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AN AIRCRAFT LANDING SYSTEM UTILIZING DECIMETRIC WAVES (UHF)

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FOREWORD

The Council of ICAO considers that in the field of non-visual aids to final approach and landing, a promising line of development lies in the field of microwave techniques and recommends that investigation along this line and along other promising lines of development in this field be pursued in order to produce a complete landing system satisfying the functional requirements to a greater extent than the ICAO Standard Instrument Landing System.

The material contained herein records the work that has been done in France on a landing system employing decimetric waves (UHF) and providing on a common carrier localizer and glide path guidance and distance information.

The material was submitted to the Fourth Session of the Communications Division by the Government of France. The Division recommended that the information should be disseminated to States in order to acquaint them with the technical features of the system and the experimental work that has been done.

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INTRODUCTION

Generally speaking, the specifications have been drawn up with the intent of clearly outlining a landing system which would overcome the technical and operational inadequacies of the ILS system, particularly with regard to the glide path terrain clearance aspect.

As regards the selection of frequencies, it is considered that the system will require:

a) that forty frequencies be available for emission from the ground equipment (common frequencies for course, elevation and distance), in line with the number of frequencies assigned for the ILS in Annex 10, although that number is in excess of operational requirements;

b) that these forty frequencies be assigned in a band adjacent to the DME reply band specified in ICAO Annex 10. In case it is decided that the "final approach to landing" function need no longer be retained in the DME, the band of forty frequencies envisaged for the future landing system should be shifted to bring it closer to the fourth reply frequency in the DME;

c) that the interrogation frequencies in the band reserved for the distance measuring function be inserted between the frequency assignments specified for the DME, in ICAO Annex 10.

In view of the directivity and small coverage of the proposed landing system, as well as the different pulse characteristics used, it is evident that by meeting the above-mentioned requirements, there will be no mutual interference between the DME system and the measuring equipment associated with the system.

Neither does it appear that there will be any disadvantage in having the interrogation frequencies of the system coincide with those of the DME.

Nine or ten frequencies appear to be sufficient for operational requirements.

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CHAPTER I

SUMMARY OF THE CHARACTERISTICS AND PERFORMANCE OF THE EXPERIMENTAL EQUIPMENT ASV 23

Components	**Ground Equipment** 1 transmitter housed in a trailer 3 antennas (2 for the localizer and 1 for the glide path) **Airborne Equipment** 1 receiver 1 indicator (2 if required) 1 control box 1 converter (if required)
Coverage	40 km over a 60° sector centred on the landing path and between 0.75 and 7° in elevation.
Carrier frequency	1300 Mc/s.
Type of transmitter	Pulse, master oscillator amplifier
Peak antenna power	200 watts
UHF transmitter tubes	Master oscillator: K.773) velocity Amplifier: AK.774) modulated) tubes
Transmitter antennas	Parabolic reflectors fed by coaxial cable.
Angular deviations producing full scale deflection of the indicator needle.	Localizer: 2.5° on each side of the path Glide path: 0.75° on each side of the path.

Descent path angle (adjustable between 2.25° and 3°)	2.5°
Modulation frequencies	F_1 = 20 kc/s. F_2 = 24 kc/s. F_3 = 30 kc/s. F_4 = 34 kc/s.
Input power	AC single phase, 6 kilowatts 220 or 380 volts 50 c/s.
Indicator	Cross-pointer instrument or cathode-ray tube.
Receiver antenna	3 half-wave elements (In phase)
Receiver intermediate frequency	22 Mc/s.
Receiver pass band	1.5 megacycles at 3 decibels down
Airborne power supply	110 volt AC/400 c/s 125 watts or 24 volt DC 160 watts
Siting	Localizer antennas 400 m from the approach end of the runway towards the stop end. The localizer antennas are located symmetrically on either side of the runway, 60 m from the centre line. The glide path "cheese" antenna is mounted on the trailer which also supports one of the localizer antennas.

CHAPTER II

GENERAL PRINCIPLES OF OPERATION

The purpose of the instrument landing system developed by the Compagnie Générale de Télégraphie sans Fil is to provide guidance to an aircraft on final approach and landing, irrespective of weather conditions, by giving the pilot direct, visual indications without any radiotelegraph or radiotelephone contact with the ground.

The system uses directional radiation patterns, the intersection of which determines a single fixed line in space known as the "landing path". An indicator in the cockpit provides continuous visual indication to the pilot of the aircraft's position with reference to this "path".

The carrier frequency of 1300 Mc/s. (approximately), has been chosen as UHF signals of this order are not adversely affected by atmospheric conditions (heavy rain, thick fog, etc.) and to permit the use of relatively small antennas.

Pulses are radiated successively along four lobes, the intersection of these lobes, in pairs, define the "localizer plane" and the "glide path" plane.

The first two lobes determining the vertical localizer plane are obtained by means of two parabolic reflector antennas located on both sides of the runway, symmetrical about the centre line.

The other two lobes determining the glide path plane are obtained by means of a single parabolic "cheese" antenna comprising two exciters close to the focal point.

The duration of the pulses is approximately 1/60 second. They are radiated along the four lobes in the following order: left (localizer), lower (glide path), right (localizer), upper (glide path). The time interval between successive pulses is approximately 1/360 second. A greater time interval of the order of 1/40 second is provided at the end of the cycle of four localizer and glide path pulses, which will subsequently permit having on board the aircraft a continuous indication of the distance between the aeroplane and the optimum point of contact on the runway.

The radiation is cut into successive pulses by means of a distributor rotating at approximately 600 r.p.m. This distributor comprises a rotating cavity tuned to the carrier frequency and which radiates through a slot passing in front of four wave guides mounted concentrically to the axis of rotation. The duration of the passage of the slot in front of each guide determines the duration of the emitted pulse. Each wave guide is connected to the proper antenna so as to maintain the pulse sequence indicated above.

The radiation is cut into rectangular pulses at a modulation frequency of 20 kc/s. for the runway antenna producing the lefthand (localizer) lobe, 24 kc/s. for the trailer antenna producing the righthand (localizer) lobe, 30 kc/s. for the upper (glide path) lobe and 34 kc/s. for the lower (glide path) lobe. The modulation frequencies are supplied by a modulator providing four sinusoidal frequencies at 20, 24, 30, and 34 kc/s. The voltages are applied to a capacitive switch mounted on the same shaft driving the rotating distributor, thereby providing the specific modulation frequency for each antenna. The voltages from the capacitive switch return to the modulator, where they are clipped and sent, through a modulation transformer, to the grid of the transmitter power tube.

