There is thus a need for a new counter rocket (or possibly other flying object) system.

SUMMARY OF THE INVENTION

In accordance with an aspect of the presently disclosed subject matter, there is provided a counter-flying object system, comprising:

a sensor array that includes at least one active sensor configured to detect and track the flying object upon its launch and at least two passive sensors; the sensor array is configured to determine the object's location and upon launching of a seeker-less interceptor missile also the seeker-less interceptor missile's location and send them to a control system, the sensor array is further configured to achieve respective clock synchronization accuracy of at least 1 nanosecond between each two sensors of the array;

the control system is configured to generate a mission data including Predicted Interception Point (PIP), a time of launch, interceptor missile separation time and transfer it to the interceptor missile launcher, the control system is further configured to calculate, selectively update and send to the interceptor missile, through an uplink communication channel, uplink messages including updated Predicted Interception Point, updated interceptor missile separation time and the location of the interceptor missile during flight;

the launcher is configured to launch the seeker-less interceptor missile at the time of launch towards said Predicted Interception Point (PIP);

the seeker-less interceptor missile includes a separable motor, a warhead, a steering system, a communication system, and a navigation system configured to repeatedly generate navigation data;

the interceptor missile is configured to selectively utilize the mission data, the uplink messages and the navigation data for separation of the separable motor and generating steering commands to the steering system for guiding the interceptor missile toward the updated PIP and activating a fragmentation warhead on or in the vicinity of the PIP when a lethality criteria is met.

There is thus a need for a new counter rocket (or possibly other flying object) system.

SUMMARY OF THE INVENTION

Disclosed herein is a counter-flying object system, comprising:

a sensor array that includes at least one active sensor configured to detect and track the flying object upon its launch and at least two passive sensors; the sensor array is configured to determine the object's location and upon launching of a seeker-less interceptor missile also the seeker-less interceptor missile's location and send them to a control system, the sensor array is further configured to achieve respective clock synchronization accuracy of at least 1 nanosecond between each two sensors of the array;

the control system is configured to generate a mission data including Predicted Interception Point (PIP), a time of launch, interceptor missile separation time and transfer it to the interceptor missile launcher, the control system is further configured to calculate, selectively update and send to the interceptor missile, through an uplink communication channel, uplink messages including updated Predicted Interception Point, updated interceptor missile separation time and the location of the interceptor missile during flight;

the launcher is configured to launch the seeker-less interceptor missile at the time of launch towards said Predicted Interception Point (PIP);

the seeker-less interceptor missile includes a separable motor, a warhead, a steering system, a communication system, and a navigation system configured to repeatedly generate navigation data;

the interceptor missile is configured to selectively utilize the mission data, the uplink messages and the navigation data for separation of the separable motor and generating steering commands to the steering system for guiding the interceptor missile toward the updated PIP and activating a fragmentation warhead on or in the vicinity of the PIP when a lethality criteria is met.

According to a first aspect of the present invention, there is provided a counter-flying object system, comprising: a sensor array that includes at least one active sensor configured to detect and track a flying object upon launch of the flying object and at least two passive sensors; the sensor array is configured to determine the flying object's location and upon launching of a seeker-less interceptor missile also the seeker-less interceptor missile's location and send the flying object's location and the seeker-less interceptor missile's location to a control system, the sensor array is further configured to achieve respective clock synchronization accuracy of at least 1 nanosecond between each two sensors of said array; the control system is configured to generate a mission data including Predicted Interception Point (PIP), a time of launch, interceptor missile separation time and transfer the mission data to an interceptor missile launcher, the control system is further configured to calculate, selectively update and send to said seeker-less interceptor missile, through an uplink communication channel, uplink messages including updated Predicted Interception Point, updated interceptor missile separation time and the location of the seeker-less interceptor missile during flight; the interceptor missile launcher is configured to launch the seeker-less interceptor missile at said time of launch towards said Predicted Interception Point (PIP); the seeker-less interceptor missile includes a separable motor, a warhead, a steering system, a communication system, and a navigation system configured to repeatedly generate navigation data; said seeker-less interceptor missile is configured to selectively utilize said mission data, said uplink messages and said navigation data for separation of said separable motor and generating steering commands to said steering system for guiding the seeker-less interceptor missile toward the updated PIP and activating a fragmentation warhead on or in a vicinity of said PIP when a lethality criteria is met, wherein synchronization is achieved by said control system performing computations based on the following equations: (Equations 1 and 2):

