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**Method and arrangement for a weapon system.**

The invention relates to a method and an arrangement for determining in a weapon system the position of one or a plurality of lead points of a moving target (1) which is carrying out manoeuvres in three-dimensional space with the aim of arriving at such a position that dropping of its ordnance against an attack object(2) becomes possible. The state of the current target position and movement as well as its predicted position (the lead point) is calculated and the position of the lead point is converted to angle adjustments of the weapon system. The positions of probable attack objects (2) are supplied to the system and are utilised in the calculations of the lead point or lead points, respectively, and a number of movement models are combined in such a manner to build up a hypothetic path shape (target model) along which the target is assumed to move.

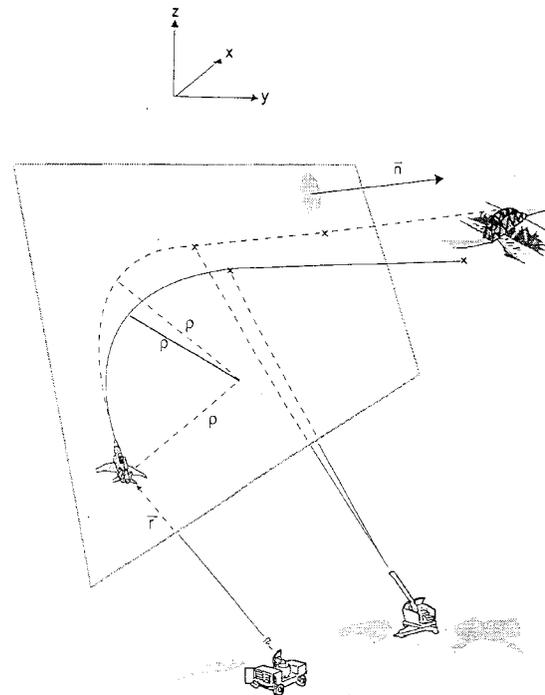


Figure 11

### Technical field

The invention relates to a method and an arrangement for determining in a weapon system the position of the lead point of a moving target which is carrying out manoeuvres in three-dimensional space with the aim of arriving at such a position that dropping of its ordnance against an attack object becomes possible. The lead point is characterised in that the time for the target to get there, that is to say the firing time, is equal to the flying time of the projectile to this point. The method presupposes that there is some type of sensor which can continuously provide the system with information on the current position of the target. Similarly, a computing unit is presupposed which can calculate the state of the target position and movement, calculate the predicted position of the target and convert the position of the lead point to angle adjustments of the weapon system. The last-mentioned also comprises compensation for ballistic influences such as wind, temperature, air pressure, and so forth.

### State of the art

When dealing with the prediction problem, a hypothesis or model is set up for how the target will behave from then on and predictions are made with respect to the target model. The model can be either deterministic or stochastic. Examples of possible target models are:

- The speed vector of the target is assumed to be constant in magnitude and direction, that is to say constant speed in the three coordinates for the entire firing time.
- The direction of the speed vector is assumed to be constant but the target is assumed to accelerate or decelerate in the direction of the vector.
- The target is assumed to follow a path with constant acceleration in the three coordinates.
- The target is assumed to move in a circular path. In this target model, either a constant speed of propagation can be assumed or acceleration along the circular periphery can be allowed.
- The target is moving with constant acceleration but changes the acceleration at randomly selected times. The acceleration value has a Gaussian distribution and the time with constant acceleration has a Poisson distribution. Acceleration can occur in one or in all three coordinates.

One problem affecting the prediction is that the measured position of the target has noise. This noise entails that the state of the target position and movement must be filtered before it can be utilised for predicting the future state of the target. However, a filter always involves delay and this results in a system which cannot instantaneously respond to fast changes in the actual state of movement of the target.

The great prediction problem is, however, that the state of movement of the target can almost never be considered to be constant for all of the firing time. In a system with anti-aircraft guns, for example, the fire control system will be able to predict the future position of the target up to 10 seconds in advance. To this time, the filter delay will then be added which can be a number of seconds. Naturally, the pilot will always attempt by manoeuvring to minimise the time for which the target is in a constant state of movement and, in consequence, the predicted position will be correct only for a firing distance with very little firing time.

The disadvantage with the first four target models referred to above is that they presuppose a constant state of movement for the entire firing time which cannot be considered to be probable. Nor does any model utilize the fact that the aim of the manoeuvres of the target is in most cases to arrive at such a position that fighting the attack object becomes possible. This position consists in a short straight-path phase in which the pilot can aim and fire his ordnance. A typical situation with a diving attack against a protected object is shown in Figure 1 which shows the disadvantages. The figure shows the target position with a number of times and positions for the lead points which are the result with traditional prediction where the state of movement of the target is assumed to be constant over the whole firing time. Action against the attacking target is only possible at a late stage at short distance. It is also likely that the target has been able to drop its ordnance before it can be fought.

It is the object of this invention to solve the prediction problem considered above or in any case to produce a better model for how the target will behave and thereby to increase the probability for the target to be fought before it is able to empty its ordnance.

The invention builds on a deterministic target model in which the state of movement (speed and acceleration) of the target is changed over the firing time, that is to say the time from firing of a projectile until it hits the target.

The invention is thereby mainly characterised in that

- the positions of probable objects of attack are supplied to the system,
- these positions are utilised in the calculation of the lead point, and
- target models, that is to say hypotheses of how the target will move, in the form of combinations of circular peripheries, spherical surfaces and/or straight lines are utilised in the calculation of the lead point.

By supplying the system with the position of probable objects of attack, this information can be utilised for effectively predicting the probable lead point of the target. The target models utilised in the lead point calculation are built up of a number of components such

as circular peripheries, spherical surfaces and straight lines and are combined in such a manner that they correspond to the aim of the manoeuvres of the target, namely to attack a predefined protected object.

The advantages produced with the invention are a longer effective range of fire for the weapon system with manoeuvring targets, higher hit probability and possibility to fight a target before it has been able to deposit its ordnance.

### DESCRIPTION OF THE FIGURES

In the text which follows, an example of the invention will be described in greater detail in connection with the attached drawings, in which

Figure 1 shows a typical situation in which the target carries out a dive attack against a protected object,

Figure 2 indicates a continuous measuring of the target position in space,

Figure 3 shows how this information is utilised for defining a plan of movement and a circular periphery along which the target is assumed to be moving,

Figure 4 shows how the position of the protected object, which is estimated to be of importance for an attacker to knock out, is measured in, for example, right-angled coordinates and is supplied to the system,

Figure 5 indicates how a plan of movement is continuously calculated during target tracking,

Figure 6 shows a first movement model,

Figure 7 shows a second movement model,

Figure 8 shows a third movement model,

Figure 9 shows a fourth movement model,

Figure 10 shows a fifth movement model,

Figure 11 shows a movement model with horizontal correction, and

Figure 12 shows a summary, that is to say which movement model will be utilised in different parts of the approach towards a protected object.

