Low earth orbit satellite for air traffic control

Technical field of the invention

The present invention relates to low earth orbit satellites for air traffic control.

Background of the invention

Air traffic control involves human staff communicating with the pilots of a plurality of planes, instructing them on flight profiles (consisting of altitudes and azimuthal routes) so as to avoid collisions. Aircrafts generally file "flight plans" indicating their routes before take-off; and from these, the controllers have some initial information on the likely positions and trajectories of aircraft. However, flight plans are inherently subject to variation (e.g. due to delays in take-offs; changes of speed due to head wind or tails wind; and permitted modifications of the course or altitude by the pilot). In busy sectors (typically, those close to airports), significant tactical control of the aircraft by the controllers is necessary.

The controllers are supplied with data on the position and altitude of the aircraft from primary and secondary radar units, such as terrestrial ADS-B receiver stations, and ask the pilots for information such as altitude, heading and speed. They instruct the pilots by radio to maintain their headings and speeds, alter their headings and speeds in a predetermined fashion, or maintain or alter their altitudes (e.g. to climb to a certain altitude or to descend to a certain altitude) to maintain safe minimum separation between aircrafts and, thus, to avoid the risk of collisions.

In order to optimize the air traffic control in busy sectors, it would be an advantage to obtain contact with an aircraft in due time before the aircraft reaches the sector. However, the control tower is limited by the range of

their radio, as well as by limited exact knowledge about how close the aircraft is from being within radio contact.

It is therefore desirable to provide a system for air traffic control, which can overcome some of these issues.

Summary of the invention

The inventors of the present invention has provided a system capable of optimizing air traffic control in busy sectors. The system is capable of obtaining contact with an aircraft in due time before the aircraft reaches the sector.

A first aspect of the present invention relates to the use of a low earth orbit, LEO, satellite for air traffic control; wherein the LEO satellite is adapted for:
a) receiving an Automatic Dependent Surveillance-Broadcast, ADS-B, signal from an aircraft;
b) receiving and/or transmitting a signal from/to a control tower;
c) receiving and/or transmitting a VHF signal from/to an aircraft;
wherein the ADS-B signal emitted by the aircraft comprises information regarding the aircrafts position, speed, and direction;
wherein the LEO satellite is further adapted for receiving a signal from a control tower, and to re-transmit said signal to an aircraft on a compensated VHF frequency for compensating for Doppler frequency shifts, and wherein the compensation is based on the information from the aircrafts ADS-B signal.

A first aspect of the present invention relates to the use of a low earth orbit, LEO, satellite for air traffic control; wherein the LEO satellite is adapted for:
a) receiving an Automatic Dependent Surveillance-Broadcast, ADS-B, signal from an aircraft;

b) receiving and/or transmitting a signal from/to a control tower;
c) receiving and/or transmitting a VHF signal from/to an aircraft;
wherein the ADS-B signal emitted by the aircraft comprises information regarding the aircrafts position, speed, and direction.

The signal received/transmitted from/to a control tower may e.g. be via the L-, S-, C-, and/or E-band.

Today, aircrafts are tracked with primary (PSR) and secondary (SSR) surface radars. Recently, with Automatic Dependent Surveillance-Broadcast (ADS-B) it has become possible to track air transport aircraft also with ADS-B ground stations complementary to radars. The ADS-B signals are not directed to a specific receiver but rather can be received by any receiver within reach of the broadcast transmitter and technically capable of receiving the signals.
The principle of ADS-B is the automatic, periodic and unaddressed broadcast of existing on-board data by each aircraft equipped with appropriate transmitters. Data to be broadcast can be, e.g. position, altitude, speed vector, intent, and/or call sign of the aircraft, or the aircraft class, etc. The data broadcast is mostly performed at the aviation frequency of 1090 MHz. The broadcast data can be received at ADS-B ground stations, which monitor this frequency and extract the Mode-S 1090 MHz. An alternative technology for broadcast of ADS-B signal is the Universal Access Transceiver operating at 978MHz.

However, many oceanic and African Flight Information Regions (FIRs) are not reachable by terrestrial systems. Therefore, the inventors have proposed to use satellites to access the ADS-B signal from the aircraft present in the airspace. Using satellites solves the problem in areas without radar coverage or in areas without coverage provided by terrestrial ADS-B receiving stations.

The satellite is a low earth orbit satellite. A higher orbit would result in a weaker signal making the technical implementation more challenging.

The satellite is constructed to be the link between a control tower and the aircraft. Preferably, it should be capable of providing means for two-way communication.

In one or more embodiments, the LEO satellite is adapted for:
- receiving and transmitting a signal from/to a control tower; and/or
- receiving and transmitting a VHF signal from/to an aircraft.

