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AIRBORNE PROXIMITY WARNING INSTRUMENT LABORATORY TESTS

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FINAL REPORT

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16. Abstract

An Airborne Proximity Warning Instrument (APWI) designed and manufactured by Rock Avionics, New York, was subjected to a short laboratory test at the Transportation Systems Center to determine the suitability of this product for further evaluation as an aid to visual detection of other aircraft. The test results were affirmative with regard to the parameters tested: namely, sensor pattern and freedom from false alarm. Sensitivity was tested only to ascertain the feasibility of field and/or flight tests.

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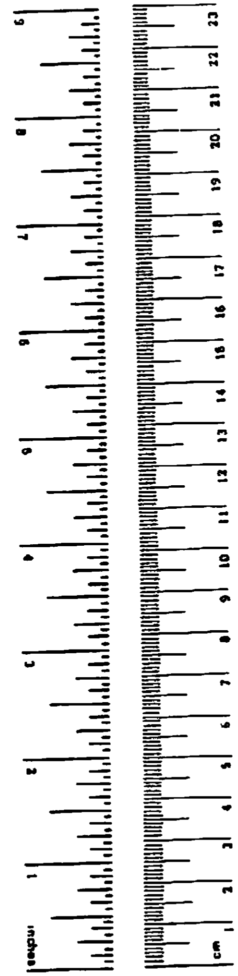
PREFACE

The search for a practical and effective anti-collision device that is economically within reach of the average owner or operator of General Aviation Aircraft has gone through several design development and test cycles. Among a large number of concepts suggested or realized at one time or another, the ingrared-sensing approach has proven to offer a low level of system complexity, and a well-understood technology. The present document reports the results of a laboratory test of a Proximity Warning Indicator (PWI) developed by Rock Avionics, that meets the effectiveness criteria generally applied to a system designed to operate under conditions when Visual Flight Rules (VFR) are applicable.

METRIC CONVERSION FACTORS

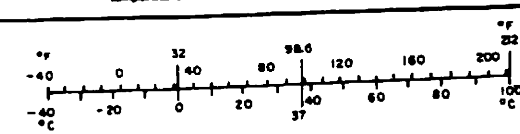
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. BACKGROUND

Early in FY75, the Transportation Systems Center performed a basic laboratory test on an Airborne Proximity Warning Indicator developed and manufactured by Rock Avionics. A brief account of the background of this instrument's development and of related government activities will serve to illuminate the test objectives.

In 1968, a team of scientists at NASA Electronic Research Center (ERC) in Cambridge investigated the feasibility of using electroptical devices for the detection of aircraft, using as a signal source the Xenon "strobe" lights frequently used as anti-collision lights on aircraft. This activity coincided with Proximity Warning Indicator (PWI) research activities then conducted under the sponsorship of the FAA (Cf. L. Leigh, IEEE, March, 1970). At that time, Loral Corporation was in the process of developing an electro-optical PWI based on the same concept and one of their units was acquired and subjected to a flight test, whose outcome however, was inconclusive. In June 1970 NASA activities at ERC ceased and the Center was reorganized under the Department of Transportation as the Transportation Systems Center (TSC). Under FAA sponsorship, a new team undertook a new, much more elaborate test of the Loral equipment, together with extensive PWI applied research. The results of that test were that while the equipment demonstrated the practical soundness of the basic concept, the design approach used had resulted in a number of functional deficiencies that rendered this particular equipment impractical, though superior to rival designs. The results of these tests were described in several reports published at TSC (Ref. Gorstein, et al Laboratory Tests; Phillips et al flight tests).

The primary problem areas of the Loral Equipment were: (1) Excessive lobing of the patterns of the multiple sensor arrangement resulted in an extremely uneven range coverage of the field of view of the device, with clearly inadequate range capability in some directions; and (2) an unacceptable high susceptibility to noise from external and internal sources, resulting in a very high false alarm rate.

During the same time period, the Collision Prevention Advisory Group (COPAG), a committee formed under the auspices of the FAA and representing the various user groups in the aviation community, generated a preliminary specification of the operational characteristics of a PWI, on the basis of theoretical considerations. Advances in solid state technology, combined with new insights into the nature of the channel characteristics of this type of system and the ongoing FAA effort in the PWI area, led to the development of a second-generation optical IR APWI by a newly formed team headed by the former Loral PWI program director, Mr. George Rock. Their efforts were directed towards an up-to-date, marketable, production-engineered and cost-effective system.