### DESCRIPTION OF THE INVENTION

#### General

As mentioned in the introduction, the great prediction problem is that the state of movement of the target is almost never constant over the firing time. The manoeuvres of the target are in most cases due to the requirement to arrive at such a position that fighting of the object of attack becomes possible. A typical situation is shown in Figure 1 where a target (aeroplane) 1 manoeuvres to a short straight-path phase in which the pilot can aim and fire his ordnance against a protected object 2. The figure shows the position of the target at a number of times and for the

lead points which are the result with traditional prediction where the state of movement of the target is assumed to be constant over the entire firing time. Action against the attacking target 1 is then only possible at a late stage at short distance. It is also probable that the target has been able to deposit its ordnance before it can be fought in such a case.

By continuously measuring the position of the target in space via a sensor and in the next stage filtering these measurement values, the state of position and movement of the target can be expressed in, for example, right-angled coordinates. These states are here made up of the vectors  $r$ ,  $v$  and  $a$  according to Figure 2. These vectors can then be utilised for defining a movement plane and a circular periphery along which the target is assumed to be moving (Figure 3, reference 1). It can also be seen that a movement plane and a circular periphery only become defined if the acceleration vector ( $a$ )  $\neq$  zero vector and the speed vector ( $v$ ) is not parallel to the acceleration vector ( $a$ ). If these conditions are not met, one is forced to assume a movement along  $v$ .

#### Solution

The system will offer the possibility of defining the position, relative to the fire control system, of actual protected objects. These protected objects are objects which are considered to be important objects to be knocked out by an attacker. In a vehicle system, the vehicle itself is certainly an important object to be protected. The position can be specified, for example, in right-angled coordinates and be supplied to the system via a thumb wheel, menu or the like. An example of the process is shown in Figure 4. This parameter input is only carried out after grouping of the system but can be changed when required. The figure shows three more protected objects as example: an aircraft hanger 2', a radar station 2'' and a bridge 2'''.

The above-mentioned plane of movement is continuously calculated with target tracking. The position of the protected object is projected in this plane and the point then obtained in the plane is then utilised by the predictor for calculating a probable target movement. The reason why the absolute coordinates of the protected object are not utilised for this purpose is of course that it is not probable that this point will be located in the calculated plane of movement. Moreover, there can be a situation according to Figure 5 which shows a type of bombing raid. In this case it is probable that the target aligns itself in the horizontal plane but not towards the height coordinate of the target.

A number of movement models is defined and changes between them are made continuously depending on the action of the target. These models are described below with illustrating figures. Abrupt changes in position of the lead point are avoided by two movement models, between which changes can

occur, producing the same lead point at the boundary transitions.

#### Movement model 1 (Figure 6)

In this case, the acceleration is 0, or alternatively there is only acceleration in the direction of propagation. Since there is no acceleration across the direction of propagation, no plane of movement is defined either. This is equivalent to having an infinite radius of curvature of the circular movement. In this case, it is assumed that the state of movement is constant over the firing time.

#### Movement model 2 (Figure 7)

For this movement, it applies that there is acceleration across the direction of propagation and thus a plane of movement can be calculated. This model is utilised when the target manoeuvres away from the projection of the protected object in the plane or when this projection is included in the precalculated circle. In both these cases, it is assumed that the state of movement of the target is constant over the entire firing time.

#### Movement model 3 (Figure 8)

Likewise, the target acceleration and speed define a plane of movement in which the target is assumed to be being propagated. If it is not assumed that the state of movement of the target is changed over the firing time, this leads to the direction of the vector of propagation of the target being assumed to pass past the projected object under protection. This is assumed to be less probable and therefore the assumption is made that the target (pilot) is selecting to level out towards the projected object under protection and to attack it. This is certainly a coarse approximation since a progressive levelling out would be more realistic, that is to say the radius of curvature increases more and more. However, the approximation is good enough since the state of movement of the target can still not be calculated accurately due to the measurement noise. The acceleration in the direction of propagation is assumed to be constant also after levelling-out.

#### Movement model 4 (Figure 9)

Assuming that movement model 3 has been utilised in an earlier stage, the change to this movement model occurs after the vector of propagation of the target has passed past the projected object under protection. This model can be seen to be peculiar since the centre of curvature of the circular path ( $p'$ ) is assumed to be displaced  $180^\circ$  with respect to the calculated one ( $p$ ). The reason is that the lag of the filter is

compensated for. This lag entails that even if the target is executing an ideal manoeuvre (circular path - straight path), a filter will produce a circular movement with successively increasing radii. A distance ( $b$ ) is calculated which specifies the probable distance to the projection of the protected object when the target has levelled out in a complete straight path. This distance is based on the distance to the target and the earlier lead point.

#### Movement model 5 (Figure 10)

Assuming that movement model 4 has been utilised in an earlier stage, the change to this model occurs after a centre of curvature has been produced which entails that the target is considered to be manoeuvring in the direction towards the projected object under protection. This target movement can be said to be identical with movement 3, with the difference that a shorter radius of curvature than that calculated is assumed. In the case where the calculated radius of curvature ( $p$ ) becomes less than that assumed ( $p'$ ), one naturally returns to movement model 3. A distance ( $b$ ) is calculated which specifies the probable distance to the projected object under protection when the target is assumed to have levelled out in a complete straight path. This distance depends on the distance to the target and the earlier lead point.

#### Movement model with horizontal correction (Figure 11)

As mentioned earlier, the absolute coordinates of the protected object are not used. Instead, the position of the protected object is continuously projected in the plane of movement which is defined by the speed and acceleration vectors of the target. This implies that all movement models, even those which assume a change in the state of movement of the target over the firing time, work with the hypothesis that the target will come to move in this plane over the whole of the firing time. To further utilise the position of the probable attack target in determination of the lead point, one can additionally make the assumption that the target will manoeuvre outside the plane of movement to come into line with the protected object. However, this correction is only allowed in the horizontal plane since it is not certain that the target will align itself with respect to the height coordinate of the protected object. The correction is also only made if the shortest distance between the protected object and the plane of movement is fairly limited. This combined movement model results in that the target is assumed to be travelling along a spherical surface and a straight line. The situation is most easily described with Figure 11 where there is some type of diving attack against a protected object. When the target is located in accordance with the figure, movement model

3 will be utilised. Without correction in the horizontal plane, the result will be that the target is assumed to follow the broken trajectory and there is a relatively large side error in the determination of the lead point. If, however, a correction is carried out in the horizontal plane, it is assumed that the target is travelling along the solidly drawn trajectory and a better result is obtained. Naturally, the correction can also be utilised for movement models 4 and 5.

#### Movement models - summary (Figure 12)

Figure 12 shows a simple example which specifies which movement model is utilised in different parts of the approach towards a protected object. The approach is shown seen from above and is only diagrammatic.

Naturally, a movement model can be conceived which is built up with components other than circular peripheries, spherical surfaces and straight lines. The unique feature of the solution is that a number of movement models are combined for building up in this manner a track-bound path shape in which the fact that the position of the attack object is known is utilised. In the case where a number of protected objects are defined, the computing unit can also be made to calculate different lead points. The fire control system can then direct the connected weapon systems (assuming that several are connected) against the different lead points and when certain lead points can be predicted, the fire is concentrated against the most probable one.