$$P_{AB}^{S} = P_{B}^{S} - P_{A}^{S} = \rho_{AB}^{S} + \delta t_{AB} \cdot c + B_{AB} + I_{AB}^{S} + T_{AB}^{S} + \varepsilon^{Code}$$

$$\Phi_{AB}^{S} = \Phi_{B}^{S} - \Phi_{A}^{S} = \rho_{AB}^{S} + \delta t_{AB} \cdot c + B_{AB} - I_{AB}^{S} + T_{AB}^{S} + F_{AB}^{S} + \varepsilon^{Phase}$$

Where samples A provided by a first sensor include:

P_{A}^{S} – Pseudo-range measurement of a satellite S at sensor A, and

Φ_{A}^{S} – Carrier-phase measurement of said satellite S at sensor A. Samples B provided by second sensor include:

P_B^S – Pseudo-range measurement of said satellite S at sensor B, and Φ_B^S – Carrier-phase measurement of said satellite S at sensor B. and wherein:

ρ_{AB}^S – Difference in Ranges between sensors A and B and satellite S ,

C – Speed of light,

B_{AB} – Difference between hardware delays between sensors A and B,

I_{AB}^S – Difference in ionospheric delays between sensors A and B and satellite S ,

T_{AB}^S – Difference in tropospheric delays between sensors A and B and satellite S,

F_{AB}^S – Difference in floating ambiguities between said sensors A and B and said satellite S,

ε^{Code} – Pseudo-range sampling noise,

ε^{Phase} – Carrier Phase sampling noise,

δt_{AB} - Time difference between said sensors A and B;

$$\tilde{P}_{AB}^S = \delta t_{AB} \cdot c + \varepsilon^{Code}$$

$$\tilde{\Phi}_{AB}^S = \delta t_{AB} \cdot c + F_{AB}^S + \varepsilon^{Phase}$$

According to a second aspect of the present invention, there is provided a method of using the above system wherein said at least two passive sensors comprises a first sensor and a second sensor, and said sensor array is deployed as follows: said first passive sensor is deployed substantially at a direction of a threat at coordinates $(0,Y_{ant1},0)$, and the second passive sensor is deployed at substantially perpendicular direction at coordinates $(X_{ant2}, Y_{ant2},0)$ and wherein the active sensor is capable of viewing backwardly and is deployed farther than said predicted interception point, where $R_t/X_{ant2}<1.5$, and $R_t/Y_{ant1}<1.5$, and $Y_{ant2}/X_{ant2}<0.5$.

CLAIMS:

1. A counter-flying object system, comprising:

a sensor array that includes at least one active sensor configured to detect and track the flying object upon its launch and at least two passive sensors; the sensor array is configured to determine the object's location and upon launching of a seeker-less interceptor missile also the seeker-less interceptor missile's location and send them to a control system, the sensor array is further configured to achieve respective clock synchronization accuracy of at least 1 nanosecond between each two sensors of said array;

the control system is configured to generate a mission data including Predicted Interception Point (PIP), a time of launch, interceptor missile separation time and transfer it to interceptor missile launcher, the control system is further configured to calculate, selectively update and send to said interceptor missile, through an uplink communication channel, uplink messages including updated Predicted Interception Point, updated interceptor missile separation time and the location of the interceptor missile during flight;

the launcher is configured to launch the seeker-less interceptor missile at said time of launch towards said Predicted Interception Point (PIP);

the seeker-less interceptor missile includes a separable motor, a warhead, a steering system, a communication system, and a navigation system configured to repeatedly generate navigation data;

said interceptor missile is configured to selectively utilize said mission data, said uplink messages and said navigation data for separation of said separable motor and generating steering commands to said steering system for guiding the interceptor missile toward the updated PIP and activating a fragmentation warhead on or in the vicinity of said PIP when a lethality criteria is met.