Figures 1 and 2 illustrate the shape and orientation of the localizer lobes. Figure 3 illustrates the shape of the glide path lobes and the slope of their axes in relation to the ground. It will be noted that the localizer lobes and the upper glide path lobe present a bulge produced by an additional exciter located near the focal points of the parabolic antennas. The object of these bulges is to increase the horizontal and vertical coverage of the system. Figure 4 shows the block diagram of the transmitter.

<u>The airborne equipment comprises</u>:

- a receiver which may be located anywhere in the aircraft;

- an indicator located on the instrument panel;

- a control box of very small dimensions located within reach of the pilot and, if necessary, a converter providing 110 volts Ab at 400 cycles per sec., in case the aircraft generating system does not supply this.

Either a cathode-ray tube or a cross-pointer indicator may be used. An additional indicator for the co-pilot may also be installed. The indicator, whether a cathode-ray tube or a cross-pointer meter, comprises two fixed rectangular reference axes, and their point of intersection gives the position of the aircraft in space.

On the cathode-ray indicator, the position of the light spot fixes the position of the glide path, in such a way that the pilot must bear left when the spot is to the left of the vertical reference axis and inversely must bear right when the spot is to the right of the reference axis. If the light spot is above the horizontal reference axis, the pilot is aware that his aeroplane is below the path and must climb, and inversely if the spot is below the axis, the aeroplane is above the path and must lose height more rapidly.

On the cross-pointer indicator, the intersection of the pointers registers the position of the glide path. As in the previous case, the pilot must take action to keep his visual reference mark (intersection of the pointers) in the centre circle, where the reference axes intersect.

The airborne equipment includes a receiving antenna made up of three half-wave elements, and moulded into the plexiglass of a streamlined housing fixed above the pilot's cockpit.

The practical coverage of the Mark I experimental equipment is 40 Km over two sectors of 30° centred on the landing path and between two elevation planes inclined at 0.75° and 7° above the horizontal, respectively. On the glide path the coverage is 100 Km over two sectors of 15° on each side of the landing path.

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CHAPTER III

DESCRIPTION OF THE EXPERIMENTAL EQUIPMENT

1.- GROUND EQUIPMENT

The essential elements of the ground equipment are a transmitter unit installed in a trailer, 3 transmitting antennas and a rigid dielectric feeder having an outer diameter of approximately 80 mm, which may be dismantled into 3.20 m lengths for transport.

One of the localizer antennas and the glide-path "cheese" antenna are attached to the trailer; the second localizer antenna, located symmetrically to the transmitter about the runway centre line, is transported separately. The ground equipment is illustrated in Figures 8 and 9.

A.- TRANSMITTER

The dimensions of the transmitter unit are:

length .... 1.15 m
depth .... 0.65 m
height .... 1.70 m

The transmitter utilizes a single carrier frequency of 1300 Mc/s. The radiation is cut into rectangular pulses having an approximate duration of 1/60 sec, modulated at 20, 24, 30 or 34 kc/s., according to the antenna to be fed.

The basic components are:

- A master oscillator velocity modulation tube (type K. 773, 2-cavity CSF klystron), capable of providing an effective power of approximately 50 watts for driving the power stage. This tube is water-cooled.

- An amplifier velocity modulation tube (type AK. 774, 2-cavity CSF klystron), capable of providing an effective power of approximately 200 watts. This tube is also water-cooled.

- A precision cavity wavemeter, providing a measurement of the transmitter frequency to within approximately 10^{-4} Mc/s.

- A device for regulating the klystron cooling liquid temperature, with an electro-thermostatic system capable of stabilizing the temperature to within $\pm$ 0.5° approximately.

- 2 anode voltage rectifiers, each with an output of 200 mA at 5000 volts, equipped with mercury vapour tubes.

- 2 grid voltage rectifiers each with an output of 50 mA at 500 volts, equipped with hard-tubes.

- The system for tuning the cavities and controlling the adaptors.

- An electronic device for stabilizing the A.C. mains voltage to $\pm$ 1% for input variations of $\pm$ 15% or less.

- A detector device for measuring standing waves in the output wave guide.

- A crystal detector used for monitoring and controlling the pulse shape by means of a control oscillograph located in the modulator.

B.- MODULATOR

The modulator is mounted on the left side of the transmitter and has the following dimensions:

length .... 0.50 m
depth .... 0.65 m
height .... 1.70 m

It comprises two racks which contain:

Rack No. 1

- An oscillograph for controlling the shape of the modulation voltages, the clipped voltages applied to the grid of the power stage, and the modulation envelopes (pulses) from the crystal detector located in the output wave guide.

- A microampmeter with a four-way selector for measuring the power radiated in each of the four lobes.

- An electronic device for monitoring the position of the path, comprising 2 microampmeter path deviation indicators, graduated directly in degrees, and two differential relays operating the alarm system in case the power radiated on one lobe differs by more than 10% from that radiated on the corresponding localizer or glide path lobe.

Rack No. 2

- 4 L.F. generators producing frequencies of 20, 24, 30 and 34 kc/s., each comprising a vacuum tube and associated circuits.

- A 3-tube clipping device for transforming the L.F. sine waves into 1/2 cycle wide rectangular waves. This clipping device is operated successively by the 4 L.F. generator tubes by means of a capacitive switch on the shaft of the rotating distributor. The switch is adjusted so that each modulation frequency is applied exactly during the passage of the distributor in front of the wave guide aperture connected to the correct antenna.

- A power modulating tube charging the grid of the klystron amplifier through a modulation transformer.

- An input stabilizer.

At the base of the modulator unit there is a compartment containing an acoustic warning signal which is operated in the following cases:

- stoppage of the valve cooling water flow.

- more than 50% decrease in the radiated power.

- when the power radiated by the two localizer antennas, or the power on the two glide path lobes differs by more than 10%.

C.- ROTATING DISTRIBUTOR

Installed in the trailer, to the right of the transmitter.

The Rotating Distributor consists of a parallelepiped cavity, tuned to the emission frequency and having a narrow slot on the longest axis of the cavity. As the cavity rotates, the slot passes in front of the aperture of each antenna wave guide. The duration of the passage of the slot in front of the aperture of each guide determines the duration of the pulse emitted. The shape of the pulse is substantially rectangular, the width of the slot being very small in relation to the dimensions of the aperture of the wave guides. The transmitter feeds the rotating cavity by means of a coaxial line rotary joint.

The transmitter assembly can be seen in Figure 6.

