FUZE SENSOR REQUIREMENTS OF THE DIFFERENT AIMABLE ANTI AIR WARHEAD LAYOUTS

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For air vehicle and TBM defence a large variety of conventional and aimable warheads or lethality enhancer systems exist. All these different types need special fuze sensor devices to pretrigger the partially multi step functions, so that the maximum possible number of effective hits on the target is achieved. First, the different ideas on warhead types with their idealised functions are presented. In a second step, their requirements or optimum detection devices for best function are highlighted.

1. ANTI AIR WARHEAD TYPES

Two different types of air targets exist ([1] and [2]) (Fig. 1). The first are aircrafts (AC), helicopters (HC), drones and air-breathing missiles (ABM), to mention the majority of these which can fly in low levels, have partially high agility and counter measure possibilities. The second are the TBM targets with nearly no manoeuvrability, but they have very high velocities. For the first type of air targets, high velocities of fragments are necessary to perform some penetrations, respectively perforations and to achieve some damage and for the second type large fragment masses, as a curtain is useful, with which the targets interact.

1.1 Anti Air Vehicles Warheads

Fragmenting warhead types with high fragment velocities can be divided in two main principles (Fig. 2):

- Radially acting fragments as an opening cylinder ([3] and [4])
- Axially acting fragmentation shower

The fragments can be built from a smooth casing or plate as so-called naturally built fragments or in a controlled manner by external and/or internal grooves in the casing or in the high explosive charge, by zone embrittling or as preformed fragments [5].

1.2 Anti TBM Warheads

In the second case the interacting velocity is already very high and therefore only a cloud or a curtain, built from heavy fragments, must be dispersed in which the target is diving in [2]. The target structures are typically strong and the high interacting velocities are splitting the fragments in many pieces. Therefore large masses are necessary [6]. Still direct hits of missiles with semi-piercing warheads will not damage all submunitions in a TBM warhead ([7], [8] and [9]). To support the destruction of a larger number or, if possible, all submunitions a concentrated fragment shower is necessary. To achieve this, two principle types of so-called lethality enhancer warheads can be considered. One is dispersing a fragment shower by an internally installed high explosive charge. And the second is to push an internal core of heavy fragments by an external high explosive charge. The functions of these warheads are described in chapter 3.

2. AIMABLE HIGH VELOCITY FRAGMENTING WARHEAD TYPES

The fragment velocities of the radially arranged fragments can be increased by an eccentric initiation of the cylindrical high explosive charge ([10] and [11]). The interacting pressure of the detonation wave to the fragment casing is in this case elongated and the fragment velocity is enhanced in the aiming direction in the range of 20% to 40%, depending on the mass ratio of metal to the high explosive charge. These types of aimable warheads are called “velocity enhanced” or “detonation wave aimed”.

With externally arranged deforming charges the casing can be deformed in such a way that a higher fragment hit density can be achieved in the target direction. This type of aimable warhead is called “mass focused” ([12]).

This deforming principle is also possible in turning the fragment plate to some angles to the warhead axis (Fig. 4).

The enhanced fragment velocity warhead and the mass focused warheads are already sufficiently described in their functions and achievable results in the open literature. They need no more description here.

3. AIMABLE LETHALITY ENHANCER WARHEADS

The conical shaped TBM targets are more or less interacting with anti TBM-missiles in mostly elliptical contours. Therefore also elliptical fragment patterns should be achieved to get a larger number of impacting and perforating fragments [2]. The axis of the elliptical pattern has to be also steered parallel to the larger axis of the target contour. To achieve this, a ring shaped internal high explosive charge is installed in the fragment casing. One or two deforming charges will be initiated to get also an internally hemispherical high explosive charge. The fragments in contact with the detonating high explosive charge are propelled at about 50% higher velocities compared to the other fragments. Therefore an elliptical pattern of the fragment cloud is achieved [13] (Fig. 5).

In a second example an internal core of large fragments is surrounded by high explosive segments. The high explosive segments to the target direction are ejected by small high explosive strips [14]. The residual remaining high explosive segments in contact to the fragment core are then initiated, which are pushing the fragment core now concentrated in the target direction (Fig. 6).