#### REFERENCES

1. Mechanics, Particle Dynamics - Part 1, Anders J. Thor, Anders Höglund.

#### **Claims**

1. A method for determining in a weapon system the position of one or more lead points of a moving target (1) which is executing manoeuvres in three-dimensional space with the aim of arriving at such a position that dropping of its ordnance against an attack object (2) becomes possible, both the current-state of position and movement of the target and its predicted position (lead point) being calculated and the position information for the lead point being converted to angle adjustments of the weapon system, characterised in that the positions of probable attack objects (2) are arranged to be supplied to the system, that these positions are utilised in calculating the lead point or lead points and that a number of movement models are combined for building up in this manner a hypothetical path shape (target model)

which the target is assumed to be following.

2. Method according to Claim 1, characterised in that the target model is built up of circular peripheries, spherical surfaces and straight lines.
3. Method according to Claim 1, characterised in that the position of an attack object (2) is specified in right-angled coordinates and is supplied to the system via thumb wheel, menu or the like.
4. Arrangement for determining in a weapon system the position of one or more lead points of a moving target (1) which is executing manoeuvres in three-dimensional space with the aim of arriving at such a position that dropping of its ordnance against an attack object (2) becomes possible, comprising elements for calculating the current state of position and movement of the target and the predicted position-of the target (lead point) and converting the position information of the lead point to angle adjustments of the weapon system, characterised by elements for supplying the positions of probable attack objects (2) to the system, and in that these positions are utilised in calculating the lead point or lead points and that a number of movement models are arranged to be combined for building up in this manner a hypothetical path shape (target model) which the target is assumed to be following.
5. Arrangement according to Claim 4, characterised in that the target model is constituted by a combination of circular peripheries, spherical surfaces and straight lines.

