THIRTEENTH EUROPEAN ROTORCRAFT FORUM

g.3

Paper No. 28

WIDE BAND LASER WARNING RECEIVER
FOR HELICOPTERS

F. BIDA
G. BROGI

SISTEL, ITALY

September 8-11, 1987

ARLES, FRANCE

ASSOCIATION AERONAUTIQUE ET ASTRONAUTIQUE DE FRANCE

WIDE BAND LASER WARNING RECEIVER
FOR HELICOPTERS

F. BIDA
G. BROGI

SISTEL, ITALY

Helicopters are, and will be even more so in the future, faced with a variety of different sophisticated threats as a consequence to their increasing roles and missions. Subsequently, the helicopter must be more effective and survivable in the various operational situations. This results unfortunately, in an increase of the unit price of the vehicle and in less procurable units.

To meet the requirements of effectiveness and survivability the guidelines are: (Fig.1)

A) improvement of flight performances: greater dash and cruise speeds, better accelerations and longer endurance;

B) increase of the "Fire Power" of the platform (i.e. Stand-Off Range to reduce the possibility of being hit, Fire and Forget capability to reduce the risk and time of exposure during the fire actions, Air to Air weapon to counter air attacks etc.;

C) extensive use of advanced Aircraft Survivability Equipment (A.S.E) either passive or active.

The resulting helicopter is something more than the pure combination of equipment because of the synergy created by the intelligent integration of systems which transform the helicopter in an extraordinary operational weapon system.

In the last few years A.S.E. has become an important reality since the survivability of the helicopters has drawn a general attention. Survivability is achieved by:

1) preventing the enemy detection;

2) avoiding of being hit if detected;

3) withstanding the enemy fire and the consequences of crash if hit.

Special Profiles, Radar Absorbing and Low Emissivity Paints and more generally, criteria allowing reduction of Radar, Infrared, Optical and Acoustical Signature is used in modern helicopter design to achieve a lower detectability.

In addition a proliferation of Radar Warning Receivers, Laser Warning Receivers, Hostile Fire Indicators, Electro-Optical Jammers, Chaff Dispensers and Smoke Generators are being produced or are in development.

Moreover, helicopter designers have adopted Redundant Flight Control Systems, Self Sealing Fuel Cells, Ballistic Protections for Crew Compartment and Critical Components, Chrashworthy Structures and Fire Protection devices.

In the United States of America, A.S.E. is not simply equipment it is a philosophy which embodies tactics and technical developments to increase helicopter survivability; thus the existence of a specific program called "A.S.E. Program" in accordance with the present concept of "Striking Deep" also with helicopters (AIRLAND BATTLE).

In Europe there is also a growing interest towards A.S.E. even though the operational employment of helicopters is different.

Aircraft performance and survivability are contrasting requirements.

A reasonable trade-off is to consider A.S.E. useful and necessary to achieve successful missions in modern battlefield scenario, as long as the number, complexity and total cost of such devices is kept low. In other words A.S.E. taken as a whole, must not penalize the aircraft neither in performance nor in cost.

To design efficient A.S.E. a knowledge of the acquisition and guidance characteristics of the various weapon systems for Anti-Aircraft defence is needed.

Regarding Laser Warning Receivers it is thus necessary to consider the following laser threats: (Fig.2)

1) Laser Rangefinders belonging to conventional Anti-Aircraft weapon systems, like the widely deployed ZSU 23-4 and QUAD 57 mm systems of Warsaw Pact. (Naturally many other similar systems could be mentioned such as the ARTEMIS, the TRINITY, the SIDAM 25 and OTOMATIC etc.);

2) the Laser Designator/Illuminator belonging to missile systems like SA14 with beamrider guidance, the semi-active laser SPIRAL AT6, (even if the AT6 is anti-tank, it is also used against other targets) the HELLFIRE, the RBS70 and ADATS beamrider systems and the RAPIER LASERFIRE.

In conventional weapon systems searching is done by Radar or by Optic/Opto-Electronic devices. An Opto-Electronic device also carries out the functions which are normally assigned to a Tracking Radar. For example, a TV camera can continuously give bearing and elevation angles of the target whereas, at the same time, a Laser Rangefinder gives accurate target range. The Computer provides calculations for future position of the target thus allowing aiming and consequently shooting. (Fig.3)

The case of semi-active guidance Designator (i.e. HELLFIRE) or of a beamrider guidance Illuminator (i.e. RBS70) is similar. The Opto-Electronic system provides two angular axis target tracking and target illumination during the engagement time.

In all cases target aiming should be done with the maximum obtainable accuracy otherwise additional errors are introduced in the guidance loop causing a larger miss-distance and probably an ineffective intercept (no-kill).

Briefly, three points are very important.

1) A good aiming at the target is needed to obtain an effective firing action in spite of the type of anti-aircraft equipment used either conventional or missile.

2) Laser transmissions continue during the entire firing action.

3) PRF pattern of laser pulses is held practically constant during this time.

Some of the parameters which characterize the typical laser threat are very important because they enable the crew to recognize and evaluate, with reasonable accuracy, the position, the type and danger of the threat.

Rangefinders usually operate from 200/300 meters to nearly 10 km, while Designators or Illuminators have a minimum range of 300/400 meters to a maximum range of 6/8 km in standard weather conditions. When dealing with a helicopter target, a direct beam hit is highly probable because the laser is directly aimed at the helicopter centroid. On the contrary, anti-tank ranging is often dealt with an indirect beam hit by aiming at an object nearby to avoid alerting the crew before firing.

However, the indirect beam hit can happen also with helicopter targets in some particular operational conditions i.e. when the helicopter is less than 50 meters away from a reflecting surface such as forest borders, buildings, mountain gorges or other objects and the laser beam is aimed at the object behind instead of the target. Obviously this happens occasionally, for a short period of time and in general as a consequence of the operator´s mistake.

On the other hand, a laser system directly aimed at the target causes a strong alarm signal whereas, a distant laser system or a nearby reflected beam causes a weak alarm signal. If on board the helicopter there is an alarm receiver with an adeguate dynamic sensitivity it can be assessed whether the threat in near or far and whether it is an immediate danger, a deferred danger or an improper danger (when the weapon system is aimed at another target and a reflected signal is received).

The measure of the laser pulses PRF (Fig.3 bis) allows the recognition of the different type of threats.

In particular, for beamrider Illuminators the values between 100 - 10.000 pps are normal; for Semi-active systems such values are between 10 - 30 pps whereas for typical Rangefinders values of 0,1 - 10 pps can be expected.

From the characteristics of the received signals it is therefore possible to evaluate its danger, to recognize the type of weapon, to estimate probable attack time and consequently to know the available time for a possible defilade manoeuvre.

Without going into detail about the operational employment of helicopter, the typical tactical situation of AA defence weapon systems in respect to friend helicopters intervention is shown in Fig.4. Illustrated are the armoured attacking units with their self-propelled Anti-Aircraft gun and the helicopter formation. This illustration, although rather schematic, represents a typical battlefield situation because in a mission there is a period of time in which the helicopters are no longer masked and may be within the range of enemy weapons.

In position A the helicopter is far away from the Anti-Aircraft enemy unit. If the AA enemy unit activates its Laser Rangefinder a low intensity warning signal will be received on board the helicopter equipped with a LWR. The pilot therefore is aware of a far away weapon system aimed directly. (In this case it is nearly impossible to have alarm signals caused by reflection because of the distances). At closer distances other situations are possible.

In position B the activation of the enemy Laser Rangefinder will be seen on the Laser Warning display of the helicopter as a strong signal thus indicating a nearby weapon aimed directly and consequently very dangerous.

In position C the activation of the enemy Laser Rangefinder will be received on board of the helicopter with a low signal coming roughly from the direction of reflecting objects provided that they are positioned at less than 50 meters away. In this case the pilot will recognize that the helicopter is not facing an immediate danger because the alarm comes from reflections.

The operational use of information given by a Laser Warning Receiver on board of a helicopter is shown in Fig.5.

