography available in the Polarion folder Processes

Abbreviations, definitions and terminology

An overview of the abbreviations, definitions and terminology used in this document can be found in document P6.2 List of abbreviations, definitions and terms available in the Polarion folder Processes

Requirement identification

The STM ATB project makes use of an automated requirement management system. In this system each requirement has been identified as a work item. Each work item has been automatically assigned with a unique ID, with the format "STMA-<number>". As a result requirement ID's are not in logical order. An overview of all the used STMA-numbers is given in document P6.3 Requirement Overview available in the Polarion folder Processes **[**STMA-14296 **]**

2 Generic principle

In this chapter a high level description of the ATBEG+Vv functionality is given. **[**STMA-25805 **]**

2.1 ATBEG

ATBEG is a function which was introduced at the Dutch Railway network in the late 1960’s to enhance safety after an accident in 1962. The way-side part of the system is an addition to the “75Hz track circuits” used for train detection. Those “75Hz track circuits” (with a length between 50 and 1200m) cover almost the complete network. To communicate the maximum speed at the next signal, the 75Hz current of the track circuits is “amplitude modulated”. The modulation frequency codes the maximum speed (at the next signal). On-board of the trains equipment is installed capable of detecting the 75Hz currents in the rails and decoding the “track signal”. The on-board shall calculate the maximum speed at the next line side signal(*) based on the “track signal”.
If the train exceeds the maximum speed retrieved from the ATBEG code while the driver is not braking (during a situation depending time) then the ATB on-board shall apply the brakes.
The relation between the maximum speed and the ATBEG code is fixed. However alternative values are mentioned in the RIS (regeling indienststelling spoorvoertuigen), and speed levels can be changed dynamically using ATBNG technology (ATBM+ mode). The same is possible using ETCS technology.

(*) More detailed: the track signal gives the minimum of the maximum speeds at the previous and the next line side signal. Therefore the current maximum speed and the maximum speed at the next line side signal are monitored.) **[**STMA-25806 **]**

2.2 ATBVv

ATBVv was introduced to reduce the risk concerning passing signals at danger. As ATBEG function doesn't know the distance to the next signal, trains will always be allowed by the ATBEG function to proceed at a certain speed (40km/h), independent of the ATBEG code in the track. This has led to a number of incidents were a train passed a signal at danger at low speed (<40km/h).
To protect trains against this danger a functionality (ATBVv) was developed (and meanwhile installed at the majority of the signals) to communicate the distance to a signal at danger (at 3m, 30m or 120m), using an active (not fail-safe) EM signal near the rails.
Trains are equipped with the functionality to detect and evaluate the information at a voluntary basis. However all available ATB on-board systems are equipped with the function. As the way-side equipment is not fail safe and the system only provides background protection without information to the driver (thus no misleading of the driver possible), also the on-board functionality only has to comply with an availability requirement (i.e. no safety requirements). The availability of the train borne equipment shall at least be comparable to the availability of the track side equipment, and is specified in [D1.4.2.2]. **[**STMA-25807 **]**

2.3 Kwiteren

Standard driver vigilance control in the Netherlands is operating at intervals of 60s.
The kwiteren function is a specific driver vigilance control function with a shorter interval and a different sound which becomes active if

- The maximum allowed driving speed, according to the track signal, is 40km/h
- The driver is not braking
- The train speed is below the limit guarded by the ATB system (40km/h plus margin).

In this way, the driver notices that he drives in a 40 km/h area.
Function:

- Every 20s a “zoemer” (sound) is started until the driver operates a special button.
- If the driver doesn’t operate the button within 5s, the EB will be commanded.

This function has been implemented in the ATBEG system as information about the speed at the next signal is necessary.
The function “Kwiteren” has been disabled in existing ATB systems since approximately 1990. Therefore the function will not be further detailed in this document. **[**STMA-25808 **]**

3 ATBEG functionality

The ATBEG functionality is:

- Command the emergency brake if the maximum speed indicated by the “track signal” is exceeded and the driver is not braking (up to a minimum level, see below) during a “warning time” (depending on train characteristics, the maximum speed and the conditions when exceeding started, see below).
  Note 1: if the maximum speed at the next signal is 0 km/h then the ATB system will guard 40km/h. As the distance to the signal is not known, a minimum speed is needed to reach the signal.
  Note 2: after an emergency brake command given by the ATB system, the brakes can only be released after a release command given by the driver at standstill.
- Display the maximum speed indicated by the “track signal” to the driver.
- Give an acoustical warning if the maximum speed at the next signal is exceeded while the driver is not braking and the emergency brake has not yet been commanded by the ATB system (signal called “rembel” which is a continuous signal). As soon as the overspeed situation ends another acoustical signal is given (signal called “losbel” which is an intermittent signal with the same sound as “rembel”)
- Give an acoustical indication if the guarded speed changes (signal called “gong”, which is a one-stroke signal).
- Indicate the state of the system to the driver (active, brake commanded, not active)

[STMA-25812 **]**

Warning times (as specified in the RIS, “Regeling indienststelling spoorvoertuigen” [D3.1]):
In case over speed arose due to a change of the maximum speed at the next signal, i.e. when passing a signal while the next signal indicates a lower speed, the “warning time” will be:

- If the maximum speed at the next signal is 40km/h (or 0km/h communicated as 40km/h): 4,6s plus the time the rolling stock responds faster than required according to UIC standards,
  i.e. plus the standard time (according to UIC) needed to build up brake force minus the train dependent time to build up brake force.
  Note: as the train dependent time shall never be less than the standard time according to UIC (as the latter shall be guaranteed for all trains), the result will always be a value equal to or higher than 4,6s.
- If the maximum speed at the next signal is different from 40km/h (or 0km/h): 8,3s plus the standard time (according to UIC) needed to build up brake force minus the train dependent time to build up brake force.

In case over speed arose due to acceleration then the “warning time” will be 5s.
[STMA-25813 **]**

The ATBEG on-board checks if the driver operates the brake up to a pre-defined minimum level. The functionality does not guarantee that the deceleration is sufficient to not exceed the maximum speed at the next signal (also not possible as the ATB doesn’t know the distance to the next signal). **[**STMA-25810 **]**

In addition to the above described functionality the system can be forced in “buiten dienst” (by the driver of from track side) in rear of track parts where no track-side ATB equipment is installed. In this mode the system will not show, nor guard a maximum speed, but a “blue indicator” is shown to the driver. **[**STMA-25811 **]**

The ATBEG functionality guards the maximum speed as “indicated by the track signal”. In most cases this is the maximum speed at the next and/or the previous line side signal. However in case the maximum speed indicated by the “track signal” is 0km/h (signal at danger), then the lowest possible speed level (40km/h) is guarded and indicated at the DMI. Also when the “signal at danger” is passed ATBEG will not command the emergency brake (as the ATB equipment is not aware of passing the signal if the speed level remains 40km/h (or 0km/h). **[**STMA-25809 **]**

4 ATBVv functionality

To reduce the number of incidents with trains passing a signal at danger, a non-mandatory function to protect against passing a signal at danger (the ATBVv function) has been added to the ATBEG concept. The ATBVv functionality is:

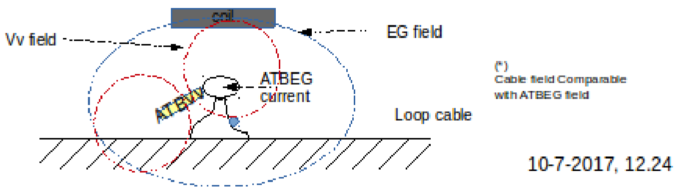
- Command the emergency brake if based on the current speed, the current distance to the “signal at danger” and the braking performance of the train, it is foreseen that a signal at danger will be passed if the emergency brake is not commanded.
  Note: To allow the train to reach the signal at danger, the emergency brake will not be commanded if the current speed is below a certain “release speed”.
- Command the emergency brake if a signal at danger is passed (at a speed below the “release speed”)

To enable passing a “signal at danger” after communication with the “signal operator” (e.g. in case of failures), an “override function” is available for the driver.
The driver is not informed about the status of the function, except in case of an “emergency brake command”, and in case the driver has triggered the “override function”.
As the information concerning the distance to the “signal at danger” is actively communicated to the trains, a failure in the system will lead to not protecting against passing the signal at danger. Thus, the concept is not fail safe. **[**STMA-25815 **]**

4.1 Track to train communication ATBEG + Vv

As described in chapter 2, for both, the ATBEG and the ATBVv functions, an EM-signal is generated track side near the rails. The senders are positioned in such a way that both can be received using the same “antenna” (a coil with EM coupling with rails and ATBVv beacon). **[**STMA-25816 **]**

Definition, STMA-25814 - *Figure EM coupling between ATBEG and ATBVv senders and on-board ATB antenna (“coil”). Loop cables can be used for ATBEG or for ATBVv (separate cables).*