Using satellites in closer orbits (LEO satellites) achieve significantly higher ground level signal strengths. By steering the antenna beam to cover different geographical areas in a repetitive pattern a wide area coverage is achieved. However, these lower orbits necessarily result in significant relative velocities between a control tower/an aircraft and the satellite, resulting in a variable Doppler frequency shift, which derogate receiver sensitivity making signal acquisition extremely difficult. Hence, the inventors have developed a satellite that compensate for the Doppler frequency shifts.

In one or more embodiments, the LEO satellite is further adapted for receiving a signal from a control tower, and to re-transmit said signal to an aircraft on a compensated VHF frequency for compensating for Doppler frequency shifts, and wherein the compensation is based on the information from the aircrafts ADS-B signal.

Another issue with using satellites as a link between the control tower and the aircraft is that the signal from the satellite may interfere with other frequencies that are used in the area.

In one or more embodiments, the LEO satellite is further adapted for receiving a signal from a control tower, and to re-transmit said signal to an aircraft at a narrow transmission bandwidth of 8.33 kHz in regions where aviation VHF channels are operated with nominally 25 kHz separation. This will minimize the interference of the signal.

In one or more embodiments, the region is identified by the information from the aircrafts ADS-B signal.

In one or more embodiments, the LEO satellite is further adapted for:
- detecting a VHF signal from an aircraft;
- correcting for Doppler frequency shifts; and
- re-transmitting said VHF signal to a control tower.

In one or more embodiments, the LEO satellite is further adapted for re-transmitting the ADS-B signal and/or the VHF signal from an aircraft to another LEO satellite in a position closer to a control tower.

In one or more embodiments, the LEO satellite is further adapted for re-transmitting the signal from a control tower to another LEO satellite in a position closer to an aircraft.

In various alternate arrangements and preferred embodiments, data transmission between individual satellites is performed for data qualifying parsing, assembling and/or distributed processing.
In one or more embodiments, the extracted information from the ADS-B signal is converted into an Air Traffic Control (ATC) standard protocol by the satellite, and forwarded to a ground station (ATC or other users).

A third aspect relates to a system for air traffic control comprising:
- one or more LEO satellites adapted for:

a) receiving an Automatic Dependent Surveillance-Broadcast, ADS-B, signal from an aircraft;
b) receiving and/or transmitting a signal from/to a control tower;
c) receiving and/or transmitting a VHF signal from/to an aircraft;
wherein the ADS-B signal emitted by the aircraft comprises information regarding the aircrafts position, speed, and direction;
- one or more control towers adapted for receiving and/or transmitting a signal from/to a LEO satellite;
wherein the LEO satellite is further adapted for receiving a signal from a control tower, and to re-transmit said signal to an aircraft on a compensated VHF frequency for compensating for Doppler frequency shifts, and wherein the compensation is based on the information from the aircrafts ADS-B signal.

A fourth aspect relates to a system for air traffic control comprising:
- one or more LEO satellites adapted for:
a) receiving an Automatic Dependent Surveillance-Broadcast, ADS-B, signal from an aircraft;
b) receiving and/or transmitting a signal from/to a control tower;
c) receiving and/or transmitting a VHF signal from/to an aircraft;
wherein the ADS-B signal emitted by the aircraft comprises information regarding the aircrafts position, speed, and direction
- one or more control towers adapted for receiving and/or transmitting a signal from/to a LEO satellite.

In one or more embodiments, the system and/or control tower is further adapted for receiving an ADS-B signal from a LEO satellite.

In various alternate arrangements and preferred embodiments, the system comprises multiple satellites, where data transmission is performed between individual satellites for data qualifying parsing, assembling and/or

distributed processing.

A fifth aspect relates to a LEO satellite for air traffic control, the LEO satellite being adapted for:
a) receiving an Automatic Dependent Surveillance-Broadcast, ADS-B, signal from an aircraft;
b) receiving and/or transmitting a signal from/to a control tower;
c) receiving and/or transmitting a VHF signal from/to an aircraft;
wherein the ADS-B signal emitted by the aircraft comprises information regarding the aircrafts position, speed, and direction;
wherein the LEO satellite is further adapted for receiving a signal from a control tower, and to re-transmit said signal to an aircraft on a compensated VHF frequency for compensating for Doppler frequency shifts, and wherein the compensation is based on the information from the aircrafts ADS-B signal.

A sixth aspect relates to a LEO satellite for air traffic control, the LEO satellite being adapted for:
a) receiving an Automatic Dependent Surveillance-Broadcast, ADS-B, signal from an aircraft;
b) receiving and/or transmitting a signal from/to a control tower;
c) receiving and/or transmitting a VHF signal from/to an aircraft;
wherein the ADS-B signal emitted by the aircraft comprises information regarding the aircrafts position, speed, and direction.