D.- ANTENNAS (See Figure 7)

The two antennas defining the localizer plane are segments of a parabola and have the following dimensions:

height .... 3.20 m
depth .... 1.60 m

Exciters located close to the focal points of these reflectors give the radiation lobes the shape illustrated in Figures 1 and 2.

The glide path "cheese" antenna and one of the localizer antennas are attached to the rear end of the trailer. These two antennas may be dismantled into three components to facilitate transport and installation.

The second localizer antenna is located on the other side of the runway and is mounted on a light folding frame. The RF energy is conveyed by means of a 120 m long non-flexible, waterproof coaxial feeder, which may be dismantled into 3.20 m lengths.

2.- AIRBORNE EQUIPMENT

A.- RECEIVER

The dimensions are:

length .... 0.430 m
depth .... 0.190 m
height .... 0.170 m

The weight is approximately 12 kg. The general design is illustrated in Figure 10. The receiver is of the superheterodyne type comprising:

- A crystal mixer.

- A KR. 203 reflex klystron local oscillator.

- A 3 stage I.F. amplifier, providing a gain of approximately 80 db for a 3 db 1.5 megacycle pass band.

- A 6 tube, 2 channel LF amplifier, with filters which provide, after detection, comparison of pairs of modulation signals corresponding to 2 localizer lobes and 2 glide path lobes.

- A 3 tube automatic frequency control which acts on the reflex electrode voltage of the local oscillator. If the transmitter carrier frequency drifts, the frequency of the local oscillator is automatically readjusted so as to maintain a constant difference frequency corresponding to the intermediate frequency of 22 Mc/s.

- A rectifier operating on 110 volts AC 400 c/s.

In addition the receiver is equipped with a powerful automatic gain control device permitting operation up to very short distances, by progressive desensitization.

B.- CONTROL BOX

The dimensions are:

length	140 mm
height	90 mm
depth	70 mm

The control box is installed within reach of the pilot, and consists of:

- A receiver OFF-ON switch.

- A push button to control the operation of the cathode-ray tube.

- A control regulating the brightness of the lights marking the reference lines of the indicator.

- 4 controls (covered) for focus, brightness and centering of the spot on the cathode-ray tube.

C.- VISUAL INDICATOR

This may be either:

- A cathode-ray tube with a 70 mm diameter screen, or
- A cross-pointer instrument.

Figure 11 shows an aircraft instrument panel on which both types of indicators have been installed for experimental purposes.

In either case a warning light in front of each axis lights up when the aircraft enters the glide path or localizer fields. The light marking the vertical line only lights up when the aircraft enters the localizer field, while the light for the horizontal line only lights up when the aircraft enters the glide path field.

D.- RECEIVER ANTENNA

The antenna consists of 3 half-wave elements coupled in series and in phase within an aerodynamic plexiglass casing. The angle of aperture of the polar diagram of this antenna in the horizontal plane is approximately 180°, which still provides correct reception when the aeroplane is at right angles to the landing path. It may be replaced by an omnidirectional antenna. It is connected to the receiver by a polythene insulated flexible coaxial line with a characteristic impedance of 75 ohms.

The receiver antenna can be seen in Figure 12.

E.- CONVERTER (if required)

This converter can supply 110 volts A.C. at 400 c/s. from a 24 volt aircraft system. It is only used when the aircraft system is not 400 c/s. The power rating of the converter is approximately 125 watts.

REMARKS

The positioning of the receiver in the aircraft is not important. Starting and stopping is controlled from the control box and in view of the automatic frequency control, the pilot does not have to do any retuning.

CHAPTER IV

TESTS PERFORMED AND RESULTS OBTAINED

The A.S.V. 23 experimental equipment was put through numerous official tests:

a) In France, during 1949, at Saint-André de l'Eure, by the Service Technique des Télécommunications de l'Air, with the assistance of the Radio Authorities and recording equipment from the Brétigny "Centre d'Essais en vol" (Flight Test Centre). The equipment has been officially demonstrated to experts of the Secrétariat Général à l'Aviation Civile and the Compagnie Nationale d'Air France (C.N.A.F.), as well as to British experts (Doctor Touch, Chief of B.L.E.U.) and United States experts (Mr. Wagner from the Wright Field Experimental Station). Following these demonstrations the C.N.A.F. decided to submit the system to the International Air Transport Association (IATA).

b) In England, during 1950, at Woodbridge and Martleshaw, by the Blind Landing Experimental Unit (BLEU), with the assistance of R.A.F. pilots and aeroplanes.

The tests comprised over 200 approaches or transverse passages, with accurate ground control using theodolite observations or photographs of the final approach taken with two synchronized cameras located on both sides of the runway close to the touch-down point.

Descents were also made using the receiver output signals to control an automatic pilot. On these descents a close check was made on board by a system of cameras photographing the ground, the instruments on the panel and the measuring instruments attached to the automatic control circuit.

In addition, during every descent, the indications of the cross-pointer instrument were recorded, either directly on a tape recorder, or by photographing the position of the cross-pointers. The following results were obtained:

a) Range: The required 40 km range was exceeded over a horizontal sector of 60° centred on the landing path. It was found that the system also provided satisfactory operation up to a distance of 100 km from the runway, over sectors within 15° on either side of the landing path.

b) Localizer coverage: Over the normal 40 km range, more than ± 30° about the landing path, for an angle between 0.75° and 7° above the horizontal.

c) Glide path coverage: Over the normal 40 km range, more than that produced by an angle between 0.75° and 7° above the horizontal. During the tests it was noted that even at 12 km from the runway, the system provided correct localizer and glide path indications at an angle of only 0.25° above the horizontal, over the coverage sector specified in b).

d) Accuracy of the localizer: Under manual or automatic piloting the accuracy of the localizer was found to be more than ± 0.3°.

e) Accuracy of the glide path: Under manual piloting the accuracy was found to be more than 0.1°, and under automatic piloting more than 0.05°.

f) Accuracy at the approach end of the runway: During descents executed by experienced pilots using the cross-pointer indicator, the accuracy of the aeroplane's approach in relation to the runway centre line, was found to be better than ± 12 metres, over a sector extending from the approach end of the runway and a line situated 150 m in front of the antennas.

