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## METHOD FOR OPTIMIZING MOBILE TARGET INTERCEPTION AND MISSILE THEREFOR

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The invention relates to systems for the single-target and multitarget interception of mobile targets by missiles, especially of aerial targets by air-to-air or surface-to-air missiles.

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As for example, Figure 1 shows a contemporary two-phase air-to-air missile 10. It comprises a receiver 11 which makes it possible, for example, to provide for the LAM aircraft/missile link. Furthermore, the missile 10 comprises a warhead 13, a propulsion device 12, a navigation and guidance device 14 and an auto-steering device 15. The missiles 10 used nowadays are said to be two-phase. As shown by Figure 2, the target engaged 30 is in general at a considerable range  $p_c$  (for example of the order of 50 to 60 km) when the missiles 10 are fired. Now, the lock-on range  $p_a$  of the auto-steering device 15 of the missile 10 is markedly lower (for example, around 10 to 15 km), thereby requiring the missile 10 to have a first flight phase (so-called inertial phase) before the final autoguidance phase.

During the first phase, the navigation and guidance device 14 therefore operates in inertial navigation mode. The interception system 20 of the aircraft sends via an aircraft/missile link LAM an estimate of the position and of the speed of the target 30. The state of the target 30 is estimated by virtue of the sensors (especially radar) in an appropriate reference frame. This estimation of the state of the target 30 may be performed simultaneously for several targets and is called tracking on discontinuous information.

The second phase is triggered by the locking-on of the auto-steering device 15 to the target 30. The navigation and guidance device 14 of the missile 10 operates onwards of this instant in autoguidance mode.

An interception system 20 conventionally comprises a first subsystem, called the firing subsystem  $20_T$ . It is responsible for ensuring the implementation of the armament means against the mobile targets 30. The firing of missile(s) 10 by the firing unit(s) of the firing subsystem  $20_T$  after fire control calculation and initialization of the missiles 10 are improvements that are already in place today.



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Other improvements have been made to air-to-air or surface-to-air target 30 interception systems 20. These are detection, tracking, identification and designation of target(s) 30 to be intercepted. They are performed by one (or more) sensor(s). These improvements are grouped  
 5 together within a second subsystem that the interception system 20 generally comprises. This subsystem is called the designation subsystem  $20_P$ . It is responsible for establishing a tactical situation associated with the engagement. In particular, it is responsible for ensuring the detection, tracking, identification functions and for designating the target(s) 30 to the  
 10 firing subsystem  $20_T$ . To do this, it relies on suitable interfaces possibly with operators. The designation subsystem  $20_P$  comprises one or more devices including sensors, especially radar and/or optronic sensors.

The tracking of the missiles 10 fired was another improvement of the interception systems 20. It may be performed by the same sensors (radar  
 15 and/or optronic) or possibly result from an estimate of the position and of the speed of the missiles 10 by trajectography estimated as a function of the firing conditions and of a modeling of the kinematics of the missiles 10 fired. The tracking of the missiles 10 fired and the management of the transmissions to these missiles 10 (for example, the management of the  
 20 aircraft/missile link LAM) as well as the other fire control functions (calculation of the firing domains, estimates of the positions of the missiles 10 fired, etc.) may be undertaken by one or the other of these subsystems  $20_P$  or  $20_T$ .

The two subsystems, designation  $20_P$  and firing  $20_T$ , may be  
 25 colocated, that is to say placed on one and the same platform (for example on board an aircraft or one and the same surface-to-air system, etc.) as in Figure 3 in the case of air-to-air fire control. In this case, the sensors (in particular radar) of the interception system 20 of the aircraft make it possible to cover a so-called radar domain  $D_R$ . The targets 30 are searched for in a  
 30 search volume  $V_S$  defined by the designation subsystem  $20_P$ . This subsystem  $20_P$  makes it possible to designate the target(s) 30 in this search volume  $V_S$ . This designation subsystem  $20_P$  of the interception system 20 of the aircraft thus ensures the tracking of the targets 30 and missiles 10 fired by the firing subsystem  $20_T$  of the interception system 20 of the same aircraft in the

volume  $V_P$  defined by the designation subsystem  $20_P$  and sends this tracking information to the fired missiles 10 via an LAM link.

