Mode S anti-reflection algorithm for eliminating false tracks due to reflected replies in ground radar systems

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[0001] The present application claims priority to Italian Patent Application No. RM2011A000633, filed on November 30, 2011, which is incorporated herein by reference in its entirety.

FIELD

[0002] The disclosure ~~diselosure~~ relates to a Mode S anti-reflection algorithm for eliminating false tracks due to reflected replies in ground radar systems.

[0003] The Mode S is a technology for data transmission utilised by the second surveillance radar (SSR) for the control of the air traffic of aircrafts provided with transponder. The "S" stands for "selective" i.e. it indicates the possibility of interrogating the aircraft in a selective way by means of univocal 24-bits address, possibility that is not offered by the prior technologies called "mode A" (or "Mode 3") and "Mode C".

[0004] The mode S is a standard of communication complying with regulations and recommendations of the ICAO, International Civil Avionic Organisation, i.e. the body entrusted for developing the principles and techniques of the international air navigation, the routes and the airports and promoting the design and the development of the International air transport making it more secure and regular.

[0005] The mode S data link is characterised by this activity of the data exchange between ground radar station and aircraft.

[0006] The characteristic of the technologies prior to mode S in the field secondary radars is that of effectuating transmission of the broadcast type, by exploiting:

- the spatial selectivity of the radar antenna (dimension of the main beam of

criteria, i.e. the result of the described algorithm, cannot be considered as wholly effective.

[0020] Document US20020180631 discloses a similar method, wherein a cinematic analisys is performed on tracks that have a valide mode code to update a reflectors map. However, in a Mode S SSR environment (air space) the so-called conspicuity code will be adopted, that is all the aircrafts equipped with mode S transponders will share the same identical Mode A code (A1000) to prevent mode A leakage due to the proliferation of air traffic. Therefore the algorithm of US20020180631 would delete all the Mode S flights.

[0021] Embodiments of~~It is object of~~ the present disclosure seek to provide a method for eliminating the flase tracks in the radar detections, which may solves the problems and overcome~~s~~ the drawbacks of the prior art.

[0022] Embodiments~~It is object~~ of the present disclosure also seek to provide means and systems configured~~on~~Fig.~~d~~ to perform the method above~~object of the present disclosure~~.

SUMMARY

[0023] According to a first aspect of the disclosure, a method for eliminating false Mode S SSR or 3A code tracks on radar display created by a radar extractor of a radar as a consequence of false replies, i.e. replies reflections against reflectors, a reflector being natural or artificial object different from an aircraft target, the radar being signals representing a target, the radar comprising the radar extractor and a radar tracker, the method comprising the execution of the following steps:

A. Creating a raw video map, that is extended to the area covered by the radar and is subdivided into cells of predefinable dimensions, each cell delimiting a portion of the area wherein a aircraft target can be present, to each cell being associated a probability of presence of false replies in such a cell;

B. For a situation corresponding to a scan by the radar:

B0. Identifying replies clusters, i.e. two or more replies sets closer to each other in azimuth and range than corresponding predefined threshold values;

B1. Associating to each cell of the raw video map a power level received by the radar in the corresponding area portion;

B2. Extracting the plots, i.e. replies cluster average points determined in case a replies set has a number of replies greater than a pre-defined threshold, by the radar extractor;

B3. Sending the extracted plots to the radar tracker along with said probability of presence of false replies in the cells to which they respectively belong;

B4. Calculating, by means of the radar tracker, the tracks relevant to the plots, updating the already existing tracks on the radar display and initiating new tracks using one or more track initiation thresholds chosen on the basis of said probability of presence of false replies calculated in step B3;

C. With respect to the all tracks of step B4, determining, by means of the radar tracker, false tracks and ~~relevant~~ initial points ~~(in fact, the radar tracker determines the presence of false tracks by using several criteria, the disclosure method concentrating on avoiding to initiate false tracks and not on the particular method of discovering false tracks, which can vary with the progress in the field)~~of the false tracks;

D. On the basis of the initial points of the false tracks determined in step C, calculating the probability of presence of said false replies in the cells corresponding to said initial points and updating the raw video map of step A;

E. Repeating steps B-D.

[0024] A scan of the radar is the detection of the radar detection in a certain time window.

[0025] The definition of plot given in B2 is the standard definition known to the skilled person. It follows that the number of plots are not necessarily equal to the number of clusters.

[0026] For example, concerning step B4, the threshold can be the number of correlating consecutive plots needed to initiate the track. Such a number can be chosen proportionally to said probability of presence. The skilled person will undersand how to use such a probability of presence with respect to the different track initiation criteria.

[0027] According to an embodiment~~another aspect~~ of the present disclosure, in step B4, a track initiation threshold is used, which is a pre-defined number of correlating consecutive plots, said track initiation threshold being an increasing function of said probability of presence of false replies calculated in step B3.