2. The system according to Claim 1, where the said ground control system further comprises an estimator for estimating the hitting point of the threatening flying object and in case that the said hitting point is of no interest, said ground control system is configured to refrain from commanding the launcher to launch said interceptor missile.
3. The system according to Claim 1, wherein said flying object is a ground to ground rocket.
4. The system according to Claim 3, wherein said rocket is selected from the small diameter rockets that includes a 122 mm diameter GRAD rocket.
5. The system according to Claims, 1 or 2 wherein the said flying object is an aircraft.
6. The system according to Claims 1 or 2, wherein the said flying object is a cruise missile.
7. The system according to any one of the preceding Claims, wherein the separable motor of the interceptor is a motor of a ground to ground (GTG) rocket.
8. The system according to any one of the preceding Claims, wherein said steering commands comply guidance law with proportional navigation rules.
9. The system according to any one of the preceding Claims, comprising at least one launcher battery each including at least two interceptor missiles for intercepting at least two simultaneously flying objects.
10. The system according to any one of the preceding Claims, wherein the said active sensor is a radar.
11. The system according to any one of Claims 1 to 9, wherein the said active sensor is a ladar.
12. The system according to any one of the preceding Claims wherein said navigation system includes an airborne computer and body angles measurement unit.
13. The system according to Claim 12, wherein the said body angles measurement unit includes three angle rate measurement units for determining navigation data including the interceptor missile body angular position in three mutually perpendicular axes.
14. The system according to Claim 13, wherein said body angles measurement unit is a part of an inertial measurement unit that includes additional three accelerometers for continuously determining interceptor missile location and the interceptor missile body angular position in three mutually perpendicular axes.

15. The system according to any one of the preceding Claims, wherein said warhead includes a proximity fuse.
16. The system according to any one of the preceding Claims, wherein the warhead activation is initialized by the said ground control system using a command for fusing transferred to the interceptor missile by the said uplink communication channel.
17. The system according to any one of Claims 1 to 15, wherein said interceptor missile includes an uplink receiver configured to receive a reflection of uplink beam energy from the flying object and to activate the warhead.
18. The system according to any one of the preceding Claims, wherein at least one said passive sensor is fitted on a mobile platform.
19. The system according to Claim 18, wherein the said mobile platform is the interceptor missile.
20. The system according to any one of the preceding Claims, wherein at least one of said passive sensors is a stationary ground sensor.
21. The system according to any one of the preceding Claims, wherein said sensor array is configured to track said launched interceptor missile for determining its updated location by processing an echo originated from the active sensor energy reflected back from the interceptor and received by said sensors.
22. The system according to any one of Claims 1 to 20, wherein said array sensor is configured to track said launched interceptor missile for determining its updated location by processing a signal originated from a transmitter fitted on the interceptor and received by said sensors.
23. The system according to any one of the preceding Claims, wherein said interceptor missile is configured to generate said steering commands only after separation of said separable motor.
24. The system according to any one of the preceding Claims wherein said sensor array is configured to achieve respective clock synchronization accuracy of at least 1 nanosecond between each two sensors of said array, including performing computations based on the following equations : (Equations 1 and 2):

$$P_{AB}^{S} = P_{B}^{S} - P_{A}^{S} = \rho_{AB}^{S} + \delta t_{AB} \cdot c + B_{AB} + I_{AB}^{S} + T_{AB}^{S} + \varepsilon^{Code}$$

$$\Phi_{AB}^{S} = \Phi_{B}^{S} - \Phi_{A}^{S} = \rho_{AB}^{S} + \delta t_{AB} \cdot c + B_{AB} - I_{AB}^{S} + T_{AB}^{S} + F_{AB}^{S} + \varepsilon^{Phase}$$

Where samples A provided by a first sensor include:

P_{A}^{S} – Pseudo-range measurement of a satellite S at sensor A, and

Φ_{A}^{S} – Carrier-phase measurement of said satellite S at sensor A. Samples B provided by second sensor include:

P_{B}^{S} – Pseudo-range measurement of said satellite S at said sensor B, and

Φ_{B}^{S} – Carrier-phase measurement of said satellite S at said sensor B.

and wherein:

ρ_{AB}^{S} – Difference in Ranges between sensors A and B and said satellite S ,

C – Speed of light,

B_{AB} – Difference between hardware delays between said sensors A and B,

I_{AB}^{S} – Difference in ionospheric delays between said sensors A and B and said satellite S ,

T_{AB}^{S} – Difference in tropospheric delays between said sensors A and B and said satellite S,

F_{AB}^{S} – Difference in floating ambiguities between said sensors A and B and said satellite S,

ε^{Code} – Pseudo-range sampling noise,

ε^{Phase} – Carrier Phase sampling noise,

δt_{AB} - Time difference between said sensors A and B;

$$\tilde{P}^{S}_{AB} = \delta t_{AB} \cdot c + \varepsilon^{Code}$$

$$\tilde{\Phi}^{S}_{AB} = \delta t_{AB} \cdot c + F^{S}_{AB} + \varepsilon^{Phase}$$

25. The system according to any one of the preceding Claims, wherein said active sensor is configured to detect and track more than one oncoming threat and more than one interceptor.