The two subsystems, designation  $20_P$  and firing  $20_T$ , may also be located separately (for example distributed between several aircraft) in this case utilizing a system for transmitting suitable data as shown by the example of Figure 4. An aircraft comprises the designation subsystem  $20_P$ . In the same manner as in the example of Figure 3, it searches for the targets 30 in the search volume  $V_S$ . However, the aircraft  $20_P$  not comprising the firing subsystem  $20_T$ , it sends the state information of the targets 30 via a "tracking-firing" link LPT to the aircraft comprising this firing subsystem  $20_T$ . Once the missile(s) 10 have been fired by the aircraft  $20_T$ , the designation subsystem  $20_P$  tracks the missiles 10 fired and the targets 30 in the tracking volume  $V_P$ . It sends this tracking information via the LPT link to the firing aircraft  $20_T$  which sends the information for tracking the targets 30 to the missiles 10 fired via the LAM link.

The interception systems 20 benefit, moreover, from the existing link between the firing subsystem  $20_T$  or the designation subsystem  $20_P$  and the missile(s) 10. This link allows the transmission to the missile(s) 10 of the coordinates (position and speed) of the target 30. These coordinates are in a trihedron in which the missile 10 can estimate its movement and reconstitute the estimated kinematic conditions of interception.

The locking-on of the auto-steering device 15 of the missile 10 is generally performed during inertial flight. It is dependent on criteria established before the firing making it possible to avoid certain errors.

Despite these improvements, the operational capabilities of current interception systems 20 are still limited. Firstly, the tracking of the missiles 10 fired with the aid of one or other type of sensors (radar or optronic, for example) is subject to errors. The errors made by the sensors of the interception system 20 regarding the state vector of the missiles 10 fired during their flight are a first limiting factor of this system 20. They are mainly due to the errors of harmonization of the respective inertial reference rigs of the interception system 20 and of the missile 10 to the errors of drifting of the navigation of the missile 10 and to the uncertainties regarding the characteristics of the missiles.

Thereafter, the tracking of the targets 30 with the aid of one or the other type of sensors (radar or optronic, for example) is, likewise, subject to errors. These errors of estimation of the sensors of the designation subsystem 20<sub>P</sub> regarding the state vector (position, speed and possibly acceleration) of the targets 30 constitute a second limiting factor of the interception system 20.

From the errors of estimation of the state vector of the missiles 10 fired stem a third limiting factor of the current interception systems 20. These are difficulties and constraints in efficiently ensuring a link between the firing subsystems 20<sub>T</sub> and the missiles 10 fired.

Let us take, next, the case where an aircraft fires a missile 10. The interception system 20 of this aircraft may know whether the LAM aircraft/missile link is subject to jamming. However, it cannot know whether the missile 10 is taking account of the information sent by the interception system 20. Neither does the interception system 20 know when the auto-steering device 15 locks onto the target 30 or onto which target. This results in errors of assignment of the missiles 10 fired which form the fourth factor limiting the current interception systems 20. These errors of assignment of the missiles 10 fired at the targets 30 to be engaged are due, in particular, to the conditions of in-flight lock-on in a multitarget situation of the auto-steering devices responsible for the terminal autoguidance of the missiles 10.

Furthermore, a fifth limiting factor of these interception systems 20 is apparent, related to the missile 10. This concerns the effect of countermeasures which intervene on the operation of the missile 10, especially in the phase of terminal autoguidance after locking of the auto-steering device 15 of the missile 10 onto the target 30 engaged.