CHAPTER V

BLOCK DIAGRAMS AND FIGURES

- A.S.V-23 -

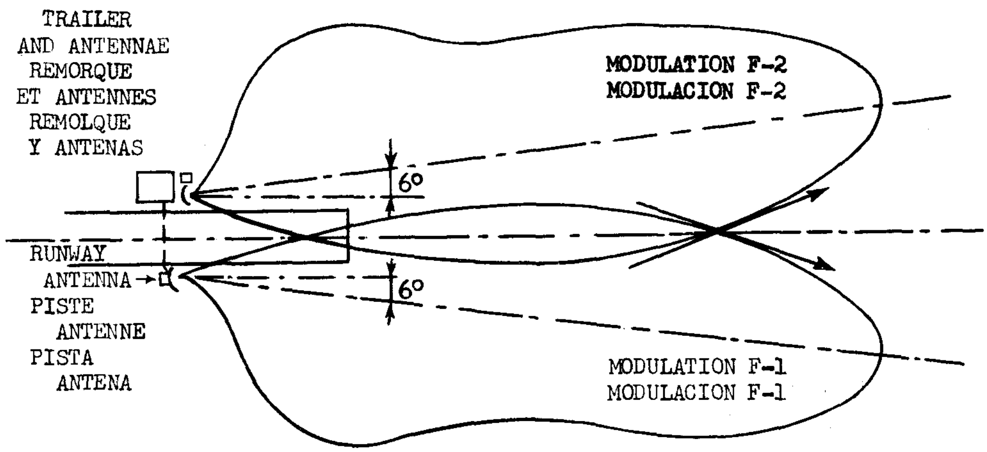

Fig. 1 - LOCALIZER PATTERNS
(POLAR COORDINATES)
Fig. 1 - DIAGRAMMES DE RAYONNEMENT DU RADIOPHARE D'ALIGNEMENT DE PISTE
(Coordonnées polaires)
Fig. 1 - DIAGRAMAS DEL LOCALIZADOR
(Coordenadas polares)

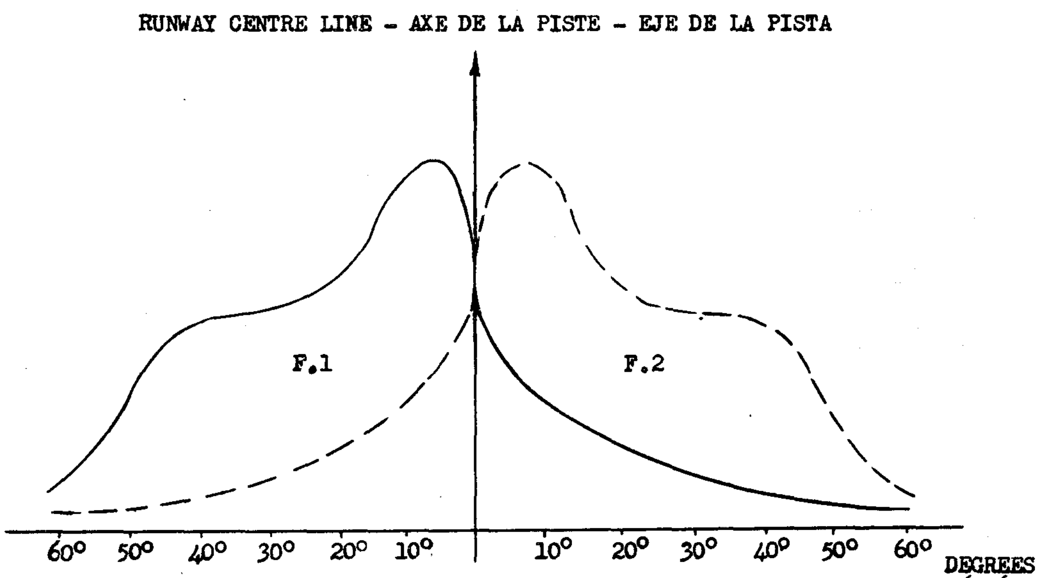

Fig. 2 - LOCALIZER PATTERNS
(RECTANGULAR COORDINATES)
Fig. 2 - DIAGRAMMES DE RAYONNEMENT DU RADIOPHARE D'ALIGNEMENT DE PISTE
(Coordonnées rectangulaires)
Fig. 2 - DIAGRAMAS DEL LOCALIZADOR
(Coordenadas rectangulares)

- A.S.V-23 -

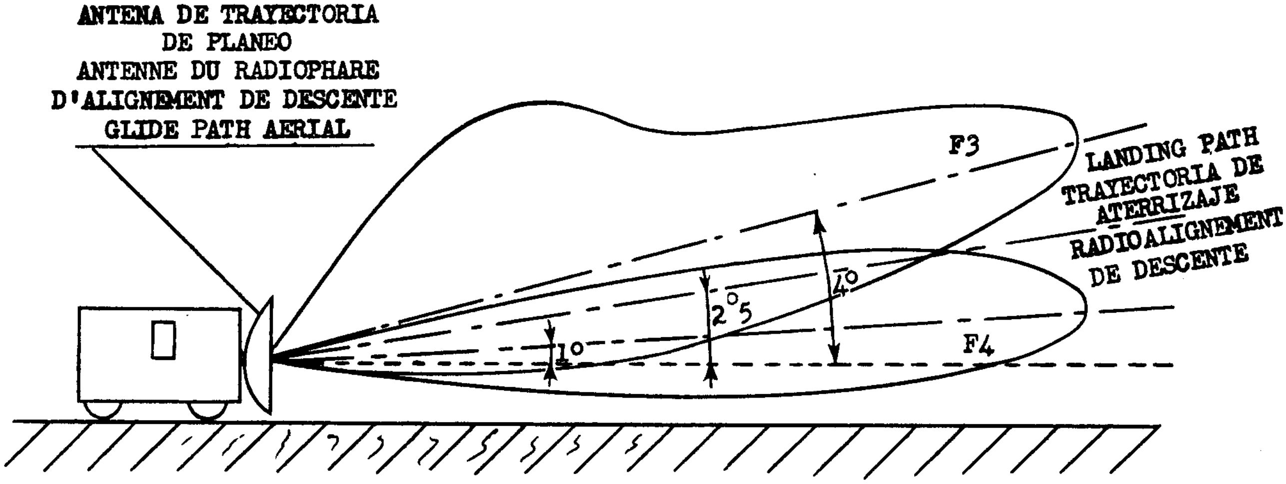

Fig. 3 - GLIDE PATH PATTERNS
Fig. 3 - DIAGRAMMES DE RAYONNEMENT DU RADIOPHARE D'ALIGNEMENT DE DESCENTE
Fig. 3 - DIAGRAMAS DE TRAYECTORIA DE PLANEO

