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Introduction to AVIONICS and Navigation System

Evolution of Aircraft Landing System and Equipment (Till 1974)

SUBMITTED BY

SUJEET SANJAY AMBERKAR 200905092

Under the Guidance of:
Mr Vishnu G Nair
Department of Aeronautical and Automobile and Engineering
Manipal Institute of Technology, Manipal Karnataka – 576104

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1.1 Abstract

This review paper summarizes the historical progression of the Instrument Landing System (ILS). This review paper traces the development of ILS from an early compass locator to Tactical Aircraft Landing Aid (TALAR). This paper also covers testing of the Flight Landing System.

1.2 Introduction

Flight Instrumental Navigation Landing System is a short-range navigation system that provides assistance to the pilot during the landing of the Aircraft. This system provides both vertical and horizontal guidance during the landing of an aircraft.

2.1 Early Development of Instrument Flying

The main reason for the development of the Instrument landing system was to navigate and land aircraft safely at night and in poor weather conditions. Advancements in navigation and landing instruments provided pilots with necessary tools and systems like localizer beams, and glide paths. Enabling pilots to have precisely controlled manoeuvres. This advancement played a very important role in increasing flight safety.

1) Famous pilots from the era like Howard Stark, pioneered the technique of flying aural beams and using watches for timing the descents.
2) The SATR requirement in 1932 set a new standard for pilot proficiency in instrument and radio-guided flight, emphasizing precision and accuracy.
3) Localizer beam, glide path, and cross pointer indicators developed by Harry Diamond provide visual cues for pilots within the cockpit.
4) The Aeronautics Branch's Hegenberger system, and Diamond's two-beam system, were pitted against each other in comparative tests to evaluate their effectiveness for landings.

2.2 Operational Evaluation and Progression to Modern Instrument Landing Systems

2.2.1 Operational Flight Testing and Its Outcomes

1) The need for a straight-line glide path and the limitation of the curved path was revealed by Flight testing with a Ford Tri-Motor aircraft under the Bureau of Standards system.

2) Observations from these tests showed the necessity for additional visual aids and VHF frequencies to improve approach and landing operations.

2.2.2 Implementation and Widespread Testing

1) Operational tests by United Airlines and military forces led to the establishment of instrument landing as a reliable technology.

2) When testing was done under all weather conditions. The reliability of the system was validated and then the integration of instrument landing systems (ILS) into commercial aviation took place.

2.2.3 Modern ILS Standards and Future Directions

1) Post-war adoption of VHF localizers, straight-beam glide paths, and precision approach radar became standard.
2) The Development and testing at FAA's Bureau of Research and Development suggest ongoing improvements to ILS, with a focus on enhancing the final approach, flare, and touchdown phases.

3. Tactical Aircraft Landing Aid

Tactical Aircraft Landing Aid (T.A.L.A.R) represents a significant advancement in precision landing technology for military aviation. It is a portable system that is designed to guide aircraft safety especially when traditional landing aids might be unavailable.
TALAR uses a high-frequency narrow beam approach that offers clear guidance through a conically scanned antenna system. It is quick to deploy and requires very few personnel to operate it. It provides Flight instrument landing systems with a higher degree of flexibility and safety in tactical operations.

3.1Working of TALAR

1) The job of ground transmitter is to establish a flight path for the aircraft to follow when landing.
2) It emits in total three beams. One main beam and two auxiliary localizer beams.
3) The main beam is narrow like a pencil and it rotates at a speed of 100 rotations per second, creating a cone-shaped path.
4) The rotation in TALAR is similar to how a radar scans the area, providing a focused path (called the boresight) for the aircraft to follow
5) Along with the main beam, the transmitter emits a sub-carrier frequency that carries additional information for vertical positioning which is modulated with frequency sidebands.
6) Inside the aircraft, the receiver picks up this sub-carrier signal and interprets the signal to help pilots understand their vertical position relative to the desired glide slope.
7) If the aircraft moves off-centre from this main beam, the receiver detects changes in the signal amplitude and phase due to amplitude modulation and an alert is generated. This variation helps indicate the aircraft's lateral position.
8) There is an indicator flag in the aeroplane which notifies the pilot that he/ she is in the correct approach path and is receiving accurate signal information to guide them.
9) The pilot aims to keep the cross-pointer indicators centred, maintaining the correct path and descent rate until he/ she can visually complete the landing.
10) The ground transmitter uses a 15.5 GHz microwave oscillator that feeds a scanned antenna. This is part of the system that generates the guiding beams.
11) A fixed magnetic pickup senses the rotation of the antenna and sends pulses to a divide-by-two multivibrator. Reduce the rotation frequency to 50 Hz. These pulses are then used to frequency modulate a 100 kHz oscillator. The output of this oscillator after being clipped regulates the magnetron in a pulsing manner. It creates a spectrum of signals that the aircraft receiver uses for navigation