After receiving a first warning signal the pilot checks if the power level exceeds a threshold value, if so, it is certainly a direct beam hit (Warning Type A). On the contrary if the power level does not exceed the threshold value it could be either a direct beam hit from a distant weapon or an indirect beam hit from a close weapon. (Warning Type B).

From Warning Type A the pilot is aware of the following:

1) the helicopter is being fired at by a close weapon system (gun, tank or missile);

2) The sector, the type of threat and its estimated intervention time;

3) the need to identify immediately an area where an effective defilade manoeuvre (ridges, valleys, river beds, wooded areas, constructions) can be carried out using the available angular information;

4) The surprise attack mission has certainly failed.

From Warning Type B the pilot has the following information:

1) The helicopter is entering a possible dangerous situation;

2) The type of threat (with its estimated intervention time) which could be encountered later on or immediately after;

3) The opportunity of identifying beforehand an area where defilade is possible;

4) The fact that the surprise attack mission may be compromised.

In addition, the pilot checks if he is near a shield which could have caused reflection. If there isn't a shield in the alarm direction within 50 meters, then the warning comes from a distant weapon and therefore the danger is not immediate. If viceversa, there is a shield in the alarm direction at less than approximately 50 meters then the warning comes from an indirect beam hit and therefore the threat is not dangerous for the time being. The pilot however, recognizes the type of threat without really having a correct indication of its bearing but this penalty is acceptable being that the threat is not an immediate danger.

Normally, in battlefield operations one takes advantage of the surprise effect. A LWR on board allows the pilot to know during his mission if the surprise effect is still present or not.

But what are the operational requirements of such a device? (Fig.6 and Fig.7)

WIDE ANGULAR COVERAGE which avoids having blind areas or at least to keep them to a minimum.

WIDE SPECTRAL RESPONSE which covers the entire wavelength range of today laser systems and possibly of those expected in the future.

ADEQUATE SENSITIVITY AND DYNAMIC RANGE which permits to receive warnings from direct and indirect beam hits thus allowing the distinction between the different type of warnings with their associated information.

ADEQUATE ANGULAR RESOLUTION which gives the bearing of the laser transmitter with reasonable accuracy. A resolution of roughly 22.5 degrees (one octant) is acceptable considering that the action of a helicopter after a laser warning is normally a defilade manoeuvre.

PRF EVALUATION CAPABILITY which helps to evaluate the threat danger. Obviously when a Rangefinder is involved, the time available between firing and salvo hit is only a few seconds if we consider the bullet speed, whereas the time available is longer when dealing with a missile system. The speed of missiles is about 300 m/sec against a speed of 1200 m/sec for bullets.

HIGH RELIABILITY is a self explanatory characteristic.

The other technical characteristics regarding the installation aspects are weight, volume and RWR integrability.

MINIMUM WEIGHT is needed since an increase of weight of the helicopter reduces its endurance: a weight increase means unmistakably less petrol on board.

LIMITED VOLUME is necessary because the space available on board the helicopter is limited whereas the systems to install are many.

RWR INTEGRABILITY is an essential characteristic of human engineering which avoids the duplication of displays having practically the same funtions, (Warnings signals of a possible threat and information on some of its characteristics).

COST is to be kept at a minimum while maintaining reasonable performance to avoid an excessive Fly Away Cost of the helicopter.

Lets now examine the characteristics of the LASER WARNING RECEIVER developed by SISTEL. This device is a prototype system which was tested in laboratory, field and flight conditions. (Fig.8)

Three parts are the main elements of the system: two interchangeable double sensors and an electronic box which are connected by two cables.

The principle of operation is the following: each sensor covers an angular sector of more than 90 degrees (about 135 degrees) in the horizontal plane thus giving four different channels for a total horizontal coverage of 360 degrees.

The transmitted signal may be received normally only on one or two sensors due to the mechanical configuration of the two sensing parts.

In fig.9 the situation which characterizes each channel by varying the angle of arrival and the intensity of the received signal is shown.

Each channel (sensor) is hit by the laser beam as a direct consequence of the angle of arrival of the transmitted pulses thus receiving a larger or smaller amount of incident energy. The number of lines represent in fact the level of the signal received by each sensor.

In the picture, the four channels are identified with the letters F.R.C. (Forward Right Channel), F.L.C. (Forward Left Channel), R.R.C. (Rear Right Channel) and R.L.C. (Rear Left Channel) while the effective helicopter axis is also identified.

The answer shown in Fig.9 is only theory because of the following effects:

1) shadowing and effective Field of View (FOV) of the four sensors (about 135 degrees each);

2) for the assumption that the received signal is perfectly matched to the maximum discernible level detectable by the sensor.

In the block diagram of the LWR (Fig.10) only one channel has been represented being that the others are exactly equal.

The received signal is spectrally filtered with an hermetic window to pass only the signals belonging to the expected bandwidth with rejection of the background and of other disturbing signals. Then it is collected by the sensitive element and amplified with a high dynamic (logarithmic) amplifier (6 decades).

The amplified signal is processed by a bank of six threshold comparators which identify six different power levels and then the output is supplied to the display. The output of the lowest threshold comparator of each channel is routed to a logic OR gate which enables the buzzer, the optical warning signal and the circuit for PRF measure which is presented in a digital format.

The technical specs of the SISTEL LWR are shown in Fig.11-12-13 and 14.

Regarding the performances of the system, Laboratory and Field Tests have been carried out to check the Technical Specs.

Moreover, Flight Tests have been made by using a commercial ECUREIL helicopter with a provisional installation. (Fig.15)

The main characteristics of the Laser Rangefinder used in the tests are shown in Fig.16.

Such equipment is a single pulse Rangefinder and thus it does not match exactly the characteristics of similar equipment for AA applications but it has been used because of its availability and low cost. It must be noted that the advantage tied to the reception of a number of pulses from a high PRF Laser Rangefinder which gives an "average effect" was not present in the tests.

Some positions of the helicopter during the Flight Tests are shown in Fig.17 and 18.

The Flight Tests were carried out with the helicopter in hovering conditions at different distances, at different altitudes and with variable bearing (steps of 30 degrees) with respect to the Laser Rangefinder. Fig.19 illustrates the test and meteo conditions.

The obtained results are summarized in Fig.20.

Test No.1 has been made at distances between 1000 and 1500 m., Test No.2 at ranges beween 200 and 600 m., Test No.3 at ranges between 1300 and 1800 m. and field background at 2000 m. and Test No. 4 at ranges between 1500 and 1650 m. and wood background at close distance. In Test No.5 the ranges were between 3100 and 3400 m. and the Test No.6 was made at distances between 4000 and 4500 m. (The values of the flight altitudes must be considered as purely indicative since they have been derived from the helicopter barometric altimeter).

Such results are considered reasonably good bearing in mind:

1) the reduced visibility in which tests were carried out which gave a lower received power (consequent to the higher atmospheric attenuation);

2) the difficulties in aiming the helicopter due to the presence of wind gusts which caused problems to keep hovering and drift in the line of sight between the Laser Rangefinder and the helicopter;

3) the variations in the attitude of helicopter during the different shots.

The installation used for the test is certainly worse than a real one especially for the reflections collected by the two rear sensors but the there was a mandatory need to avoid heavy modification to the used helicopter.

The installation of this LWR is particulaly attractive due to:

- reduced dimensions
- reduced weight
- significant length of interconnecting cables (which may reach 10 m).

This allows:

A) a wide choice of possible position (with the only prescription that the field of view of the sensors must be without obstacles);

B) no effects or insignificant effects on the helicopter aerodynamics.

The present activities on the LWR are (Fig.21)

- Provision of a new command from the fire control computer for blanking of the receiver during the operation of onboard laser.
- Implementation of a new interface circuit according to the specification of MIL 1553B General Purpose Aircraft Data Bus.
- Spectral bandwidth response extension to cover the band 1.2-11 /u which is characteristic of a new and growing family of laser threat.

- Environmental testing and qualification in order to assure device compliance with MIL-E-5400T class B.

Regarding the spectral bandwidth extension it should be noted that the continuing evolution in military laser systems signed its technical milestone in the last year with the shift of the most popular devices from RUBY laser to Nd-GLASS and subsequently to Nd YAG.