In one or more embodiments, the LEO satellite is further adapted for re-transmitting the ADS-B signal to the control tower.

In one or more embodiments, the satellite further comprises means adapted for rebroadcasting the received ADS-B signal to other satellites or to an aircraft as an Automatic Dependent Surveillance-Rebroadcast, ADS-

R.

A seventh aspect relates to a LEO satellite for air traffic control, the LEO satellite comprising:

a) means for receiving an Automatic Dependent Surveillance-Broadcast, ADS-B, signal from an aircraft;

b) means for receiving and/or transmitting a signal from/to a control tower;

c) means for receiving and/or transmitting a VHF signal from/to an aircraft;

wherein the ADS-B signal emitted by the aircraft comprises information regarding the aircrafts position, speed, and direction.

In one or more embodiments, the means for transmitting a VHF signal to an aircraft is configured for transmitting on a compensated VHF frequency for compensating for Doppler frequency shifts, and wherein the compensation is based on the information from the aircrafts ADS-B signal.

In one or more embodiments, the means for transmitting a VHF signal to an aircraft is configured for transmitting a signal to an aircraft at a narrow transmission bandwidth of 8.33 kHz in regions where aviation VHF channels are operated with nominally 25 kHz separation. This will minimize the interference of the signal.

It should be noted that embodiments and features described in the context of one of the aspects of the present invention also apply to the other aspects of the invention.

Brief description of the figures

Figure 1 shows a system for air traffic control in accordance with various embodiments of the invention; and

Figure 2 shows a LEO satellite for air traffic control in accordance with various embodiments of the invention.

Detailed description of the invention

The general aspects of the invention is described in the following as a solution to optimize air traffic control in busy sectors. The system is capable of obtaining contact with an aircraft in due time before the aircraft reaches the sector.

A schematic view of a system 100 for air traffic control in accordance with various embodiments of the invention is shown in Figure 1. The system comprises one or more satellites 110 and a control tower 120.

The one or more LEO satellites 110 are adapted for receiving an Automatic Dependent Surveillance-Broadcast, ADS-B, signal from an aircraft. The ADS-B signal emitted by the aircraft comprises information regarding the aircrafts position, speed, and direction. This information may be relayed directly to the control tower 120, or may be relayed to another LEO satellite, and then to the control tower 120. This information is important for the control tower 120 for them to plan the flight profiles for the aircraft that is about to enter a given sector.

The pilot needs to be informed about any changes in his flight plan. Thus, in order to inform the pilot in good time, the LEO satellites 110 are also adapted for receiving and/or transmitting a signal from/to a control tower; as well as adapted for receiving and/or transmitting a VHF signal from/to an aircraft.

The one or more control towers 120 should also be adapted for receiving and/or transmitting a signal from/to a LEO satellite 110.

In Figure 2, a LEO satellite for air traffic control is shown.

The LEO satellite 110 comprises:

a) means 118 for receiving an Automatic Dependent Surveillance-Broadcast, ADS-B, signal from an aircraft 10;

b) means 116 for receiving and/or transmitting a signal from/to a control tower 120; and

c) means 112 for receiving and/or transmitting a VHF signal from/to an aircraft.

The LEO satellite 110 is also shown comprising means 114 for receiving and/or transmitting a signal from/to another LEO satellite.

The means 112 for transmitting a VHF signal to an aircraft is configured for transmitting on a compensated VHF frequency for compensating for Doppler frequency shifts, and wherein the compensation is based on the information from the aircrafts ADS-B signal.

The means 112 for transmitting a VHF signal to an aircraft is also configured for transmitting a signal to an aircraft at a narrow transmission bandwidth of 8.33 kHz in regions where aviation VHF channels are operated with nominally 25 kHz separation. This will minimize the interference of the signal.

References

10	Aircraft
100	System
110	LEO satellite
112	Means for receiving and/or transmitting a VHF signal from/to an aircraft
114	Means for receiving and/or transmitting a signal from/to another LEO satellite
116	Means for receiving and/or transmitting a signal from/to a control tower
118	Means for receiving an ADS-B signal from an aircraft
120	Control tower

Claims

1. Use of a low earth orbit, LEO, satellite for air traffic control; wherein the LEO satellite is adapted for:

a) receiving an Automatic Dependent Surveillance-Broadcast, ADS-B, signal from an aircraft;

b) receiving and/or transmitting a signal from/to a control tower;

c) receiving and/or transmitting a VHF signal from or to said aircraft;

wherein the ADS-B signal emitted by said aircraft comprises information regarding the aircraft's position, speed, and direction;

wherein the LEO satellite is further adapted for receiving a signal from said control tower, and to re-transmit said signal to said aircraft on a compensated VHF frequency for compensating for Doppler frequency shifts, and wherein the compensation is based on the information from said aircraft's ADS-B signal.