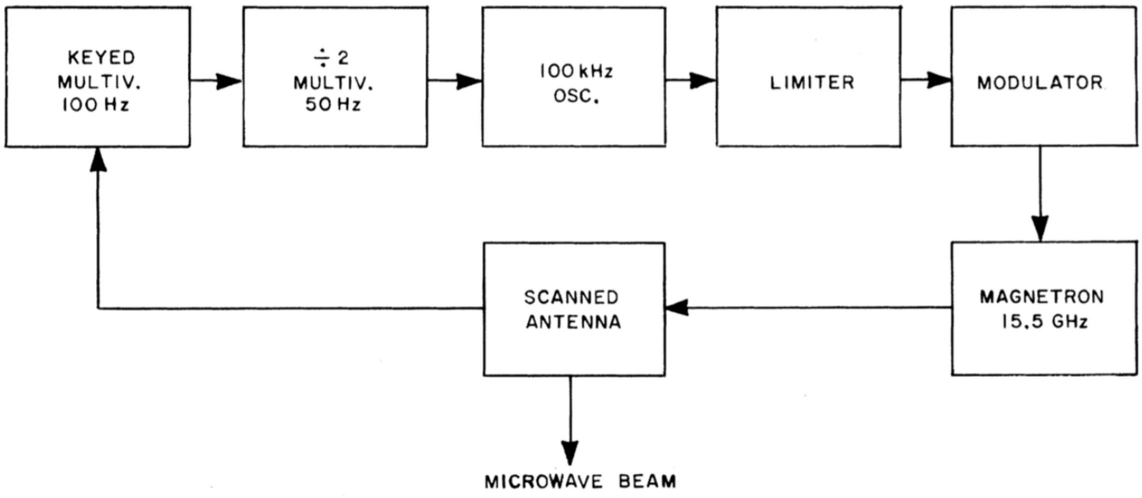


FIGURE 1. TALAR TRANSMITTER

1) Keyed Multivibrator: Generates timing pulses.
2) ÷ 2 Multivibrator: Halves the pulse frequency for synchronization.
3) 100 kHz Oscillator: Creates a reference frequency.
4) Limiter: Ensures signal strength consistency.
5) Modulator: Encodes the reference frequency onto the microwave signal. \
6) Broadcasts the encoded signal in a sweeping motion.
7) Magnetron: Produces the microwaves that carry the signal.

3.2 Airborne Receiver for TALAR

The Airborne Receiver for TALAR is an advanced system that assists aircraft in precision landings. The Airborne Receiver captures specific high-frequency signals from a ground-based transmitter and processes these signals to determine the aircraft's alignment with the desired landing path. It then communicates this positioning to the pilot through intuitive indicators, ensuring accurate guidance for a safe touchdown.

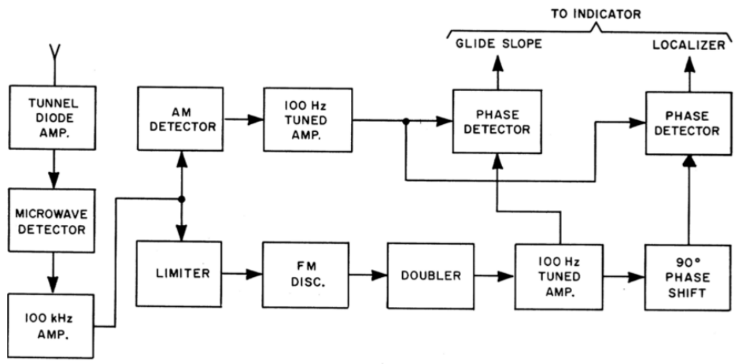


Figure 2: TALAR Receiver

1) The system catches the high-frequency microwaves from the transmitter through an antenna. The microwaves have been sent out specifically to guide the plane.
2) The signal is boosted by an amplifier making it strong enough to work with without changing what the signal is actually saying,
3) The signal is then split into two parts.
    a. One part checks the strength of the signal (which changes depending on where the plane is
    b. The other part looks at the timing of the signal (which helps figure out the plane's exact spot in the sky)
4) For a short duration, the frequency of the signal is doubled to make it super precise for the next steps.
5) These checks on strength and timing are then changed into signals that the pilot can understand, showing up as directions on the aircraft's instruments.
6) The pilot uses these directions to keep the plane on the right path to land safely. The pilot follows the localizer to get the correct lateral position and then adjusts the plane's angle of descent according to the glide slope.