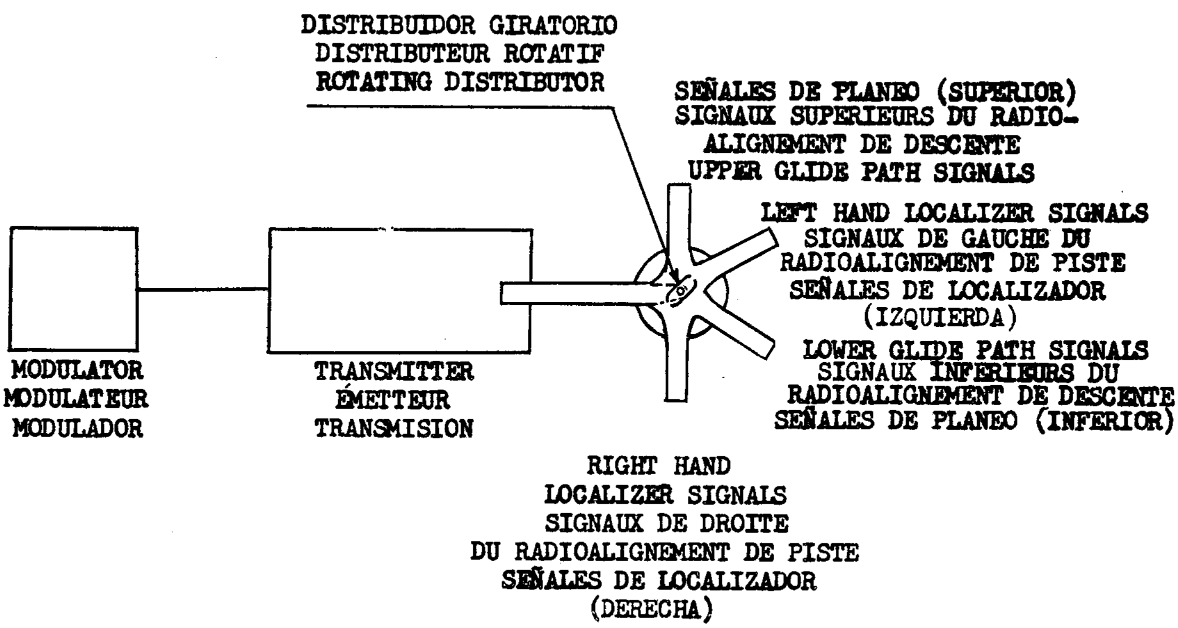

Fig. 4 - BLOCK DIAGRAM OF THE TRANSMITTER
Fig. 4 - SCHÉMA D'ENSEMBLE DE L'ÉMETTEUR
Fig. 4 - ESQUEMA DE PRINCIPIO DEL EMISOR

- A.S.V-23 -

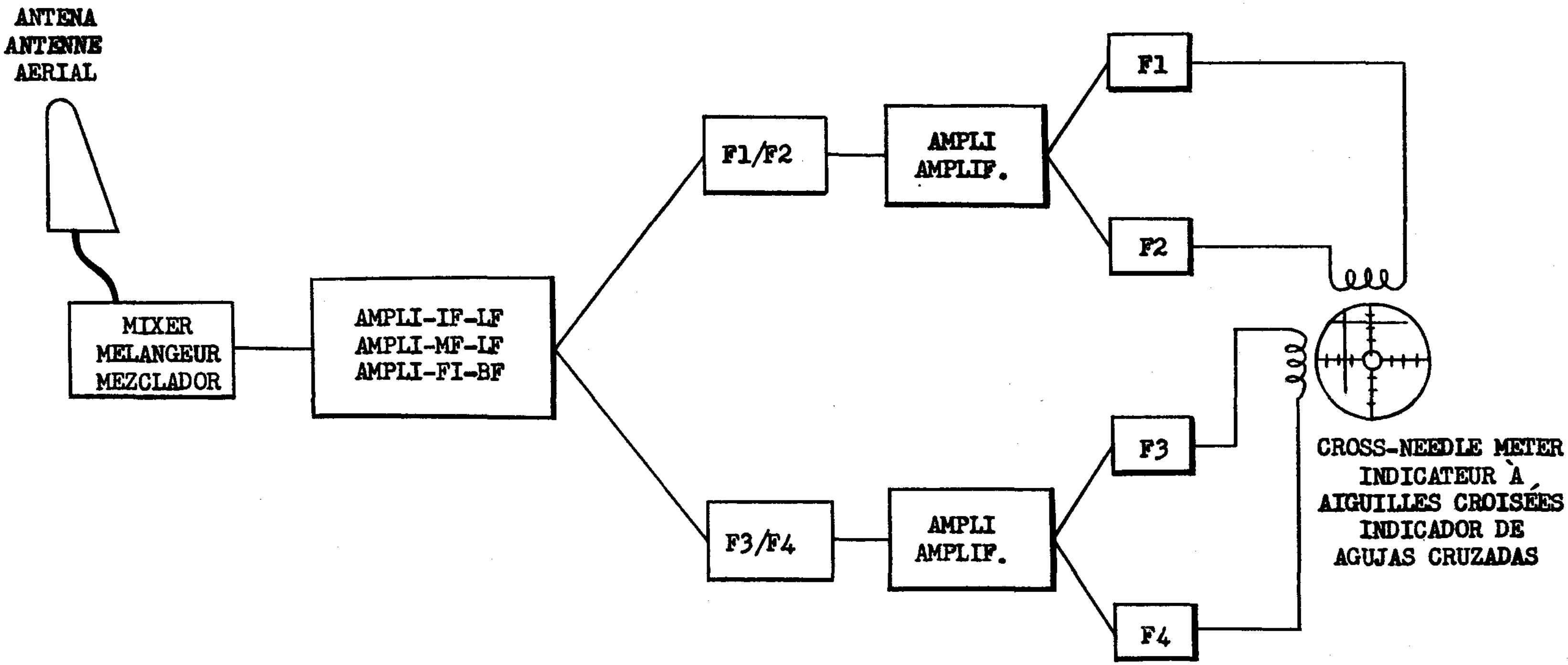

Fig. 5 - BLOCK DIAGRAM OF THE AIRBORNE RECEIVER
Fig. 5 - DIAGRAMME D'ENSEMBLE DU RÉCEPTEUR DE BORD
Fig. 5 - ESQUEMA DE PRINCIPIO DEL RECEPTOR