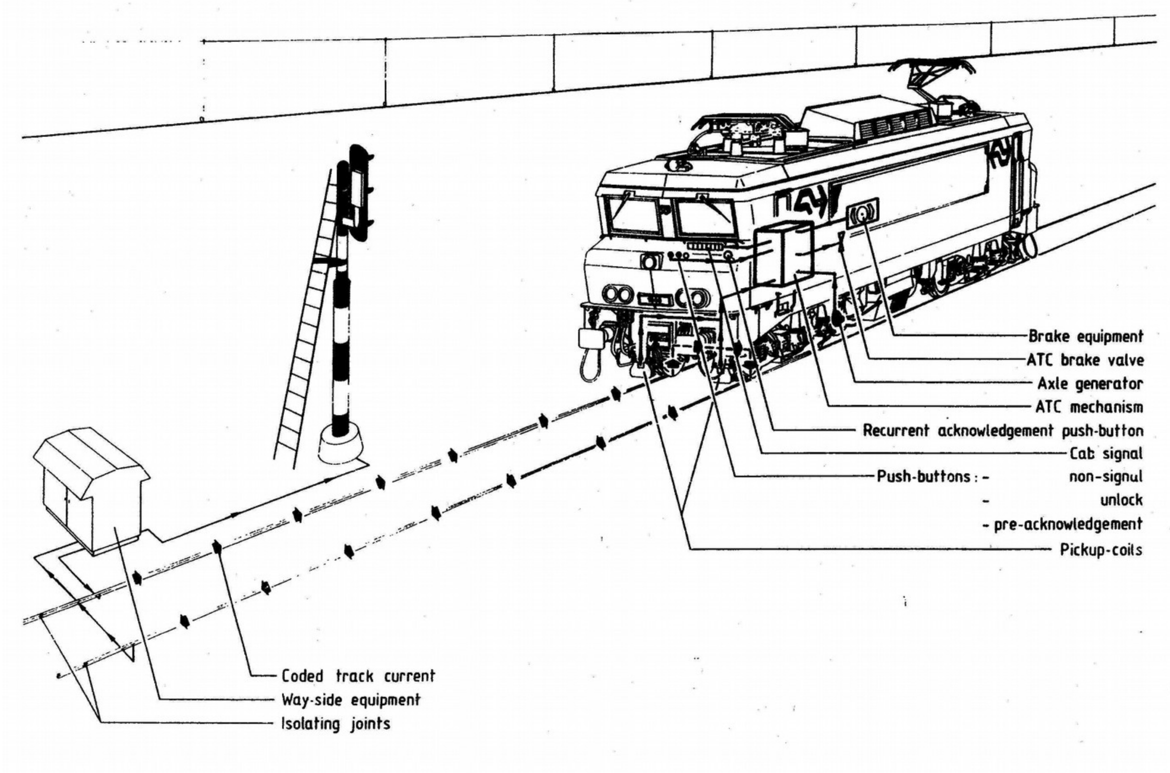


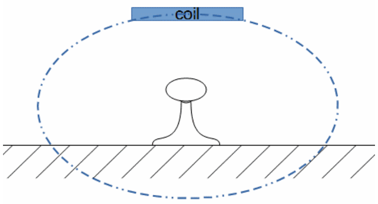
The ATBEG signal is transmitted using a current through the rails, or if the latter is not possible, a cable directly connected to the rails.
The ATBVv signal is transmitted using 80cm long coils (mounted at the right rail in the driving direction), and in addition to be able to sent a release signal over a longer distance a cable directly connected to the right rail.
Below the communication for ATBEG and ATBVv is described in detail. **[**STMA-25817 **]**

4.1.1 ATBEG track signal

The ATBEG track signal consists of an AM(*) modulated 75Hz signal floating round in sections through the rails. The AM frequency determines the maximum speed at the next signal. By floating round the direction of the current through the two rails is opposite.
(*) The 75Hz base frequency is either switched on and off, or switched between a high level and a low level. The on/high level shall be above 6,5A (rms) and the low level shall be below 2,5A (rms). Although in praxis those criteria are not always met. **[**ST MA-25818 **]**

Definition, STMA-25820 - *Figure ATBEG communication concept*





In some cases, where it’s not possible to provide sufficient separation of the ATBEG current from traction return currents (e.g. in switches), cables attached to the rails are used for the ATBEG current.

The safety of the ATBEG concept is based on the following principles:

- The system switches to a safe state (guarding the lowest speed level) if no code (i.e. no valid amplitude modulated signal) is recognized in the currents through the rails.
- Disturbing currents are floating only in one rail or through both rails in the same direction.
- The ATB currents are floating in both rails and in opposite directions.
- The specific form of the signal makes it highly unlikely that disturbances (way-side as well as on-board) in combination with an ATBEG current in the track simulate another valid ATBEG code than contained in the ATBEG current.

[STMA-25819 **]**

4.1.2 Characteristics of the ATBEG track signal

According to the RIS [3.1] the ATBEG track signal (normally) meets the following criteria:

- Base frequency: 75Hz +/-3Hz
- AM frequencies: 1.25Hz, 1.6Hz, 2Hz, 2.45Hz, 3Hz and 3,67Hz (all +/- 0.05Hz)
    - 1,25Hz (code75 = 75 pulses/minute = 1,25Hz): switch of ATBEG speed monitoring
    - 1,6Hz (code96): 140km/h
    - 2Hz (code 120): 130km/h
    - 2,45Hz (code147): 80 km/h
    - 3Hz (code180): 80km/h
    - 3,67Hz (code220): 60km/h
    - not recognizing any of the above signals (noCode): 40km/h
- Duty cycle of the modulation, between 30-70 and 70-30 (although 20-80/80-20 is possible)

- low level during amplitude modulation: 0-3A, high level: 6,5-25A (although higher low and lower high values are possible.)

[STMA-25824 **]**

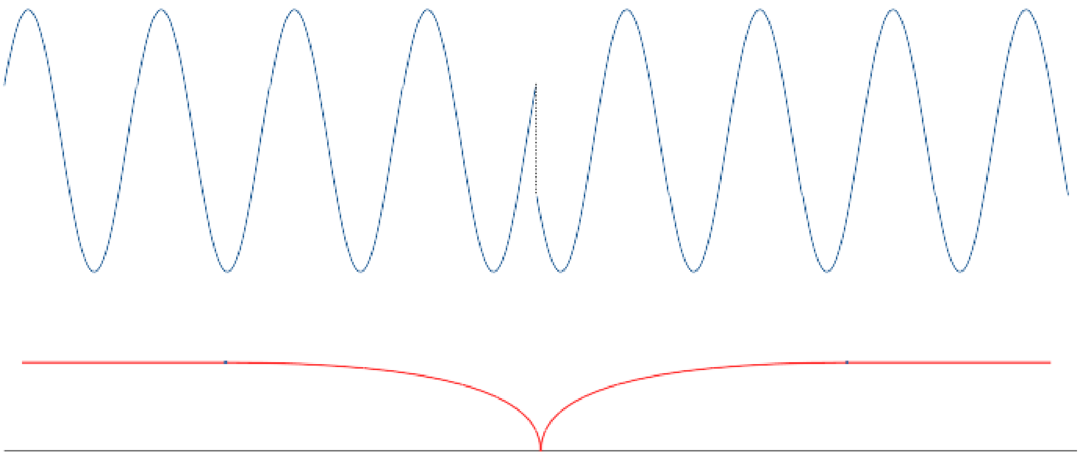
Further the track side equipment and the way sections are connected to each-other (needed because the rails are also used for traction return currents), together with the speed the train passes the transitions between sections, determines the shape of the ATBEG track signals as seen by the on-board equipment. Below a schematic view on sections along a line is given. Switches are represented as one way sections as trains pass them only in one direction at a time. **[**STMA-25823 **]**

Definition, STMA-25822 - *Figure An example of infrastructure divided into "sections" of different length and with different ways of connecting between sections: balanced, two single sided insulated, three balanced. Each section has it's own source of ATBEG current.*

The length of a section is normally at least 5 times the period time of the code in the section multiplied by the maximum speed of the train in the section.
As the code frequencies are relatively close to each-other (least frequency difference is 0,35Hz) it will take 1 (for the faster codes with a bigger frequency difference) to more than 2s to be able to distinguish between the different codes. **[**STMA-25828 **]**

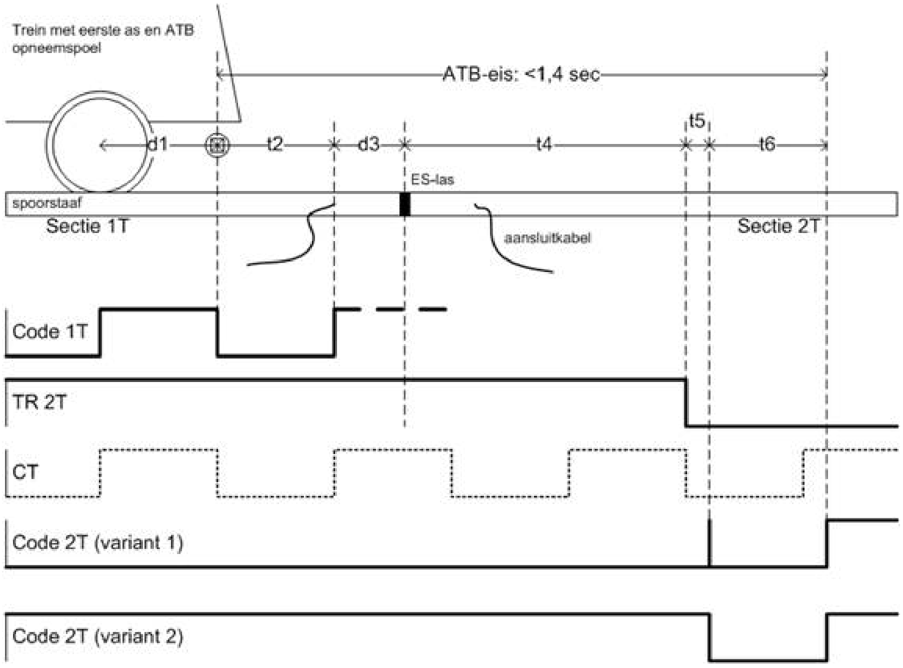
Crossing a border between sections
The ATBEG signals are derived from a 75Hz source covering large area's. Therefore the 75Hz current normally has the same phase before and after crossing a section border or the phase "jumps" by 180 degrees (see figure 5). In more rare cases jumps at other angles are also possible. **[**STMA-25826 **]**

