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AIRBORNE PROXIMITY WARNING INSTRUMENT LABORATORY TESTS

Ernst Meyer



JANUARY 1977 FINAL REPORT

DOCUMENT IS AVAILABLE TO THE U.S. PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

Prepared for U.S. DEPARTMENT OF TRANSPORTATION FEDERAL AVIATION ADMINISTRATION Systems Research and Development Service Washington DC 20591

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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 wellunderstood 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.

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METRIC CONVERSION FACTORS

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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 electrooptical 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 goaloriented 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 The need for some bearing resolution in an APWI system isolations. 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.

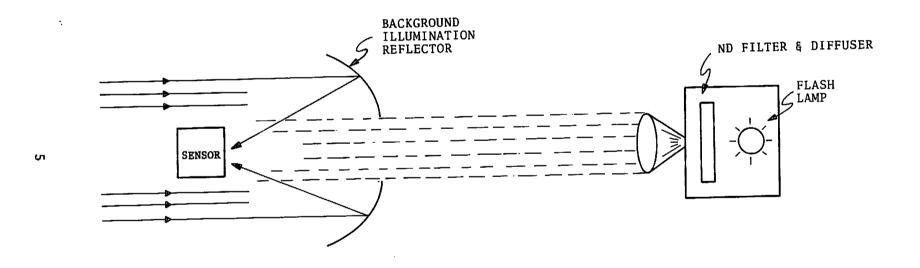
The Rock Avionics designers accomplished this breakthrough by the application to a commercial product of a principle described in the literature as "channel-optics" and hitherto used only in specialized laboratory devices. The advantage of this approach is that while it provides the signal enhancing 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 $\pm 65^{\circ}$ and $\pm 6^{\circ}$. The test flash was directed through the center of a reflective screen, which was illuminated



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Figure 1. Basic Test Setup

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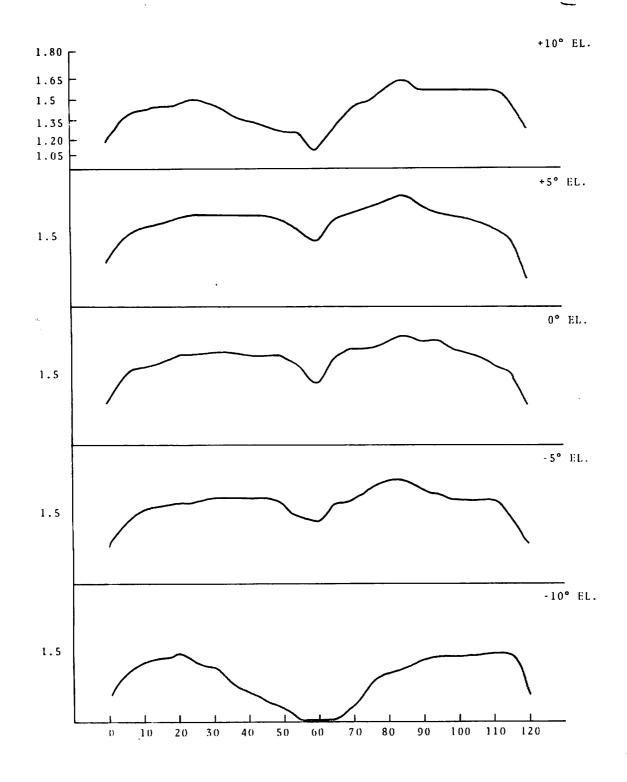


Figure 2. RANGE Variation vs Azimuth (Normalized)

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

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

TABLE 1. DIRECTION SENSITIVITY BEARING ANGLE VERSUS MILLIVOLTS

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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

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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.