4. FUZES FOR ANTI AIR TARGET WARHEADS

Fuze sensors for both target types can be also divided into two different target detection device principles. One is a “cone sensor”, which takes the relative velocity of target and anti-target missile principally into account and the second is the so-called “predictor concept”, which gives the passing distance and the azimuth angle [15]. The latter has to be used if the fragment velocities are small compared to the relative velocities (Fig. 7).

4.1 Cone sensors against Air Vehicles

The warheads with radial fragments are up to now mostly fired, if the target is entering the sensor cone of an optical or radar proximity fuze. The opening angle of the cone is defined by the mean relative velocity of the missiles and the targets, divided by the fragment velocities. This sometimes so-called “fixed angle fuze” is described in great detail in [16]. Such a system can be remarkably improved in a relatively simple way by taking into account the relative velocities of targets and anti-target missiles by the Doppler frequency of a radar sensor, whereby the opening angle of the fuze cone is automatically adapted (Fig. 8). But with changing crossing angles between the missile and the target trajectories in early and late bird conditions and with inclined angles of attacks of the missiles the hit probabilities of the fragment showers will be considerably reduced (Fig. 9). To compensate this, sometimes the contour of the fragmenting warhead is changed from a cylindrical casing, which has an opening angle of about 20°, to a barrel shape which gives an opening angle in the range of 50° (Fig. 10). This means a reduced number of fragment hits, but still at least some hits in worst conditions, to compensate the weakness of the conical fuze sensors. A concave warhead would give a narrower fragment beam with more kill probabilities, if the fragment shower gets into the vulnerable components of the target.

4.2 Predictor Fuze Concepts against TBM Targets

The predictor concept is measuring the incoming target to the anti-TBM missile with respect to:

- distance d as a function of time t, which gives the reactive velocity
- the deviations in the planes in the x and y directions at the times t
- the latter predicts with increasing accuracy the miss distance r and the angle α a in the fragment plane.

The lethality enhancer warhead will be fired at the time t_a, which is given by the distance r divided by the fragment velocity v_{Frag}, which is equal to the distance d of the target to the warhead fragmenting plane, divided by the relative velocity v_{rel}.

$$t_a = r/\upsilon_{Frag} = d/\upsilon_{rel}$$

The azimuth angle α is necessary, if aimable warhead concepts are used.

5. FUZE SENSOR REQUIREMENTS

The exact fuze sensor requirements can be only precisely defined if an exact layout of the used warhead is given. Here, only general rules can be presented for the wide spectrum of realization possibilities of every warhead type.

5.1 Velocity enhanced Warhead Types

Velocity enhanced warheads are mostly designed with 4, or with 8 eccentric initiation lines ([10] and [11]). With 4 initiation lines, the velocities can be radially enhanced every 45° by the initiation of 1 line or 2 lines, while in the latter case the fragment velocity is increased in the diagonal direction. For this, the target direction has to be found at every 45°, respectively every 22,5°.

This means the azimuth angle should be defined at least with this resolution, whereby to be on the safe side, a factor of two should be taken into account.

Velocity Enhanced Warhead

Initiation lines	Fragment α angle	Fuze α angle
4	45°	15°
8	22,5°	7°

This angle resolution has to be additionally taken into account, whereby the initiation times for the warhead can be achieved by the fuze cone sensor concept.

5.2 Mass focused Warhead Types

The feasibility of mass focussed warheads for about 20 kg heavy warhead classes was demonstrated with 20 deforming charges which needs an azimuth resolution of the fuze sensor of 18°. Principle tests have also shown, that 36 deforming charges can be installed which needs then an azimuth resolution of about 10°. The deforming charges have typically given a strong focussing effect in both, elevation and azimuthal directions. This very narrow concentrated fragment shower was typically smaller than the required azimuth resolution by the number of deforming charges. In reality the fragment shower has to be widened at least a little in azimuth and in elevation direction. People experienced in the field of detonation can achieve such things without any too big problems.