Definition, STMA-25827 - *Figure: Phase jump of 180 degrees in the 75Hz base signal at a section border. When calculating the 75Hz level of the signal over a certain period this will lead to a dip in the 75Hz level (red line).*



As the 75Hz base frequency, the modulation is generated at central locations, but when the code changes from one code to another (also at the section border), or if the train moves to an area covered by a different "code relay", the phase can change with any value (figure 5).
Further the modulation is only started after the train is detected in the new section. Switching on modulation can take up to 1.4s (figure STMA-11600). Again, when switching on it can start at any phase of the modulation, therefore it can take longer before the first switch between low and high level (or the other direction) is made. **[**STMA-25825 **]**

Definition, STMA-11600 - Figure: Timing of ATBEG code between sections

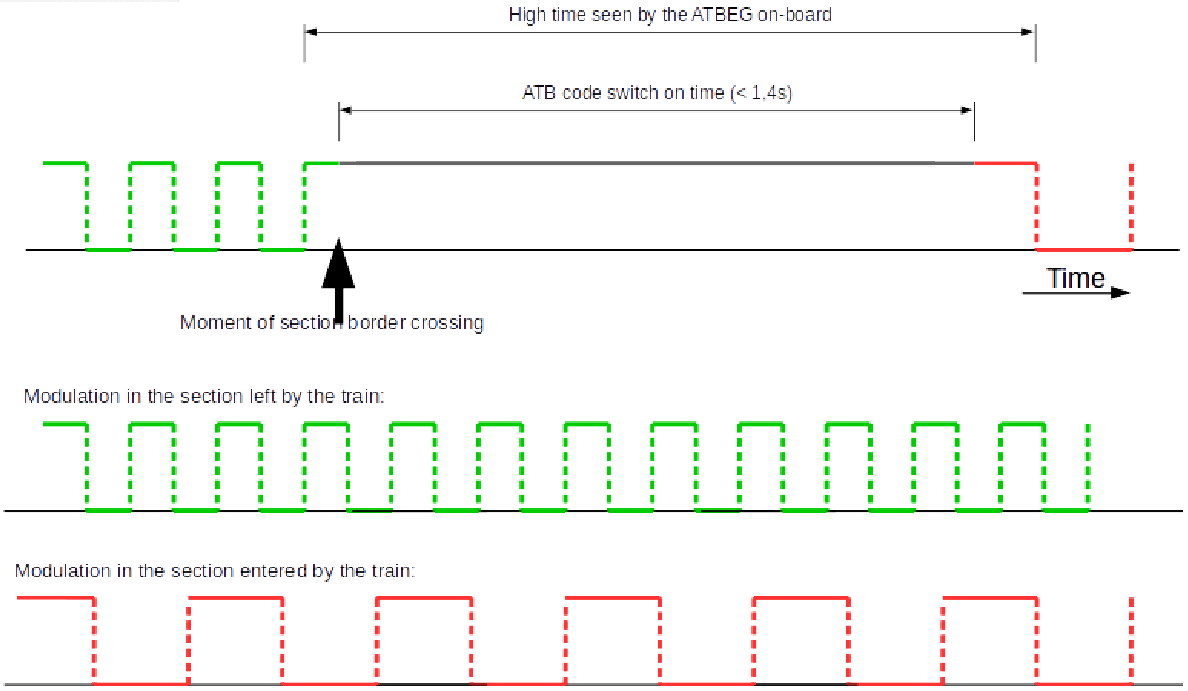


Clarification of the components of the delay time

- *t1 (d1): Time to travel the distance between coil and wheel-rail contact, i.e. the time the coil is above the next section while the train doesn't occupy that section*
- *t2: The code pulse in section 1T is worst case (equal to the intial level in section 2T), therefore the ATBEG on-board will "see" a constant level during t2 before entering section 2T. in case of code96 this time is 0,5 times 640ms = 320ms*
- *t3 (d3): The last 0,5m of section 1T there might be no code because of the location where the cable is connected. taking into account a speed of 11m/s (below it's not relevant if the code is shortly rejected while the lowest speed level is 40km/h): = app 50mst1: Section 2T is only triggered after the first axle enters section 2T. The distance between the antenna and the first axle taken into account is 1,5m taking into account a speed of 11m/s (below it's not relevant if the code is shortly rejected while the lowest speed level is 40km/h): = app 140ms*
- *t4: delay time for detecting the train: 500ms*
- *t5: switching times: 10ms*
- *t6: The first code pulse in section 2T is worst case (equal to the initial level in section 2T), therefore the ATBEG on-board will "see" a constant level during after the code has been swithed on in section 2T. in case of code96 (slowest code taken into account) this time is 0,5 times 640ms = 320ms*

The total time is therefore 1340ms **[**STMA-25829 **]**

Definition, STMA-25830 - *Figure: Schematic view on the code seen from the train during a section crossing.*



At a section border the code can change from any value to any other value. Except in case another train passes a “signal at danger” or other disturbance, within a section a code can only change to a less restrictive (lower modulation frequency) code. **[**S TMA-25832 **]**

4.1.3 Effect of disturbances on the validity of the ATBEG track signal

An ATBEG track signal received by the on-board coils is valid if it can be proven that the coded signal is a current floating round in the section, thus the available in both rails (left and right) and is not originating from a source outside the section nor from a traction return current.
Sources of disturbances from track side can be:

- ATBEG track side code generators (and/or train detection circuits) outside the current section. Due to imperfect isolation between sections a part of the current from a section can float through another section. (in Dutch “omloopstromen”)
  According to the RIS these currents can be maximum 3,5A@75Hz. However higher currents are found in case of defects in the infrastructure.
  As the currents can originate from ATBEG code generators, they will often consist of an amplitude modulated 75Hz current, thus look like a valid ATBEG signal.
  In most cases currents from train detection or ATBEG circuits outside the current section use the same 75Hz source as the ATBEG circuit inside the current section. Therefore it’s likely that the 75Hz currents will have the same phase as the ATBEG current originating from the current section.
- Traction return currents from the train in the current section or from other trains, i.e. (according to the RIS):
  - DC traction return currents up to 4000A (can be 8000A)
  - 50Hz currents up to 250A
  - harmonics in the 75Hz band up to 3A, can be higher in exceptional cases.
    It’s very unlikely but not impossible that the currents contain an amplitude modulated like 75Hz signal.
    The chance that a 75Hz harmonic originating from traction equipment is (more or less, i.e. less than 30 degrees different) in phase with the ATBEG current originating from the current section is app. 1:6.
  - Harmonics in a wide frequency range, mentioned are 66,67Hz, 100Hz 300Hz, 315Hz, 400Hz, 450Hz at maximum 5A. Although less likely, also other frequencies are possible. Especially for lower frequencies higher values (up to 50A are possible.

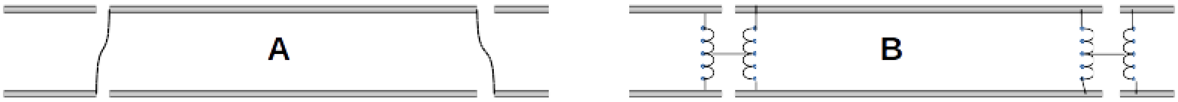
[STMA-25833 **]**

Currents from external sources and traction return currents have the same direction (phase) in both rails, or only float in one rail. Depending on the way the sections are insulated for detection/ATBEG currents and connected for DC currents, currents from external sources and traction return currents are divided between the left and right rail:

- 100% through left or right rail (situation A, see below)
- A division between (L:40%, R:60%) and (L:60%, R:40%) (situation B, see below)
  However a more imbalanced division is possible in case of defects.

[STMA-25831 **]**

Definition, STMA-25834 - Figure: Different types of insulation of sections, isolation for detection/ATBEG currents.



