Autonomous Landing Guidance (ALG)

1. Introduction

The Autonomous Landing Guidance (ALG) system provides the capability to land an aircraft in extremely low visibility conditions, where neither the aircraft nor the runway is equipped for an instrument landing. The key component in the ALG system is a 94 GigaHertz millimeter-wave (mmW) Imaging Radar subsystem and processor which provides a real-time image of the landing environment ahead of the aircraft, for display on either a Head-Up Display or Head-Down display to the pilot.

The current system has been extensively flight tested in low visibility conditions on several platforms including the Speckled Trout (C-135) at Edwards AFB, B727-200, Cessna 402 and a C-130. In 1998, at the direction of AMC and DARPA, the ALG system was installed on a USAF C-130H3 aircraft and was successfully flight tested at the Air Force Flight Test Center. The results of this flight test are documented in AFFTC-TR-99-16. The culmination of this demonstration was the clearance for the system to be operated in 0/0 conditions, and landings were demonstrated in actual weather conditions as low as 700 feet visibility. The landings to Zero-Zero conditions were granted after testing in simulated IFR conditions, runway incursion identification testing and in fog to aircraft minimums had successfully demonstrated the system capabilities and pilot situational awareness. BAE SYSTEMS has a strategic plan to provide Autonomous Landing Guidance solutions for both military and commercial A/C users, with the intent to be fully certified for civilian use in either case and also provide more mission specific capabilities for military users.

2. Radar Description

ALG is a Frequency Modulated Continuous Wave (FMCW) Millimeter Wave (MMW) imaging radar system consisting of a scanning antenna, a transmitter/receiver (transceiver) unit, and a Radar Signal Processor (RSP). The baseline ALG configuration is designed as an Enhanced Vision System (EVS) to aid the pilot during aircraft approach, landing, taxi & takeoff. The ALG system provides real-time images to the pilot, which penetrate extremely low-visibility meteorological conditions, dust, snow and smoke. The radar image is processed so that it can be displayed on a Head-Up Display (HUD), Head-Down display or any standard CRT or video monitor, and matches the realworld with a one to one registration. The radar uses a nominal 94 GHz center frequency and a modulation frequency of ±100 MHz. The FMCW waveform is linearly ramped from 93.9 GHz to 94.1 GHz (200 MHz bandwidth) in 1.8 ms. The information bandwidth of the radar return is 2.5 ±0.1 MHz. The baseline radar provides a nominal azimuth sweep of ±15° about the centerline and a variable elevation of 15° about the pivot point.

The BAE SYSTEMS 94 GHz mmW radar sub-system includes a radar antenna, transceiver, and the radar signal-processing unit. This is the first radar application of MMIC LNA technology in a 94 GHz FMCW imaging radar. The antenna is a forward looking twisted cassegrain type, which is mounted within a nose radome of the aircraft.

3. Antenna

The current antenna as shown at Figure 1 is a mechanically scanned reverse twisted cassegrain bistatic antenna. This antenna design was selected to limit wave-guide losses by having the horns affixed directly from the transmitter and receiver that are mounted immediately behind the antenna. The key antenna specifications include a. 28 degree azimuth resolution and a 3 meter range resolution which essentially defines the image resolution. The antenna also has excellent isolation (65 dB) and excellent gain (42 dB).

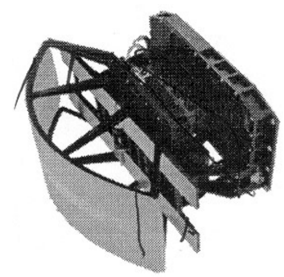

Figure 1. ALG Radar Antenna/Transceiver

The ALG antenna's bistatic configuration achieves excellent transmit to receive isolation, which is important for continuously transmitting radar such as ALG to avoid self-jamming. Each antenna (TX & RX) is a twist Cassegrain design made as one piece to achieve TX & RX beam registration. The twist plates reciprocate at 10 strokes per second to give the frame rate in the cockpit that is consistent with human factors minimum rates for pilot acceptability. The flat twist plate means the beam shape is highly consistent across the scan giving uniform image quality. The instantaneous azimuth angle is measured on a potentiometer pick off, the result is processed inseparably with the radar return to ensure image integrity.

The antenna's azimuth drive is simply by means of a tacho controlled crank. The scan width is +15 to –15 degrees, which matches a 30-degree azimuth field of view in the HUD. The azimuth alignment of the radar is set so that the radar return from an object ahead appears in the HUD screen at exactly the position as the pilot views that object from the pilot's eye point.

As mentioned above the elevation angle of a radar return is derived from the range. The radar has 3 meter range resolution which allows many range bins to be averaged to give one elevation pixel so improving the signal to noise ratio and image quality when viewing scenes at long range. The position in elevation on the HUD is slaved to the artificial horizon.

The antenna and transceiver are carried on an elevation gimbal axis. This is driven by a limited angle toque motor servo. The elevation angle is not used by the image processor because the elevation beamwidth is so large i.e. 4.5 degrees. The elevation control is used purely to stabilize the beam from aircraft pitch variations so that the part of the image that is of interest is illuminated. This requires pitch updates from the aircraft INS at a rate typical of other aircraft systems. Ground clutter effects caused by high return from the runway while the aircraft is taxiing is reduced by adjusting the gain in the near field when the height above ground is below a certain level. The antenna elevation is adjusted to optimize the image at all times, based on the pitch angle of the aircraft and the height above ground.

4. Low Probability of Detection & Intercept (LPI/LPD)

Although the ALG system is an active radar, the combination of very low power (250 milliwatts) and its FMCW waveform make it quite difficult to detect. The waveform, which is linearly ramped from 93.9 GHz to 94.1 GHz in 1.8 ms would be extremely difficult to lock onto. This is especially true considering that it is implemented at W-band (94 GHz) where electronic intelligence equipment is very highly specialized and expensive. One figure of merit for delectability is the bandwidth compression ratio (RF bandwidth to final video bandwidth) the system suggested has a compression ratio of about one million. Therefore, in addition to the obstacle detection capability, the ALG radar provided an added benefit of being low probability of detection and intercept.