2. DESCRIPTION OF THE ROCK AVIONICS APWI

The Rock APWI combines the virtues of simplicity and goal-oriented design. It consists of two sensor heads, a signal processing unit which includes the power supply, and an indicator.

The sensor heads, identical except for their right and left mirror symmetry, are designed to mount in the wing tips of the aircraft behind transparent fairings. They are fully vibration isolated to guard against microphonic noise. Each sensor head contains two sensors, each of which covers a field of view (FOV) of about 60° by 12°. The two sensors are mounted so that their fields overlap by a few degrees. This general arrangement represents a fairly radical departure from previous designs and carries with it several implications deserving discussion in some detail: the 60° azimuth of the FOV of a single sensor means that the bearing resolution of the PWI is providing target bearing indication within a 60° sector, in comparison to the higher resolution offered by other PWI concepts previously tested at TSC. In addition, other concepts have been developed which offer coarser bearing isolations. The need for some bearing resolution in an APWI system has been established in a simulation conducted at TSC. Such relatively coarse resolution was previously not achieveable due to signal to noise ratio problems. Greater simplicity of this system probably outweighs the minor disadvantages of reduced resolution.

3. PERFORMANCE OF TEST

Tests were conducted on the Rock System in four areas: Beam Pattern; Noise Susceptibility; Multiple Target Capability; and Sensitivity. The test setup is shown in Figure 1; the results are shown in Figure 2.

The Rock Avionics designers accomplished this breakthrough by the application to a commercial product of a principle described in the literature as "channel-optics" and hitherto used only in specialized laboratory devices. The advantage of this approach is that while it provides the signal enhancing properties of large aperture, it is non-imaging and thus is capable of sensing signals while exposed to direct sunlight.

Physically, the sensor consists of a plastic precision cast cylinder lens, which operates in the refractive mode in elevation and in the reflective mode in azimuth, by virtue of an external coating on the four sides. The back portion of the solid lens contains the silicon diode, which forms the active part of the sensor. The sensor assembly also contains the preamplifier, which determines the system's bandwidth and provides the signals to the logic, noise control and threshold circuits.

The signal processing unit contains a novel application of computer technology to the task of signal discrimination. It is not described here because of its proprietary nature, but was tested for proper functioning.

3.1 PATTERN

The most extensive test performed concerned the sensor pattern of the system. An optical bench was set up, as shown in Figure 1. The light from an anticollision strobe was collimated so that a 3 inch diameter beam was formed. A sensor head was mounted on a double rotary head, permitting its orientation with respect to the beam through arcs of ±65° and ±6°. The test flash was directed through the center of a reflective screen, which was illuminated