These limitations will be accentuated by the foreseeable trends in the development of interception systems 20, especially of air-to-air or surface-to-air interception systems. The first development is related to the increase in the range desired for the missiles 10. This increase in range is brought about through the search for interception of the target 30 before it can engage its own interception system 20. A second development is related to the limitation of the signatures of the targets. Specifically, the latter become "discreet" (control of transmissions) or stealthy during the major part of the interception.

The present invention makes it possible to alleviate these drawbacks at least in part. The subject of this invention is a process for optimizing the interception of mobile target(s) 30 comprising the following steps: the tracking of the target(s) 30, the tracking of the missile(s) 10 fired, the transmission from the interception system 20 to the missile(s) 10 fired of the information regarding the tracking of the target(s) 30 and the transmission of information by the missile(s) 10 fired to the interception system 20 so as to improve its performance over at least one of the steps of tracking and/or transmission of the interception system 20.

This process for optimizing interception is implemented in the invention by an interception system 20 comprising: a designation subsystem 20<sub>P</sub> and a firing subsystem 20<sub>T</sub> that may or may not be colocated, a device 21<sub>E</sub> for transmitting to the missile(s) 10 in any one of the designation 20<sub>P</sub> and firing 20<sub>T</sub> subsystems, and a device 21<sub>R</sub> for receiving the signals transmitted by the missile(s) in any one of the designation 20<sub>P</sub> and firing 20<sub>T</sub> subsystems.

Another subject of the invention is that the designation subsystem 20<sub>P</sub> and the missile 10 each comprise a GPS type locating device, the information from the GPS of the missile 10 being transmitted by the missile 10 to the interception system 20 which uses it to improve its performance. A variant of the invention consists in the GPS type locating devices operating in relative mode.

The characteristics and advantages of the invention will become more clearly apparent on reading the description, given by way of example, and of the figures relating thereto which represent:

- Figure 1, the diagram of a two-phase missile 10 according to the state of the art,

- Figure 2, the operation of a two-phase interception system 20 according to the state of the art,

- Figure 3, the operation of an interception system 20 with designation subsystem 20<sub>P</sub> and firing subsystem 20<sub>T</sub> colocated according to the state of the art,

- Figure 4, the operation of an interception system 20 with designation subsystem 20<sub>P</sub> and firing subsystem 20<sub>T</sub> located separately according to the state of the art,

- Figure 5, a diagram of the interception system 20 according to the invention,
- Figure 6, a simplified graphical representation of the tracking of the missiles 10 fired and of the targets 30 to be reached,
- 5       - Figure 7, a block diagram of the process for optimizing interception according to the invention.

The interception system 20 of Figure 5 consists of two subsystems, a designation subsystem 20<sub>P</sub> and a firing subsystem 20<sub>T</sub>.

10       To the existing link from the interception system 20 to the missile 10 ("uplink"), our invention adds a "return" link from the missile 10 to the interception system 20 ("downlink"). These links are established, as shown diagrammatically in Figure 5, with the aid of the transmitter/receiver 11\*<sub>E/R</sub> coupled to the antenna A1 of the missile 10 and the transmitter/receiver 21<sub>E/R</sub> coupled to the antenna A2 of the interception system 20.

15       In a first variant of the interception system 20, the transmitter 21<sub>E</sub> and the receiver 21<sub>R</sub> are colocated in any one of the designation 20<sub>P</sub> and firing 20<sub>T</sub> subsystems. In a second variant, they are separated. The transmitter 21<sub>E</sub> is in the firing subsystem 20<sub>T</sub> and the receiver 21<sub>R</sub> in the designation subsystem 20<sub>P</sub> or vice versa.

20       The transmission from the missile 10 to the interception system 20 allows the latter to improve its performance. In particular, the interception system 20 can use the information received regarding the state of the missile 10 fired to improve the performance of the various functions that it implements.

25       Various types of information may be transmitted by the missile 10. It may relate, for example, to the general state of the missile 10. It then involves, in particular the position, the speed, the acceleration of the missile 10, means used by the missile 10 to obtain this information, etc.