[0028] According to another embodiment~~aspect~~ of the present disclosure, the power level associated to each cell in step B1 is determined by the intensity of the reply signal(s) within the the cell, said probability of presence for the cell being calculated over multiple radar scans as:

$$E\ \{P^{i}_{RX} * N_{scan\ with\ reflection} / P_{MAX} * N_{scan\ TOT}\}$$

wherein:

- $N_{scan\ with\ reflection}$ is the number of radar scans for which false tracks have been determined in the cell in step C;
- $N_{scan\ TOT}$ is the number of multiple radar scans;
- P^{i}_{RX} indicates the power of the signal received from the i-th reply falling in the cell, with i=1,...k where k is the total number of replies in the cell and depends on the geographical extension of the same cell;
- P_{MAX} indicates the highest power receivable from the cell;

And wherein E{} indicates an average operation executed on the replies in the cell.

[0029] According to another embodimentaspect of the present disclosure, said probability of presence in each cell is calculated as a percentage of the current average power stored in the cell P_r^n:

$$P_{fl} = b\, P_r^n$$

wherein b is a configurable parameter.

[0030] According to another embodimentaspect of the present disclosure, in step B1, for each cell, the power level received in the current scan P_r is averaged with a power level P_r^{n-1} already associated to the cell, and an averaged value P_r^n is currently associated to the cell, according to the following:

$$\text{If } P_r \geq P_r^{n-1}, \text{ then } P_r^n = P_r$$

$$\text{Else } P_r^n = \alpha\, P_r + (1-\alpha)\, P_r^{n-1}$$

Wherein α is a real number weight, equal for all cells, parametrising a "memory" of cell average power that affects the one or more track initiation thresholds in step B4, the value α being suitable to be pre-set to meet changing detection situations such as traffic density and environment changing speed, and, once a track has been identified as false in step C, α value will be set to a different value $\alpha_r < \alpha$ to increase algorithm memory of the false track.

[0031] According to another embodimentaspect of the present disclosure, in step C the radar tracker determines false tracks on the basis of one or more pre-defined criteria, a false track being determined when a track:

- has an unsteady trajectory defined by a variance of the range and/or azimuth speed larger than a pre-defined threshold;
- is chosen out of two tracks having the same Mode S address and manoeuvering at the same time, wherein manouvering condition is estimated according to the

innovation energy criterium of the Kalman filtering, by calculating the range distance between the two tracks and using following choice criteria:

- if said range distance is larger than a pre-defined range distance threshold, particularly radar range accuracy, the track with the largest range distance is chosen;
- otherwise the track is chosen that is the first track terminated in time;

– The false track is the one of two tracks having the same mode S address, for which the roll call interrogations do not succeed;

– Is chosen by an operator who manually inputs information in the radar tracker about which one of the tracks are false tracks.

[0032] According to another embodiment~~aspect~~ of the present disclosure, during step D, the radar tracker communicates the initial points of the false tracks individuated in step C to the radar extractor, which carries out the calculation of probability of presence.

[0033] According to another embodiment~~aspect~~ of the present disclosure, during step A, when the system ADS-B is at disposal, in case an ADS-B plot is present which is correlating in position with a SSR plot, all the remaining plots will be marked as reflections and the relevant cells of the raw video map will be marked with probability 100%.

[0034] According to a second aspect of the present invention, there is provided~~It is further specific subject matter of the present disclosure~~ a computer program product comprising a computer usable medium having control logic stored therein for causing a computer to execute~~characterised in that it comprises code means conFig.d to carry out, when operating on a computer,~~ step A-E of the method for eliminating false Mode S SSR or 3A code tracks on radar display created by a radar extractor as a consequence of the false replies, according to the first aspect~~according to the disclosure~~.

[0035] According to a third aspect of the present invention, there is provided a tangible~~It is further specific subject matter of the present disclosure a~~ memory medium readable by a computer, having a program memorized on it, wherein~~characterised in that~~ the program is the computer program according to the second aspect~~disclosure~~.

[0036] According to a fourth aspect of the present invention, there is provided~~It is further specific subject matter of the present disclosure~~ a system for eliminating false Mode S SSR or 3A code tracks on a radar display created by a radar extractor as a consequence of false replies, the system ~~being characterised in that it~~ comprises~~ing~~ means to execute the method according to the first aspect~~disclosure~~, the system comprising:

- a radar extractor, including electronic means configured~~conFig.d~~ to perform steps A, B0-B3, D;
- a radar tracker, including electronic means configured~~conFig.d~~ to perform steps B4, C.

[0037] The details of one or more embodiments of the disclosure are set forth in the accompanying drawings and the description below. Further embodiments of the disclosure will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF DRAWINGS

[0038] The accompanying drawings, which are incorporated into and constitute a part of this specification, illustrate one or more embodiments of the present disclosure and, together with the description of example embodiments, serve to explain the principles and implementations of the disclosure.

[0039] Fig. 1 shows the flowchart that is typical for a traditional antireflection mode S algorithm;

[0040] Fig. 2 shows an example of raw video without landing target (a) can and with take-off target (b, c, d, and d);

[0041] Fig. 3 shows an example of geometrical analysis of the row video;

[0042] Fig. 4 shows a first hypothesis about the position of the reflectors in the raw video of Fig. 3;

[0043] Fig. 5 shows a second hypothesis about the position of the reflectors in the raw