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DEVELOPMENT OF A PORTABLE, PRECISION LANDING SYSTEM

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Abstract

A portable, tactical approach guidance (PTAG) system, based on a novel, X-band, precision-approach concept, has been developed and flight-tested as a part of NASA's Rotorcraft All-Weather Operations Research Program. The system is based on state-of-the-art X-band technology and digital processing techniques. The PTAG airborne hardware consists of an X-band receiver and a small microprocessor installed in conjunction with the aircraft instrument landing system (ILS) receiver. The microprocessor analyzes the X-band, PTAG pulses and outputs ILS-compatible localizer and glide slope signals. The ground stations are inexpensive, portable units, each weighing less than 85 lb, including battery, that can be quickly deployed at a landing site. Results from the flight-test program show that PTAG has a significant potential for providing tactical aircraft with low-cost, portable, precision instrument approach capability.

INTRODUCTION

A self-contained navigation system that could be set up with a minimum of ground-based equipment would expand the all-weather operating capability of tactical aircraft and rotorcraft. In an attempt to develop such a system, NASA Ames Research Center has been conducting research, originally with the University of Nevada, Reno, and most recently with the Sierra Nevada Corporation of Reno, Nevada, to develop novel, X-band precision-approach guidance systems for approaches and landings.

In the first phase of this effort, the detection of passive, ground-based corner reflectors using a device called an echo processor was successfully demonstrated.[1] Use of this passive-reflector detection scheme in the overland environment provides pilots with a target on their radar display, thus giving them the range and bearing information they need to make nonprecision, airborne radar approaches.

To expand on the echo processor technology, a second phase of the research program was undertaken with the objective of developing and demonstrating the feasibility of a weather-radar-based precision-approach concept. The feasibility criteria for this concept included 1) minimal, passive, or battery-powered ground-based equipment; 2) minimal airborne modifications, requiring at most an easy retrofit to current radar-equipped aircraft; 3) piloting techniques similar to those used for instrument landing system (ILS) approaches; and 4) precision-approach tracking performance.

Initially, a concept was pursued in which an array of directional passive reflectors oriented along the localizer track would provide the directional signals necessary to derive precision guidance. By using an on-board digital microprocessor installed in conjunction with the airborne weather radar, glide slope, and localizer guidance would be calculated and displayed to the pilot on the existing ILS course deviation indicator (CDI). The reflector-based ground station would consist of at least five and preferably eight reflectors and require no ground power. The spacing between reflectors must be longer than the typical 180-m (600-ft) pulse length of civil mapping radars. Therefore, the reflector-based ground station would require 1.2 to 2.1 km (4000 to 7000 ft) of terrain for installation. Although this requirement would not be a problem for aircraft landing on conventional runways, it would be impractical for heliports, and battle-damaged runways.

As an alternative to the radar reflector array, a program was conducted in 1982 and 1983[2] in which an X-band transponder beacon with multiple-pulse reply capability was modified to reply through an array of directional antennas (Fig. 1). The first-generation beacon-based ground station was packaged in an inexpensive, battery-powered, portable unit. Localizer and glide slope information from the on-board microprocessor were hard-wired into the aircraft's CDI, and a cockpit switch was required for switching between beacon landing system (BLS) guidance and ILS guidance.

Although the early testing of the BLS demonstrated its feasibility, the system had some undesirable features. For example, during BLS approaches, the weather/mapping radar had to be switched to use a wide-coverage, nonscanning antenna rather than the normal 30- to 45-cm (12- to 18-in.) scanning antenna. Therefore, during approaches, the radar was not available to the pilot for weather detection and obstacle avoidance. Also, the additional cockpit switch was considered undesirable because it increased the complexity of the aircraft modifications and created a potential for pilot error in selecting the proper switch position for ILS and BLS approaches. Early testing also established the need for antenna sizing studies to eliminate multipath interference problems. Also, although the colocated localizer and glide slope BLS was acceptable for rotorcraft, a split-site capability would be preferable for fixed-wing aircraft.

The most recent phase of the research program was designed to address the shortcomings disclosed in early BLS work, and to apply the BLS technology in the development of a split-site localizer and glide slope system for recovery of tactical aircraft. The current version of the landing system, called the portable tactical approach guidance (PTAG) system, operates independently of the airborne weather-mapping radar. An improved cockpit interface has been installed using existing ILS receivers. PTAG guidance information is reformatted in an ILS-compatible format and input to the airborne ILS receiver. Therefore, the pilot has no additional cockpit switches, and PTAG approach procedures are nearly identical to ILS approaches. Other features of the PTAG system include a more compact ground station, improved resistance to multipath interference, and split-site localizer/glide slope operation. This paper describes the PTAG concept, provides a description of the concept-demonstration system, and presents the results of the flight evaluation.

SYSTEM DESCRIPTION

PTAG incorporates many of the principles that are used in a standard ILS. The PTAG system and the ILS are both fixed-beam systems in which four directional beams are projected into space to provide localizer and glide slope information. The guidance in both systems is derived by beam-amplitude comparison. Operationally both PTAG and ILS provide a single-approach corridor, typically with the localizer course aligned with the runway and a glide slope of 3° emanating from the touchdown point.

The major differences between the PTAG system and the ILS are the carrier frequency, the glide slope beam-projection technique, and the beam-discrimination methods. First, the carrier frequency for the ILS beam is two orders of magnitude lower than the frequency for the X-band PTAG. Since antennas size to achieve a given beam width is inversely proportional to carrier frequency, the high frequency of the PTAG makes it possible to use small antenna at the ground site. Second, an ILS uses a ground-bounce technique to project the glide slope beams into space, while PTAG requires no ground-bounce, projecting the glide slope beams directly into space. Third, the techniques for discriminating between the four beams are very different. For an ILS, the ground signals are transmitted on a continuous wave (CW) basis, and they are tone-modulated for purposes of discriminating between the beams. ILS localizer and glide slope transmitters use separate frequencies, and channelization is accomplished using separate, crystal-controlled frequencies. PTAG uses multiple-pulse transmissions on a single frequency, with beam discrimation and channelization accomplished using pulse-position modulation techniques. The on-board microprocessor discriminates between the guidance beams based on the time sequencing of the pulses.