30       Or else, this information may be detailed indications as to the state of the missile 10, in particular the state of one or the other of the devices of the missile 10. Hence, the jamming conditions, end of engagement conditions (for example, the activation of the proximity fuse), etc. may also form part of this information. The indications regarding the state of the

various devices of the missile 10 are regarding their physical and/or mechanical state.

The navigation device 14 and auto-guidance device 15 of the missile 10 also supply part of the information transmitted by the missile 10.

5 This is the phase of the navigation and guidance device 14: inertial or auto-guided, the conditions prior to and resulting from the lock-on of the autoguidance device 15. Or else, this is information relating to the targets 30 engaged such as the relative positions and speeds, the radial distances, speed and accelerations of these targets, etc.

10 All this information is date-stamped and the date-stamp of the information is transmitted with the latter by the missile 10.

The devices 26 of the interception system 20 and 16 of the missile 10 are locating devices. They may be of GPS type (Global Positioning System). In our example, they are mainly and in nominal mode GPS locating  
15 devices in relative operating mode. The relative operation of the GPS makes it possible to obtain information with better accuracy.

The GPS type locating device has another advantage. It allows accurate date-stamping of the state vector of the missile 10. This vector comprises the position and the speed of the missile 10 in a reference  
20 trihedron known to the interception system 20 and to the other missiles 10 in flight. The GPS therefore allows operation of all these elements (missiles and interception system 20) with an extremely accurate common time reference.

The use of the GPS locating devices 16 and 26 may therefore allow an improvement in the temporal synchronization of the missiles 10 fired  
25 and of the interception system 20, especially of the designation subsystem  $20_P$  and/or of the firing subsystem  $20_T$ .

Should the GPS not exist or be unavailable, the improvements described remain accessible through the inertial navigation system (not represented) of the missile 10 but under conditions of lesser performance.

30 The designation subsystem 20 possesses a locating device 26 as shown by Figure 5. Also, if the two subsystems  $20_P$  and  $20_T$  are not colocated, the firing subsystem  $20_T$  comprises, likewise, a second locating device 26" (not represented in the figure). In this case, the information exchanges between these two subsystems  $20_P$  and  $20_T$  are ensured by a  
35 bidirectional link. It allows GPS operation in relative mode in particular.

However, the operation of the GPS in relative mode presupposes, for the participants of the system, the interception system 20 and the missile(s) fired, estimation of the positions on the basis of one and the same subset of the constellation of GPS satellites 40, which is accessible at the same time to the participants concerned. This is why the missile 10 will use the link effected with the aid of the transmitter  $11^*_E$  and of the receiver  $21_R$  to transmit the identification of the GPS satellites used 40 with the state vector computed by the GPS locating device 16. The interception system 20 will establish its position with the aid of the GPS locating device 26 for each possible subset of GPS satellites 40 so as to be able to establish the relative position of the missile 10 fired by virtue of the information received from the missile 10 as to its GPS position and to the subset of GPS satellites used 40 to establish it.

For fast lock-on, operation in relative GPS mode also presupposes a timewise initialization procedure and specific exchanges between the various GPS locating devices 16 and 26 generally performed before firing or in the first phase of firing.

The entire information transmitted by the missile 10 to the interception system 20 is used by the latter within the monitoring device 23 to optimize the interception of the target(s) 30 (not shown in Figure 5).

Firstly, the device 23 uses this information to improve the detection and tracking processing available such as, for example, radar and/or optronic on the missiles 10 fired. Specifically, by virtue of the locating device 16, and in particular through the use of GPS in relative mode with the aid of the locating device 26, the state vector of each missile 10 is known accurately. This knowledge makes it possible to improve the operation of the search and tracking modes. For example, the state information obtained through the various search and tracking modes (radar and/or optronic and/or GPS) can be merged either for estimating errors, in particular of bias type, or for harmonization between radar and optronics.