Therefore currents from external sources and traction return currents can be distinguished from ATBEG currents (originating from the concerning section) by the phase of the signal and because the currents from external sources and traction return currents are floating in:
A.1 The right rail, thus no current from an external source floats through the left rail
A.2 The left rail, thus no current from an external source floats through the right rail
B. Both rails, normally balanced (close to 50-50%), however in failure cases significant inbalance can occur.
For ATB inbalance between 40-60% and 60-40% shall be taken into account, however the ATB system shall not respond to higher inbalances.
In this situation, in normal cases if the current from external sources is balanced (close to 50%), the difference between the left and right rail current will contain no or little components from external sources.
Thus in normal cases, currents from external sources and traction return currents are not or limited present in:

- the left rail current (situation A1)
- the right rail current (situation A2), or
- the difference of the currents (situation B)

[STMA-25836 **]**

The track side configuration (A or B, see figure 7) is however not known on-board. To use the information it shall be derived from the total left rail and right rail currents.
If (in case B, figure 7) a 75Hz current from an external source, with the same phase as the ATBEG current is floating through the section then it sums up with the ATBEG current in one rail and it is subtracted from the ATBEG current in the other rail.
Depending on the code in the current section the current from an external source can interfere in different ways. **[**STMA-25837 **]**

Below some examples of the interference are described. The examples are:

1. Constant 75Hz from the track circuit and a AM signal from outside (figure 8a), i.e. An ATBEG code is disturbed by a constant 75Hz current from outside the section. This can lead to masking the ATBEG code.
2. AM signal from the track circuit and constant 75Hz from outside (figure 8b), i.e. A constant 75Hz current (no code) in the section is disturbed by a 75Hz amplitude. modulated current (ATBEG code) originating from a source outside the section.
3. AM signal from the track circuit and an AM signal with the half frequency from outside (figure 8c), i.e. An ATBEG code is disturbed by a 75Hz amplitude modulated current (ATBEG code) originating from a source outside the section. Worst case is a disturbing current with a lower modulation frequency (thus less restrictive code).
4. AM signal from the track circuit and an AM signal with 1/3 of the AM frequency from outside (figure 8d).
5. AM signal from the track circuit and an AM signal with the double AM frequency from outside (figure 8e).

[STMA-25835 **]**

In the examples the envelope of the left and right rail signals are given, plus the envelope of the difference between left and right and the sum of left and right. For those examples a 75%-25% division (unbalance) of disturbance currents floating through the rails if chosen. Although it’s an unlikely division (as out of specification) the division is chosen because it will lead to a difference signal (assumed round floating current) equal to 50%, which is worst case in many cases.
In the examples the absolute 75Hz value is taken into account. If the phase of the signal is also used, “negative” 75Hz levels (180 degrees out of phase) could also be recognized which improves the decoding. However that would lead to susceptability for changes in frequency within the time the signal is analysed. **[**STMA-25838 **]**

In the figures below (the “envelope” is the amplitude of the 75Hz signal):

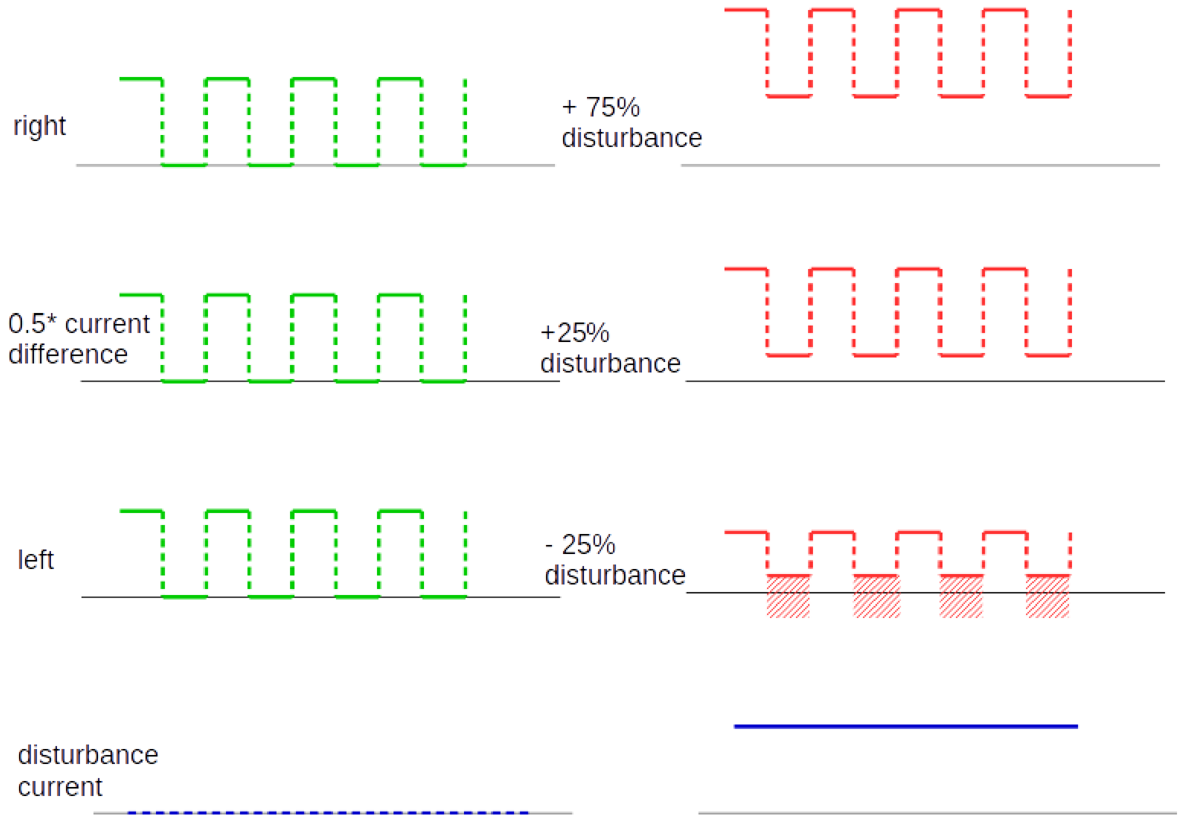
- Lines in green represent the ATBEG current envelopes without external disturbances
- Lines in red represent the ATBEG current envelopesincluding external disturbances
- The blue lines represent the envelope of the disturbance current
- right: 75Hz signal level in the right rail current
- left: 75Hz signal level in the left rail current
- 0.5*Difference current: 75Hz signal level in the difference between the left and right rail current divided by 2 (to scale to the same level as the left and right signal level)
- 0.5*Disturbance current: 75Hz signal level in the sum of the left and right rail current divided by 2 (to scale to the same level as the left and right signal level)
- shaded area's: 75Hz out of phase, therefore the sign of the envelope is inverted

[STMA-25839 **]**

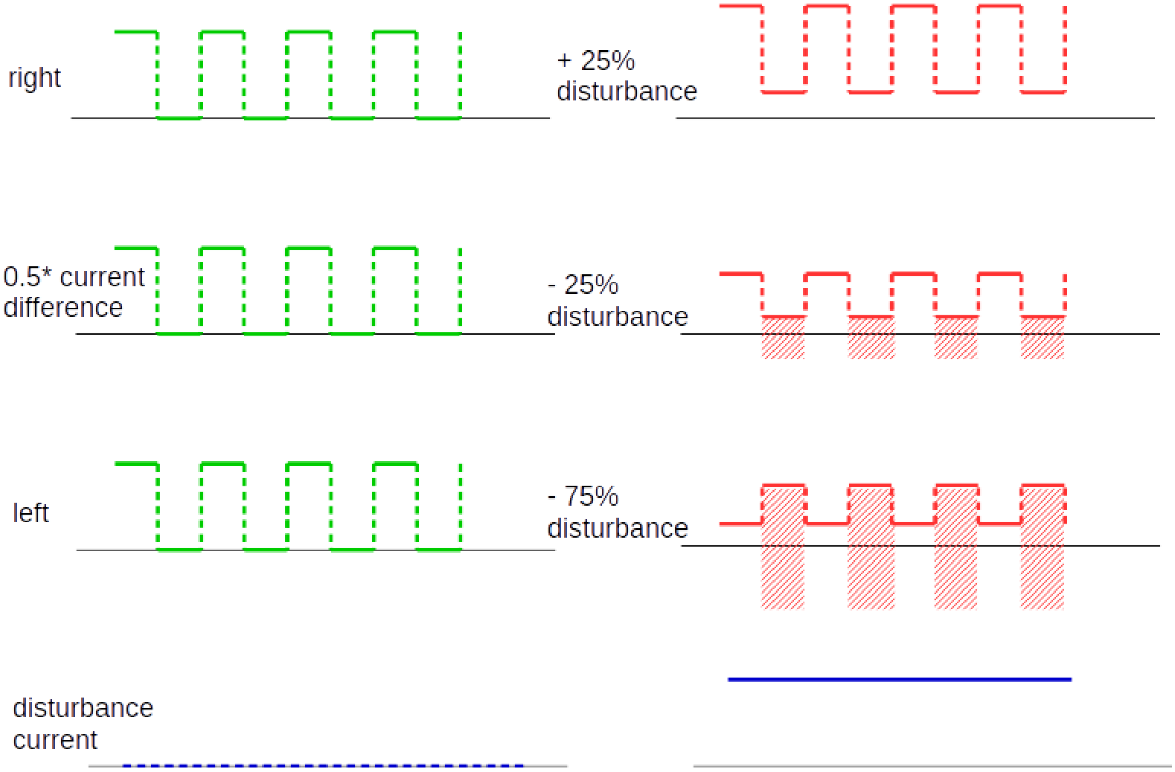
4.1.3.1 ATB signal disturbed with a constant 75Hz current

This paragraph describes the impact of an ATBEG code originating from the current section, disturbed by a constant 75Hz current from a source outside the section. The effect is that the signal level in the left coil signal is significantly decreased, which could lead to an availability failure. **[**STMA-25859 **]**