The PTAG system has several unique attributes which would be useful for many military tactical aircraft missions. To attain a comparable beamwidth, an ILS localizer antenna must be 85 times wider than a PTAG localizer antenna, and an ILS glide slope antenna must be 14 times taller than a PTAG glide slope antenna. Also, because PTAG does not require ground bounce for the glide slope beams, it does not require any surface preparation in front of the glide slope antenna. This makes PTAG well suited for landing sites where surface preparation would be impossible. Additionally, because of the narrow guidance beams and the pulsed transmission characteristics, PTAG has demonstrated resistance to multipath interference. Also, inherent in the pulsed-type system is a high resistance to signal jamming.

The PTAG system operates on the principle of four overlapping, narrow, X-band beams transmitted from highly directional antennas and oriented left, right, above, and below the desired flightpath. Figure 2 depicts the two beams that form the glide slope, one above and one below the desired flight path. With this beam orientation, as the aircraft deviates from the desired glide slope, one signal increases in amplitude and the other decreases. When both signals are of equal intensity, the aircraft is on the glide slope. Glide slope deviation from the desired course is proportional to the difference in received signal strength of the up-down beams. Localizer deviation is similarly derived using highly directional left-right beams. False course suppression on the localizer is provided by two sector antennas oriented left and right of the course. Similarly for glide slope, one sector antenna oriented straight out from the glide slope ground station provides false course suppression. The PTAG airborne processor compares the amplitude of the signals transmitted from the sector antennas with the signals transmitted from the highly directional antennas and rejects signals of lower amplitudes than those of the sector antennas. This eliminates false courses generated by beam sidelobes. A more complete description of the ground and airborne systems follows.

Ground-Based System

The PTAG ground-based system consists of two ground stations, each containing only a few components. Each ground station consists of an X-band transmitter, a microwave switch and its associated control logic circuitry, an antenna array, and a 24-Vdc battery.

The transmitter used for the concept-demonstration PTAG system is an X-band beacon. The beacon is modified so that for each ground station, four pulses are sequentially transmitted through the left sector antenna, the two precision antennas (left, right for localizer or up, down for glide slope), and the right sector antenna. On the glide slope ground station, there is only one sector antenna, which serves as both the left- and right-sector antenna. The beacon continuously squitters transmissions at a rate of 110 pulse-trains/sec for the localizer ground station and 115 pulse-trains/sec for the glide slope ground station. The difference in pulse-repetition rate between the localizer ground station and the glide slope ground station keeps the ground stations from transmitting in phase with each other.

These beacon transmissions are controlled by adding a switch-control logic circuit. This logic circuit is a single-pole, four-throw, solid-state microwave switch. It continuously switches between the four positions, allowing sequential transmission for the four beacon pulses through the four directional antennas.

As seen in Fig. 1, the four directional antennas used for the first-generation BLS ground station were standard 30-cm (12-in.) weather-radar, flat-plate antennas. These antennas were chosen for test purposes because of their low cost and availability, but testing revealed multipath problems associated with such small antennas. A study of antenna size versus system performance indicated that BLS antennas 60 to 120 cm (2 to 4 ft) in height would be best.

The current PTAG localizer ground station (Fig. 3) contains two highly directional antennas and two sector antennas. The glide slope ground station contains two highly directional antennas and one sector antenna. The highly directional antennas are 23 cm (9 in.) wide and 99 cm (39 in.) high; the two sector antennas are 8 cm (3 in.) wide and 51 cm (24 in.) high. Each highly directional antenna is appropriately oriented so that on the localizer ground station, one antenna provides the left beam and the other the right beam; on the glide slope ground station, one antenna provides the up beam and the other the down beam. These highly directional antennas have a 2.4° vertical beamwidth and a 10° horizontal beamwidth. The left-right antennas are aimed ±5.5° from the localizer centerline and are 4 dB down from peak gain when on the localizer course. The up-down beams are aimed ±1.2° from the desired glide slope and are 3 dB down from peak gain when on glide slope. These antennas allow for PTAG operations at glide slopes of 2.5° or greater. The sector antennas provide false course suppression in addition to proper localizer CDI indications up to ±35° from course centerline; they are aimed ±30° left and right of the localizer course (fig. 4).

This antenna arrangement provides precision, linear left-right guidance at angles up to ±5° from the localizer centerline, and sector-derived coarse guidance for full-scale fly-left/fly-right cockpit indications is available ±35° from localizer centerline. Deviations greater than ±35° from centerline result in off-flags.

The current ground station, incorporating the two highly directional antennas, the two sector antennas, the beacon, and microwave switches, is packaged on a compact, portable pallet (Fig. 3). Each ground station weighs less than 85 lb (including a 10-lb battery), is 66 cm (26 in.) wide, 119 cm (47 in.) high, and 33 cm (13 in.) deep. It requires 30 W (1.2A at 24 Vdc) of power, and can be set up by two people in less than 10 min. The adjustable feet on the base of the pallet make it easy to level and align.

Airborne System

The PTAG airborne equipment (Fig. 5) comprises a small X-band antenna, an X-band receiver, and a processor. It uses 15 W of 28 Vdc input power, and the PTAG equipment is easily interfaced with on-board avionics. The X-band antenna used in testing was a small waveguide/horn antenna 2.7 cm (1.06 in.) wide, 3.2 cm (1.25 in.) high, and 5 cm (3 in.) deep. The antenna is interfaced directly into the 400-cm^3 (24-$in.^3$) X-band receiver, and both are mounted in the aircraft's radome; the receiver bandwidth is 10 MHz. The processor uses a 16-bit digital microprocessor with analog to digital (A/D) and D/A converters. The processor analyzes the received X-band video signal to calculate localizer and glide slope deviation, and automatic gain control (AGC) for the receiver. The localizer and glide slope signals are output from the processor in ILS-format, tone-modulated signals on 108.1 MHz for localizer and on 334.7 MHz for glide slope. These ILS-format signals are input to the localizer and glide slope antennas lines using BNC "T" connections. The pilot simply tunes the ILS receiver to the frequency of 108.1 MHz and the PTAG guidance information is available on the CDI as if it were a standard ILS. Also the flight director and autopilot can be engaged on PTAG approaches in the same manner as would be accomplished on ILS approaches.

The current version of the processor has a volume of 1500 cm^3 (90 $in.^3$). A production version is expected to have a volume of less than 1000 cm^3 (60 $in.^3$) and to weigh less than 1.8 Kg (4 lb).