Operationally, this shift allowed the addition of target designation and line of sight illumination to the traditonal ranging functions. In line with such an evolution, the tendency of using longer wavelength are affirming steadily in laser telemetry and designation devices for the 90's. This is due essentially to a reduction in cost and an increase in efficiency and reliability of such devices together with the following operational and technical aspects:

1) longer wavelength lasers have a better penetration of haze, mist, smoke and dust clouds;

2) increased eye safety for the personnel;

3) reduced detectability of the laser beam.

Laser Warning Receivers have now to face threats based on two new classes of lasers.

1) Rare earths (Ho, He) doped or Nd shifted lasers operating in the spectral band between 1.5 and 2.0 /u

2) CO2 lasers operating in the spectral band between 9.5 /u and 11.6 /u with typical emission at 10.6 /u.

The first kind is compatible with optical and TV systems operating in the visible part of the spectrum or in the near infrared but have only limited operational advantages.

On the other hand, CO2 lasers have reached a growing interest because they fully have the before mentioned operational advantages and also show a total compatibility with thermal vision equipment operating in the long wave infrared (LWIR) band (8-12 /u).

To detect this kind of threat another detector per quadrant is needed. In fact, silicon sensors are still mandatory to detect lasers signals in the more common spectral band of near infrared (0.65 /u 1.1 /u) for radiometric sensitivity reasons. It is also necessary to modify the hermetic window of the sensor head and to bear an increase in weight, dimensions and cost. The technical extension of the operation of a direct detection-orthogonal sensor axis device from one spectral band to two spectral bands is very straightforward (Ref. 1).

The only thing needed is to verify that the radiometric sensitivity in both spectral bands is sufficient to detect the laser radiation with high probability and that the angular sensor response is regular and extended so that correct angular indication can be generated using difference signal from adjacent channels.

Both conditions are met in the implemented project.

For radiometric sensitivity, Fig. 22 shows the signal to threshold ratio in function of range in good meteorological conditions for a 1.06 /u Nd-YAG laser emitter while in the similar Fig. 23 a 10.6 /u CO2 laser is considered. The family of 4 different curves is computed for metric distances of beam axis to sensor ranging from 0 to 3 m. in 1 m. step.

For angular response Fig.24 is to be referred to. It shows in logarithmic scale the response of two orthogonal Si sensors to the incoming radiation in function of the angle between first sensor axis and beam axis. In Fig.25 the same diagram for Hg Cd Te sensors is shown.

Preliminary tests carried out on a pair of liquifying Ni temperature cooled LWIR Hg Cd Te sensors having the peak responsivity at a wavelength of 11 /u and critical wavelength at 10 percent responsivity of 12 /u confirm that a nominal radiometric sensitivity sensor with angular noise of 10 degrees rms are obtained in laboratory conditions.

The assembly of a complete unit is presently in progress and Field Tests will commence in the next few months while Flight Tests will be completed within the year.

REFERENCE

1. Khalil Seyrafi, Ph.D., Electro-Optical Systems Analysis, Publication of Electro-Optical Research Company Los Angeles, California.