But back to the fuze requirement: for mass focussed warhead this means that with 20 deforming charges the target direction has to be defined at least with an azimuth angle of 18° and for the 36 deforming charges with 10°. As mentioned before, the fuzing resolution should be in this case higher than the focussing effect of the warhead by a factor of 3 than the focusing possibilities of these warhead type.

Mass focussed fuze requirements

Deforming charges	Fragment α angle	Fuze α angle
20	18°	6°
36	10°	3°

The angle to the vulnerable parts of the targets has to be found out with high probability because we have only a very narrow focused fragment beam in the target direction and nearly no fragments in the forward +/-90° sectors around the concentrated fragment beam. Additionally, fragments in a semi-circle are propelled only on the rear side of the warhead. This is different to the velocity enhanced warhead where, besides fragments with the higher velocities in the aiming direction, also fragments in the other directions exist, however, with reduced velocities (see Fig. 4).

5.3 Fuze Requirements for LE with internal HE

In the feasibility studies for this warhead type 8 charges for deforming the internal ring charge were used (see Fig. 5). This means by firing one or two neighbouring charges, the axis of the elliptical pattern can be changed every 22,5°. Therefore the azimuth direction should be defined at least under this angle and for safer predictions with angles of around 10°.

The deformation of the ring charge into the semicircle shape needs a time of about 1 ms. The velocities of the heavy fragments are in the range of 100 m/s to 200 m/s. Therefore the deformed internal main charge has to be initiated some time before the interaction of the target with the fragment shower happens. For example the miss distance should be 1m. The fragment curtain needs an opening time of 5 ms for the long elliptical axis. The relative velocity between the TBM target and the missile of 4.000 m/s requires an initiation of the deformed high explosive charge if the target has a distance of 20 m to the fragment plane.

The relative velocity can be easily measured, better than 1 ‰, but the expected miss distance should be defined better than 10%.

LE with internal HE

Deforming charges	Fragment α angle	Fuze α angle	V_{rel}	Distance
8	22,5	10°	1 °°/°	<10%

5.4 Fuze Requirements for LE with external high explosive Charges

This concept was demonstrated with 20 ejectable outside segments which means an angle of resolution of 18°. But this concept can be improved without too much risk to 36 ejectable external high explosive charges. This would give 10° azimuth angle resolutions for the fragment shower.

As discussed before, the fuzing angle has to give a higher angular accuracy than the angle of the fragment shower. This would require azimuth angle resolutions of 6° for the demonstrated feasible 20 kg warhead concepts or for the improved version of 3°.

The external high explosive segments are ejected with velocities of around 200 m/s. This means they have about 0,5 ms earlier to be ejected before the residual attached high explosive segments to the fragment core are initiated.

This fragment bulk moves roughly with 100 m/s which gives a travelling time of 10 ms for 1 m miss distance. Therefore the event for firing the warhead in the aiming direction has to be taken at 10,5 ms before the target enters the fragment plane under the above mentioned conditions (υ_{rel} = 4000 m/s).

The requirements are relatively similar to the lethality enhancer discussed under 5.3. Only the azimuth resolution has to be increased essentially.

LE with external HE

HE segments	Fragment α angle	Fuze α angle	V_{rel}	Radial Distance
20	18°	6°	1 ‰	<10%
36	10°	3°	1 ‰	<10%

6. CONCLUSIONS

The functional principles of the different aimable fragmenting warhead types and aimable lethality enhancer concepts are schematically described. These concepts achieve higher lethality effects against the targets. But these concepts need special fuzing concepts, especially the detection of the azimuth angles of the targets.

In the case of fragmenting warheads with higher fragment velocities, the fuzing cone concept can be used in principle where the azimuth angle direction has to be additionally defined. In the case of the low velocity heavy fragments masses for TBM defence, the predictor fuze concepts have to be used which have to define the passing distance and in addition the azimuth angles in the fragment plane.