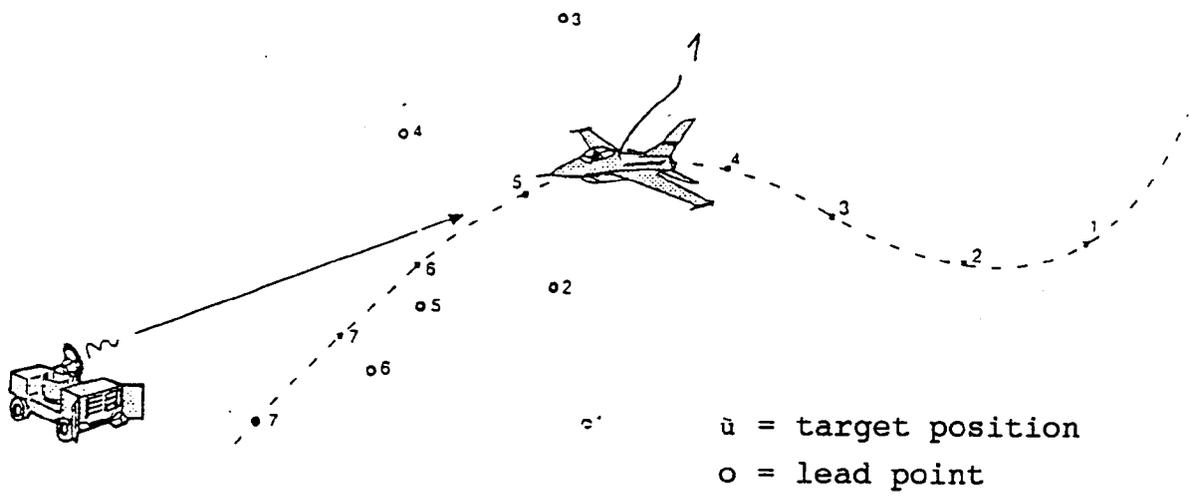


Figure 1

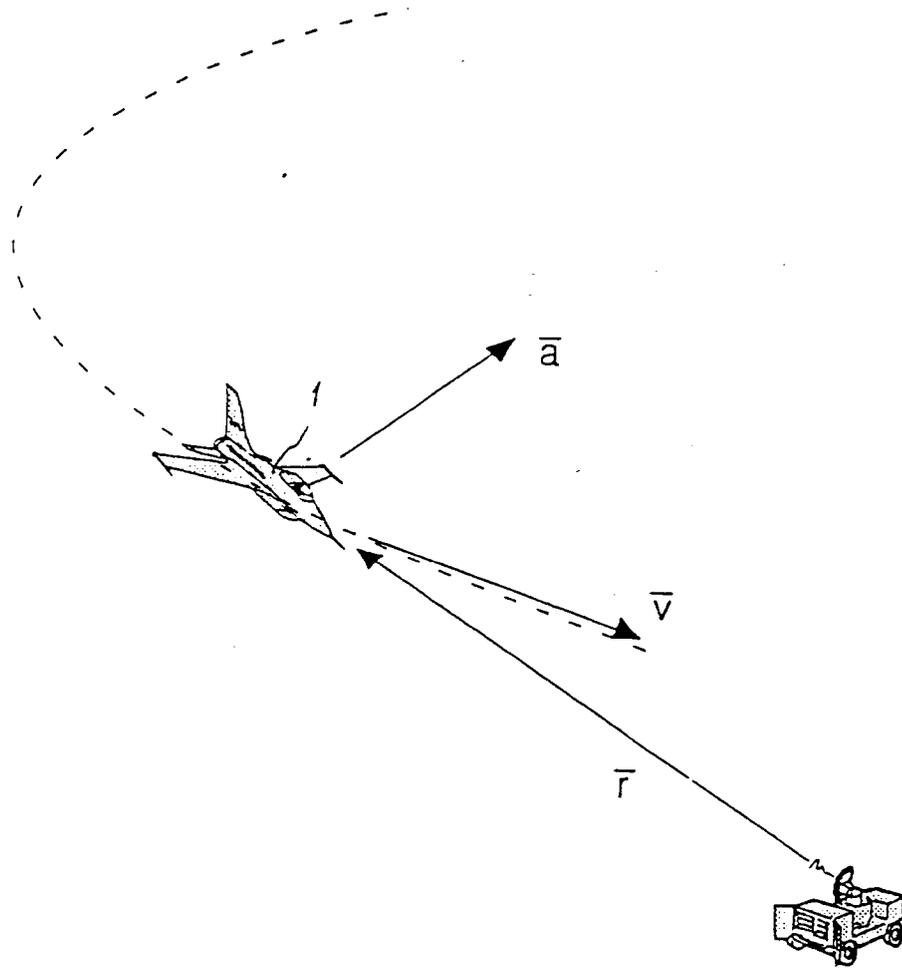


Figure 2