26. The system according to Claim 25, wherein said control unit is configured to manage more than one interception process and can prioritize threats.

27. The system according to Claim 26, wherein said prioritization is according to the estimated hitting point of the threat.

28. The system according to any one of the preceding Claims wherein said launcher is a rocket launcher.

29. A method of using the system according to any one of the preceding Claims, wherein said sensor array is deployed as following: said first passive sensor is deployed substantially at the direction of the threat at coordinates $(0,Y_{ant1},0)$, and the second sensor is deployed at substantially perpendicular direction at coordinates $(X_{ant2}, Y_{ant2},,0)$ and wherein the active sensor is devoid of viewing backwardly and is deployed close to underneath the planned interception point, where

$$R_t/X_{ant2} < 1.5, \quad \text{and } R_t/Y_{ant1} < 1.5, \quad \text{and } Y_{ant2}/X_{ant2} < 0.5$$

30. A method of using the system according to any one of Claims 1 to 28, wherein said sensor array is deployed as follows: said first passive sensor is deployed substantially at the direction of the threat at coordinates $(0,Y_{ant1},0)$, and the second sensor is deployed at substantially perpendicular direction at coordinates $(X_{ant2}, Y_{ant2},,0)$ and wherein the active sensor is capable of viewing backwardly and is deployed farther than said planned interception point, where

$$R_t/X_{ant2} < 1.5, \quad \text{and } R_t/Y_{ant1} < 1.5, \quad \text{and } Y_{ant2}/X_{ant2} < 0.5$$

31. The system according to any one of the preceding Claims, wherein said navigation system is configured to repeatedly generate said navigation data without handling "hand over" errors.
32. The system according to any one of the preceding Claims, wherein said PIP data is generated by said control system based on said active sensor and said updated PIP is more accurate and generated by said control system based also on said passive sensors.
33. The system according to any one of the preceding Claims, substantially as described in the specification.
34. The system according to any one of the preceding Claims, substantially as illustrated in the drawings.
35. A seeker-less interceptor missile comprising a motor, an uplink communication system, a navigation system configured to repeatedly determine navigation data , a steering system and a warhead;

the interceptor is configured to receive through the uplink receiver unit mission data including:

a. Predicted Interception Point as determined by at least three accurately time synchronized external sensors; -
b. time of launch,
c. interceptor missile separation time, and
d. interceptor location data

and is further configured to repeatedly receive updated portions of said data including updated PIP, updated missile separation time and updated interceptor location data;

said navigation system is configured to generate, based on at least a portion of the mission data updated data mission portion data and the navigation data, steering commands for the steering system for guiding said interceptor missile towards an updated PIP; and

in response to meeting a lethality criteria, activating said warhead for damaging said flying object on or in the vicinity of said PIP.

36. The system according to Claim 35, wherein said accuracy is in the order of 1 nanosecond.

37. The system according to Claims 35 or 36, wherein said PIP is initially determined based on an external active sensor of said sensors and at least some of said repeatedly determined updated PIP are determined based on the at least three accurately time synchronized external sensors.

38. The seeker-less interceptor missile according to any one of Claims 35 to 37, wherein said navigation system includes body angles measurement unit including three angle rate measurement units for repeatedly determining navigation data including the interceptor missile body angular position in three mutually perpendicular axes.

39. A method for intercepting an oncoming threat, comprising:

a. providing a sensor array that includes an active sensor and at least two passive sensors;

b. achieving respective clocks synchronization accuracy of at least 1 nanosecond between each two sensors of said array;

c. detecting and tracking a flying object and determining its location;

d. generating mission data including:

i. Predicted Interception Point as determined by said accurately time synchronized sensors;

ii. time of launch,

iii. interceptor missile separation time, and

iv. interceptor location data

e. launching an interceptor at the proper time towards the Predicted Interception Point;

f. repeatedly updating and transmitting portions of said mission data;

g. utilizing said mission data, updated data and navigation data for generating steering commands for guiding the interceptor towards the updated PIP; and

h. activating a warhead in the vicinity of said PIP when a lethality criteria is met, for destroying said flying object.