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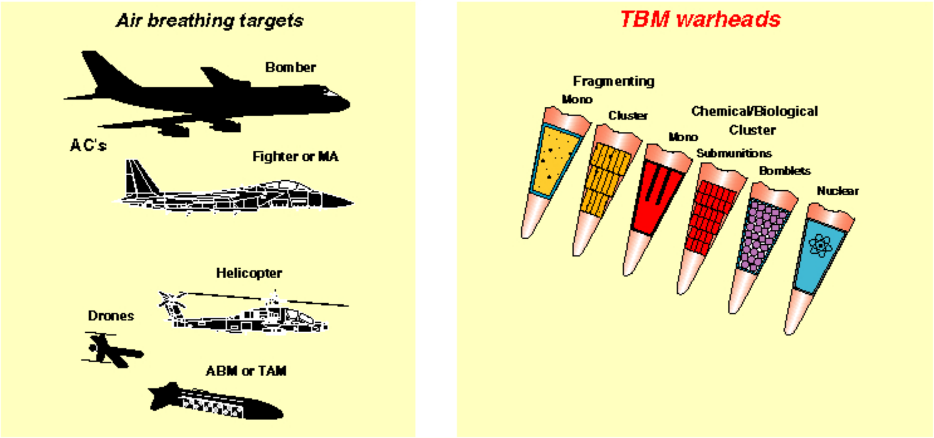


Fig. 1 Air Targets

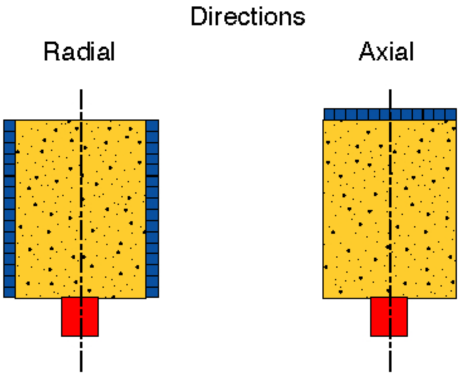


Fig. 2 Fragmenting Warhead Types

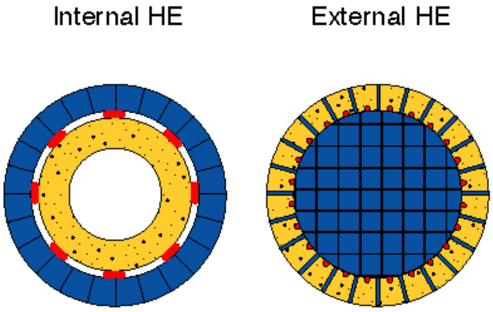
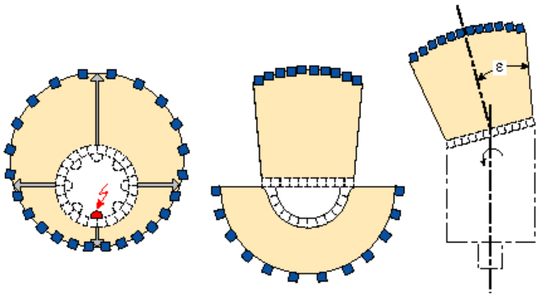