SYSTEM OPERATION

Figure 6 shows a trace of the four localizer guidance pulses and the four glide slope guidance pulses. For the glide slope pulses, the four pulses are spaced at 6-μsec intervals. For the localizer pulses, the first three pulses are spaced at 6-μsec intervals and the last one at a 9-μsec interval. The PTAG microprocessor is programmed to search for the two sector-antenna pulses that are 18-μsec apart and to identify them as glide slope framing pulses; similarly, it is programmed to search for the two sector-antenna pulses that are 21-μsec apart and to identify them as localizer framing pulses. When consistent sector-antenna returns are received, the largest of the four pulses is used to adjust the AGC voltage, keeping the X-band receiver in its linear range and ensuring that sidelobes of the directional precision-guidance antennas do not generate false courses. For each pair of guidance signals, the signal amplitudes are differenced, scaled, and filtered for output to the ILS formatting circuit in the PTAG processor.

FLIGHT-TEST PROGRAM

Initial flight tests of the BLS demonstrated the system's ability to achieve precision-approach tracking performance.[2] The PTAG flight-test program had the following objectives: to obtain pilot comments on the PTAG system as a whole, and in particular on the operational suitability of the ILS output module; to demonstrate improved resistance to multipath interference; to obtain data on system navigation accuracy; to determine the limits of PTAG localizer and glide slope coverage; and to search for any false courses of the localizer and glide slope. Maximum range and operationally feasible glides slopes were also determined. Resistance to multipath interference was tested by conducting flight tests at locations known to be susceptible to multipath interference. Data on navigation accuracy were obtained by flying approaches that encompassed the entire coverage on both localizer and glide slope. Limits of localizer and glide slope coverage in azimuth and localizer false courses were determined by flying constant-altitude, constant-range circular arcs in the front two quadrants. Limits of localizer and glides slope coverage in elevation and glide slope false courses were determined by constant-altitude fly-overs.

Aircraft

Two aircraft were used in the evaluation of the PTAG system. The primary aircraft was a Beechcraft Super King Air (Fig. 7). The King Air is a twin-engine turboprop with a gross weight of 5670 kg (12,500 lb). The maximum airspeed is 260 knots. The on-board avionics system allowed the left and right seats to be tuned to two different frequencies, thus allowing an evaluation of PTAG colocated with an ILS. During flight testing, two pilots (typically a NASA pilot and a guest evaluation pilot) and two to four experimenters and observers were aboard.

The other test aircraft, which was used primarily for quantitative data acquisition, was an instrument-flight-rules (IFR) equipped Sikorsky SH-3G helicopter (Fig. 8), the military equivalent of the S-61N. The SH-3G is a twin-turbine, five-bladed, single-rotor helicopter with emergency amphibious capabilities. The aircraft has a flying-boat hull and two outrigger sponsons; the main landing wheels retract into the sponsons. The rotor diameter is 19 m (62 ft), the gross weight is 8,660 kg (19,100 lb), and the maximum airspeed is 120 knots. During flight testing, two pilots, the aircraft crew chief, and one to four experimenters were onboard. Experimental equipment and data-acquisition system equipment were mounted on a rack in the cargo area.

Test Locations

The King Air and the SH-3G helicopter are based at Ames Research Center. System checkout and initial evaluation flights were made at Moffett Field, and quantitative data-collection flights were made at the NASA Ames Flight Systems Research Facility at Crows Landing, Patterson, California. Radar tracking systems, a data telemetry receiver, and ground-based data monitoring and recording equipment were used to record quantitative data to analyze PTAG performance. In addition to these locations, PTAG approaches were made to small civil airports.

The approach procedures used were similar to those used for standard ILS approaches. Conventional en route navigation aids (such as VOR/DME, TACAN, LORAN, NDB, and weather radar) were used to position the aircraft for PTAG intercept. Following acquisition of the PTAG guidance, and warning flags on the ILS course-deviation indicator disappear, and the pilot intercepts and tracks inbound on the PTAG course.

Flight-Test Results

Figure 9 shows a typical view of the King Air during testing on approach to the battery-powered, PTAG glide slope ground station. Testing with the PTAG ground stations has demonstrated PTAG guidance intercept at ranges in excess of 37 km (20 n. mi.) and glide slopes ranging from 2.5° to 7.5°.

The test program also confirmed the ability of the PTAG equipment to operate in high-radar-noise environments. In flight tests, the PTAG and airborne weather radar have been operated concurrently, and neither system affects the normal operation of the other. Bench testing with the airborne equipment has been conducted with up to 10,000 noise-pulses/sec injected into the received X-band signal. During flight tests, the X-band tracking radars at Crows Landing produce 2,000 pulses/sec of noise, and the airborne weather radar provides an additional 120 pulses/sec. In the presence of the these noise pulses, PTAG performance is normal, confirming its resistance to interference and jamming.

The ILS-compatible output format has also performed well, and pilot response to this method of interfacing the PTAG with the aircraft systems has been positive. Since the PTAG guidance is displayed on the normal ILS instruments, ILS and PTAG approaches are virtually indistinguishable. Use of this ILS output format has also allowed fully coupled autopilot approaches to the PTAG, and no wires were cut to install the equipment. Pilots have been particularly impressed because no cockpit switches were added, and no additional training was required to make PTAG approaches.

On one particular flight, PTAG was colocated with an ILS at Stockton, California. The pilot was asked to fly two separate approaches; on the first he made S-turns on the localizer course and on the second he made S-turns on the glide slope. PTAG and ILS signals recorded on a two-channel strip chart recorder are shown in Fig. 10. The anomaly in the PTAG and ILS localizer signals occurred when the strip-chart recorder jammed for a few seconds during the approach. One can readily see that the PTAG and ILS signals are virtually indistinguishable for both localizer and glide slope down to a 200-ft decision height.

The PTAG has also demonstrated considerable resistance to multipath interference. During early testing of PTAG, a localizer course wander was noted at low elevation angles to the localizer station. Further investigation identified multipath problems from mismatched localizer beam sidelobes. A minor modification to the localizer antenna corrected the problem. Many of the PTAG approaches were made at locations susceptible to multipath interference. These locations included South Lake Tahoe, California, an access road at Crows Landing next to a dirt embankment, and Moffett Field, where large hangars are present on both sides of the runway. Traces of the PTAG guidance signals were recorded on a strip chart and no oscillations in the signals were found, confirming the resistance of the PTAG system to multipath interference. Also, pilot evaluations of the PTAG system at these locations point out the absence of course bends, wiggles, and other undesirable characteristics normally attributable to multipath interference.