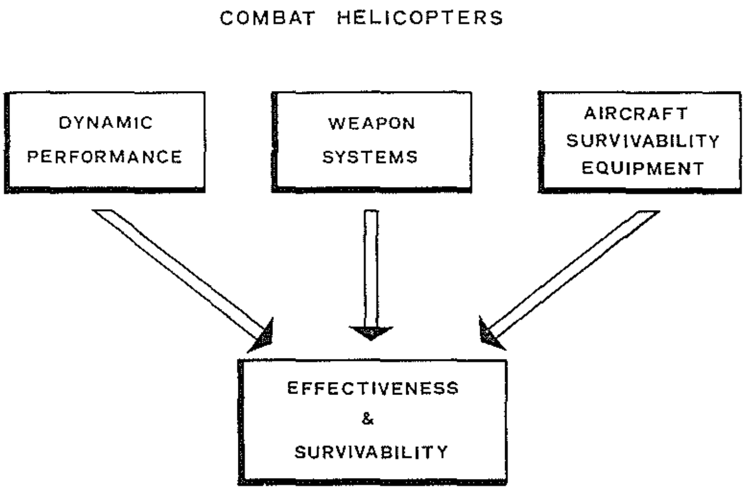

COMBAT HELICOPTERS
DYNAMIC PERFORMANCE
WEAPON SYSTEMS
AIRCRAFT SURVIVABILITY EQUIPMENT
EFFECTIVENESS & SURVIVABILITY

Fig. 1

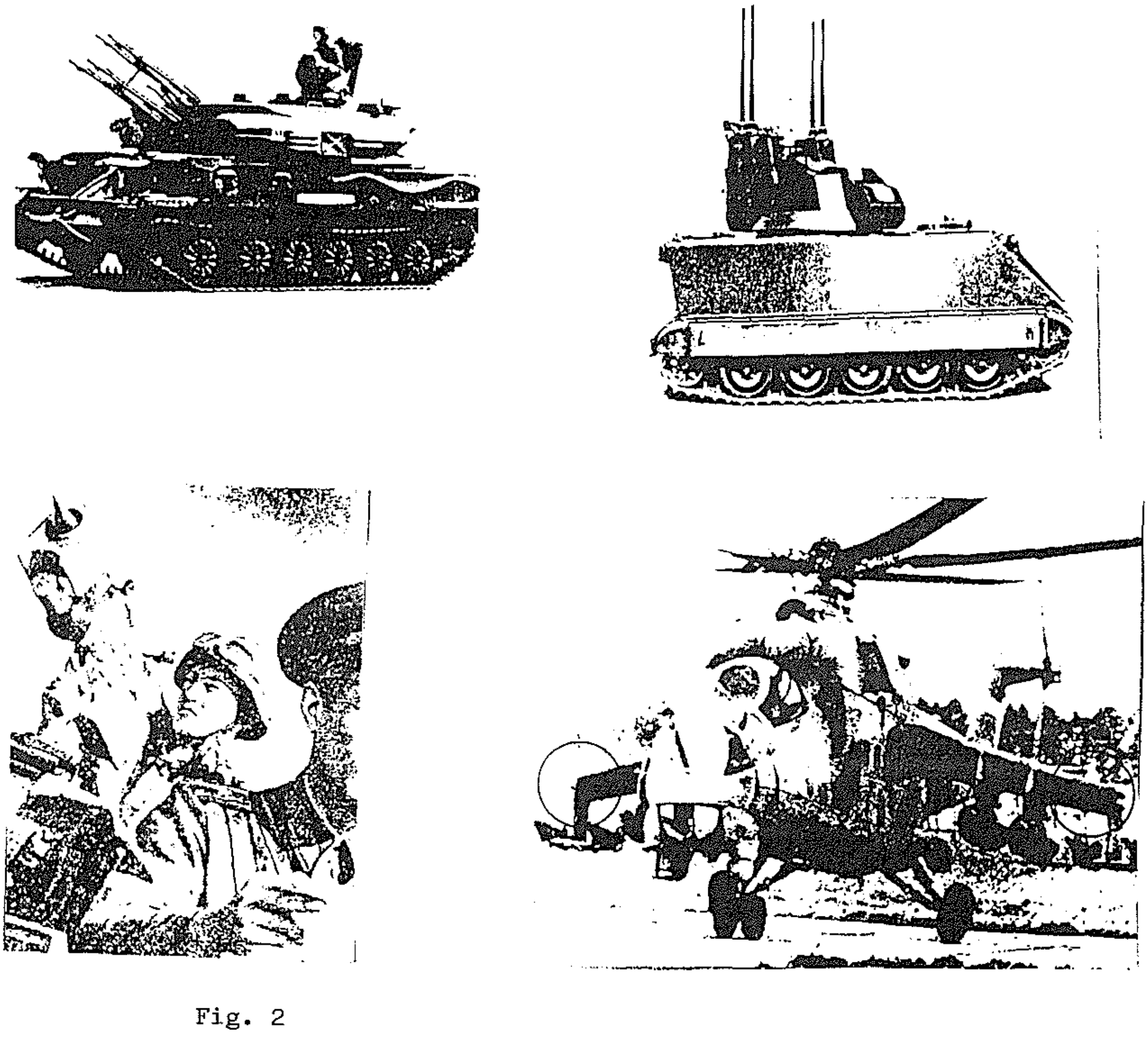


Fig. 2

THE LASER THREAT

LASER FUNCTIONS IN ANTI-AIRCRAFT SYSTEMS

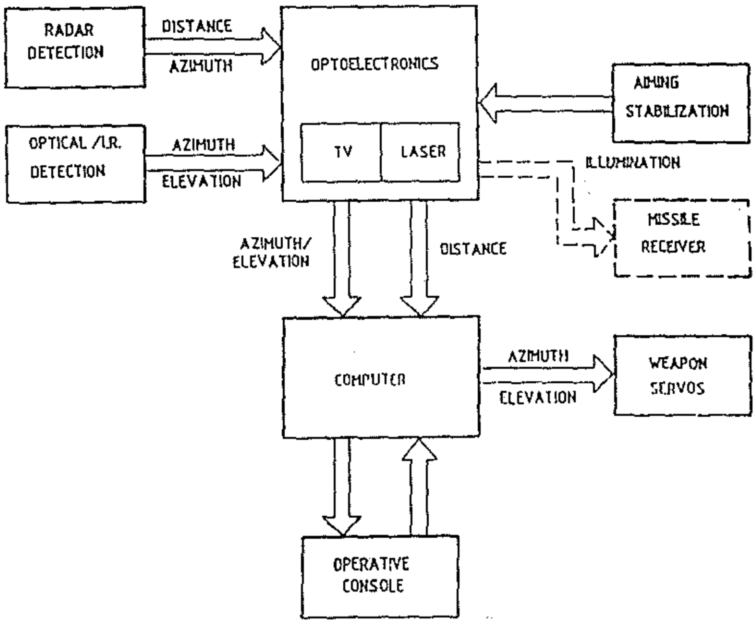


FIG. 3

THE LASER THREAT

PULSE REPETITION FREQUENCY (P.R.F.)

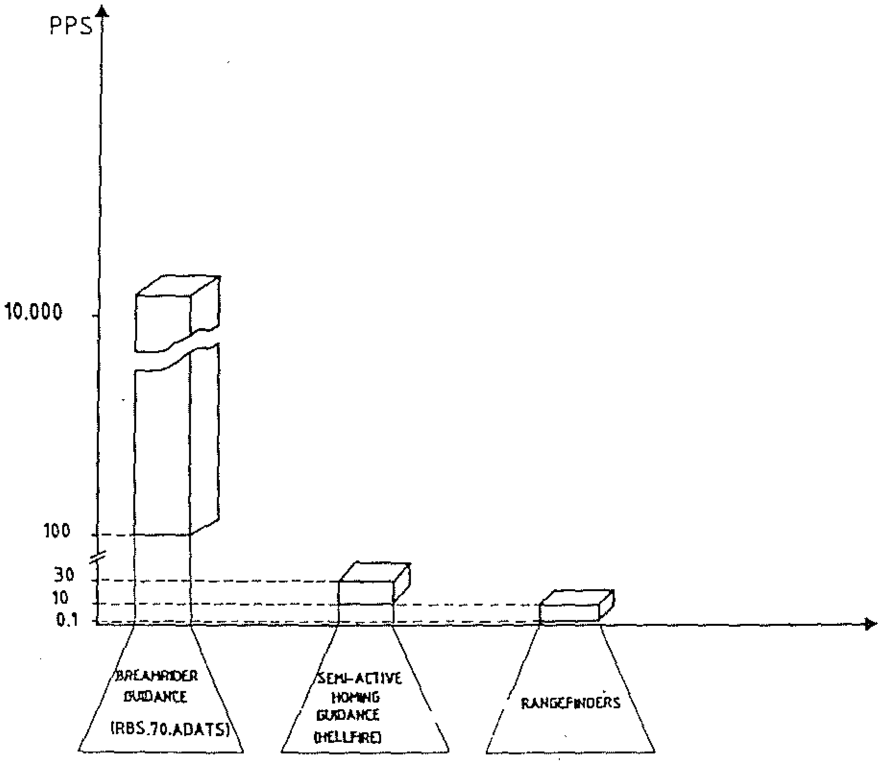
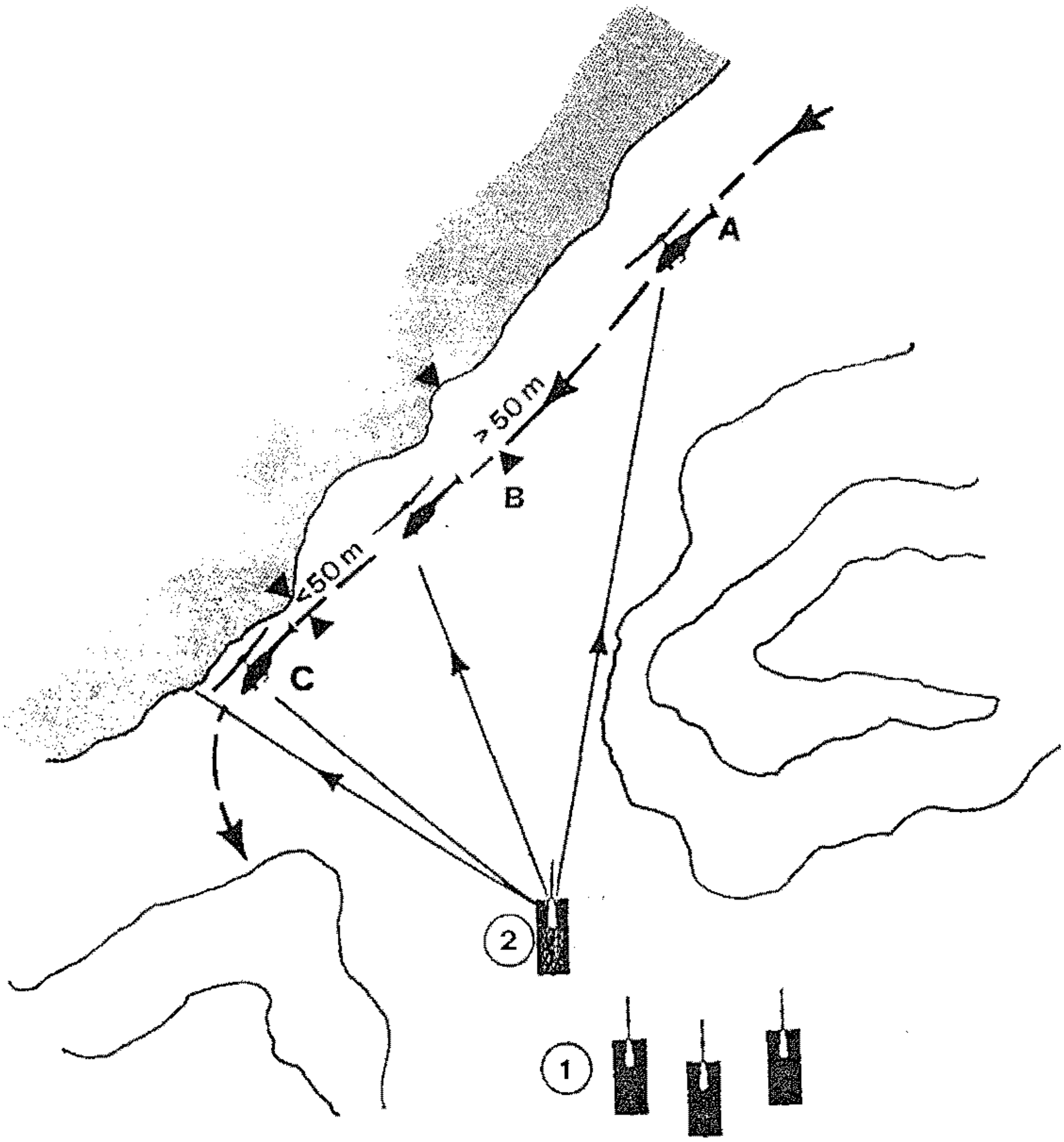