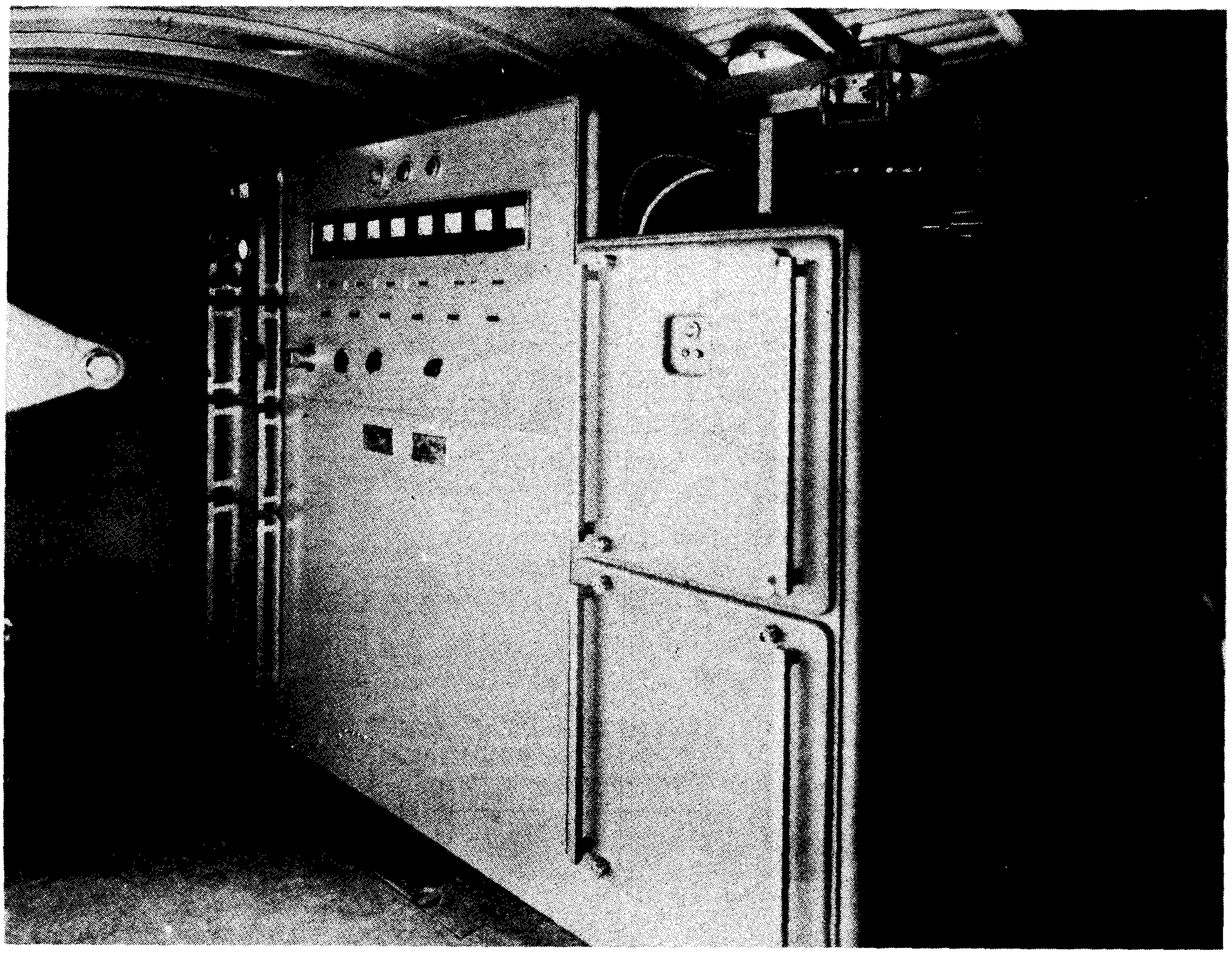

Fig. 6 - TRANSMITTER (front view)