2. Use according to claim 1, wherein said LEO satellite is further adapted for receiving a signal from said control tower, and to re-transmit said signal to said aircraft at a narrow transmission bandwidth of 8.33 kHz in regions where aviation VHF channels are operated with nominally 25 kHz separation.

3. Use according to claim 2, wherein said region is identified by the information from said aircraft's ADS-B signal.

4. Use according to any one of the claims 1-3, wherein said LEO satellite is further adapted for:

- detecting a VHF signal from said aircraft;
- correcting for Doppler frequency shifts; and
- re-transmitting said VHF signal to said control tower.

5. Use according to any one of the claims 1-4, wherein said LEO satellite is

further adapted for re-transmitting said ADS-B signal and/or said VHF signal from said aircraft to another LEO satellite in a position closer to said control tower.

6. Use according to any one of the claims 1-5, wherein said LEO satellite is further adapted for re-transmitting said signal from said control tower to another LEO satellite in a position closer to said aircraft.

7. A system (100) for air traffic control comprising:
- one or more LEO satellites (110) adapted for:
a) receiving an Automatic Dependent Surveillance-Broadcast, ADS-B, signal from an aircraft (10);
b) receiving and/or transmitting a signal from/to a control tower (120);
c) receiving and/or transmitting a VHF signal from/to said aircraft (10);
wherein the ADS-B signal emitted by said aircraft (10) comprises information regarding said aircraft's position, speed, and direction;
- one or more control towers (300) adapted for receiving and/or transmitting a signal from or to said LEO satellite(s);
wherein said LEO satellite(s) are further adapted for receiving a signal from said control tower(s), and to re-transmit said signal to said aircraft on a compensated VHF frequency for compensating for Doppler frequency shifts, and wherein the compensation is based on the information from said aircraft's ADS-B signal.

8. A system for air traffic control according to claim 7, wherein said LEO satellite(s) are further adapted for receiving a signal from said control tower(s), and to re-transmit said signal to said aircraft at a narrow transmission bandwidth of 8.33 kHz in regions where aviation VHF channels are operated with nominally 25 kHz separation.

9. A system for air traffic control according to claim 8, wherein said region is

identified by the information from said aircraft's ADS-B signal.

10. A system for air traffic control according to any one of the claims 7-9, wherein said LEO satellite(s) are further adapted for re-transmitting the ADS-B signal and/or the VHF signal from said aircraft to another LEO satellite in a position closer to said control tower(s).

11. A system for air traffic control according to any one of the claims 7-10, wherein said LEO satellite(s) are further adapted for:
- detecting a VHF signal from said aircraft;
- correcting for Doppler frequency shifts; and
- re-transmitting said VHF signal to said control tower(s).

12. A system for air traffic control according to any one of the claims 7-11, wherein said LEO satellite(s) are further adapted for re-transmitting said signal from said control tower(s) to another LEO satellite in a position closer to said aircraft.

13. A LEO satellite for air traffic control, the LEO satellite being adapted for:
a) receiving an Automatic Dependent Surveillance-Broadcast, ADS-B, signal from an aircraft;
b) receiving and/or transmitting a signal from/to a control tower;
c) receiving and/or transmitting a VHF signal from or to said aircraft;
wherein the ADS-B signal emitted by said aircraft comprises information regarding said aircraft's position, speed, and direction;
wherein said LEO satellite is further adapted for receiving a signal from said control tower, and to re-transmit said signal to said aircraft on a compensated VHF frequency for compensating for Doppler frequency shifts, and wherein the compensation is based on the information from said aircraft's ADS-B signal.

14. A LEO satellite for air traffic control according to claim 13, wherein said LEO satellite is further adapted for receiving a signal from said control tower, and to re-transmit said signal to said aircraft at a narrow transmission bandwidth of 8.33 kHz in regions where aviation VHF channels are operated with nominally 25 kHz separation.

15. A LEO satellite for air traffic control according to claim 14, wherein said region is identified by the information from said aircraft's ADS-B signal.

16. A LEO satellite for air traffic control according to any one of the claims 13-15, wherein said LEO satellite is further adapted for re-transmitting the ADS-B signal and/or the VHF signal from said aircraft to another LEO satellite in a position closer to said control tower.

17. A LEO satellite for air traffic control according to any one of the claims 13-16, wherein said LEO satellite is further adapted for:
- detecting a VHF signal from said aircraft;
- correcting for Doppler frequency shifts; and
- re-transmitting said VHF signal to said control tower.

18. A LEO satellite for air traffic control according to any one of the claims 13-17, wherein said LEO satellite is further adapted for re-transmitting the signal from said control tower to another LEO satellite in a position closer to said aircraft.