Definition, STMA-25861 - 75% fraction of the disturbance current in phase, 25% fraction out of phase:



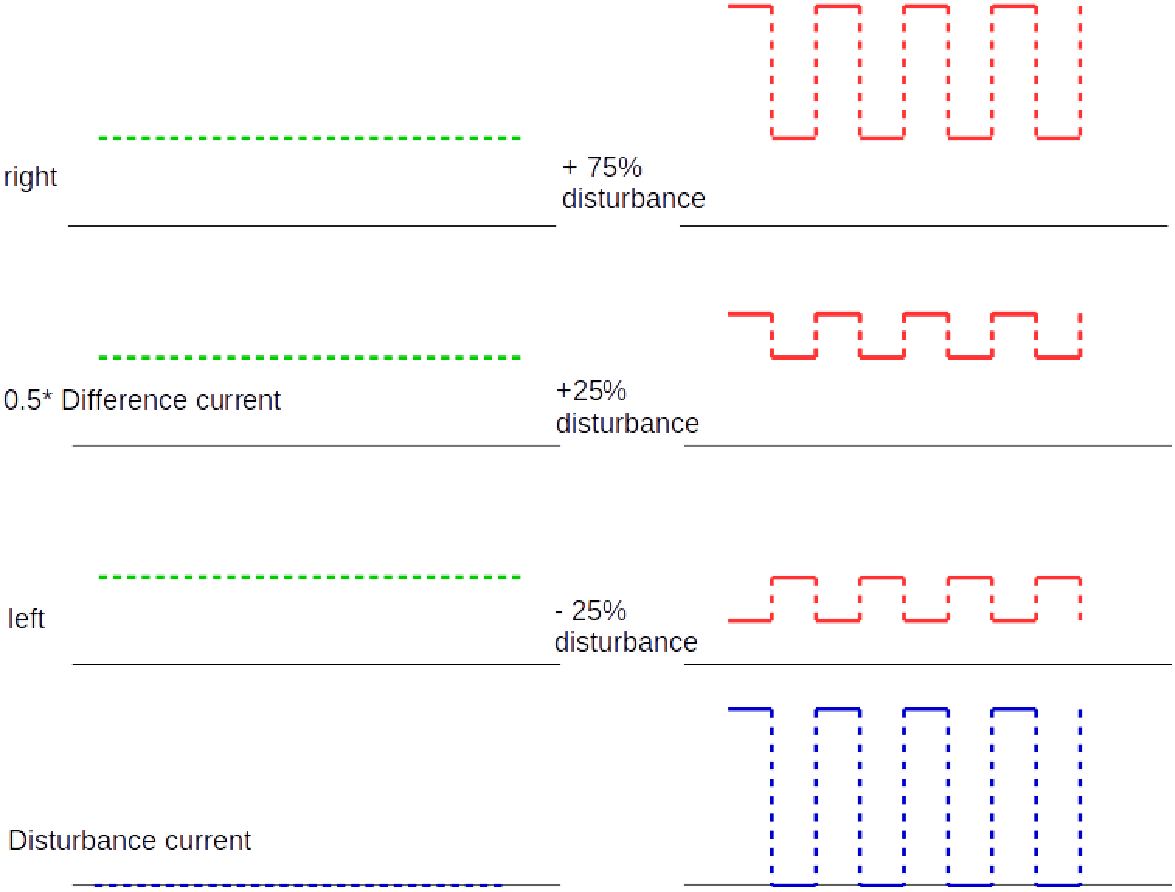
Definition, STMA-25862 - 25% fraction of the disturbance current in phase, 75% fraction out of phase:



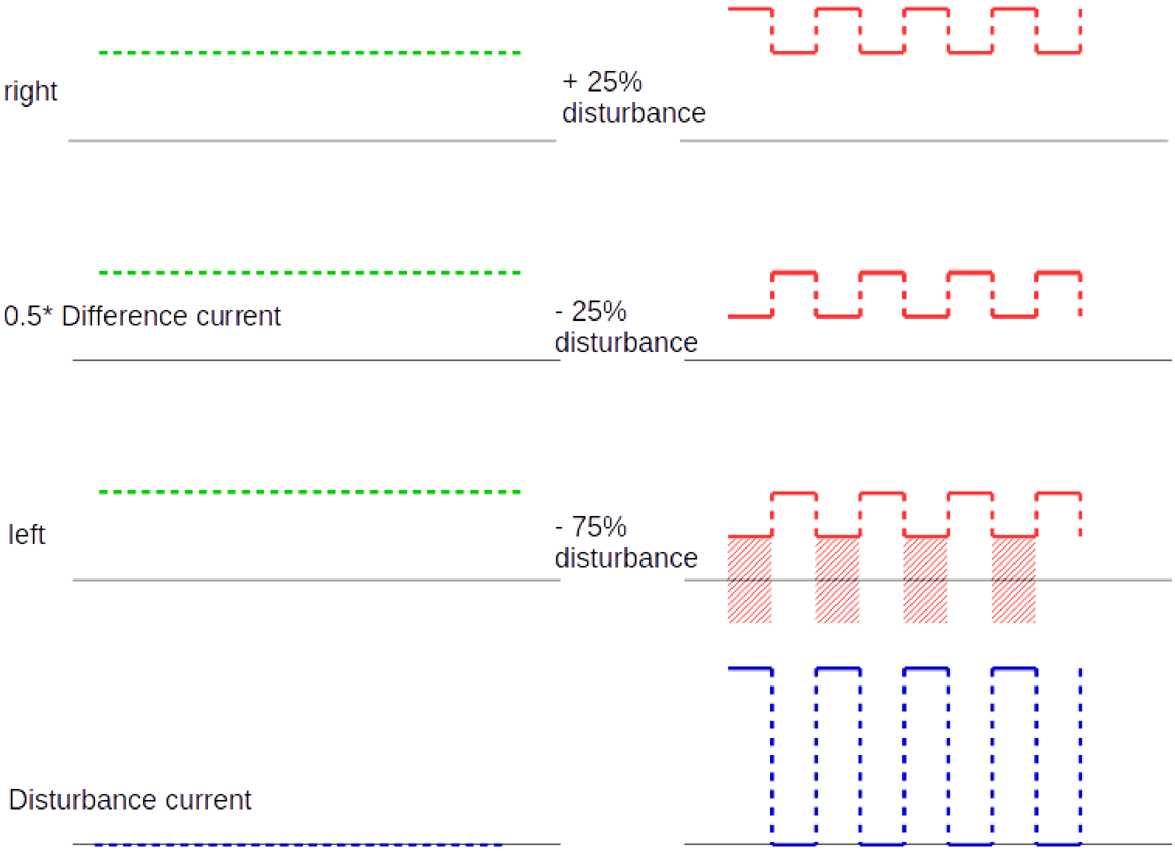
4.1.3.2 Constant 75Hz disturbed by a modulated 75Hz current

This paragraph shows the impact of a constant 75Hz current in the section disturbed by an amplitude modulated 75Hz current from a source outside the section. **[**STMA-25864 **]**

Definition, STMA-25865 - 75% fraction of the disturbance current in phase, 25% fraction out of phase:



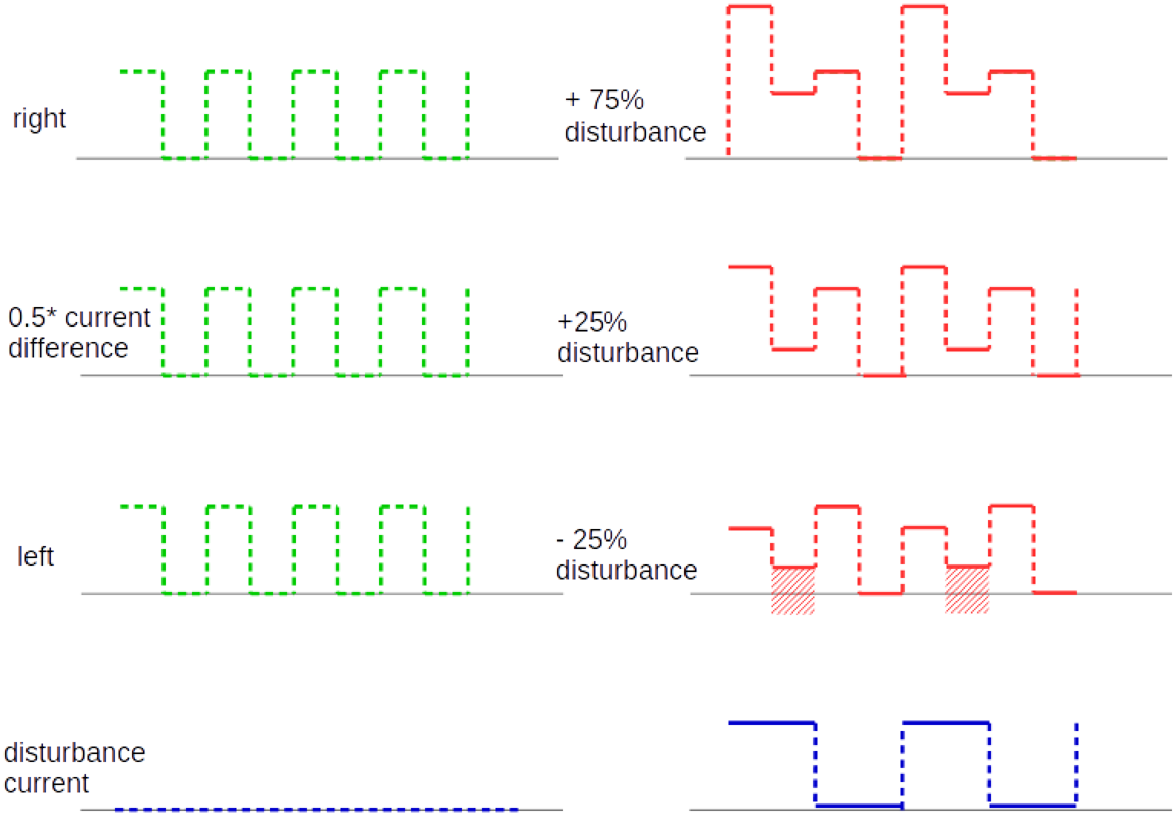
Definition, STMA-25866 - 25% fraction of the disturbance current in phase, 75% fraction out of phase:



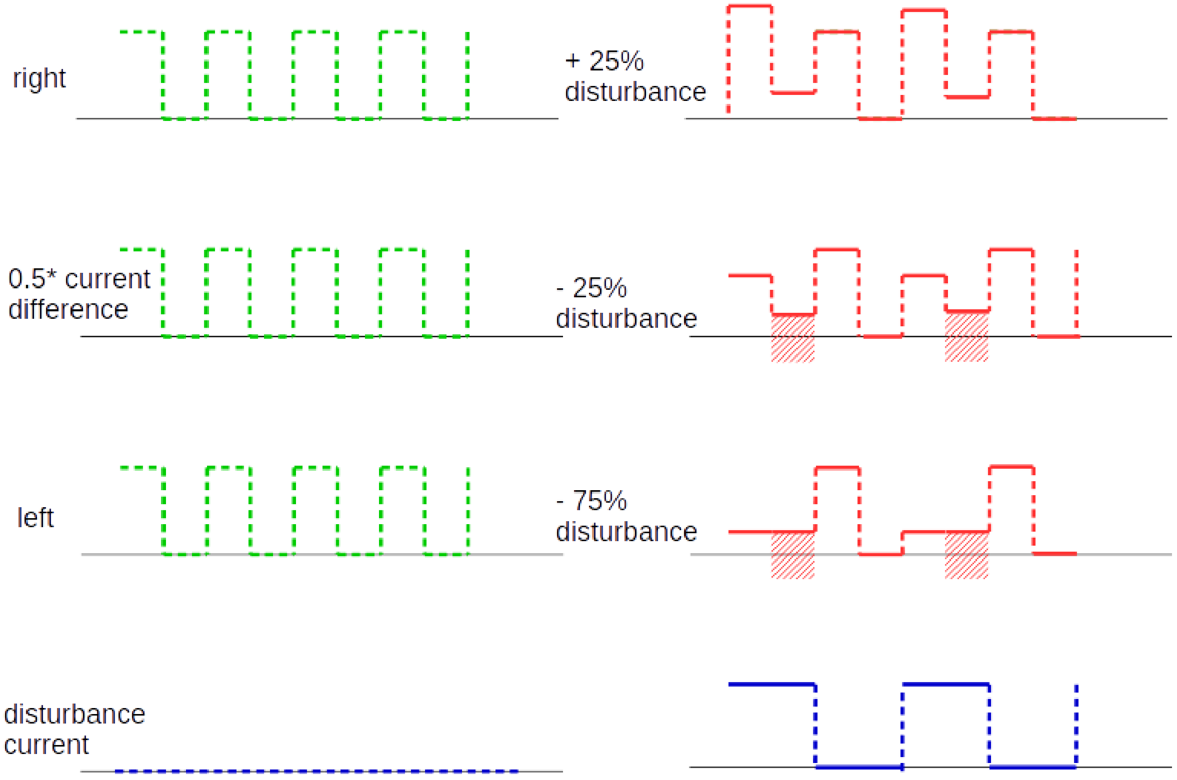
4.1.3.3 ATBEG signal disturbed by a modulated 75Hz current

This paragraph shows the impact of an ATBEG code originating from the current section, disturbed by an amplitude modulated 75Hz current from a source outside the section with 0,5x the code frequency. Due to the inbalance between the left and right rail signal the code from the external source is found in all signals (left, right and difference) **[**STMA-25868 **]**

Definition, STMA-25869 - 75% fraction of the disturbance current in phase, 25% fraction out of phase:



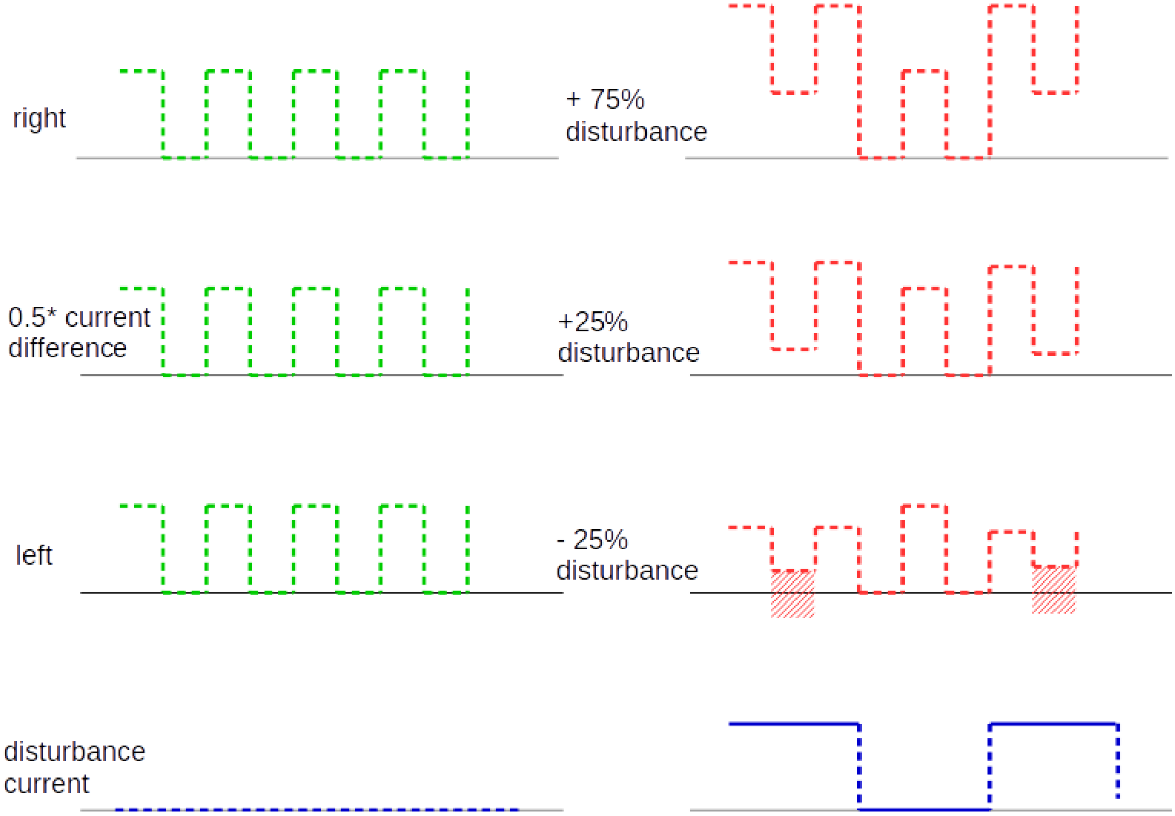
Definition, STMA-25870 - 25% fraction of the disturbance current in phase, 75% fraction out of phase:



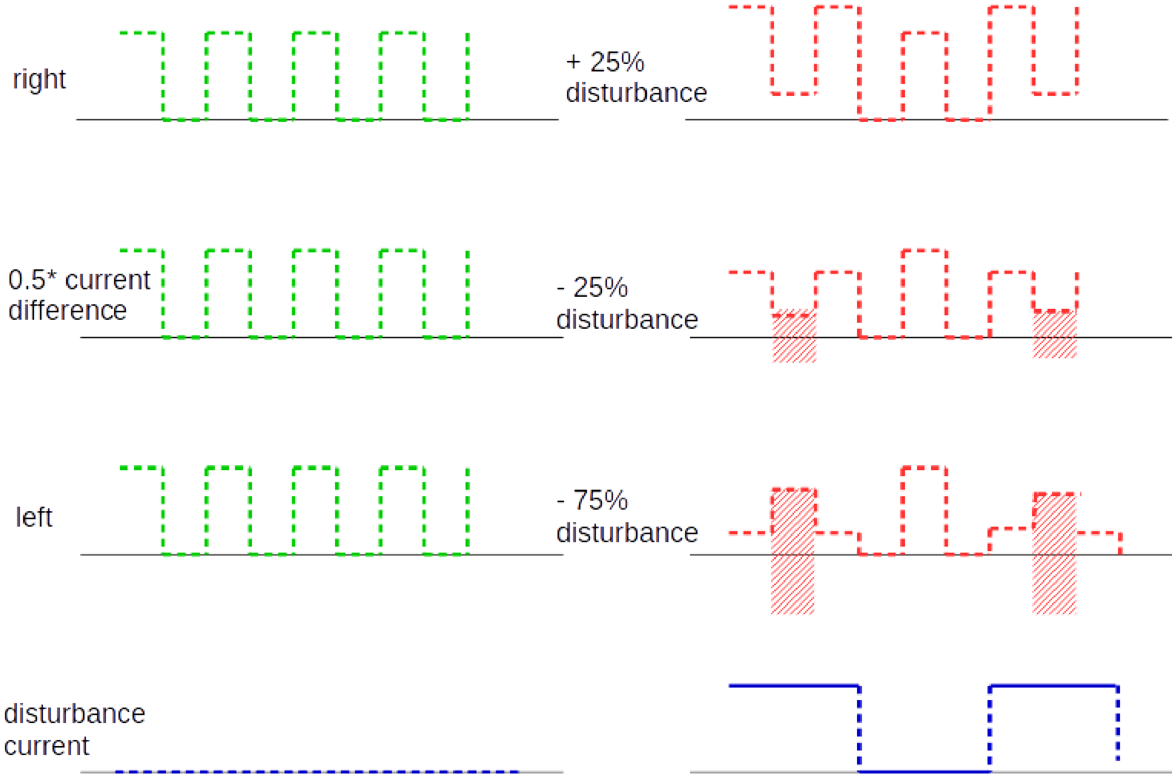
4.1.3.4 ATBEG code disturbed by a 75Hz current modulated at 1/3 of the ATB code frequency