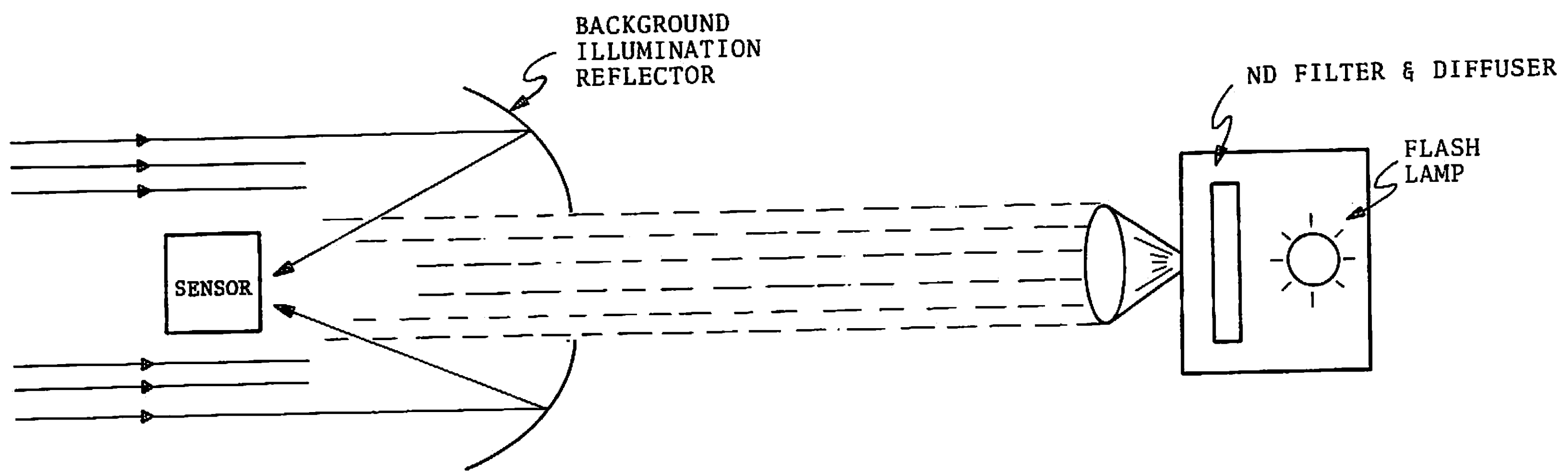

Figure 1. Basic Test Setup

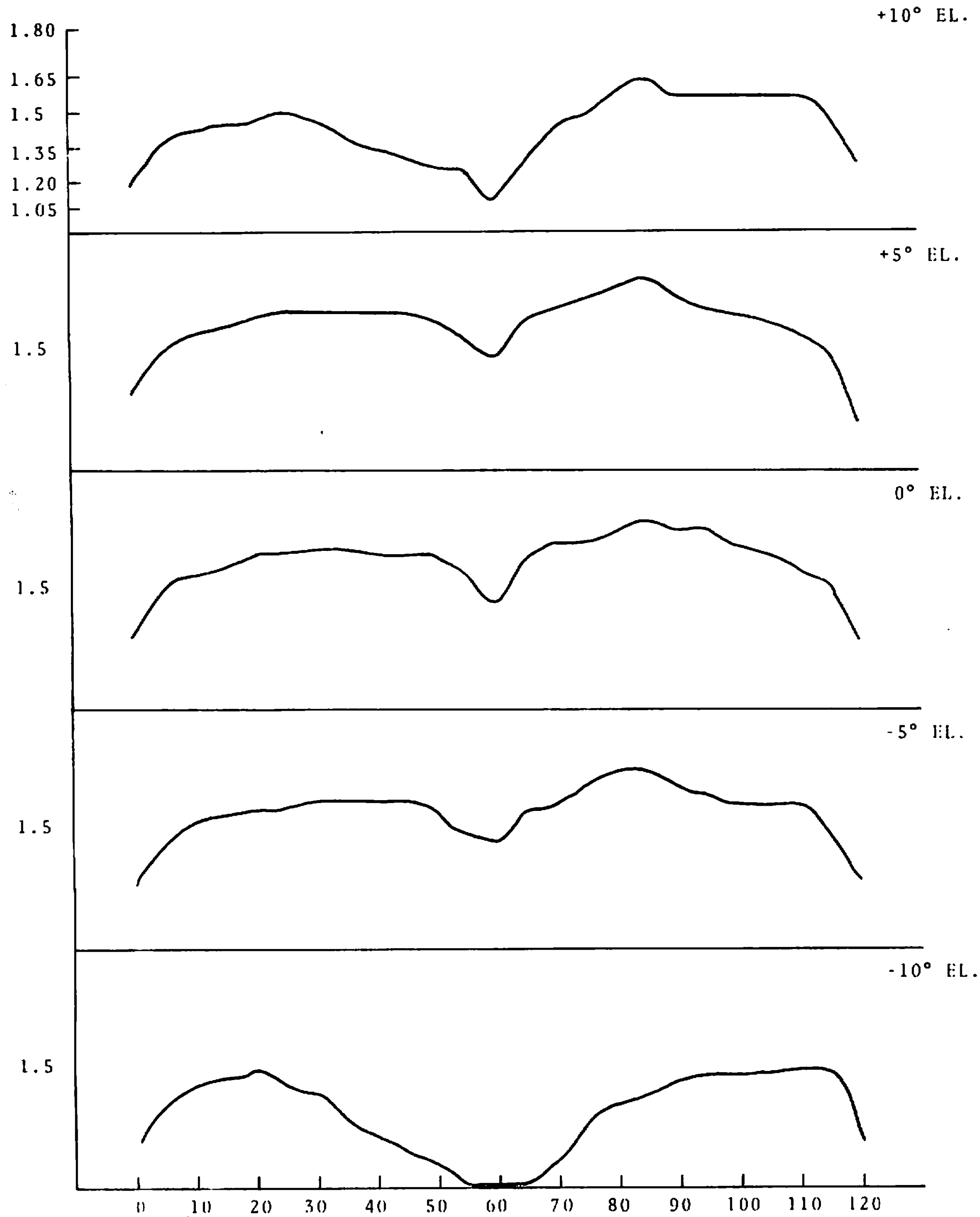

Figure 2. RANGE Variation vs Azimuth (Normalized)

alternately with a 100 watt desk lamp, and a 500 watt projection lamp, providing illumination levels comparable to light dusk and overcast daylight, respectively. The pattern measurements were all performed at the lower background illumination level. The intensity of the collimated beam flash was adjusted by field stops and neutral density filters so that during an exploratory sweep of the sensor head through its FOV, the signal did not saturate in the most sensitive positions and was strong enough to produce an aural alarm and bearing indication 2° beyond the corners of the FOV. At that intensity, five horizontal and two vertical sweeps were taken through the FOV of one sensor.