FIG. 3 BIS

TYPICAL TACTICAL SITUATIONS



① ARMORED ATTACKING UNIT

② SELF-PROPELLED ANTI-AIRCRAFT GUN

Fig. 4

LWR - OPERATIONAL FLOW CHART

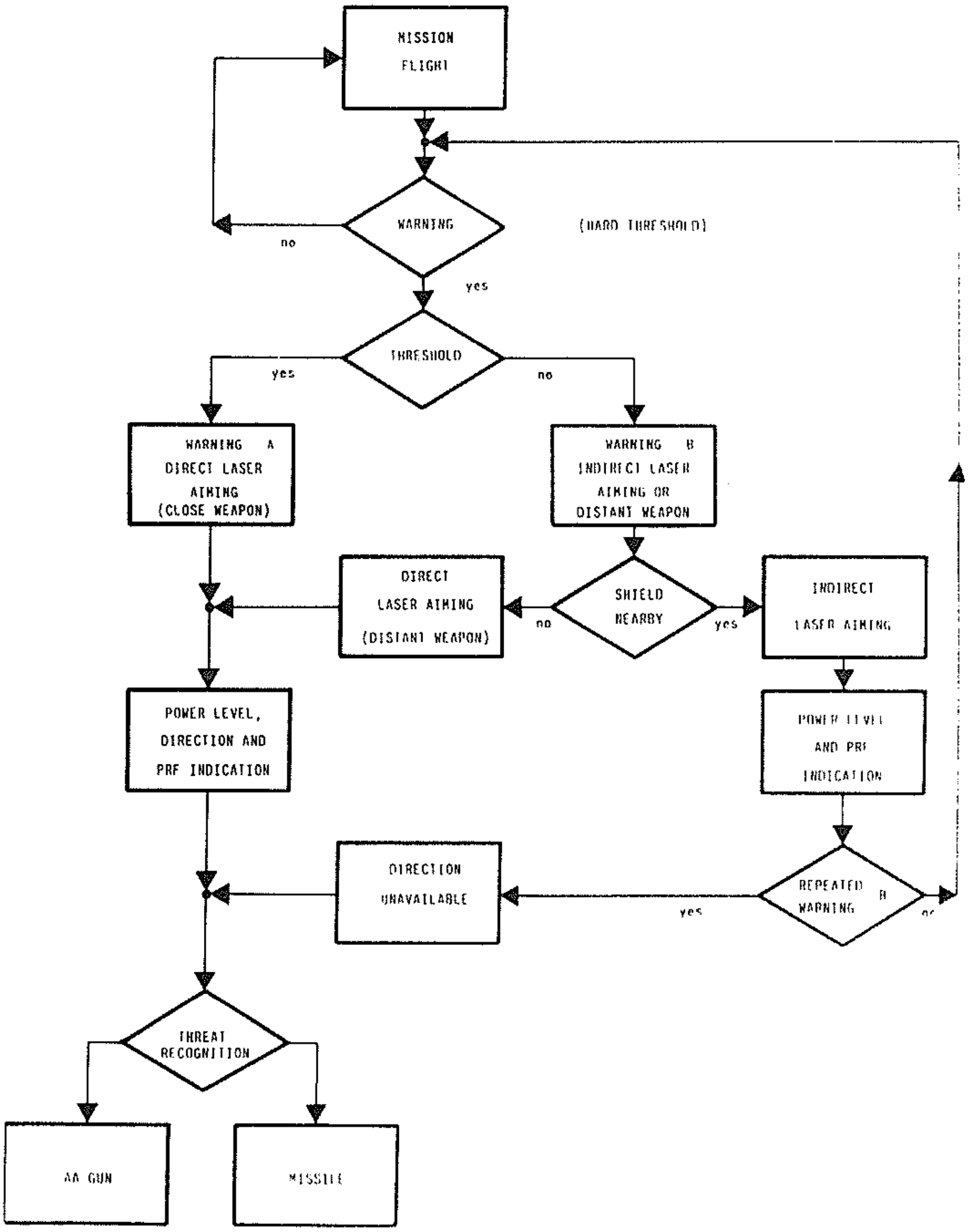
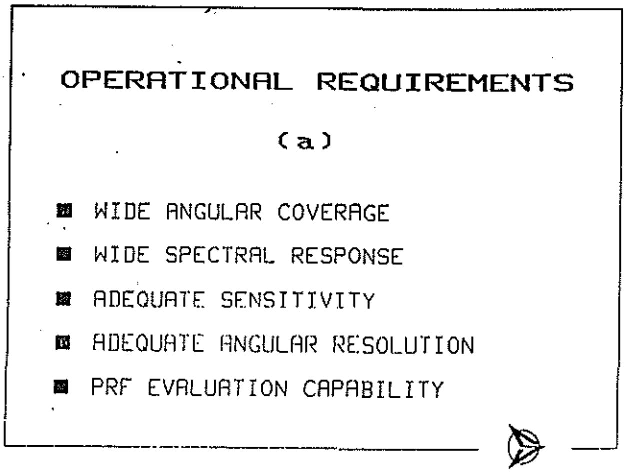


FIG. 5

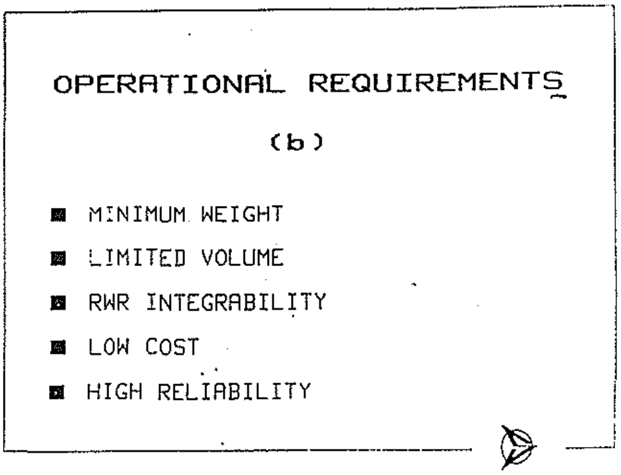


OPERATIONAL REQUIREMENTS

(a)

- WIDE ANGULAR COVERAGE
- WIDE SPECTRAL RESPONSE
- ADEQUATE SENSITIVITY
- ADEQUATE ANGULAR RESOLUTION
- PRF EVALUATION CAPABILITY

Fig. 6



OPERATIONAL REQUIREMENTS

(b)

- MINIMUM WEIGHT
- LIMITED VOLUME
- RWR INTEGRABILITY
- LOW COST
- HIGH RELIABILITY

Fig. 7

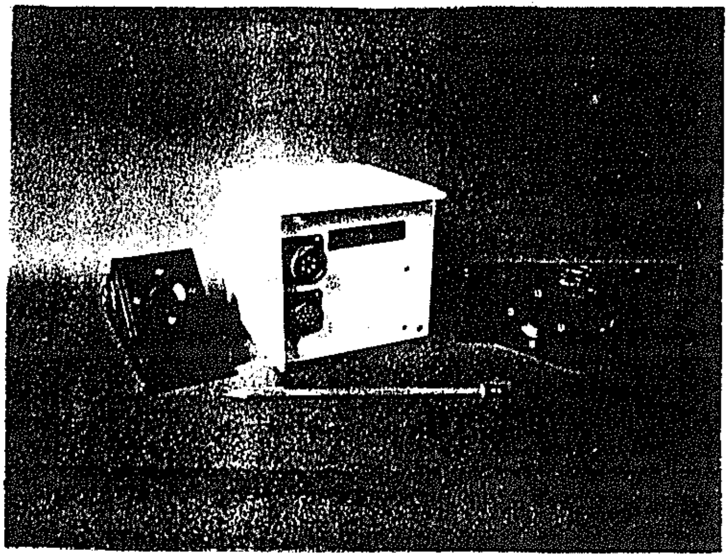
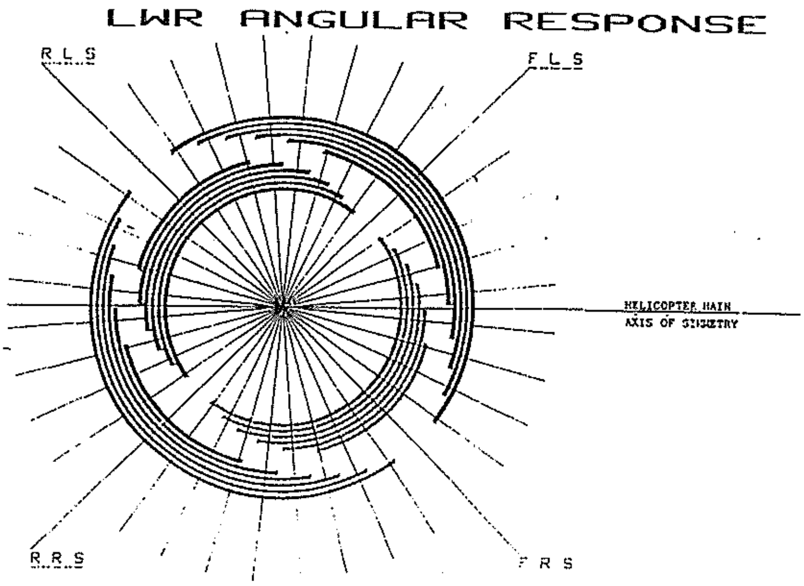