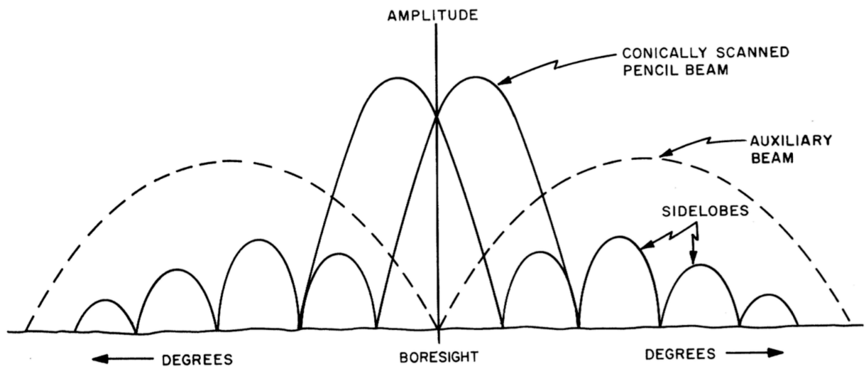


Figure 3: TALAR LOCALIZER ANTENNA PATTERNS

1) The main feature in Figure 3 is the sharply focused main beam, called a pencil beam, which moves in a cone shape to guide the aircraft precisely.
2) The pencil beam is surrounded by auxiliary beams and sidelobes. These beams act as weaker echoes of the main signal spreading in all directions.
3) The main beam provides a strong signal directly in line with the runway (boresight)
4) Pilots use the strength and direction of these beams to align the aircraft with the runway's centerline during approach

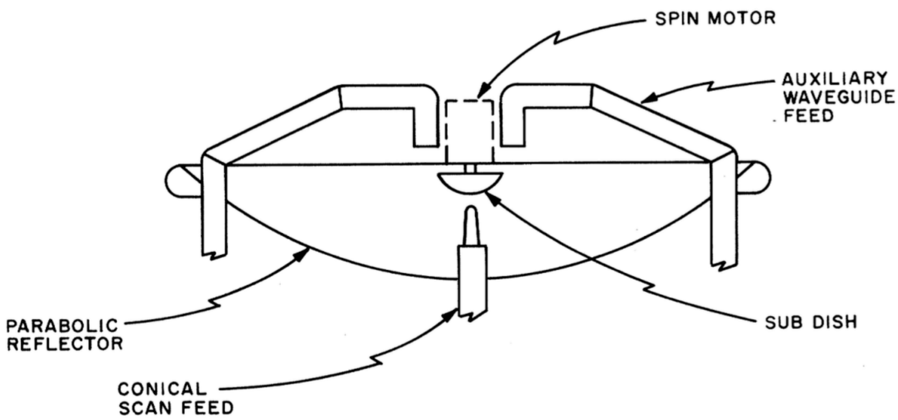


Figure 4: TALAR Antena

1) The antenna system uses a parabolic reflector to focus the microwave signals into a beam
2) A conical scan feed which is located at the heart of the system spins to direct the beam across the desired scanning area.
3) Auxiliary feeds add additional guidance by partially illuminating the parabolic reflector. This creates auxiliary beams as shown in Figure 4
4) The entire system is powered by a spin motor that rotates the hyperboloidal sub-reflector. This ensures that the main beam sweeps the area it's supposed to cover

4. Improvements in the Instrument Landing System

A localizer is an essential part of the Instrument Landing System (ILS) that provides lateral guidance to pilots as they approach a runway for landing. The Instrument Landing System uses radio signals to help align the aircraft with the centre line of the runway from a distance. The need for a localizer arose from the necessity to assist aircraft in landing safely in poor visibility conditions. It functions by transmitting a signal that is interpreted by the aircraft's navigation system guiding the pilot left or right towards the correct approach path for landing.