This paragraph shows the impact of an ATBEG code originating from the current section, disturbed by an amplitude modulated 75Hz current from a source outside the section with 0,33x the code frequency. Due to the inbalance between the left and right rail signal the code from the external source is found in all signals (left, right and difference) **[**STMA-25872 **]**

Definition, STMA-25873 - 75% fraction of the disturbance current in phase, 25% fraction out of phase:



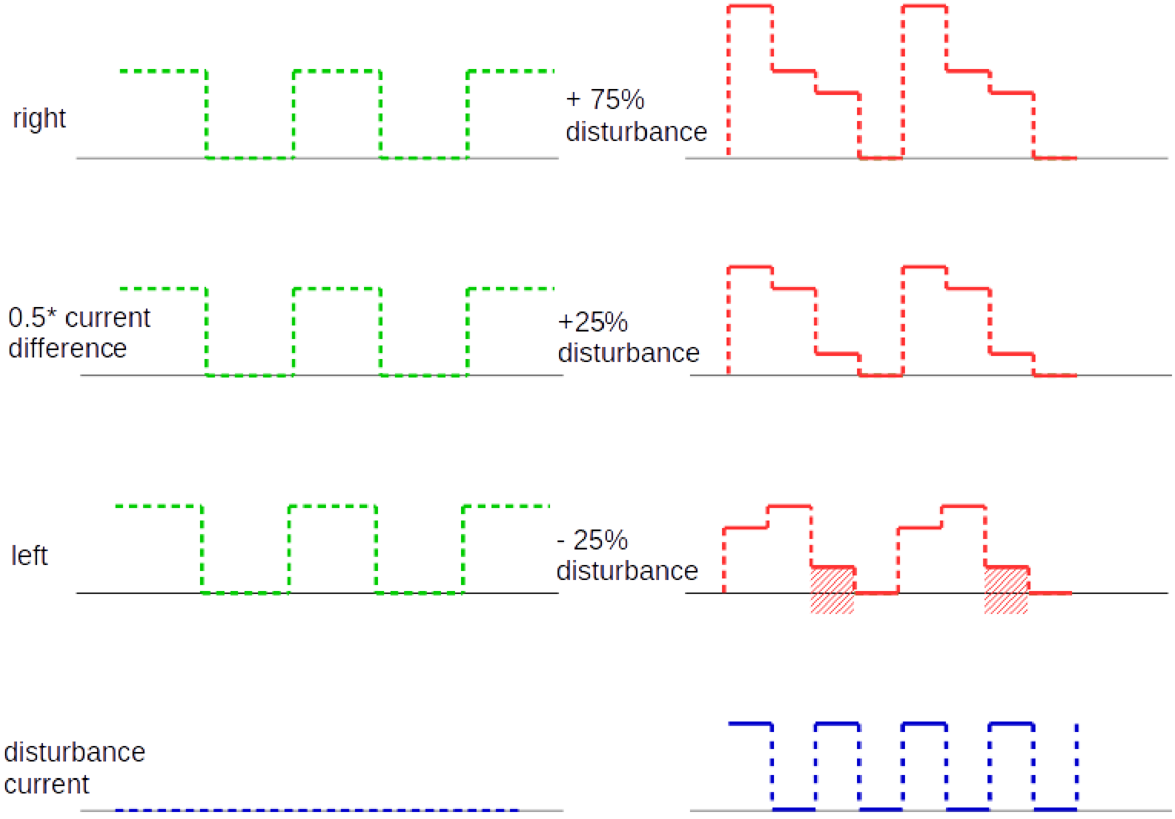
Definition, STMA-25874 - 25% fraction of the disturbance current in phase, 75% fraction out of phase:



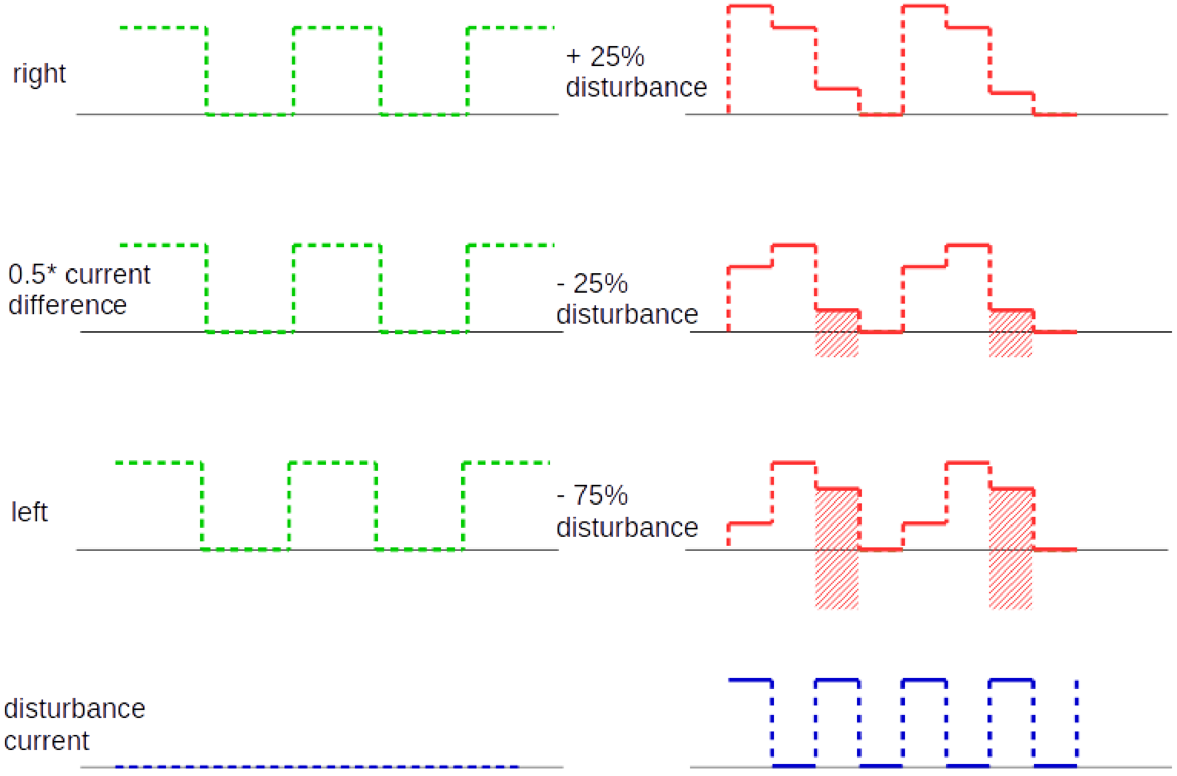
4.1.3.5 ATBEG code disturbed by a 75Hz current modulated at 2 times the ATB code frequency

This paragraph shows the impact of an ATBEG code originating from the current section, disturbed by an amplitude modulated 75Hz current from a source outside the section with 2x the code frequency. Due to the phase change in the left coil signal, the disturbance frequency is limited in the left coil signal, therefore the external code will not be recognized in the left coil signal. **[**ST MA-25878 **]**

Definition, STMA-25876 - 75% fraction of the disturbance current in phase, 25% fraction out of phase:



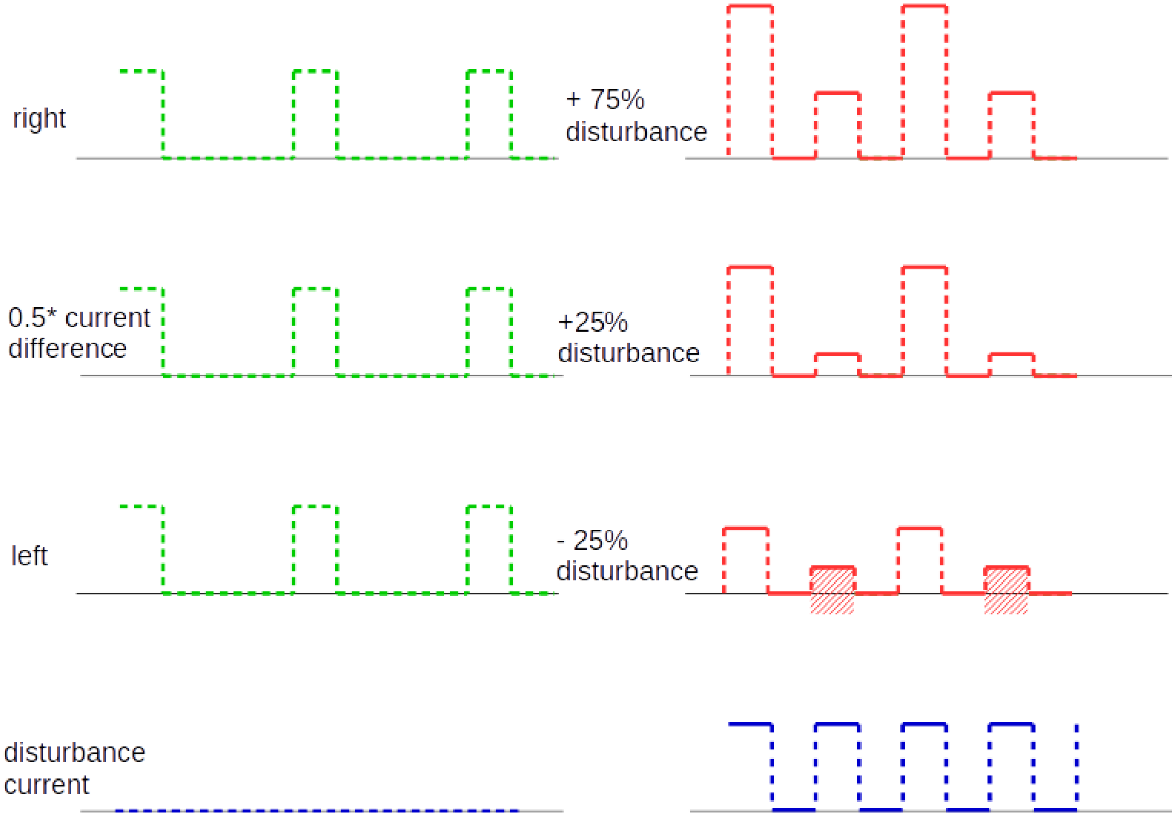
Definition, STMA-25875 - 25% fraction of the disturbance current in phase, 75% fraction out of phase:



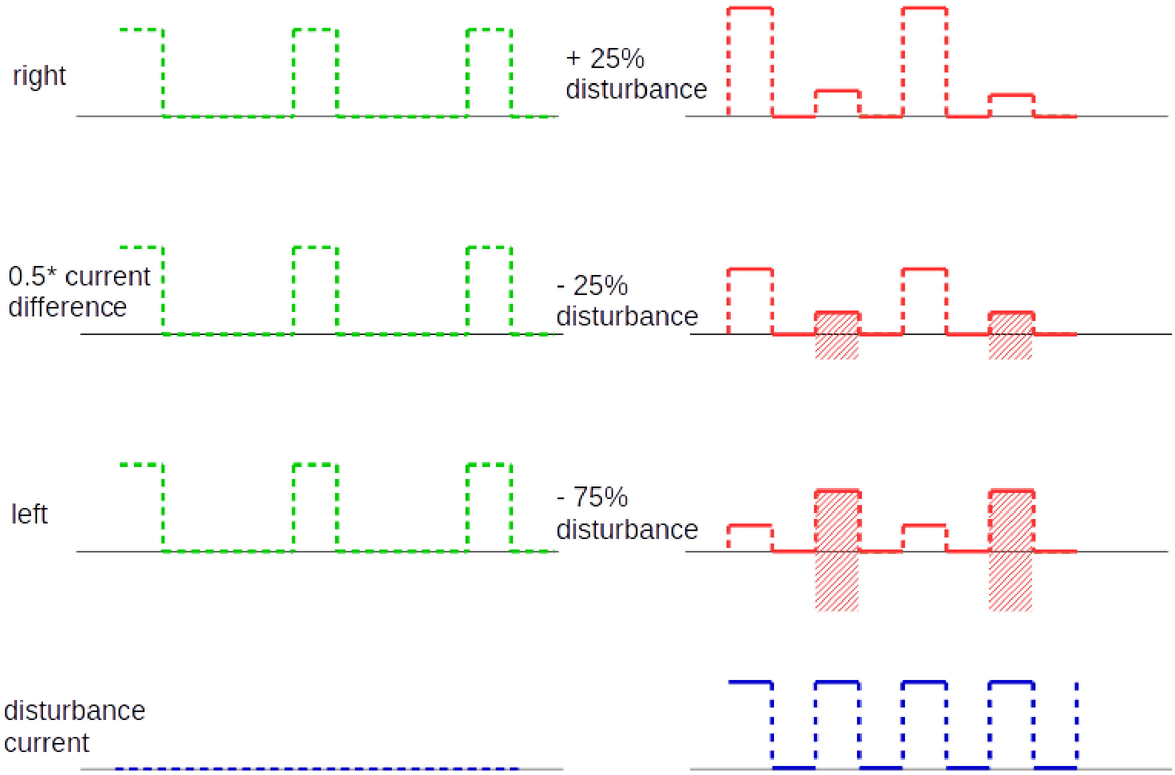
4.1.3.6 ATBEG code with DC = 25% disturbed by a 75Hz current modulated at 2 times the ATB code frequency

This paragraph shows the impact of an ATBEG code originating from the current section (with 25% duty cycle), disturbed by an amplitude modulated 75Hz current from a source outside the section with 2x the code frequency. Due to the phase change in the left coil signal, the disturbance frequency is limited in the left coil signal, therefore the external code will not be recognized in the left coil signal.

Definition, STMA-25881 - 75% fraction of the disturbance current in phase, 25% fraction out of phase:



Definition, STMA-25879 - 25% fraction of the disturbance current in phase, 75% fraction out of phase:



4.1.3.7 Generic description of ATB code plus disturbances

Below a more mathematical description is given: **[**STMA-25886 **]**

A track signal always consist of a signal from a track circuit (s(t)) and a disturbance signal (d(t)). The difference between the two is:

- s(t) is a current floating “round”, therefore the signal in one rail is opposite to the signal in the other rail.
- d(t) is a current floating through the rails, in both rails in the same direction. The signal is either floating in the right or in the left rail, or divided between the two rails with a maximum unbalance of 20% (between 40%-60% and 60%-40%).

[STMA-25883 **]**

In formulas (assumption s(t) is positive for the right rail, and A is the fraction of the disturbing current through the right rail):

- $i_{right}(t) = s(t) + A*d(t)$
- $i_{left}(t) = -s(t) + (1-A)*d(t)$
- $i_{difference} = 2*s(t) + (2A-1)*d(t)$
- $i_{sum} = d(t)$

Both s(t) and d(t) consist of a constant 75Hz part and an AM part, where s(t) will only contain one modulation frequency and d(t) can contain more than one modulation frequency, i.e.:

- $s(t) = s_c(t) + s_{APO}(t)$
- $d(t) = d_c(t) + d_{75}(t) + \ldots + d_{220}(t)$

[STMA-25884 **]**

Codes from a disturbing signal are characterized by the lack of phase difference between left and right leading to a low value for $i_{difference}$ and high value for i_{sum}. However if signals with different codes from a track circuit (s(t)) and from disturbances (d(t)) are mixed the result cannot always be easily recognized. **[**STMA-25882 **]**

Special case: a low frequency with bad duty cycle as s(t), leads also to the double frequency harmonics. Such a signal will be valid but too low, as the level of the base frequency will be at least as high. However adding a signal to one of the rails can increase the double frequency, which could lead to accepting the higher frequency. **[**STMA-25887 **]**

5 ATBVv track signal

The ATBVv track signal is provided to the train via beacons mounted to the right rail (figure 1). The beacons sent a signal with a single constant frequency in the range between 1kHz and 3kHz (1445Hz, 1745Hz, 2353Hz and 2671Hz). The frequency is a code for the distance to the “signal at danger”. Possible values are 120m, 30m, 3m and “release”.
To be able to communicate “clearance of the signal” to trains at standstill, a loop can be used. When present the loop frequency (1145Hz) releases the distance monitoring to the “signal at danger”. Receiving an ATBEG code will have the same effect.
The ATBVv beacons are 80cm long. According to the “ATBVv system description” the train shall be capable of detecting the signals if the speed is below 70km/h. Therefore the minimum time the signal is present is app. 30ms. The maximum time can be infinite. It has to be taken into account that the signal level at the edges of the beacons is app. 40% lower compared to the signal level at the center.
Loops (mounted at the right rail in the running direction) can be tens of meters long. Loops are twisted to protect them from impulse currents through the rails. The loop signal is switched on and off to save energy, this is not relevant for the on-board function (i.e. release if the signal is received).
The ATBVv signal level is very high compared to all disturbances (app. 60dB S/N ratio). Therefore disturbances are not relevant for the on-board equipment.
The ATBVv track signal can be received with the same on-board “antenna” as the ATBEG signal.
[STMA-25888 **]**