40. An early warning system for warning against oncoming flying objects, comprising:

a sensor array that includes at least one active sensor configured to detect and track the flying object upon its launch and at least two passive sensors; the sensor array is configured to determine the object's location;

a control system configured to achieve respective clock synchronization accuracy of at least 1 nanosecond between each two sensors of said array.

41. The system according to Claim 40, further comprising an estimator for estimating the hitting point of the threatening flying object and in case it is designated to a protected area, providing an alert indication.

42. A method of using the system according to any one of Claims 40 or 41, wherein said sensor array is deployed as following: said first passive antenna is deployed substantially in the direction of the threat at coordinates $(0,Y_{ant1},0)$, and the second antenna is deployed at substantially perpendicular direction at coordinates $(X_{ant2}, Y_{ant2},0)$ and wherein the active sensor is devoid of viewing backwardly and is deployed close to underneath the planned interception point, where

$$R_t/X_{ant2} < 1.5, \quad \text{and } R_t/Y_{ant1} < 1.5, \quad \text{and } Y_{ant2}/X_{ant2} < 0.5$$

43. A method of using the system according to any one of Claims 40 or 41, wherein said sensor array is deployed as following: said first passive antenna is deployed substantially in the direction of the threat at coordinates $(0,Y_{ant1},0)$, and the second antenna is deployed at substantially perpendicular direction at coordinates $(X_{ant2}, Y_{ant2},0)$ and wherein the active sensor is capable of viewing backwardly and is deployed farther than said planned interception point, where

$$R_t/X_{ant2} < 1.5, \quad \text{and } R_t/Y_{ant1} < 1.5, \quad \text{and } Y_{ant2}/X_{ant2} < 0.5$$

44. A counter-flying object system, comprising:

a sensor array including at least one active sensor and at least two passive sensors, configured to detect and track the flying object location and,

a missile launcher configured to launch a seeker-less interceptor to intercept the flying object,

wherein upon launching of the seeker-less interceptor, the sensor array is configured to track the location of the interceptor and send said object and interceptor locations to a control system;

the control system being configured to provide updated mission data to the interceptor based on said object and interceptor locations for guiding the interceptor toward the flying object and activating a fragmentation warhead on or in the vicinity of said flying object when a lethality criteria is met.

45. The counter-flying system of claim 44, wherein the control system is configured to provide mission data to the interceptor for guiding the interceptor during the whole flight trajectory of the interceptor toward the target.

46. The counter-flying system of any of claims 44-45, wherein the sensor array is further configured to achieve a clock synchronization between each two sensors of said array enabling to achieve a miss distance between the object and the interceptor smaller than the lethality criteria.

47. The counter-flying system of claim 46, wherein the clock synchronization accuracy between each two sensors of the sensor array is of at least 1 nanosecond.

CLAIMS:

1. A counter-flying object system, comprising:

a sensor array that includes at least one active sensor configured to detect and track a flying object upon launch of the flying object and at least two passive sensors; the sensor array is configured to determine the flying object's location and upon launching of a seeker-less interceptor missile also the seeker-less interceptor missile's location and send the flying object's location and the seeker-less interceptor missile's location to a control system, the sensor array is further configured to achieve respective clock synchronization accuracy of at least 1 nanosecond between each two sensors of said array;

the control system is configured to generate a mission data including Predicted Interception Point (PIP), a time of launch, interceptor missile separation time and transfer the mission data to an interceptor missile launcher,

the control system is further configured to calculate, selectively update and send to said seeker-less interceptor missile, through an uplink communication channel, uplink messages including updated Predicted Interception Point, updated interceptor missile separation time and the location of the seeker-less interceptor missile during flight;

the interceptor missile launcher is configured to launch the seeker-less interceptor missile at said time of launch towards said Predicted Interception Point (PIP);

the seeker-less interceptor missile includes a separable motor, a warhead, a steering system, a communication system, and a navigation system configured to repeatedly generate navigation data;