False-Course Rejection and Coverage

Localizer false-course rejection is provided by the two sector antennas mounted on the localizer ground station. Glide slope false-course rejection is provided by the single sector antenna mounted on the glide slope ground station. The PTAG airborne processor compares the amplitude of the signals transmitted from the precision antennas with the amplitude of the signals transmitted from the sector antennas. The processor rejects signals of lower amplitude than the sector signals. This eliminates false courses generated by beam sidelobes. The design requirement for the PTAG system was to eliminate all false courses below the desired glide path and up to 3° above the desired glide path, and the design goal was to have no false glide slopes in the front two quadrants. Also, localizer false courses should not exist in the front ±90°. Analysis of the data shows that there is a false glide slope course 3.6° above the actual glide slope. This false course could be eliminated by using a sector antenna with a slightly larger vertical beamwidth. The data also show that there are no localizer false courses in the two front quadrants.

In addition to providing false-course rejection, the sector antennas also provide proper localizer CDI indications out to ±35° from course centerline. Actual coverage measurements showed ±33° to 36° coverage at 5 n. mi. and ±42° coverage at 3 n. mi. out from the localizer. The localizer CDI sensitivity is software-programmable and can vary from ±2.5° to ±5° peg-to-peg. Valid localizer signals can be received by the aircraft up to 4° above and below the glide path. Proper glide slope CDI indications are provided ±7.5° from course centerline and the CDI sensitivity is scaled to ±0.7° peg-to-peg. The minimum glide slope without significant ground-bounce multipath interference is 2.5°.

PTAG Navigation Accuracy

Quantitative data were taken during PTAG testing to analyze errors in the PTAG signals. The 1-σ navigation accuracy achieved with the PTAG ground stations was ±0.075° in localizer and ±0.035° in glide slope. Figures 11 and 12 show composite data from flight tests, comparing the localizer and glide slope positions calculated by PTAG with the actual localizer and glide slope deviations as determined using the tracking radar. The navigation accuracy data points were taken over a period of one week on two separate data flights. The data include points taken on each approach down to a 200-ft decision height.

Figures 13 and 14 show composite plots, from several approaches, of the errors in the localizer and glide slope signals plotted versus range to touchdown. The errors on both localizer and glide slope do not exhibit any significant trends. These plots, when combined with pilot comments and the engineer's observations aboard the aircraft during testing confirm PTAG's resistance to multipath interference.

One localizer anomaly of the PTAG concept demonstration system has been documented in flight and ground tests. The vertical patterns of the left and right precision antennas are only matched over a region ±1.2° of the centroid. As a result, at elevation angles below 1.3° (elevation angle to the localizer), the PTAG centerline course displaces slightly to the right of runway centerline. Because of the geometry of the test setup for the quantitative data, the minimum elevation angle to the localizer was 1.6°, thereby avoiding the region of antenna mismatch. However, for a production PTAG system, antenna manufacturers have stated that matched antenna pairs could be supplied at almost no increase in cost.

Alternative System Configurations

During the course of the PTAG research program, alternative system configurations were devised using the PTAG guidance principles, and those configurations demonstrate the flexibility of the PTAG design. First, a colocated localizer and glide slope ground station was developed and has been demonstrated for typical rotorcraft operations.[3] Second, a configuration incorporating a DME or TACAN ground station along with the PTAG ground stations could have wide applicability. This configuration would allow DME-equipped aircraft to obtain range information without an airborne radar. Lastly, the PTAG airborne equipment has been interfaced with an airborne weather radar to provide range information for the pilot. This configuration allows aircraft equipped with weather radar to have a self-contained range and guidance system.

CONCLUSIONS

An X-band, portable, precision-approach guidance system was successfully developed and demonstrated in flight testing. The portable tactical approach guidance system has sigificant potential for tactical military missions. The portability and low power consumption of the PTAG ground stations are also attactive for emergency and rapid-deployment missions that require precision-approach capability. Specific project conclusions are as follows:

1) Using the PTAG concepts, portable, compact, inexpensive, lightweight, and battery-powered ground stations can be designed.

2) ILS-type guidance can be derived using a small X-band receiver and a small microprocessor, both of which are easily interfaced with the aircraft's existing avionics.
3) Pilot workload and techniques for PTAG approaches are similar to those for conventional ILS approaches.

4) PTAG is resistant to interference from other X-band signals. Also, concurrent airborne weather-radar and PTAG operation demonstrated that the systems do not interfere with each other.

5) Input of PTAG guidance signals to the aircraft's ILS receiver provided a suitable, yet simple, way of interfacing with pilot displays and aircraft autopilots.

6) Use of 99-cm-high (39 in.) antennas allows for multipath resistant operation at glide slopes of 2.5° or greater.

7) One-sigma (1σ) navigation accuracy achieved with the PTAG equipment was ±0.075° in localizer and ±0.035° in glide slope.

8) PTAG localizer and glide slope signal errors as a function of range to touchdown do not exhibit significant course bends or multipath distortion.

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2. Clary, George R., and Chisholm, John P., "Development of an X-Band Precision Approach Concept for Remote Area Rotorcraft Operations," Paper No. 88, IEEE/AIAA 5th Digital Avionics Systems Conference, Seattle, WA, Nov. 1983.

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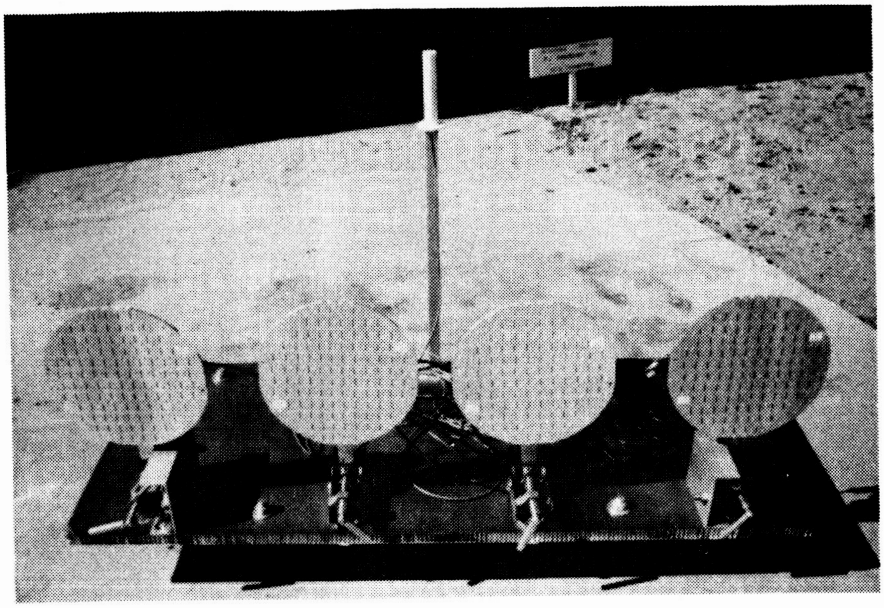