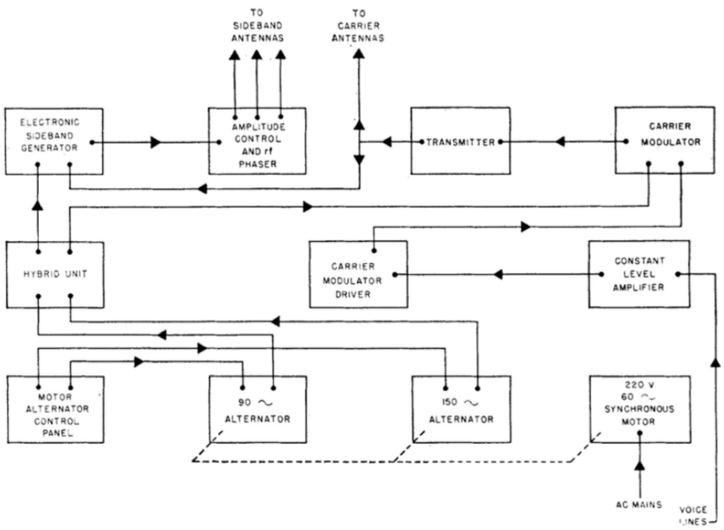


Figure 5: Block diagram of the CAA localizer.

1) Generation of Signals: An electronic sideband generator creates the necessary signals for the localizer system.
2) Modulation and Amplification: These signals are then modulated. The signals are mixed with a carrier signal in a carrier modulator. This mixing is necessary for the signals to be transmitted effectively over long distances.
3) Power and Control: The modulated signal is amplified to a constant level to ensure it remains strong and consistent. It is then sent to the transmitter
4) Distribution: The hybrid unit acts as a distributor directing parts of the signal to different components for further processing.
5) Transmission to Antennas: Ultimately processed signals are sent out through the antennas to the approaching aircraft.

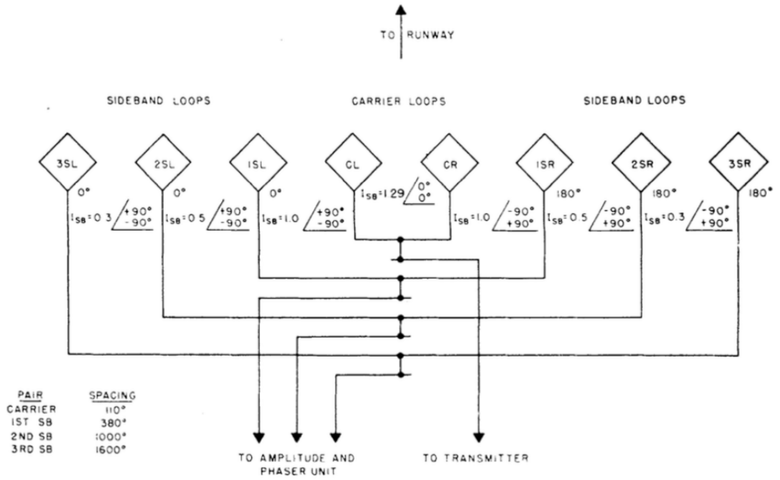


Figure 6 :CAA localizer antenna array

1) Array Configuration: The antenna array is configured with multiple loops (sideband loops and a carrier loop) which are responsible for transmitting different parts of the signals.
2) Phase Adjustments: The sideband loops are set up with specific phase angles to ensure that the signals combine in a way that they cancel each other out directly along the approach path, creating a null area or zero signal area. This is crucial for the localizer to give the correct guidance.
3) Signal Transmission Direction: The signals from these loops are directed towards the transmitter after their amplitude and phase are adjusted, which affects how the waves will be received by the aircraft's instruments.
4) Alignment with Runway: The entire system is aimed at providing clear guidance to the aircraft to align with the centre line of the runway for a safe approach and landing of the aeroplane.

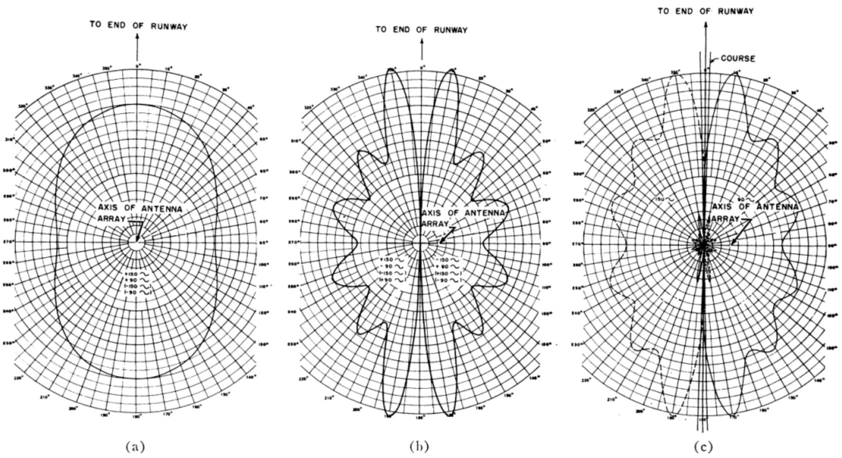


Figure 7:Localizer field-strength patterns. (a) Carrier antenna; (b) sideband antenna; (c) sideband field strength, all loops excited.

a) Carrier Antenna Pattern:
This figure shows a consistent circular pattern indicating uniform signal strength in all directions. This pattern ensures the aircraft's navigation system can receive a stable signal regardless of its angle to the runway which is critical for activating the automatic volume control (AVC) in the aircraft's receiver.