Figure 6 shows a simplified graphical representation of the tracking of the missiles 10 fired and of the targets 30 to be reached. In reality, in the graphical representation of the tracking that may possibly be presented to an operator by the operator interface 22 of the interception system 20, not only the position estimates but also the trajectory estimates are displayable

for the entire set of missiles fired 10 and the set of targets 30 to be reached. In this simplified example, a single missile 10 is displayed. The first estimate of position  $\hat{M}_R$  of the missile 10 is that obtained with the aid of the radar sensors, the second estimate of position  $\hat{M}_O$  is that obtained with the aid of the optronic sensors. Moreover, the position  $M_{GPS}$  determined by the GPS locating device 16 of the missile 10 and transmitted by the latter to the interception system 20 so as to be represented on the tracking graph. The radar estimate  $\hat{B}_R$  and optronic estimate  $\hat{B}_O$  of a target 30 are represented in the same way. These estimates may be corrected on the basis of the estimate of the radar and optronic errors calculated on the basis of the radar, optronic estimates of the missile 10 and of the GPS position of this missile 10. This makes it possible to significantly improve the tracking of the targets 30 and to render it more reactive in the presence of "evasive maneuvers".

Figure 7 proposes an exemplary functional diagram for optimizing the interception of target(s) 30. In a first step E10, various information is acquired by the missile regarding its state, the state of operation of its various devices, the state of the targets 30 that it acquires and then tracks, etc. This information is date-stamped, treated and then transmitted during a step S1 to the interception system 20.

The various types of information received by the designation subsystem  $20_P$  are then processed in parallel. For example, during a step S21, the information regarding the position, the speed and the acceleration of the missile 10 that was acquired with the aid of the GPS locating device 16 of this missile 10 is used to improve the tracking of this missile 10, as was described previously. The temporal information acquired by the GPS locating device 16 of the missile 10 also allows, during a step S22, the synchronizing of the missile 10 with the interception system 20. By using the information acquired by the GPS locating device 16 of the missile 10 and the estimations of state of the missile 10 and of the targets 30, the errors of the radar and/or optronic sensors are estimated in step S23 and used in step S33 to improve the tracking of the targets 30, as was described previously.

During a step S24, the monitoring device 23 of the tracking subsystem  $20_P$  analyzes the set of information received from the various missiles 10 fired. During this analysis, it can identify the number of missiles 10 locked onto the same target 30. If several missiles 10 are locked on to

one and the same target 30, it will go to the next step S34. During this step S34, the monitoring device 23 will calculate a new distribution of the missiles 10 onto the various targets 30, utilizing all the information available and, for example, using criteria of proximity with respect to the targets 30. In this example, the missile 10 closest to the target, called the primary missile hereinafter, has its target confirmed. Also, the other missiles 10, dubbed secondary missiles, get assigned to other targets 30.

The information obtained during these various steps is transmitted by the transmitter-receiver 21 <sub>E/R</sub> of the interception system 20 to the missile(s) fired. The information regarding the tracking of target 30, change of target 30 during a new distribution are transmitted only to the missile 10 for which the target 30 is designated. The target change order may be due to the intervention of the firing system, for example through an appropriate automatic mechanism, or of the operator by virtue of the interface 22. Or else, this order may result from the analysis done by the monitoring device 23, so allowing a new distribution of the missiles 10.

Figure 7 shows only a part of the functions that may be envisaged. Specifically, the utilization of the state of the missile 10 and of its devices (auto-guidance device 15, proximity fuse - not represented -, etc.) by the interception system 20, allows the latter to accurately improve the overall tactical situation and the consideration of the objectives, including the terminal conditions. For example, the improving of the "kill-assessment" (evaluation of the results of firings) by homing of the sensors concerned capable of performing a fine technical analysis over the zone where the impact must occur.