Fig. 1. First-generation ground station

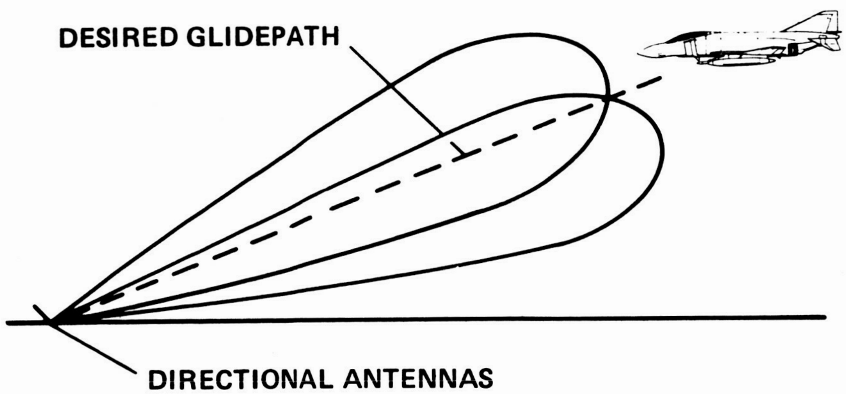

Fig. 2. Overlapping directional antenna beams provide course guidance

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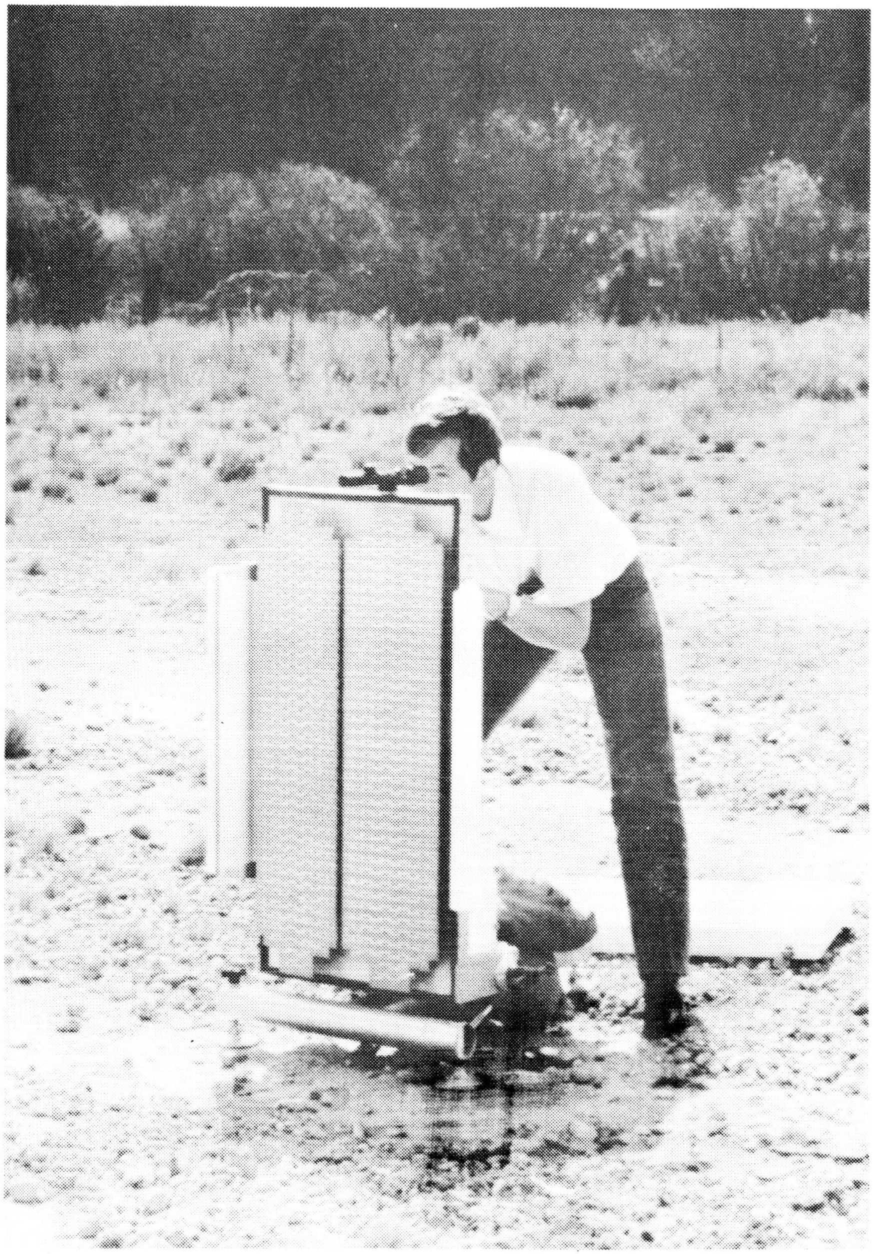