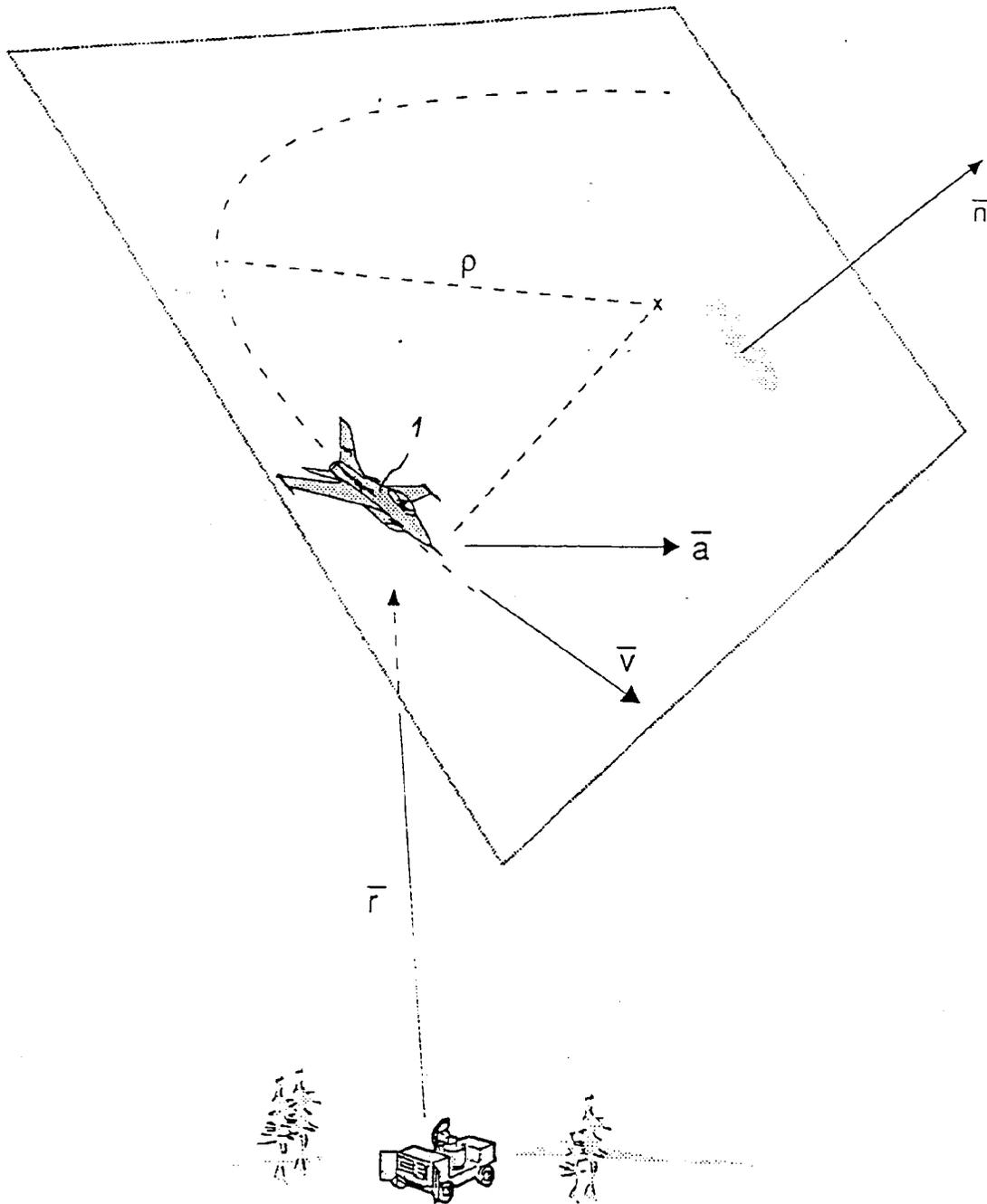


Figure 3

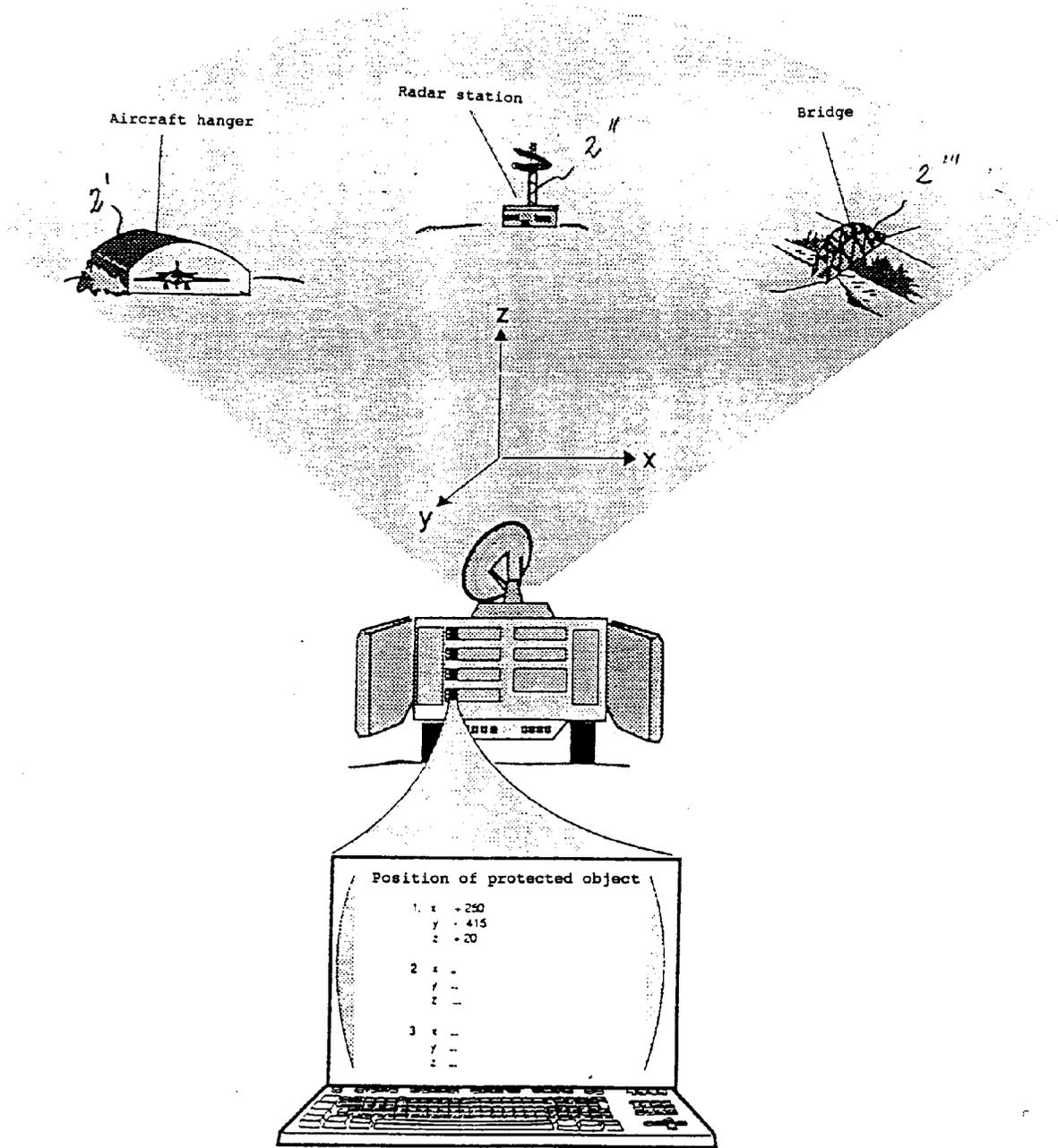
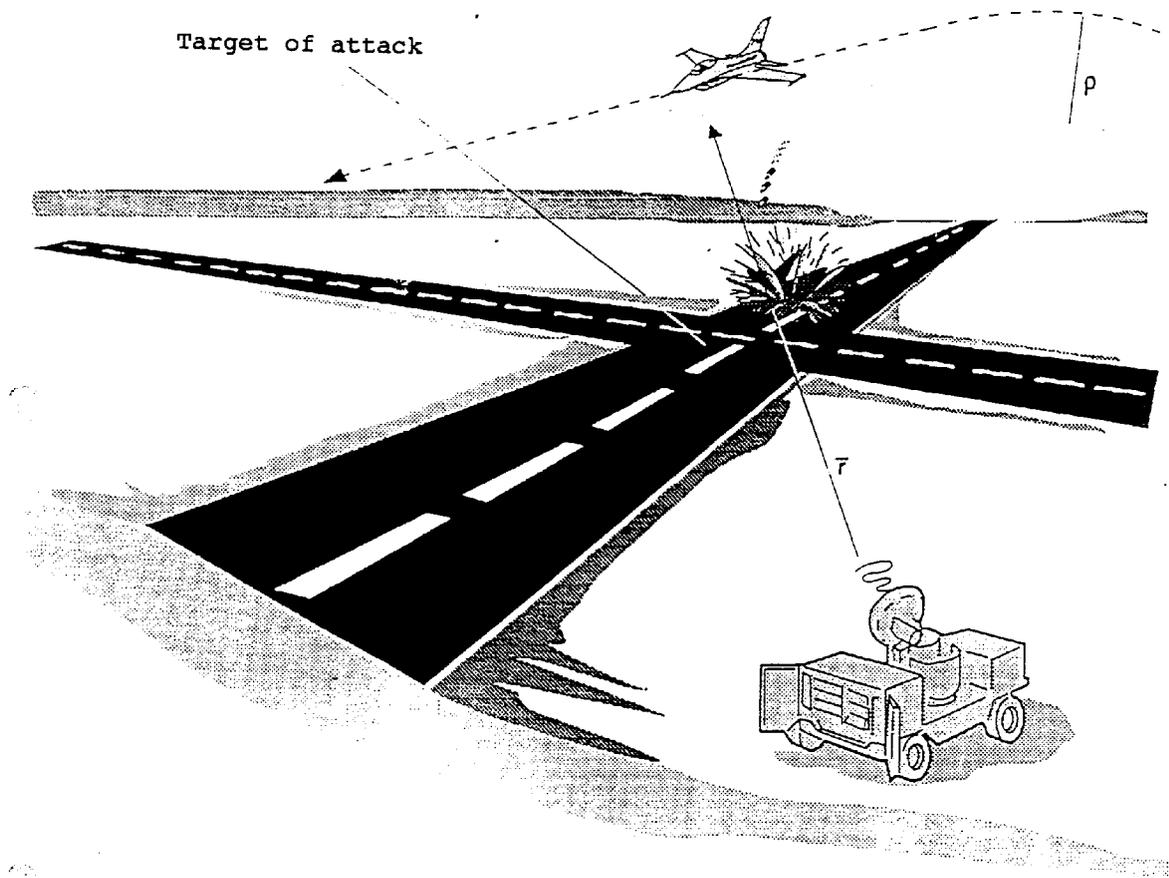


