The MAGLEV Radio System – Features for Future Applications

Author: Dr. Peter Egner, Co-author: Juergen Dangelmeyr
TELEFUNKEN Radio Communication Systems
Eberhard-Finckh-Str. 55, 89075 Ulm, Germany
Phone 0049 731 1553 214, FAX 0049 731 1553 10 214
eMail: Juergen.Dangelmeyr@tfk-racoms.com, www.tfk-racoms.com

Keywords

Communication, high availability, high data rate, Radio System

Abstract

The communication between vehicles and the centralised system parts of a maglev train system is handled by a mmW-radio communication system in the frequency range of 38 GHz. With the requirement of a highly available communication link primarily operational information will be transferred at the moment. Future maglev projects in addition will have requirements for new services with the need of more data transfer capability.

Due to poor performance of other types of communication systems, since 1989 the German Maglev train system uses a microwave radio system for the communication between the vehicles and its central control facilities. During that period the now called TELEFUNKEN Radio Communication Systems is developing and integrating such technology very successfully. After developing the communication system for the TR 07, the refurbishment of the test facility in the mid of the nineties, in the Shanghai scenario the latest technology proves it's capability day after day. Nevertheless the company is developing eagerly to improve the system for the demands of tomorrow.

Interfacing the radio system

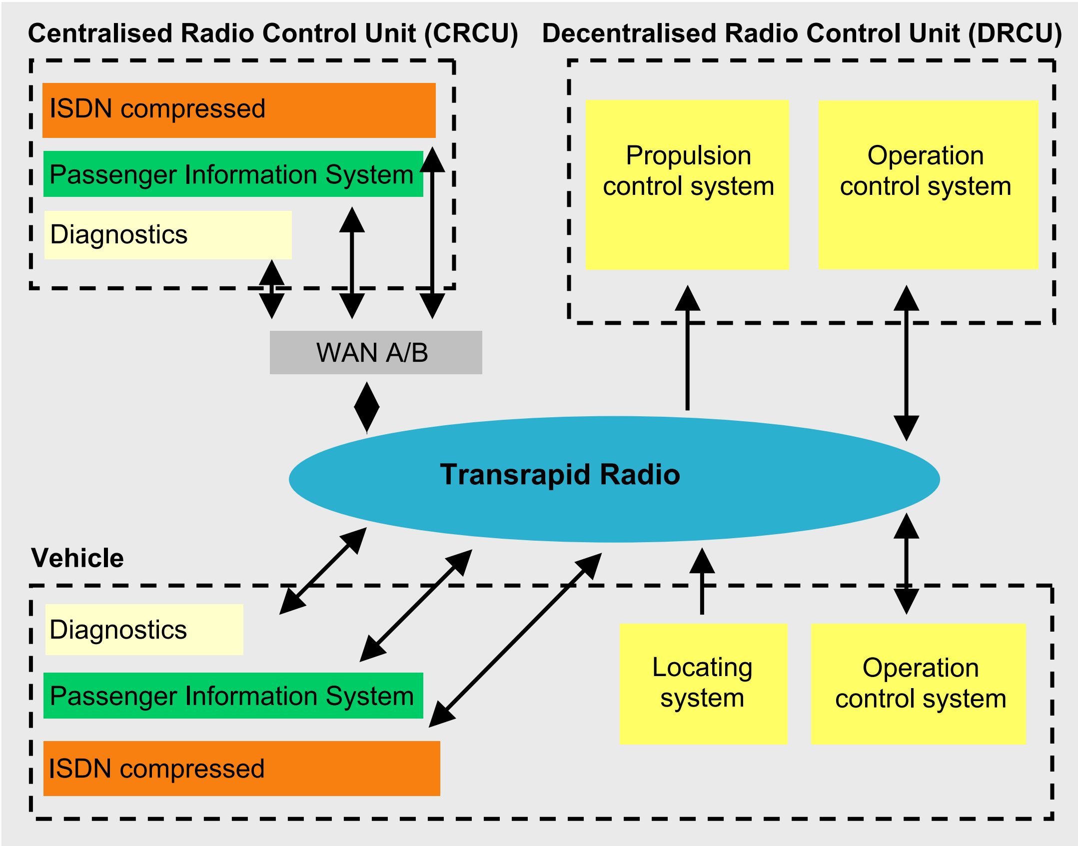

Figure 1 Interfaces of the Radio System

The radio system of the Shanghai Maglev train supports a variety of interfaces to different subsystems. Some of the main requirements for such a communication system are:

Hierarchical configuration of the radio system

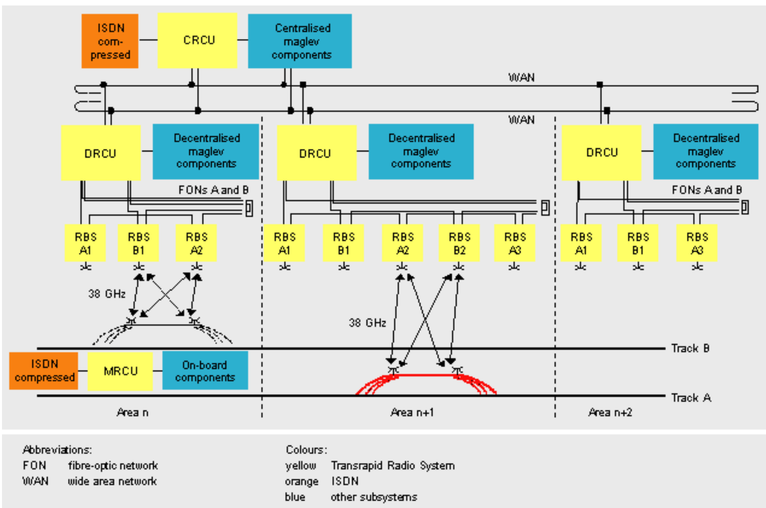

Figure 1 Structure of the Radio System

The radio system is structured according to the following hierarchical levels (Figure 2):
On the track side:

- Centralised Radio Control Unit (CRCU)
- Decentralised Radio Control Unit (DRCU)
- Radio Base Stations (RBS)

On the vehicles:

- Vehicle Radio sets (Mobile Station Transceivers / MST)
- Vehicle Radio System (Mobile Radio Control Unit / MRCU)

Key Requirements today

Data Transmission for OCS, Propulsion, Diagnosis

The requirements for the transmission of data to different subsystems are depending on their specific needs.
So, the data for the Operation Control System (OCS) need to be delivered with a very low error rate, which means a Bit error rate of less than 10 per million. Whereas the data for the propulsion system are more dedicated to a very low dwell time, from the generation of the data in a vehicle to it's delivery to a central control facility the delay has to be less than 5 milliseconds.
For diagnosis purposes additionally there is an Ethernet channel, using the standard TCP/IP and UDP/IP protocols. In order to eliminate the specific delay of the Radio system relevant protocol stacks were implemented.

Operational and Passenger Voice Communication

For operational communication there are two separate voice communication lines implemented, which at the moment serve standard European ISDN terminals. These data will be compressed for the transmission.
Additionally there is also a complete ISDN So-Interface for passenger services available.

System Reliability

The mandatory high availability and reliability of the radio system with such a public transportation maglev train system is a result of different factors. One thing for sure is the dedicated design of all it's single components, but additional also the strictly redundant construction methods and short reaction times in case of failures provide a short mean time to repair (MTTR). A precondition for that is a wide range diagnosis and the concept for an easy replacement of exchangeable components.

System Availability

Another requirement is the provision of a radio link to every vehicle, everywhere in the system and anytime. Such an requirement inevitably leads to a system design which covers each point of the whole track by two independent radio links and even under harsh environmental conditions (snow, fog, dust and rain).

Extremely short Processing Delays

Every large vehicle capable of travelling with a ground speed of more than 500 km/hour or 300 miles/hour need to have a safe operational guidance and a very precise and reliable information about it's position. Additionally for the propulsion of a maglev train the magnetic wheel angle (MWA) is necessary.
Coming from the high speed the transmission of information across the whole system from vehicle to centralised or decentralised facilities and backwards should be extremely fast and free of system internal delays. In this case the transmissions should be done within a few milliseconds.

Multi Vehicle Operation

At least in a multi track guideway situation, but also in a maintenance area and regular stations there is an requirement for a multi vehicle operation, which has to be served simultaneously by the radio system. This feature has already been implemented in the Shanghai scenario.

Key Requirements tomorrow (additional)

Radio systems of future maglev projects will face additional operational requirements influencing also the capable data transmission system, but the above mentioned system characteristics should not easily be dismissed in order to maintain a reliable operation.

Different Aspects concerning Short/Long Distance Applications

A maglev application with a track length of about 30 km means, that the ride takes only less than 10 minutes. Passengers on long distance trips with a stay on board of even more than 1 hour will generate additional needs. Beside all kinds of convenience and entertainment, especially the communication part with access to internet applications and telephone calls via mobile phones will increase.

Security Operations

Modern public transportation systems enhance their passenger safety with surveillance systems controlled and monitored by centralised controll institutions. With respect to a physical limited transmission capability between a moving vehicle and centralised facilities, there is a need for intelligent solutions, transferring only relevant information.