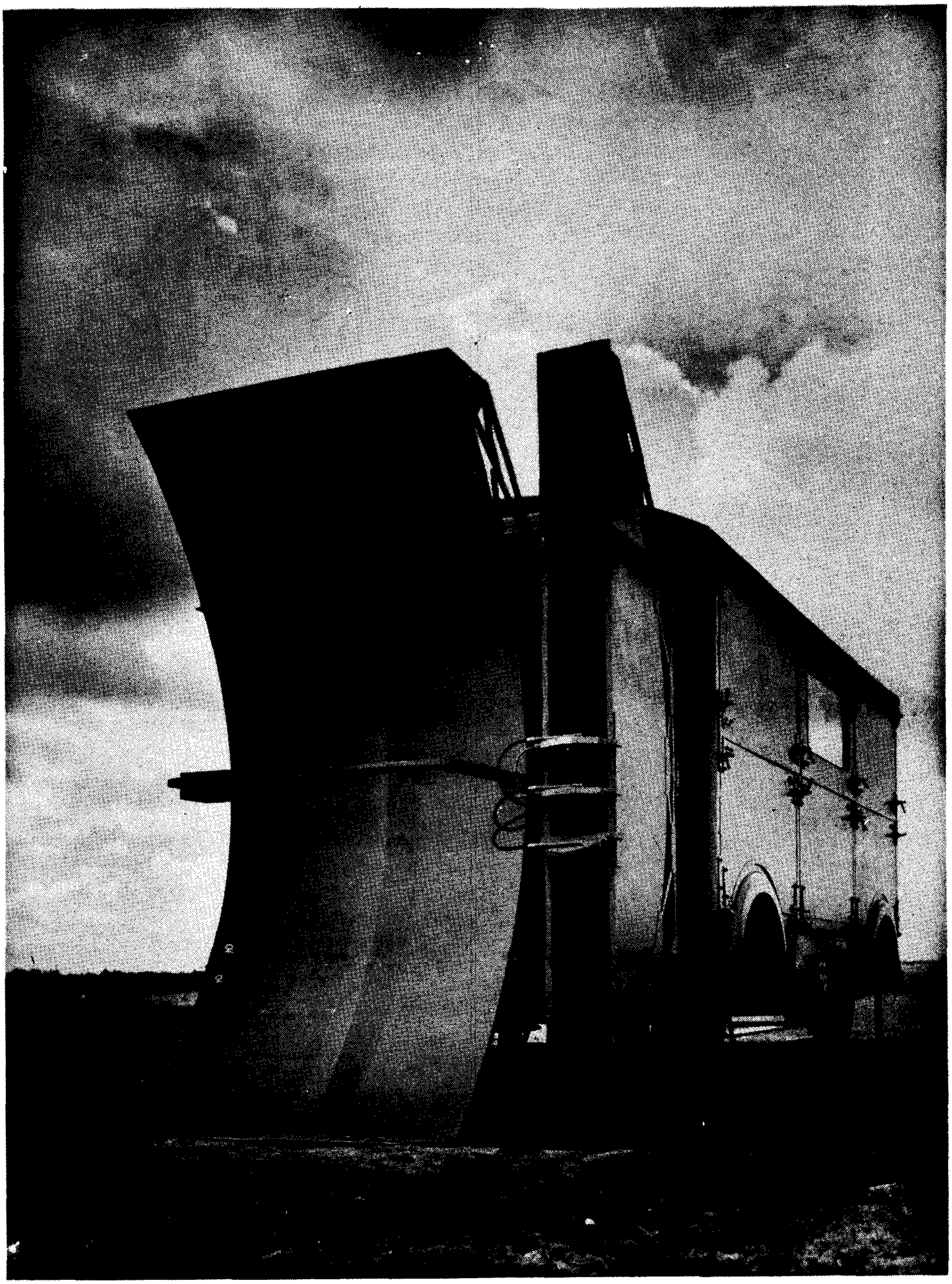

Fig. 7 - TRANSMITTER TRAILER

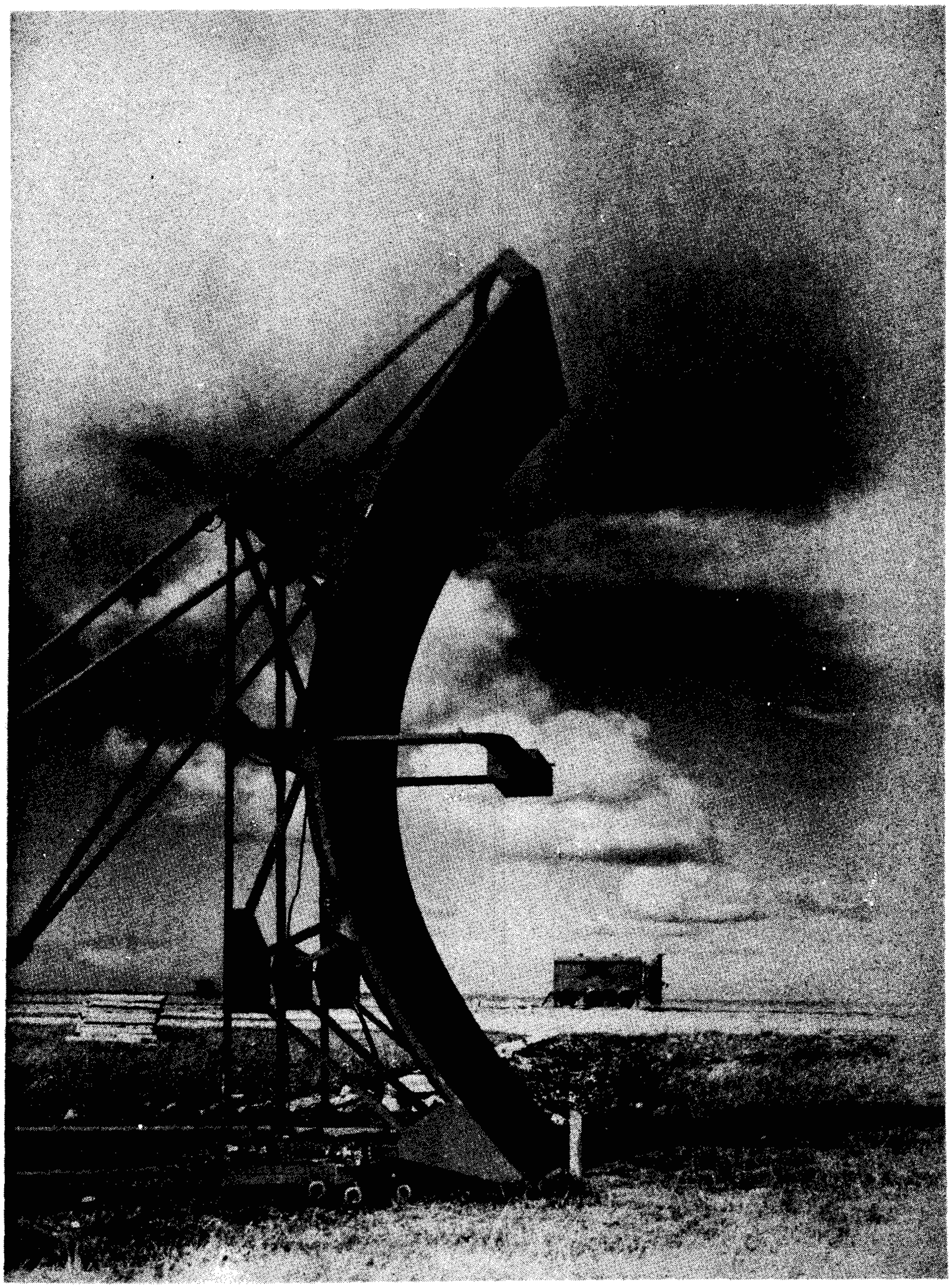

Fig. 8 - LOCALIZER ANTENNA
(Remote from other antenna mounted on trailer)