The analysis of the information transmitted by the various missiles 10 fired therefore allows the monitoring device 23 of the interception system 20 to analyze the precise situation as a function of the relative state of the missiles 10 and targets 30, to compute and then transmit to each missile 10 particular instructions such as, for example, the activation of the autoguidance device 15 (possibly simultaneous activation on several missiles 10 so as to create a salvo), the possible activation of the active autoguidance device of the missile 10, lock-on to a designated target 30, loss of lock-on of the autoguidance device 15 or of navigation and/or guidance commands for

the navigation and guidance device 14 in the event of jamming of the autoguidance device 15, etc.

These instructions and commands allow better management of interception, later activation of the active autoguidance devices 15, and  
5 hence a gain in discretion, and better assigning of the targets 30 through a possible overall analysis in respect of the interception system 20 of the situation seen by the autoguidance devices 15. This analysis is made possible through the utilization of the entire set of information available for all the missiles 10 and interception system 20 with a quality, a date stamping  
10 and an availability that are significantly improved by the developments proposed in respect of the interception system 20.

**CLAIMS**

1. A method for optimizing the interception of mobile target(s) comprising the following steps:
  - the tracking of the target(s),
  - 5 - the tracking of the missile(s) fired,
  - the transmission from the interception system to the missile(s) fired of the information regarding the tracking of the target(s) using the information regarding the tracking of the missile(s) fired,characterized in that it furthermore comprises the transmission of information  
10 by the fired missile(s) to the interception system so as to improve its performance over at least one of the steps of tracking and/or transmission of the interception system.
2. The optimization method as claimed in the preceding claim, characterized in that the state information transmitted by the missile comprises:
  - 15 - the position, the speed of the missile,
  - and/or the positions and speed of the targets locked on/tracked by the autoguidance device,
  - and the accurate date-stamping of these data.
3. The optimization method as claimed in the preceding claim, characterized  
20 in that it comprises the estimation of the tracking error of each missile fired with respect to the state information transmitted by the said missile.
4. The optimization method as claimed in the preceding claim, characterized in that it comprises the correction of the tracking of the target(s) by using the estimation of the errors of tracking of the missiles.
- 25 5. The optimization method as claimed in any one of claims 2 to 4, characterized in that it comprises the correction of the tracking of each missile fired with the aid of the state information transmitted by said missile.
6. The optimization method as claimed in any one of the preceding claims, characterized in that it comprises the transmission of an order of change of  
30 assignment of target to a given missile.
7. The optimization method as claimed in the preceding claim, characterized in that this order of change of target results from the intervention of an operator with the aid of an interface of the interception system.

8. The optimization method as claimed in the preceding claim, characterized in that it comprises the analysis of the tactical situation comprising the number of missiles and the identification of the missiles fired locked on to each target.

- 5 9. The optimization method as claimed in claim 6, characterized in that:
- the analysis makes it possible to determine a primary missile and one or more secondary missile(s) when the number of missiles locked on to one and the same target is greater than one, and
  - the order of change of target is transmitted to these secondary missiles.

10 10. An interception system using the optimization process as claimed in any one of the preceding claims, comprising:

- a designation subsystem and a firing subsystem that may or may not be colocated,
- a device for transmitting to the missile(s) in any one of the designation and firing subsystems,

15 characterized in that it comprises a device for receiving the signals transmitted by the missile(s) in any one of the designation and firing subsystems.

20 11. The interception system as claimed in the preceding claim, characterized in that the designation subsystem comprises a GPS type locating device.

12. The interception system as claimed in the preceding claim, characterized in that the GPS type locating device operates in relative mode in conjunction with the GPS type locating device of the missile.

13. A missile characterized in that it comprises:

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- a receiver which allows it to receive information originating from the interception system as claimed in one of claims 11 to 13,
  - a propulsion device,
  - a warhead,
  - a navigation and guidance device,
- 30 - an autoguidance device

characterized in that it comprises a transmitter which allows it to transmit to the interception system the information produced by any one of its devices.

14. The missile as claimed in the preceding claim, characterized in that it comprises a GPS type locating device.

15. The missile as claimed in the preceding claim, characterized in that the GPS type locating device operates in relative mode in conjunction with the GPS type locating device of the interception system.