Voice Communications (VoIP, GSM)

Cellular mobile networks along a maglev track and mobile phones travelling through this celluar structure with more than 350km per hour will face a communication problem which the handover from cell to cell and some other physical effects will cause. Especially in long distance projects inside the maglev train there must be a solution to provide a traveller with it's familiar possibility of telephone communication. Maybe a kind of repeater functionality with a link to the typical service provider will be necessary. The transmission of the corresponding signals between vehicle and a centralised interface might be a new feature of the radio system, however VoIP-telephony must be seen as a potential issue.

Internet Applications

Business people like to spend their time in a transportation system as efficient as possible, especially on long distance trips. Beside the possible use of the internet as an important source of information, the ability of a VPN-channel into the company's network becomes more and more attractive. To work with online company-internal data combined with a use of the personal e-mail system provides a comfort which is adding value to the other advantages of the maglev system. To provide these possibilities to a multiplicity of passengers in a maglev train and with an acceptable performance a corresponding data transmission rate has to be allocated, which is beyond conventional mobile networks.

Data Rate

As above mentioned, these features require to increase the accessible data rate of the existing radio system. And additionally this high data rate should be available continuously also under different operational conditions. The reduction of data rate – as usual in a variety of mobile application (e.g. WLan)- is not helpful in this case, as these reduction normally occur in combination with movements of an object, which in this context can be described to be even slow. For a maglev train consequently this will mean at least a constant limitation during all movements.
Converse to this is the requirement of a constantly available link with a high data throughput.

The extremely high availability of a radio link also for minor restrictive passenger data has to be opposed to economic aspects.
A combination of transmissions for operational data with a high availability and also of transmissions for passenger services with a lower availability will be an ideal solution.

Modulation Methods

To achieve a reasonable and guaranteed data transmission rate widely independent of the vehicle speed, a practical type of modulation has to be used. This is a trade off process or compromise between robustness of a modulation scheme and efficiency in using the frequency bandwidth. Studies have shown, that usual modulation schemes of e.g. WLan systems seem to be not utilisable in such an application.

Tunnel Operations

Neither on the German Test Facility, nor in the Shanghai project tunnel constructions are part of the maglev track. But, with respect to future maglev projects also tunnel like constructions have to be considered for propagation purposes of a radio system, as the propagation of radio waves inside a tunnel system are always a challenge. Physical phenomena like reflections in the tunnel tube abet overlays of multiple signals at the point of reception.
Combined with a high velocity a wide variation of the signal strength will result and at higher data rates also Intersymbolic interferences will occur.

Diagnosis and Maintenance

Hard requirements about the overall availability of a communication system shortly tend -as already mentioned above- to the necessity, to detect each failure of any component very rapidly and accurate. Combined with an adequate logistic and spare parts concept MTTR figures in the range of a few hours must be possible.
The defined easily replaceable units (ERU) have to be designed for the short time replacement, whereas maintenance tasks will be done simultaneous to the normal operation.
In tunnels the replacement of components during the operation will not be feasible due to safety reasons. Therefore other methods have to be developed to meet the requirements.

Leaky Feeder

At the German Maglev Test Facility, at the moment, there are tests of a leaky feeder configuration. The requirements for the tests are the same as for the current radio system.
If the leaky feeder system proves to be technically feasible for the data transmission under the operational conditions, it can be used – for example for economical reasons - as an alternative at least on some parts of a maglev track. To achieve this, also the existing system interfaces and their characteristics should be maintained.

General System Aspects

Subsequent some aspects of the radio system will be addressed, which can be defined by operational requirements of a customer.

Using other Frequencies/ Permission Procedure

For a radio communication system, there are two sorts of frequencies which can be used.
The first one are frequencies open for different applications - called ISM-frequencies - which don't need a kind of permission or license by regulation authorities. This main advantage of ISM for some applications is also unacceptable if a high reliability is mandatory.
Therefore, for a lot of applications only frequencies dedicated for special tasks will be licensed from the regulation authorities according to a frequency plan.
Such a scenario needs an adaptation to usable frequencies for the radio system depending on national aspects of a specific "maglev country". The modularity of the radio system addresses exactly this

situation without the need of a principle new development of the entire system. Simply the installation space of the antenna systems have to be considered.

Separation of OCS and Passenger Data Transmission

In principle there are two different requirements for data transmissions in a maglev train.
The hardest requirements regarding a high reliability are for small data amounts necessary for the mandatory operational aspects - namely OCS and propulsion.
The requirements of the very large data amount for passenger services are much easier to handle, as their reliability is less important.
Coming from that point, the division of the tasks into separate communication system for each seems to be an attractive solution. But, already the fact, that the infrastructure alongside the tracks has to be doubled – independent from the system characteristics- shows, that such an approach can be less economic and will fail.

Alternative Antenna Configurations

Solutions for completely different frequency ranges and other application environments will also lead to a different consideration of alternative antenna concepts. Consequently, technical examinations for the limitations of blind spots in the vicinity of a radio base station, as well as a modification in the antenna positioning have to be done.