Figure 4



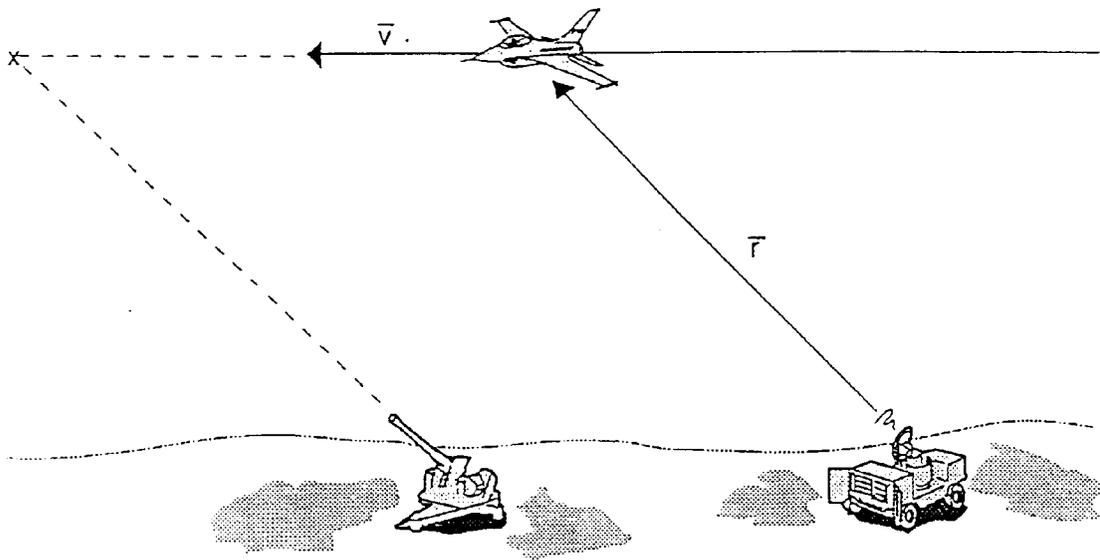


Figure 6

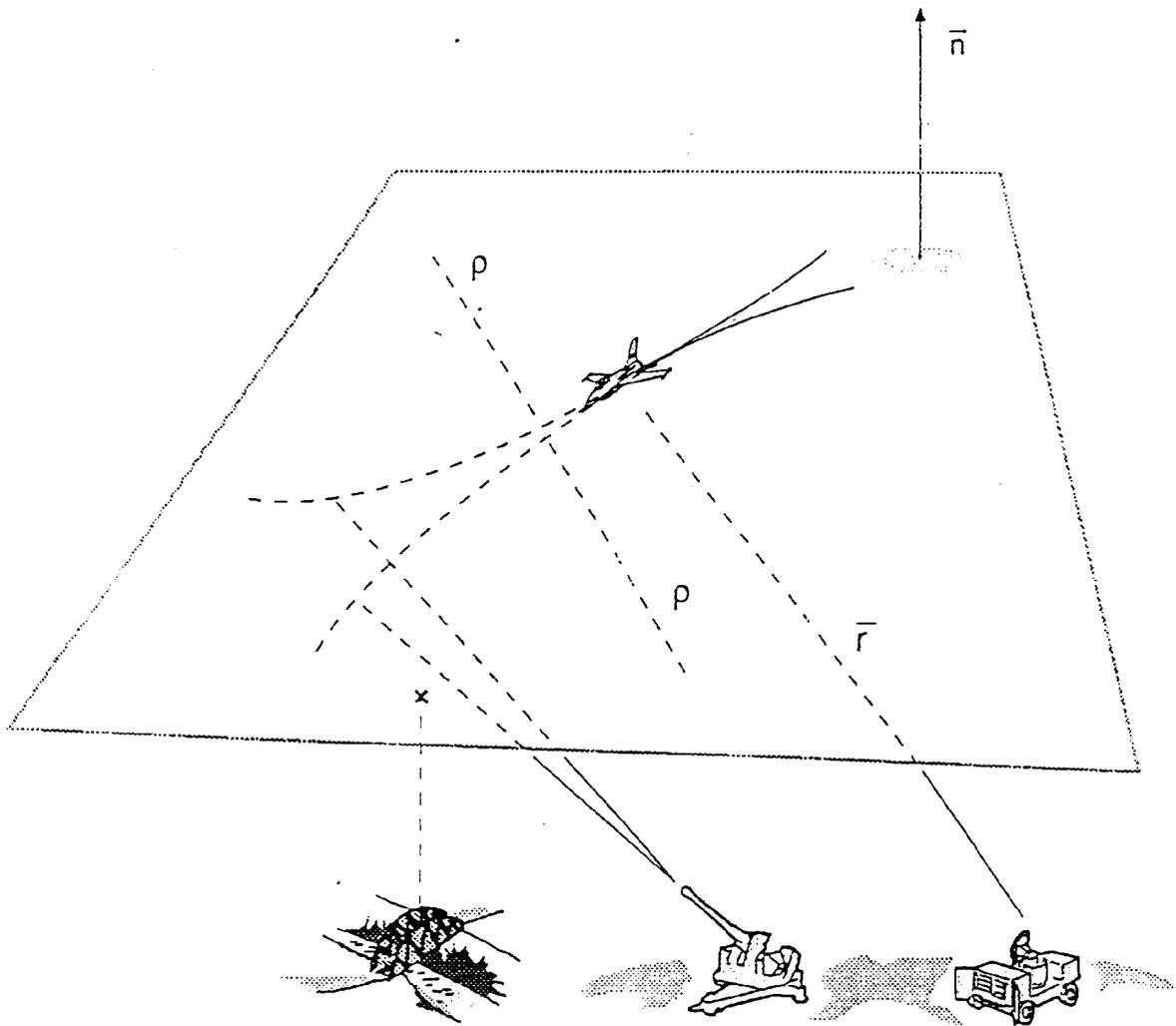


Figure 7

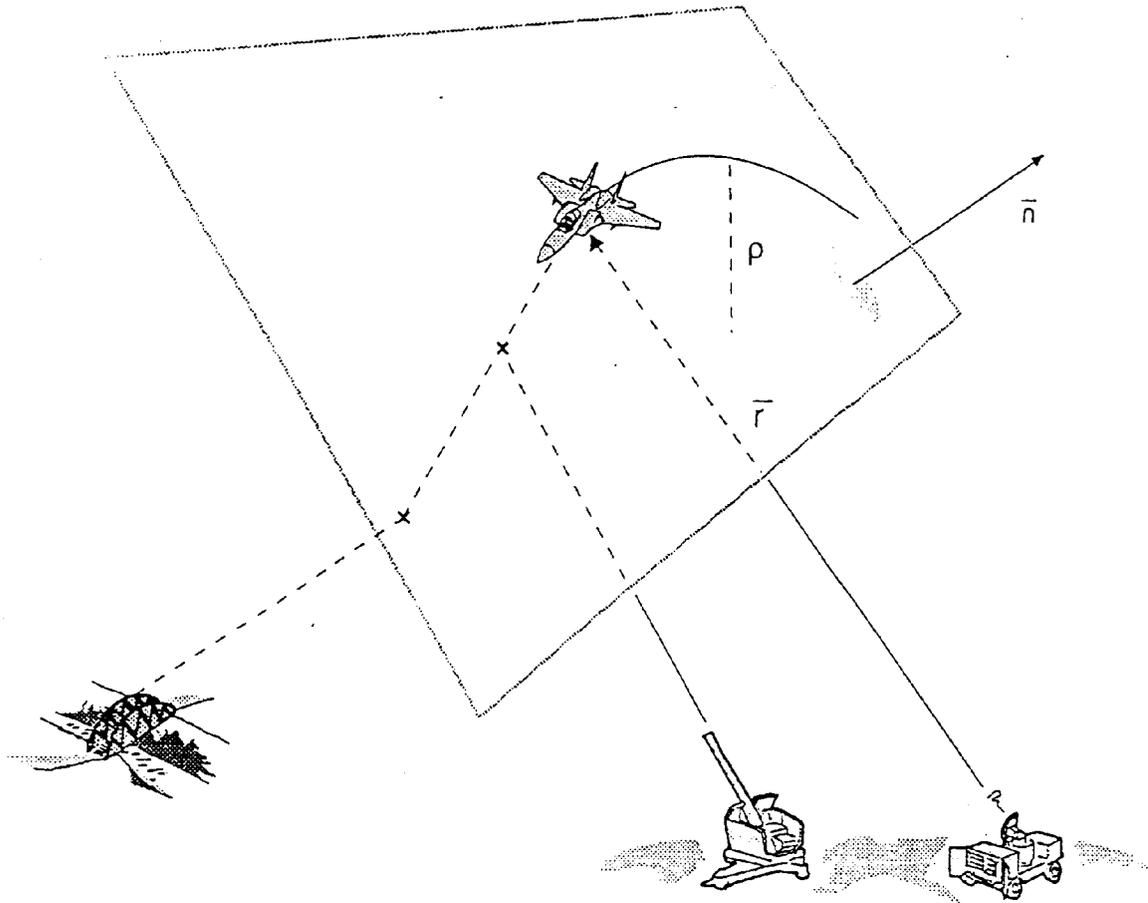


Figure 8

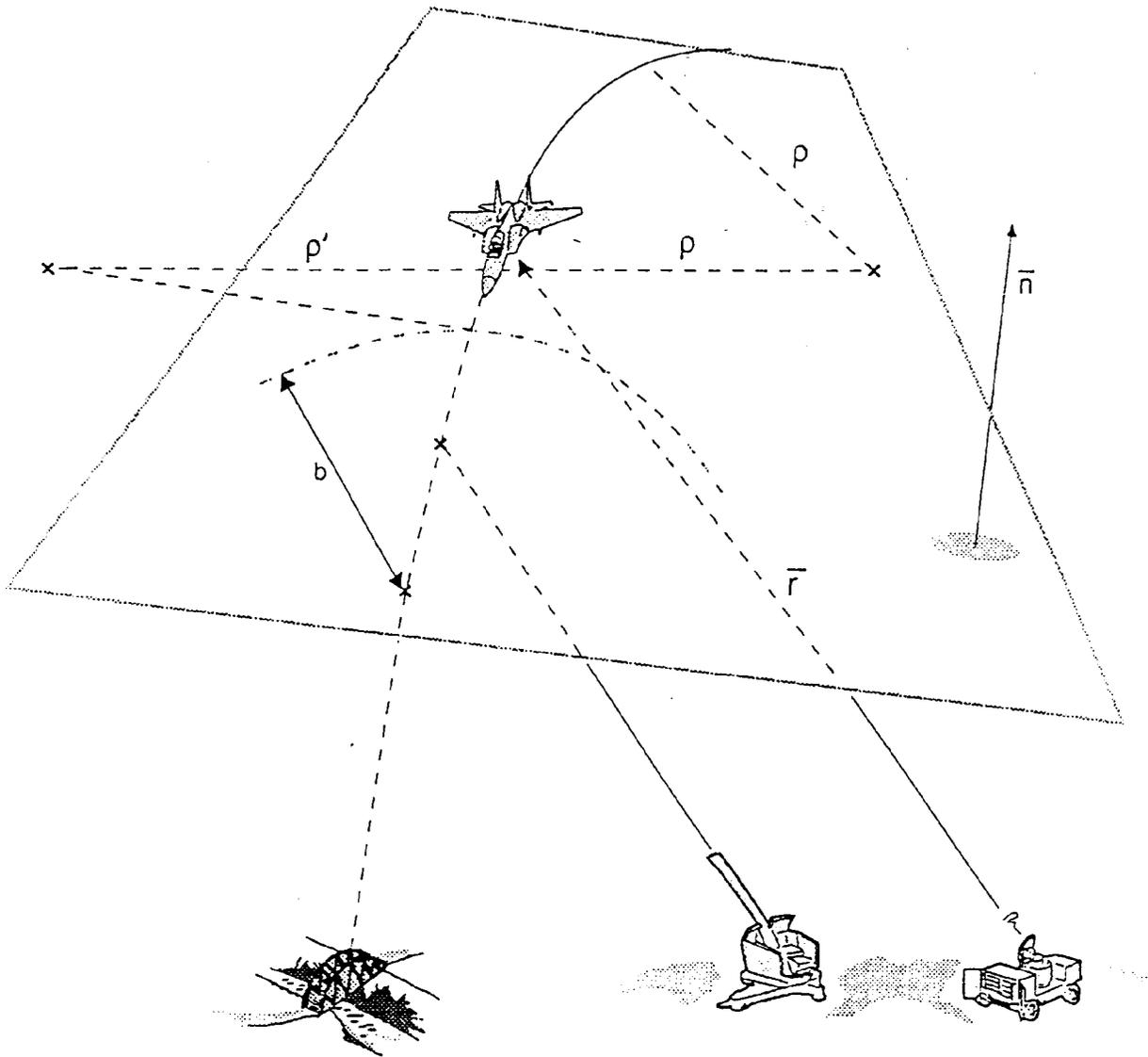


Figure 9

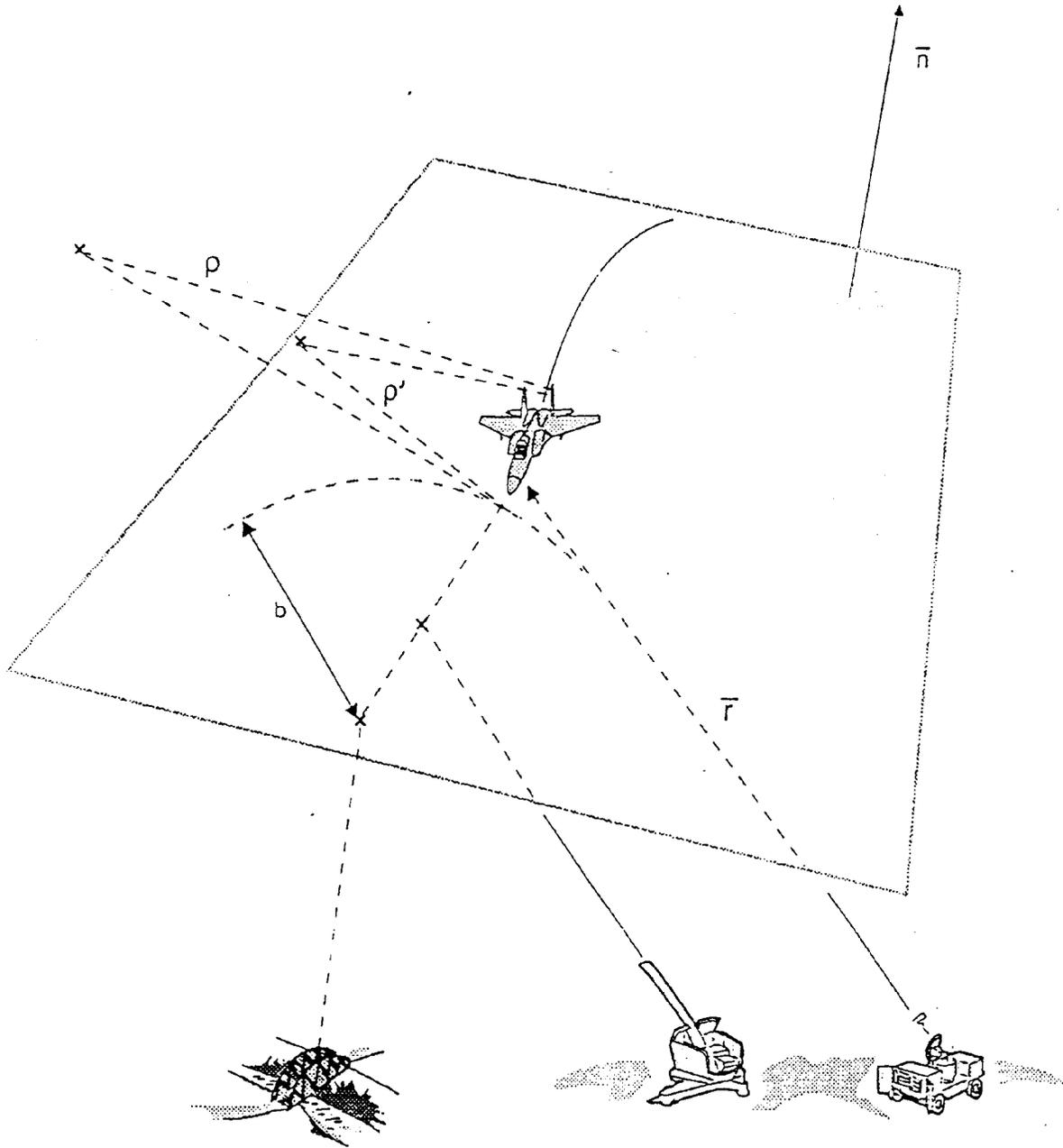


Figure 10

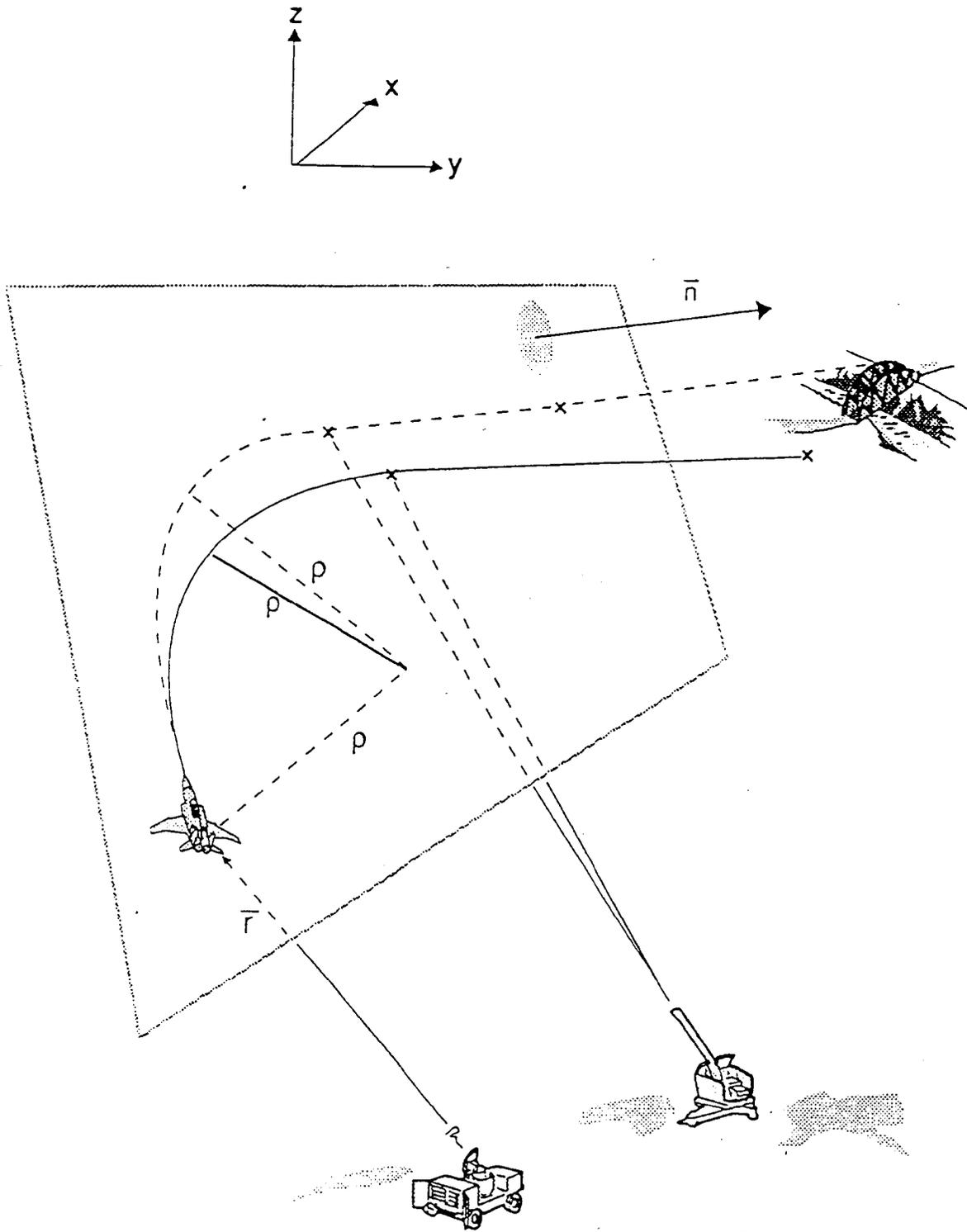


Figure 11

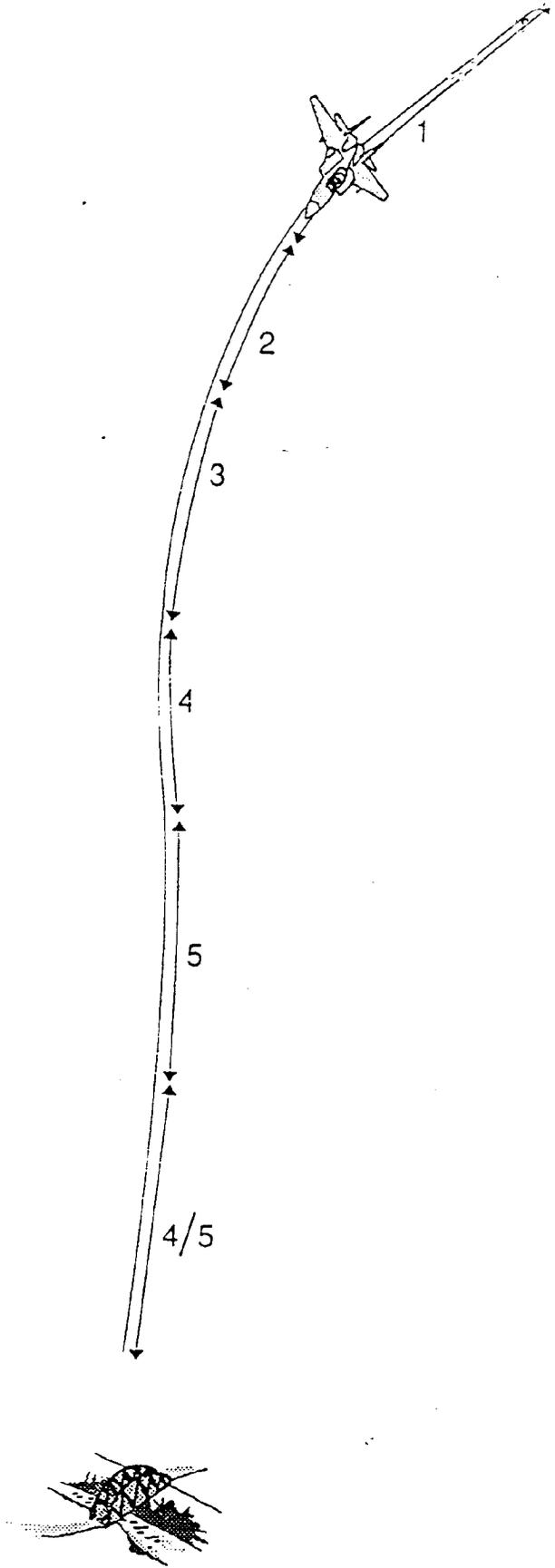


Figure 12



European Patent  
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EUROPEAN SEARCH REPORT

Application Number

EP 92 85 0149

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	GB-A-2 212 252 (BRITISH AEROSPACE PLC) * Abstract; page 4, line 20 - page 5, line 18; figure 1 * ---	1,4	F 41 G 5/08
A	US-A-4 794 235 (BURKE et al.) * Abstract; column 3, line 12 - column 7, line 45; figures 1-6 * ---	1,2,4,5	
A	EP-A-0 207 521 (CONTRAVES AG) * Abstract; page 4, line 27 - page 12, line 3; figures 1,2 * ---	1,4	
P,A	EP-A-0 463 856 (NOKIA MOBILE PHONES LTD) * Abstract; column 2, lines 21-35; figures 1-3 * ---	3	
A	US-A-4 320 287 (RAWICZ) * Abstract; column 1, lines 61 - column 6, line 48; figures 1-3 * -----	1,4	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			F 41 G
Place of search THE HAGUE		Date of completion of the search 29-09-1992	Examiner BLONDEL F.J.M.L.J.
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ..... & : member of the same patent family, corresponding document	
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