Fig. 3 Lethality Enhancer Warhead Types

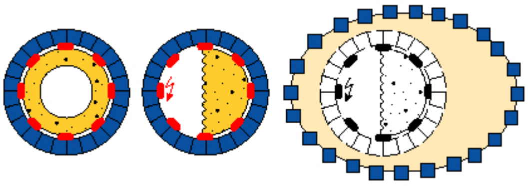


Radial Velocity Enhanced

Radial Mass Focused

Axial Steerable Direction

Fig. 4 Aimable Fragmenting Warhead Types



Deformed Internal HECharge Achieves Eliptical Fragment Curtain

Fig. 5 Aimable Lethality Enhancer with Internal HE

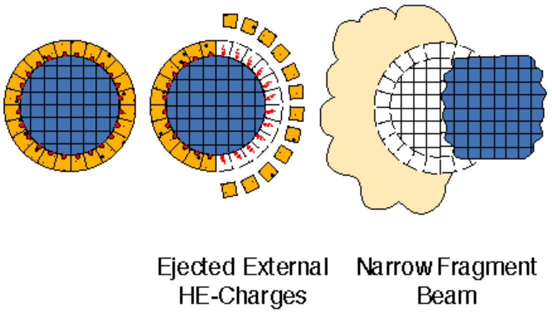


Fig. 6 Aimable Lethality Enhancer with External HE

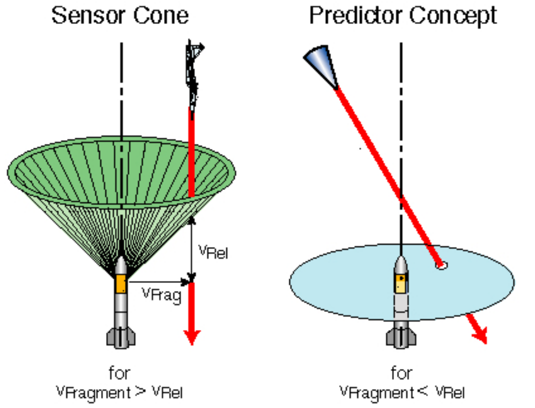


Fig. 7 Fuze Sensors

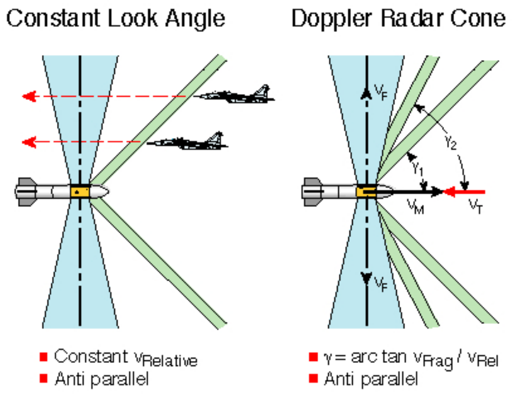


Fig. 8 Fuze Cone Sensor

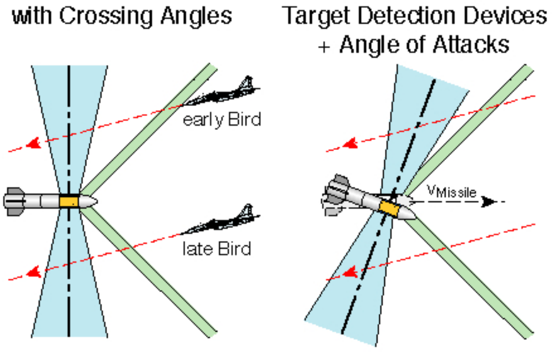


Fig. 9 Problem with Cone Sensors

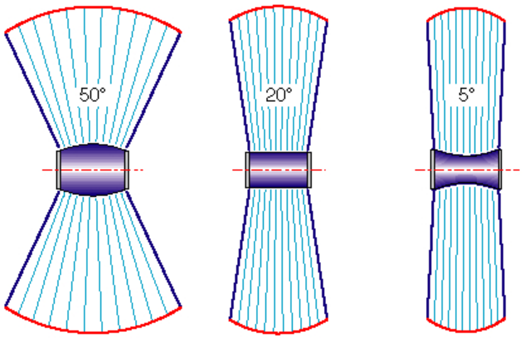
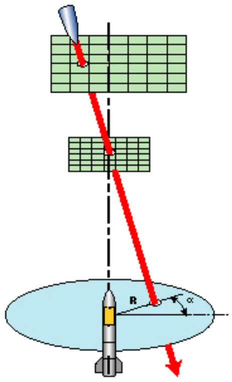


Fig. 10 Fragmenting Casing Contours



3 dimensional continnously target observation in

- distance d (t)
- x (t) and y (t) to missile axis

gives v_{Rel}
predicts R with α angle in fragment plane
WH fired at $t_a = R / v_{Fr} = d / v_{Rel}$
α is necessary for aimable WH concepts

Fig. 11 Possible Predictor Concepts