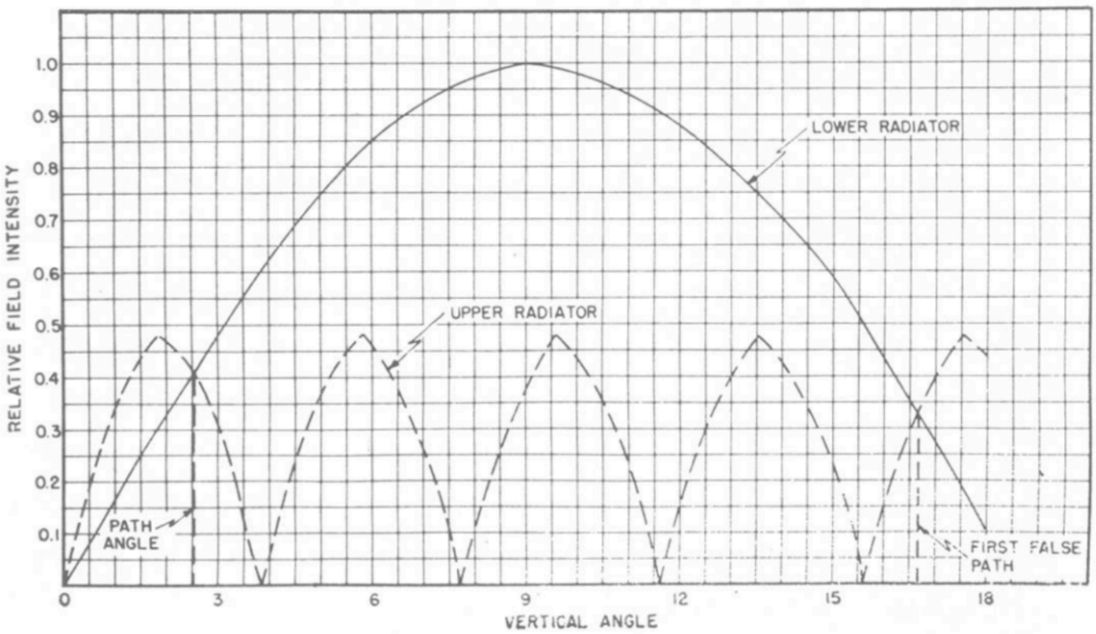
b) Sideband Antenna Pattern:
This figure illustrates a highly directional pattern with strong signals at specific angles (approximately 10° off the centre line of the runway) and a null directly on the course line. This design helps the pilot to determine if the aircraft is left or right of the runway centre line.

c) Combined Field Strength:
This figure depicts the superimposed effects of both carrier and sideband antennas. This shows how the localizer receiver on the aircraft combines these signals to determine the correct path to the runway. The null or zero signal area is directly along the runway axis which helps the pilot to align the aircraft with the centre line.

5 The Glide Slope

The Glide Slope is an integral part of the Instrument Landing System. This offers vertical guidance to pilots during the aircraft's descent towards the runway. It ensures a safe approach angle guiding the pilot to maintain the correct path for landing. This system has undergone a huge evolution from an along system to a Morden digital system to address challenges in varied terrains and improve reliability for aircraft landing under instrument flight rules (IFR).

1) It provides vertical guidance for aircraft during landing.
2) Early systems used constant field-intensity types but had limitations like curved glide paths.
3) Improvements led to amplitude comparison techniques for a straight-line glide slope, which are more effective and reliable.
4) Current systems use a null-reference system that overcomes limitations of earlier systems such as being affected by heavy snowfall.



1) The two overlapping radiation lobes are from different antennas. The upper and lower radiators create the glide path that the aircraft follows on its descent.

2) The point where these two patterns intersect at the same intensity determines the optimal path angle for descent ensuring a steady approach to the runway.

3) Peaks outside the path angle represent false paths. These are misleading signals that a pilot must avoid to stay on the correct glide slope.

4) The consistent amplitude across the glide path allows for a clear signal for the pilot, with deviations above or below this path resulting in a guidance signal to adjust altitude to remain on the correct approach trajectory.

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