The results are shown in Table 1. The measurements were taken as analog peak signal voltages, read on an oscilloscope, with a monitor on the threshold DC voltage, which remained constant. Each datum point recorded represents the average value of ten observations. The other sensor head was spot checked at one upper and one lower corner and at the center of the field of each sensor. The data obtained being virtually identical with those of the first head, the pattern measurement was considered completed.

As the graph shows, the least sensitive point of the sensor pattern lies at -10° elevation at the junction of the two lobes. The present graphs are normalized to this poing, a procedure that may be regarded as overly conservative. In practice, it would be advantageous to the owner of such a device to optimize the coverage vs. range performance by physical adjustment of the two optical elements with respect to each other. Even without such adjustment, the range uniformity obtained was excellent.

3.2 FREEDOM FROM SPURIOUS ALARMS

A high noise level near the threshold detector will result in a high number of spurious alarms. A rigorous laboratory test to determine the frequency of false alarms requires a far more elaborate effort than available resources allowed. However, the test did provide a sufficient level of background illumination to provide reasonable assurance that under normal sky-illumination (1000 ft. lamberts) the spurious alarm rate should be low. During the

TABLE 1. DIRECTION SENSITIVITY BEARING ANGLE VERSUS MILLIVOLTS

Azimuth Angle	+10°	+5°	±0°	-5°	-10°
0	24	30	30	28	24
5	32	39	39	36	32
10	35	42	42	40	35
15	36	44	44	42	37
20	37	46	46	43	38
25	38	48	48	44	36
30	37	48	49	45	34
35	34	48	49	45	28
40	32	48	48	45	26
45	30	48	47	45	23
50	29	46	47	43	21
55	28	42	42	41	16
060	22	38	36	36	15
65	29	46	46	43	19
70	35	49	50	45	22
75	38	52	50	50	29
80	43	53	52	52	32
85	45	55	54	52	34
90	42	52	52	48	36
95	42	50	52	46	37
100	42	47	48	44	37
105	42	46	47	44	38
110	42	43	45	44	39
115	38	39	40	42	37
120	24	25	28	28	24

test, false alarms did not occur. The peak noise level, whenever observed, never exceeded 35-50 millivolt (at a threshold level of one volt). We must note, however, that background illumination is not the only source of noise. It can be stated that, on the basis of the remarkably noise free behavior under normal test conditions, and the corroborating statements of the manufacturer about the behavior of the instrument in a flight environment, that the chances for a successful flight test are not likely to be diminished by a high incidence of false alarms.

3.3 MULTIPLE TARGET CAPABILITY

While the unit was exposed to a series of flashes from an angle of about 10°, a second, non-synchronous flash source was energized, from an angle of about 110°. Both sectors indicated targets as required. Movement of the second source through the 100° arc toward the first source resulted in a double aural alarm, again as specified. This test demonstrated the required multiple target capability and should prove quite satisfactory in flight tests, as reported by the manufacturer.

3.4 ESTIMATE OF SENSITIVITY

The laboratory test of the Rock Avionics APWI did not permit a precise sensitivity test because the spectral transmission of the Infra red filter that forms part of the unit's optical system is unknown. In any event, the range of the device is a statistical measure depending on the illumination level and must be determined in a flight environment since the threshold voltage is a function of the total electronic noise level. The general performance of the device in the laboratory lends significant weight to the credibility of the manufacturer, who represents the instrument as attaining an operational range of 1.5 miles.

4. CONCLUSION

Reference 1, reporting on the flight performance of earlier IR sensitive APWI's, pointed to the need of improvement of suce systems with regard to range uniformity and freedom from spurious alarms.

On the basis of the simple tests reported here, it can be stated that the range uniformity over the field of view is better than 2:1 for the Rock Avionics APWI, as compared to 6:1 and worse for earlier systems.

Similarly, freedom from spurious alarms was remarkable on the unit tested at TSC.

It is recommended that this APWI be subjected to a flight test to determine its range performance, and its false alarm rate under operational conditions.