Fig. 3. Current PTAG-localizer ground station

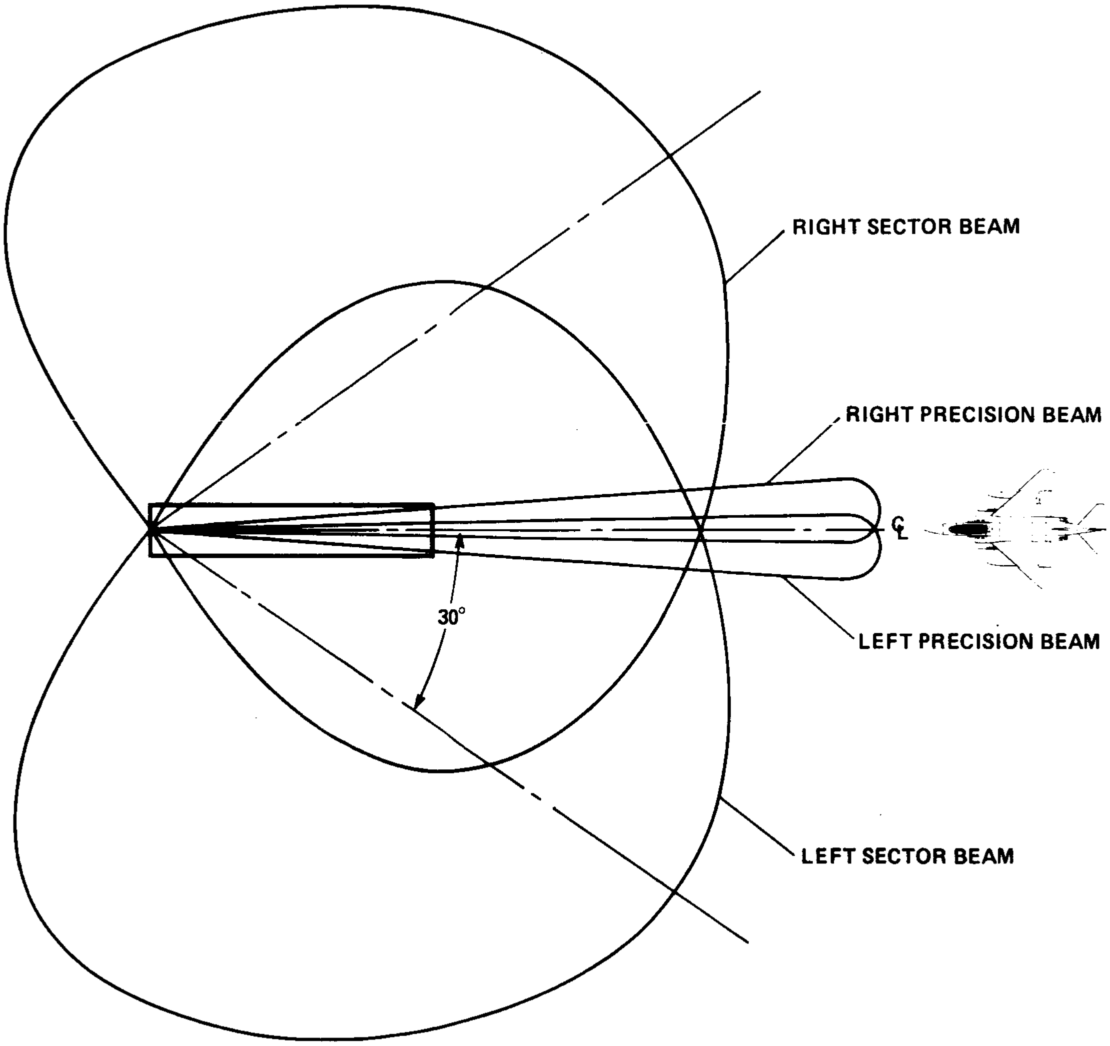

Fig. 4. PTAG-localizer beam configuration

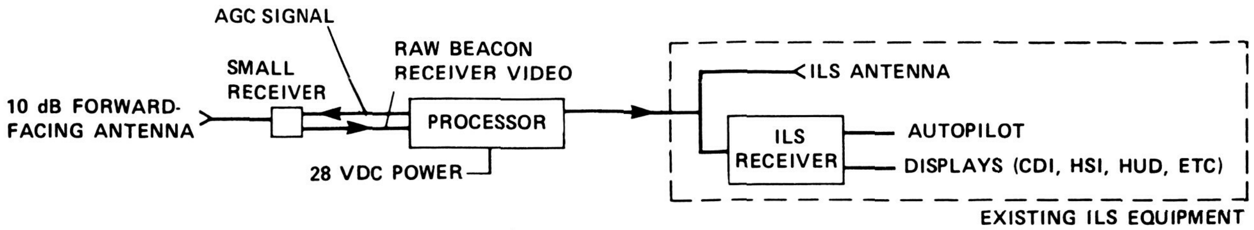

Fig. 5. PTAG airborne equipment

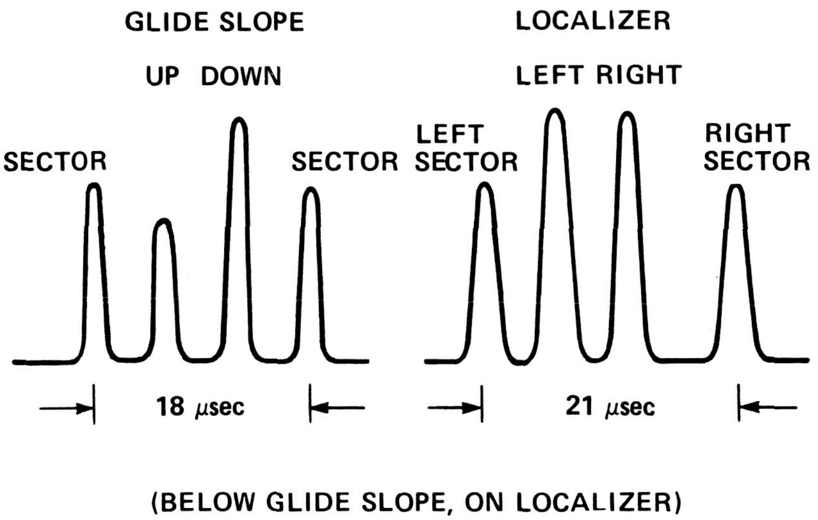

Fig. 6. Received beacon video signal aboard the aircraft

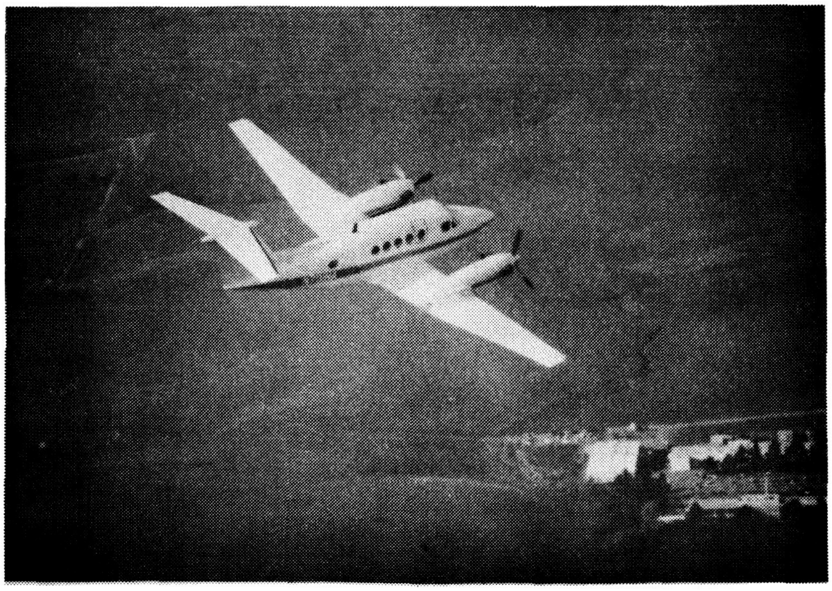

Fig. 7. Beechcraft King Air test aircraft

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Fig. 8. Sikorsky SH-3G flight-test helicopter