said seeker-less interceptor missile is configured to selectively utilize said mission data, said uplink messages and said navigation data for separation of said separable motor and generating steering commands to said steering system for guiding the seeker-less interceptor missile toward the updated PIP and activating a fragmentation warhead on or in a vicinity of said PIP when a lethality criteria is met,

wherein synchronization is achieved by said control system performing computations based on the following equations: (Equations 1 and 2):

$$P_{AB}^{S} = P_{B}^{S} - P_{A}^{S} = \rho_{AB}^{S} + \delta t_{AB} \cdot c + B_{AB} + I_{AB}^{S} + T_{AB}^{S} + \varepsilon^{Code}$$

$$\Phi_{AB}^{S} = \Phi_{B}^{S} - \Phi_{A}^{S} = \rho_{AB}^{S} + \delta t_{AB} \cdot c + B_{AB} - I_{AB}^{S} + T_{AB}^{S} + F_{AB}^{S} + \varepsilon^{Phase}$$

wherein samples A provided by a first sensor include:

P_A^S – Pseudo-range measurement of a satellite S at sensor A, and

Φ_A^S – Carrier-phase measurement of said satellite S at sensor A. Samples B provided by second sensor include:

P_B^S – Pseudo-range measurement of said satellite S at sensor B, and

Φ_B^S – Carrier-phase measurement of said satellite S at sensor B,

and wherein:

ρ_{AB}^S – Difference in Ranges between sensors A and B and satellite S ,

C – Speed of light,

B_{AB} – Difference between hardware delays between sensors A and B,

I_{AB}^S – Difference in ionospheric delays between sensors A and B and satellite S ,

T_{AB}^S – Difference in tropospheric delays between sensors A and B and satellite S,

F_{AB}^S – Difference in floating ambiguities between said sensors A and B and said satellite S,

ε^{Code} – Pseudo-range sampling noise,

ε^{Phase} – Carrier Phase sampling noise,

δt_{AB} - Time difference between said sensors A and B;

$$\tilde{P}_{AB}^S = \delta t_{AB} \cdot c + \varepsilon^{Code}$$

$$\tilde{\Phi}_{AB}^S = \delta t_{AB} \cdot c + F_{AB}^S + \varepsilon^{Phase}$$

2. The system according to claim 1, wherein said control system further comprises an estimator for estimating a hitting point of the flying object and in case that the hitting point is of no interest, said control system is configured to refrain from commanding the interceptor missile launcher to launch said seeker-less interceptor missile.

3. The system according to claim 1, wherein said flying object is a ground to ground rocket.

4. The system according to claim 1 wherein the said flying object is an aircraft.

5. The system according to claim 1 wherein the said flying object is a cruise missile.

6. The system according to claim 1 wherein the separable motor of the interceptor is a motor of a ground to ground (GTG) rocket.

7. The system according to claim 1 comprising at least one interceptor launcher battery including at least two seeker-less interceptor missiles for intercepting at least two simultaneously flying objects.

8. The system according to claim 1 wherein the said active sensor is a radar.

9. The system according to claim 1 wherein the said active sensor is a ladar.

10. The system according to claim 1 wherein said warhead includes a proximity fuse.

11. The system according to claim 1 wherein the activation of said fragmentation warhead is initialized by said control system using a command for fusing transferred to the seeker-less interceptor missile by said uplink communication channel.

12. The system according to claim 1 wherein at least one of said at least one said passive sensor is fitted on a mobile platform.

13. The system according to claim 12, wherein the said mobile platform is the interceptor missile.

14. The system according to claim 1 wherein said array sensor is configured to track said launched seeker-less interceptor missile for determining an updated location of said launched seeker-less interceptor missile by processing a signal originated from a transmitter fitted on the seeker-less interceptor missile and received by said sensors.

15. A method of using the system according to claim 1 wherein said at least two passive sensors comprises a first sensor and a second sensor, and said sensor array is deployed as follows: said first passive sensor is deployed substantially at a direction of a threat at coordinates $(0,Y_{ant1},0)$, and the second passive sensor is deployed at substantially perpendicular direction at coordinates $(X_{ant2}, Y_{ant2},0)$ and wherein the active sensor is capable of

viewing backwardly and is deployed farther than said predicted interception point, where $R_t/X_{ant2}<1.5$, and $R_t/Y_{ant1}<1.5$, and $Y_{ant2}/X_{ant2}<0.5$.