Fig. 8



LWR ANGULAR RESPONSE

Fig. 9

LASER WARNING RECEIVER

ONE CHANNEL BLOCK DIAGRAM

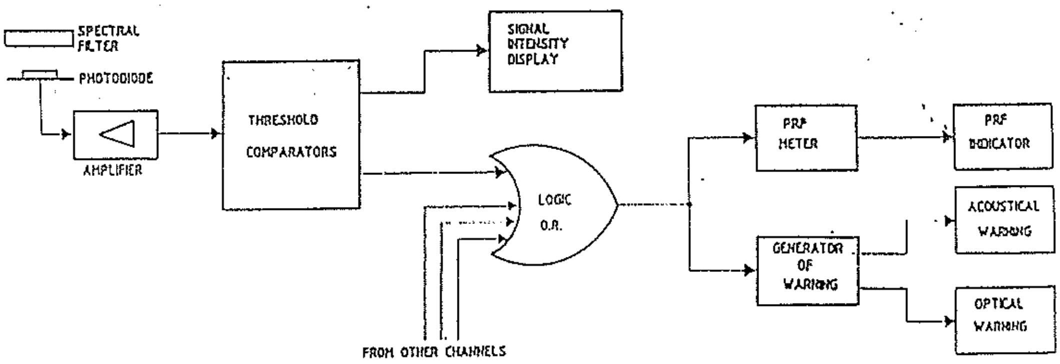
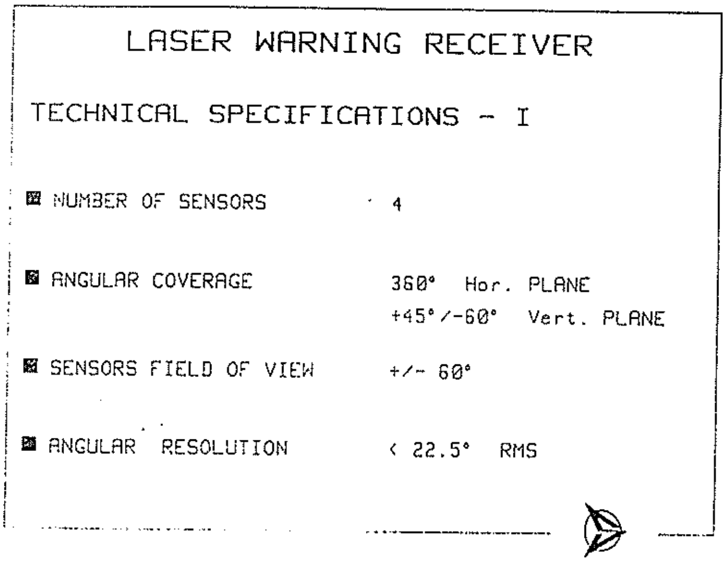


Fig. 10

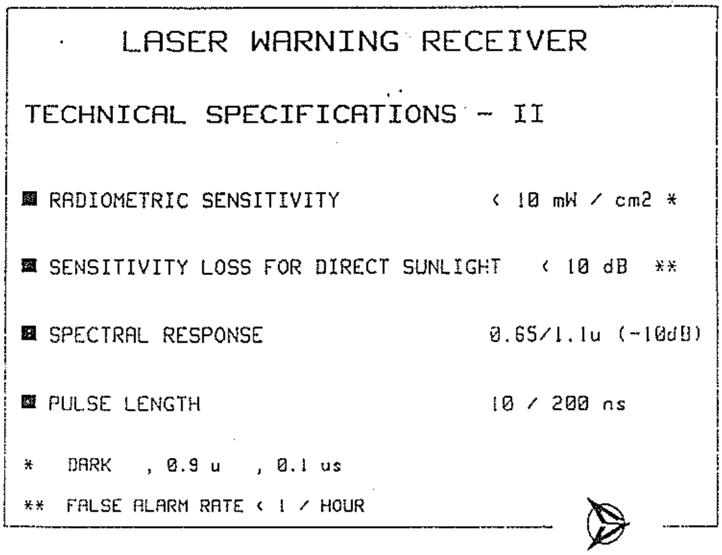


LASER WARNING RECEIVER

TECHNICAL SPECIFICATIONS - I

- ■ NUMBER OF SENSORS 4
- ■ ANGULAR COVERAGE 360° Hor. PLANE
+45°/-60° Vert. PLANE
- ■ SENSORS FIELD OF VIEW +/- 60°
- ■ ANGULAR RESOLUTION < 22.5° RMS

Fig. 11



LASER WARNING RECEIVER

TECHNICAL SPECIFICATIONS - II

- ■ RADIOMETRIC SENSITIVITY < 10 mW / cm2 *
- ■ SENSITIVITY LOSS FOR DIRECT SUNLIGHT < 10 dB **
- ■ SPECTRAL RESPONSE 0.65/1.1u (-10dB)
- ■ PULSE LENGTH 10 / 200 ns

* DARK , 0.9 u , 0.1 us

** FALSE ALARM RATE < 1 / HOUR

Fig. 12

LASER WARNING RECEIVER

TECHNICAL SPECIFICATIONS – III

■ MEASURED PRF (4 INDICATORS)	0.01/20000 Hz
■ POWER DISCRIMINATION	6 LEVELS
■ INDICATION OF BEAM DIRECTION	32 SECTORS
■ WARNING SIGNAL INDICATIONS	OPTICAL/ACOUSTICAL
■ POWER SUPPLY	28 V DC ,1 A

Fig. 13

LASER WARNING RECEIVER

ADDITIONAL TECHNICAL SPECIFICATIONS – IV

■ NUMBER OF SENSORS		4 Hor.+ 1 Ver.(OPT.)
■ COVERAGE		> EMISPHERIC
■ SERIAL INTERF.WITH RWR		EIA RS 422A (TALK ONLY) (MIL STD 188-114)
■ WEIGHT	– SENSORS	0.5 Kg (TOTAL)
	– ELECTRONICS	2.7 Kg
■ VOLUME	– SENSORS	1 LITER (TOTAL)
	– ELECTRONICS	2 LITERS

