Summary
We developed an on-board control system for the second phase of ATACS (Advanced Train Administration and Communications System)[1][2][3][4], and made experiments. ATACS controls trains through radio channels without track circuits. On-board devices detect its own position and make brake patterns according to the LMA (Limit of Movement Authority) received from the field controller and make the level crossing information to control level crossings.
Especially, the position detection, the making of brake patterns, and information to control level crossings are characteristic functions of ATACS. We confirmed that on-board controller detected position correctly, that they made brake patterns correctly allowing to stop before LMA, that they made level crossing information correctly, that the field controller controlled the level crossings and that the standard deviation of rumbling time of level crossing became about 2 seconds smaller than the conventional system.

Keyword: wireless communication, on-board, ATP, position detect, level crossing control, brake patterns

1 Introduction
East Japan Railway Company has developed system specifications, conducted test runs, and confirmed system performances. Hitachi Ltd. has developed processing specifications, realized an on-board controller, collected data in test runs, and confirmed processing performances.
ATACS is the system that detects train positions and control trains by radio without track circuits. Trains compute their own positions and send them to the field controller by radio. The field controller sends LMA to trains by radio to control them. Trains receiving LMA make brake patterns to stop before LMA and control their own velocity so that it will not exceed brake patterns.
To adjust rumbling time of level crossings according to train status, trains compute information necessary to control level crossings and send it to the field controller with position information.
It is a special feature of ATACS that trains have more functions than conventional systems. In this paper, we introduce the structure of on-board controller, position detection function, functions to make brake patterns and level crossing information.
We developed these functions and tested them at Senseki line (See Fig.1)
We show the structure of the on-board controller in Fig.2.
The on-board controller has fundamental functions, such as position detection and making brake patterns. Trains and the field controller exchange information by radio. The receiving transponder device receives transponder messages to detect the train position.
The on-board controller controls the train with information received from the field controller and velocity information. It uses the bus comparison and the output comparison for keeping fail safe. The line information, such as gradients and speed limits, is stored in the on-board ROM. The on-board controller shows the running status at displays. Running records are recorded to the data management device, where we can analyze them.
3 Position detection
Trains detect their own position when they receive messages from transponders and compute position according to running distances. They compute the running distance according to outputs from the tachometer-generator. When they receive messages from another transponder, they correct their own positions to cancel the position detection error.

3.1 Position detection when trains are turned on
In the case where trains can receive messages from transponders when they are tuned on, they detect positions and begin position detection. But in the case where they cannot receive messages from transponders because of a gap in the train stop position when they are turned on, they cannot detect position and cannot control themselves.

In such cases, the field controller records the positions of trains when trains are turned off. Then, the field controllers send recorded positions to trains as an estimated position, and trains begin position detection from the received estimated position. With such processes, in the case where trains cannot receive messages from the transponder, trains can begin position detection and control themselves.

The on-board controller applies service brake until receive the estimated position, and limits the velocity of the train to 15km/h after the train receives the estimated position until the train receives message from the transponder.

4 Making brake patterns
In ATACS trains run to LMA. Thus, trains make brake patterns to stop before LMA and brake automatically when the velocity exceeds brake patterns.

The on-board controller makes two brake patterns, one is a service pattern for service braking, another is an emergency pattern for emergency braking. When the velocity of the train exceeds the service pattern, trains apply the service brake. When the velocity of the train exceeds the emergency pattern, the on-board controller applies the emergency brake.

Brake patterns can be separated into two parts. One is a pattern to stop before LMA, another is a pattern not to exceed the speed limit. We explain these two patterns.

4.1 Brake patterns for LMA
Trains make service brake pattern and an emergency brake pattern from LMA. When trains make brake patterns, the brake performance and the effect of gradient are considered. They make the brake patterns by 5km/h. The origin of the service pattern is 4m apart from LMA (See Fig.3).
4.2 Temporary speed limit
Trains receive information about the temporary speed limit from the field controller by radio. When trains receive information, they remake brake patterns handling the temporary speed limit the same as the normal speed limit. The temporary speed limit information consists of start, end positions and speed.

5 Making level crossing information
In ATACS, in order to adjust rumbling time of level crossing, trains make information necessary in order for the field controller to control level crossing and to send it to the field controller by radio with train position information.
Level crossing control information that trains make are the following two.
   _ 1 _ An estimated train position after a pre-determined time
   _ 2 _ An estimated time until reaching the brake pattern for level crossing
The field controllers control level crossing according to these level crossing information. Using these information enables the adjustment of the rumbling time of level crossing according to the performance and status of the train. We explain methods to compute these information.

5.1 An estimated train position after a pre-determined time
Trains compute where they can reach in a pre-determined time at full speed as an estimated train position (See Fig.4). They compute information under the following constraints.
   _ 1 _ The performance of acceleration and effect of gradient are considered.
   _ 2 _ Trains run under the speed limit.
   _ 3 _ LMA is ignored.
The reason that LMA is ignored is that it is possible that LMA is renewed in a pre-determined time.

The estimated train position after a pre-determined time

5.2 An estimated time until reaching the brake pattern
The estimated time until reaching the brake pattern is how long it takes for the trains to reach brake patterns for level crossing at full speed(See Fig.5). It is computed under the following constraints, which is the same as an estimated train position.
   _ 1 _ The performance of acceleration and effect of gradient are considered.
   _ 2 _ Trains run under the speed limit.
6 Conclusion

East Japan Railway Company conducted test runs at Senseki line and confirmed system performances. Hitachi Ltd. collected data in the test runs and confirmed processing performances.

As a result, we confirmed that trains detected their own position correctly for the function of position detection, and that they began position detection correctly by receiving an estimated position from the field controller if they could not receive messages from transponders when they were turned on.

In regard to the function of making brake patterns, we confirmed that trains apply the brake when the velocity of the train exceeded brake patterns and that trains stopped before LMA.

We tested the function to control level crossings as a pre-determined time is 45 seconds. As a result, we confirmed that the standard deviation of rumbling time of level crossing became about 2 seconds smaller than the conventional system.

We have developed the on-board controller with the use of a time-proven controller for in-service ATP. We have confirmed that the developed on-board controller has adequate performance for required functions.

We consider that we confirmed fundamental functions necessary to realize an on-board controller of ATACS.