Fig. 9. PTAG flight demonstration on short final approach

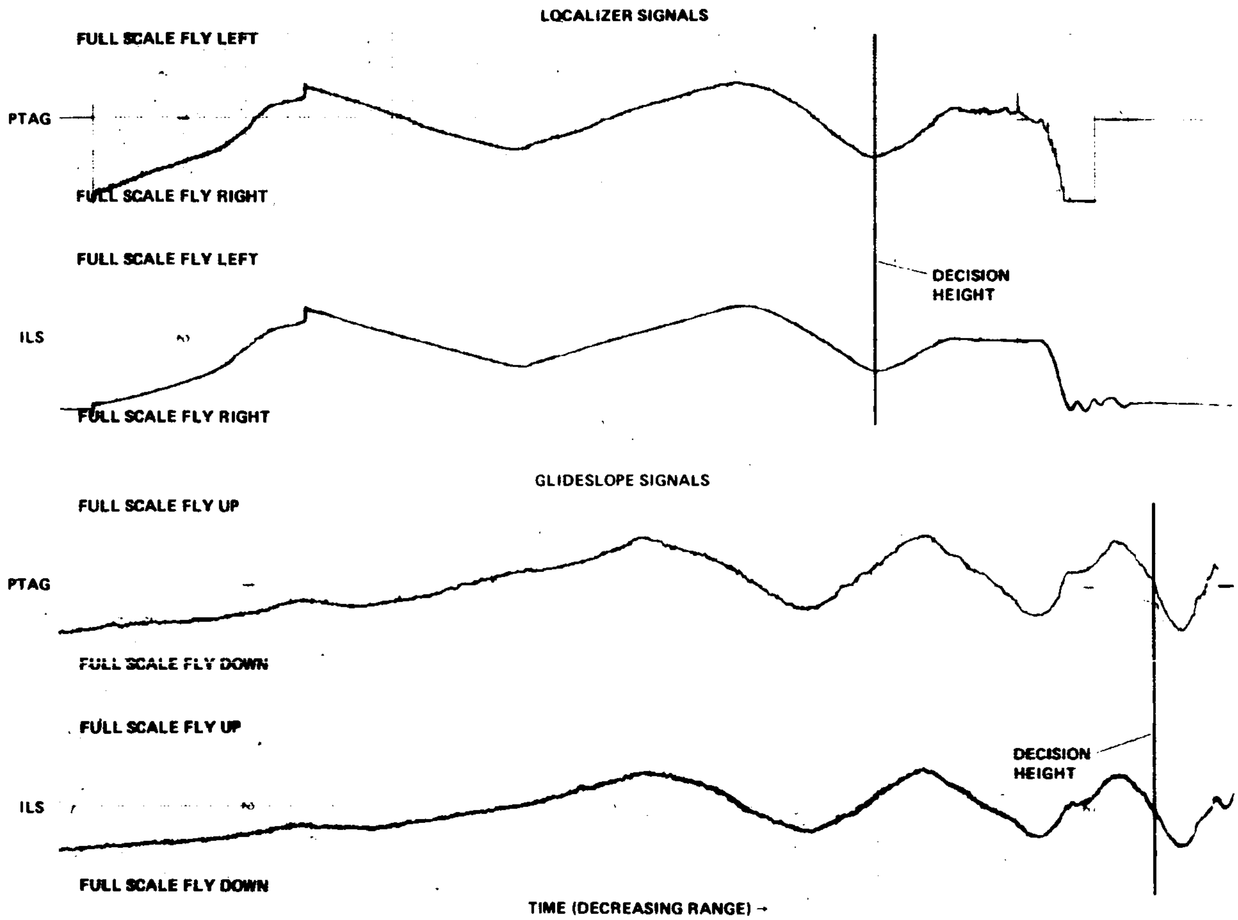

Fig. 10. Comparison of ILS/PTAG signals

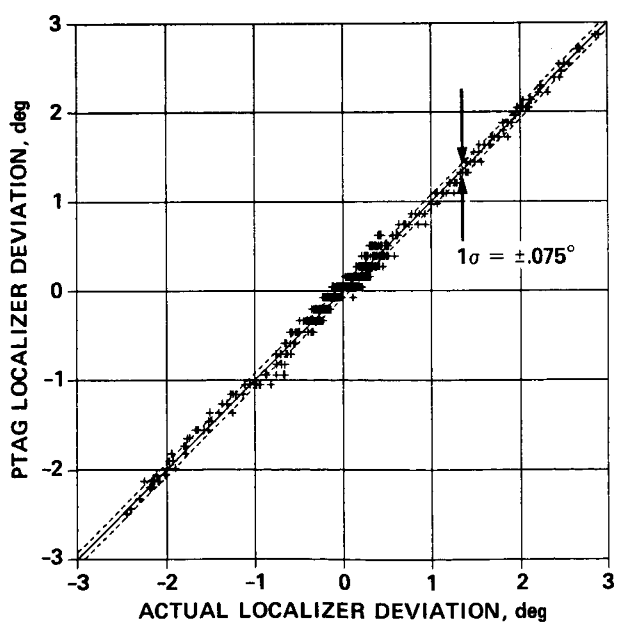

Fig. 11. Composite showing PTAG localizer navigation accuracy

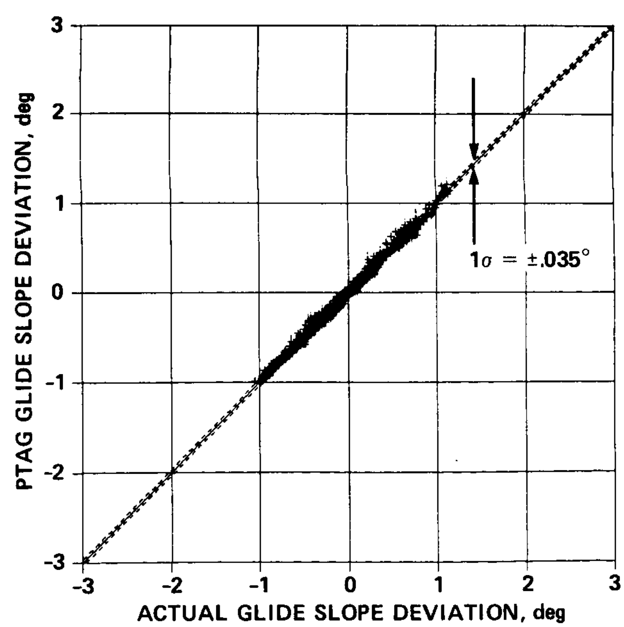

Fig. 12. Composite showing PTAG glide slope navigation accuracy

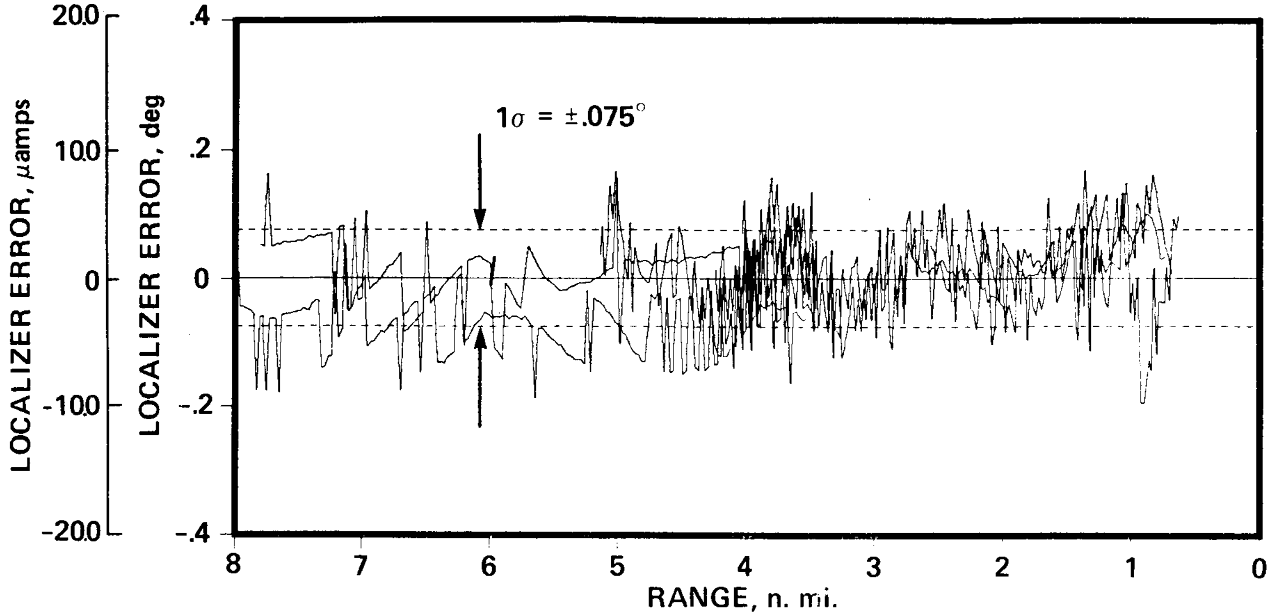

Fig. 13. Composite showing PTAG localizer signal error vs. range to touchdown

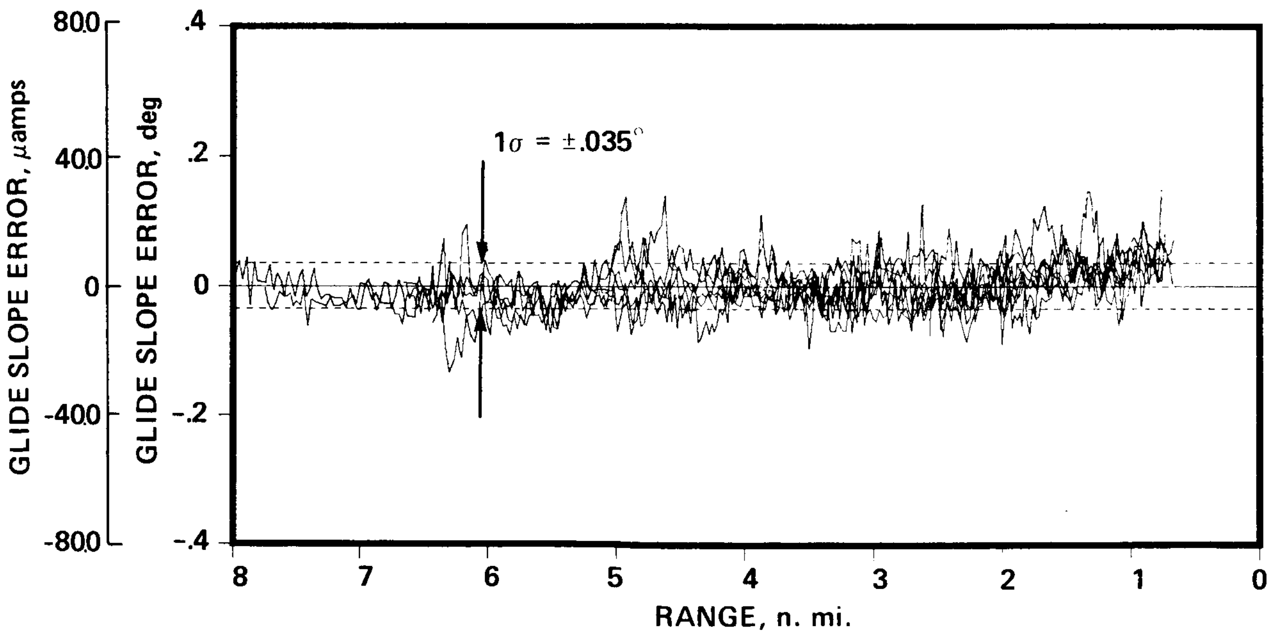

Fig. 14. Composite showing PTAG glide slope signal error vs. range to touchdown.

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16. Abstract

A portable, tactical approach guidance (PTAG) system, based on a novel, X-band, precision-approach concept, has been developed and flight-tested as a part of NASA's Rotorcraft All-Weather Operations Research Program. The system is based on state-of-the-art X-band technology and digital processing techniques. The PTAG airborne hardware consists of an X-band receiver and a small microprocessor installed in conjunction with the aircraft instrument landing system (ILS) receiver. The microprocessor analyzes the X-band, PTAG pulses and outputs ILS-compatible localizer and glide slope signals. The ground stations are inexpensive, portable units, each weighing less than 85 lb, including battery, that can be quickly deployed at a landing site. Results from the flight-test program show that PTAG has a significant potential for providing tactical aircraft with low-cost, portable, precision instrument approach capability.

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