Fig. 14

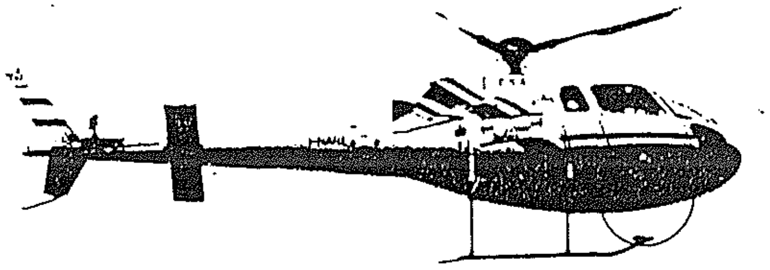
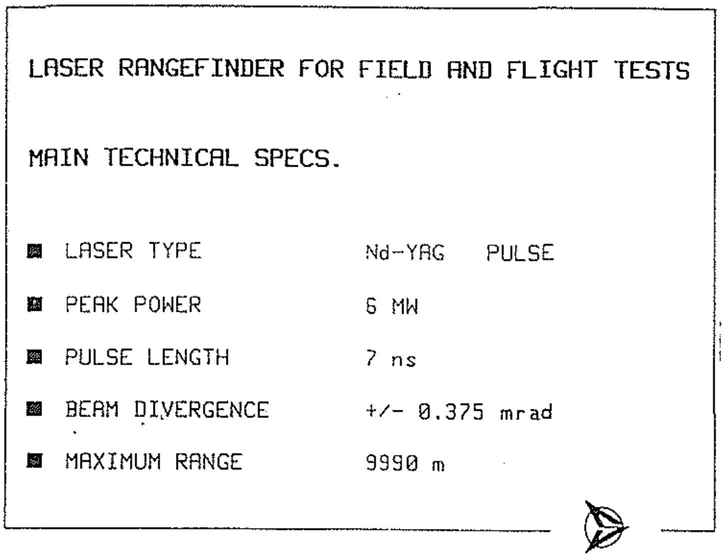


Fig. 15



LASER RANGEFINDER FOR FIELD AND FLIGHT TESTS

MAIN TECHNICAL SPECS.

▨ LASER TYPE	Nd-YAG PULSE
▨ PEAK POWER	6 MW
▨ PULSE LENGTH	7 ns
▨ BEAM DIVERGENCE	+/- 0.375 mrad
▨ MAXIMUM RANGE	9990 m

Fig. 16

Fig. 17

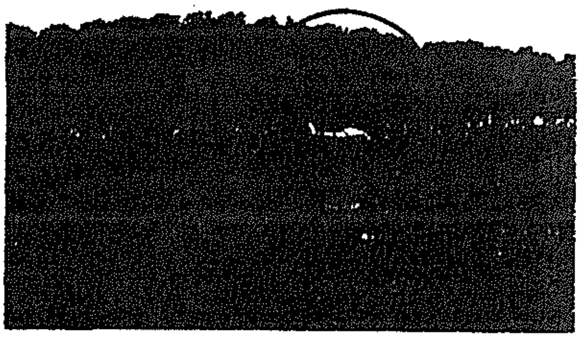
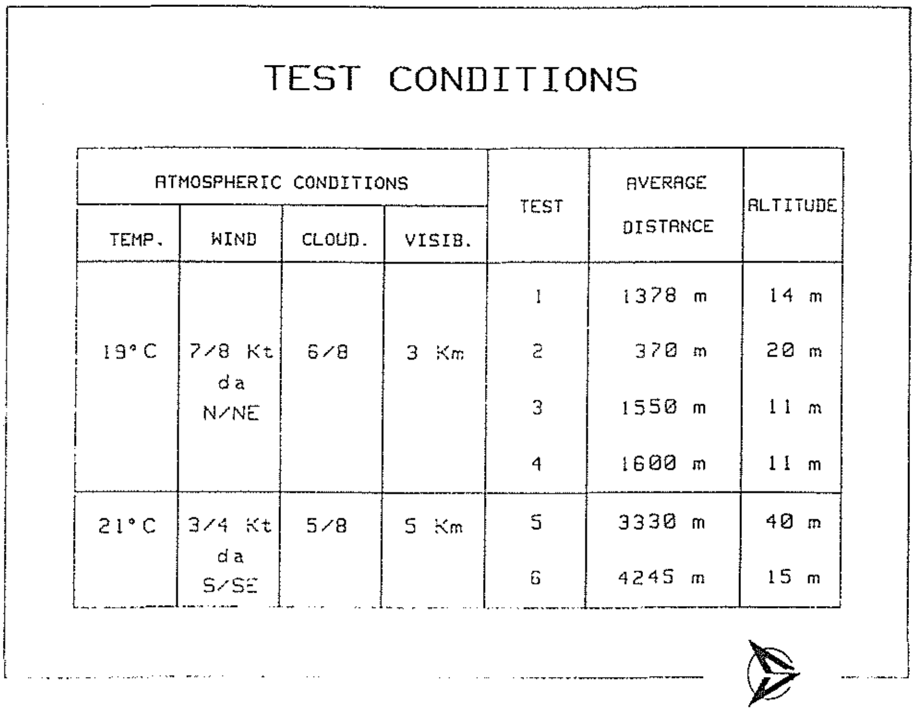


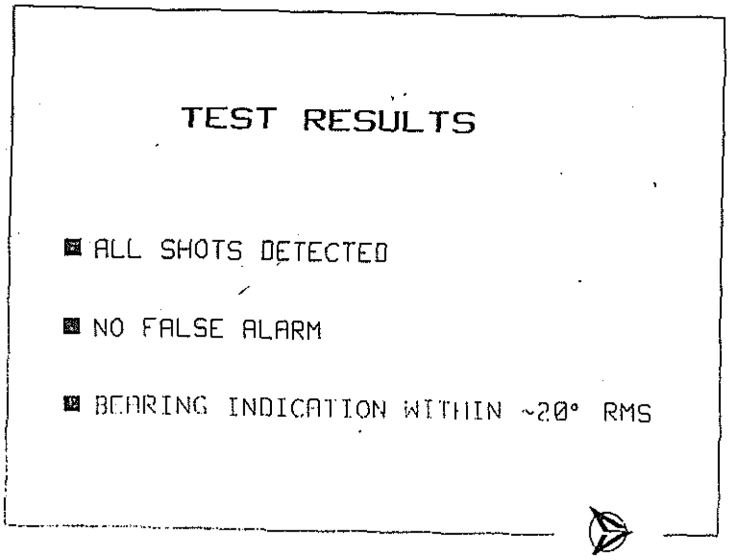
Fig. 18



TEST CONDITIONS

ATMOSPHERIC CONDITIONS				TEST	AVERAGE DISTANCE	ALTITUDE
TEMP.	WIND	CLOUD.	VISIB.			
19°C	7/8 Kt da N/NE	6/8	3 Km	1	1378 m	14 m
				2	370 m	20 m
				3	1550 m	11 m
				4	1600 m	11 m
21°C	3/4 Kt da S/SE	5/8	5 Km	5	3330 m	40 m
				6	4245 m	15 m

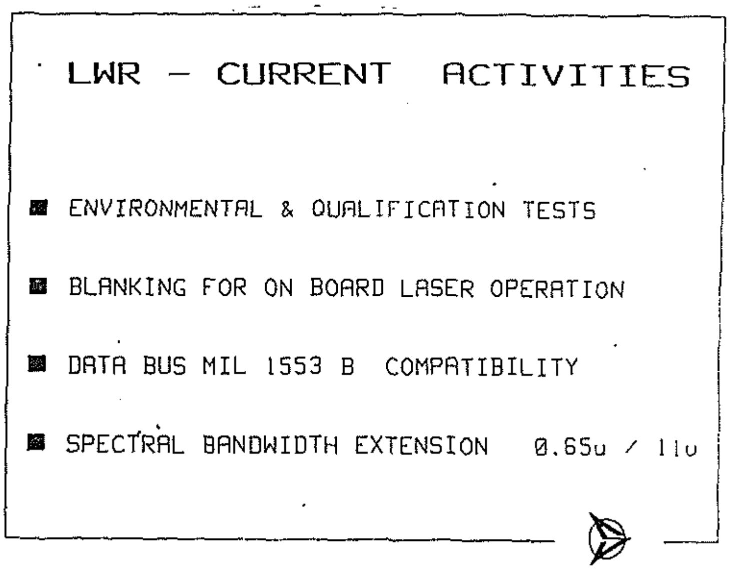
Fig. 19



TEST RESULTS

- ALL SHOTS DETECTED
- NO FALSE ALARM
- BEARING INDICATION WITHIN ~20° RMS

Fig. 20



LWR – CURRENT ACTIVITIES

- ENVIRONMENTAL & QUALIFICATION TESTS
- BLANKING FOR ON BOARD LASER OPERATION
- DATA BUS MIL 1553 B COMPATIBILITY
- SPECTRAL BANDWIDTH EXTENSION 0.65u / 11u

Fig. 21

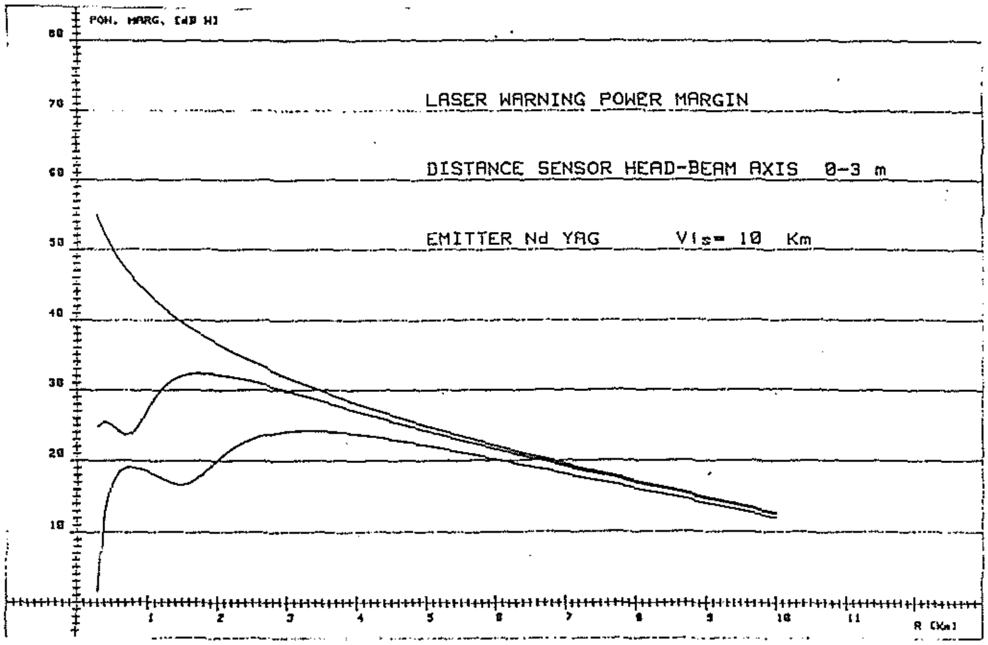


Fig. 22

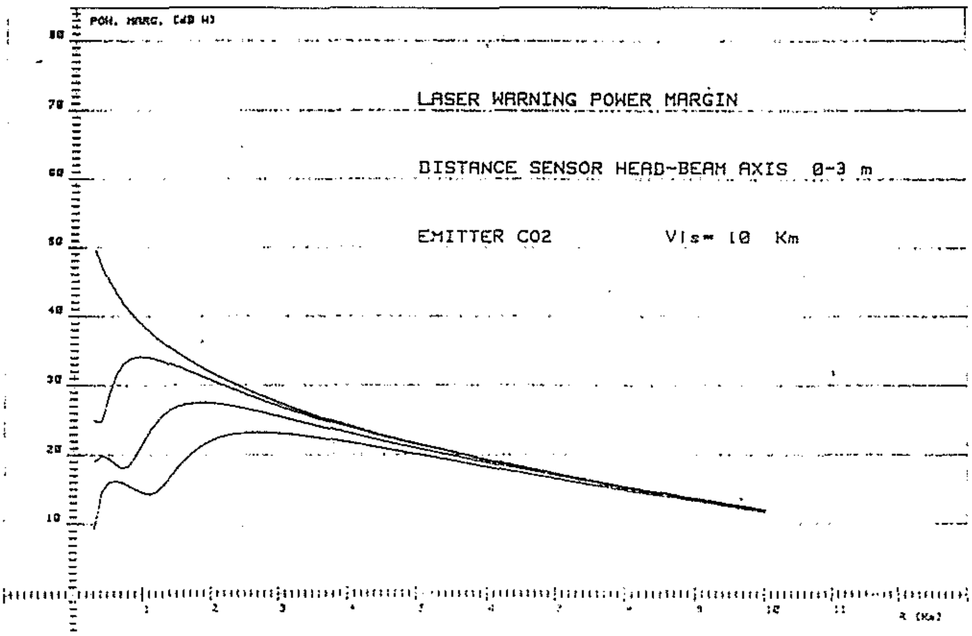


Fig. 23

Laser Warning Angular Response - NdYAG Sensor
Da= 21.0 H= 6.3 Dp= 11.3

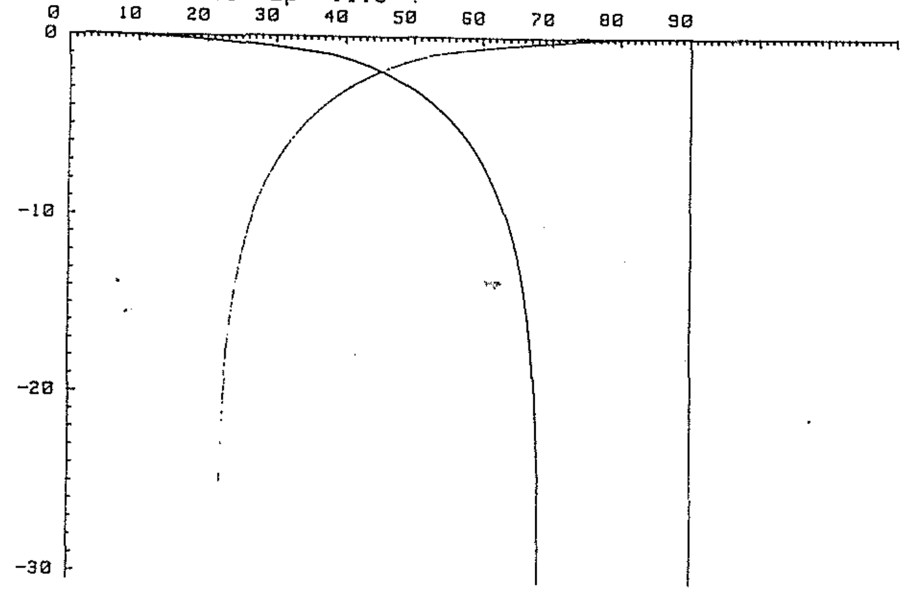


Fig. 24

Laser Warning Angular Response - CO2 Sensor
Da= 8.5 H= 3.2 Lx= 3.6 Ly= 1.0

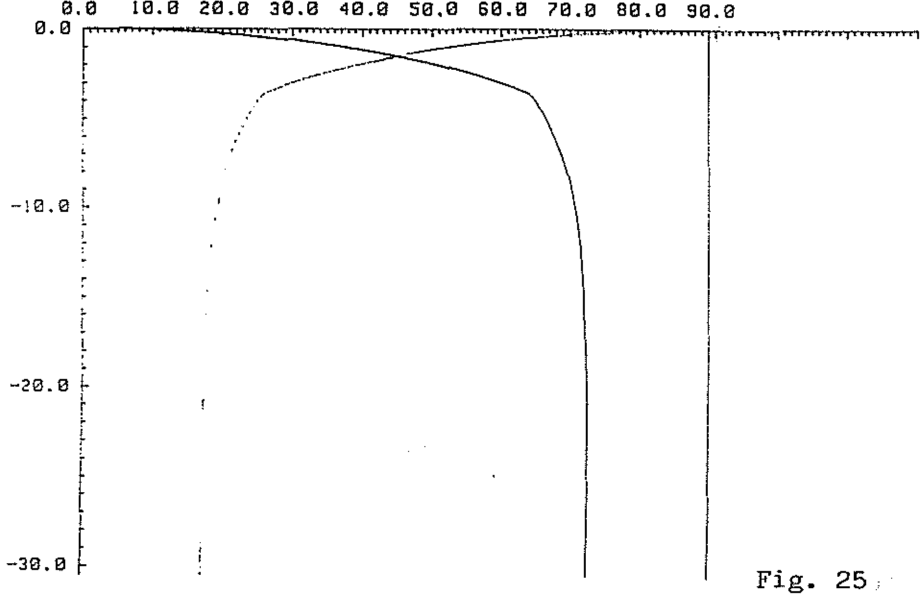


Fig. 25