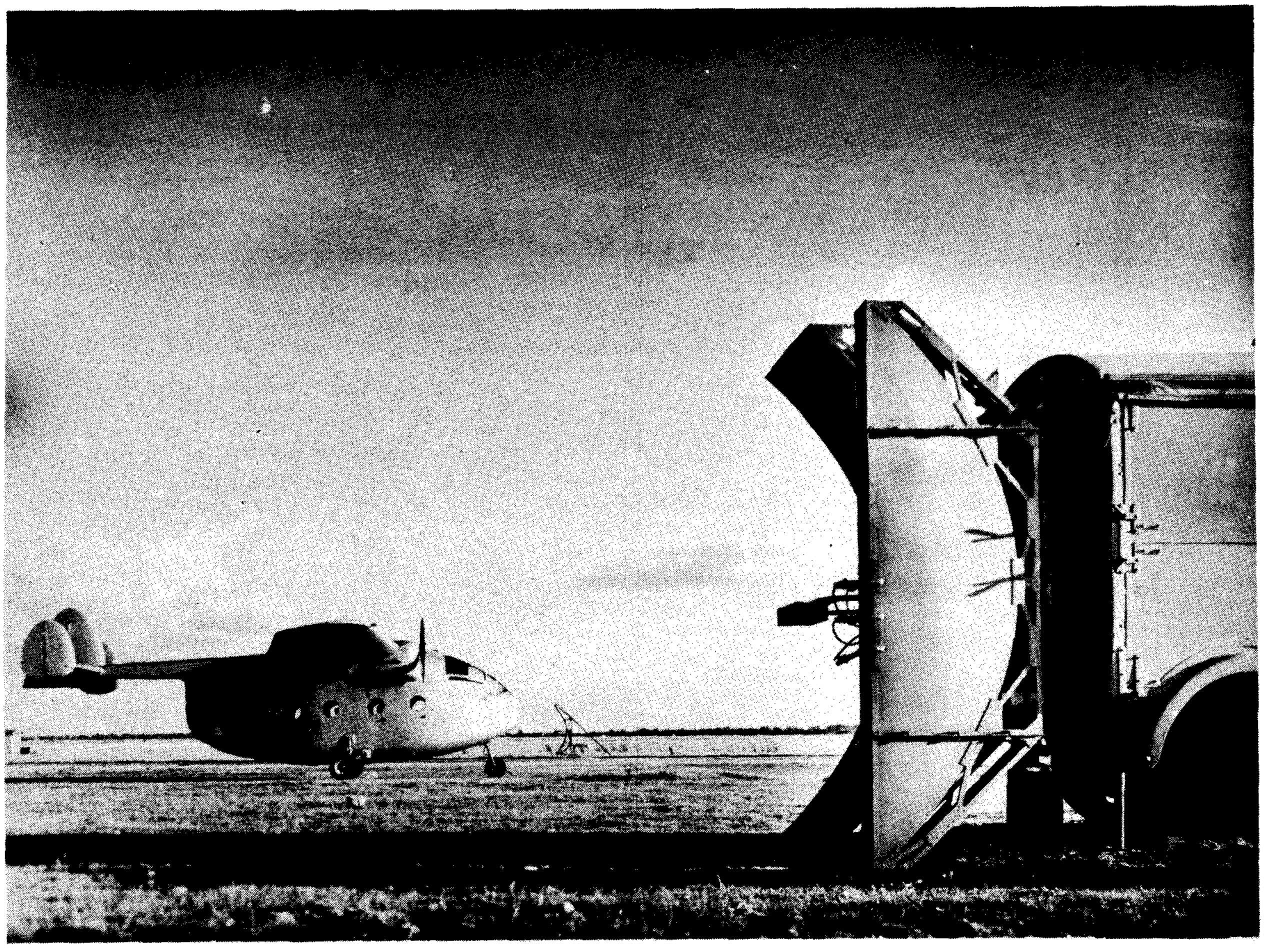

Fig. 9 - GLIDE PATH AND LOCALIZER ANTENNAS ON TRAILER

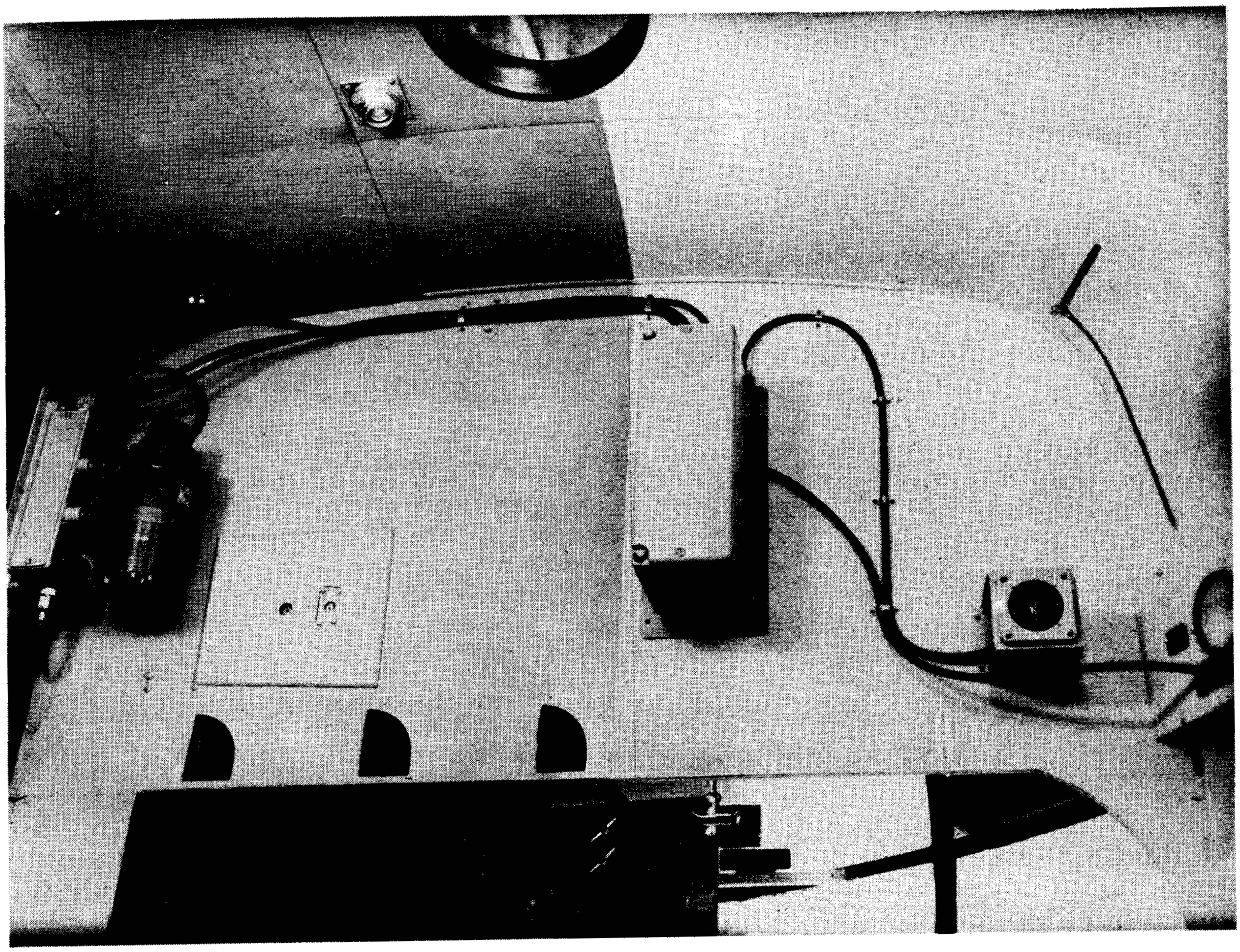

Fig. 10 - AIRBORNE EQUIPMENT

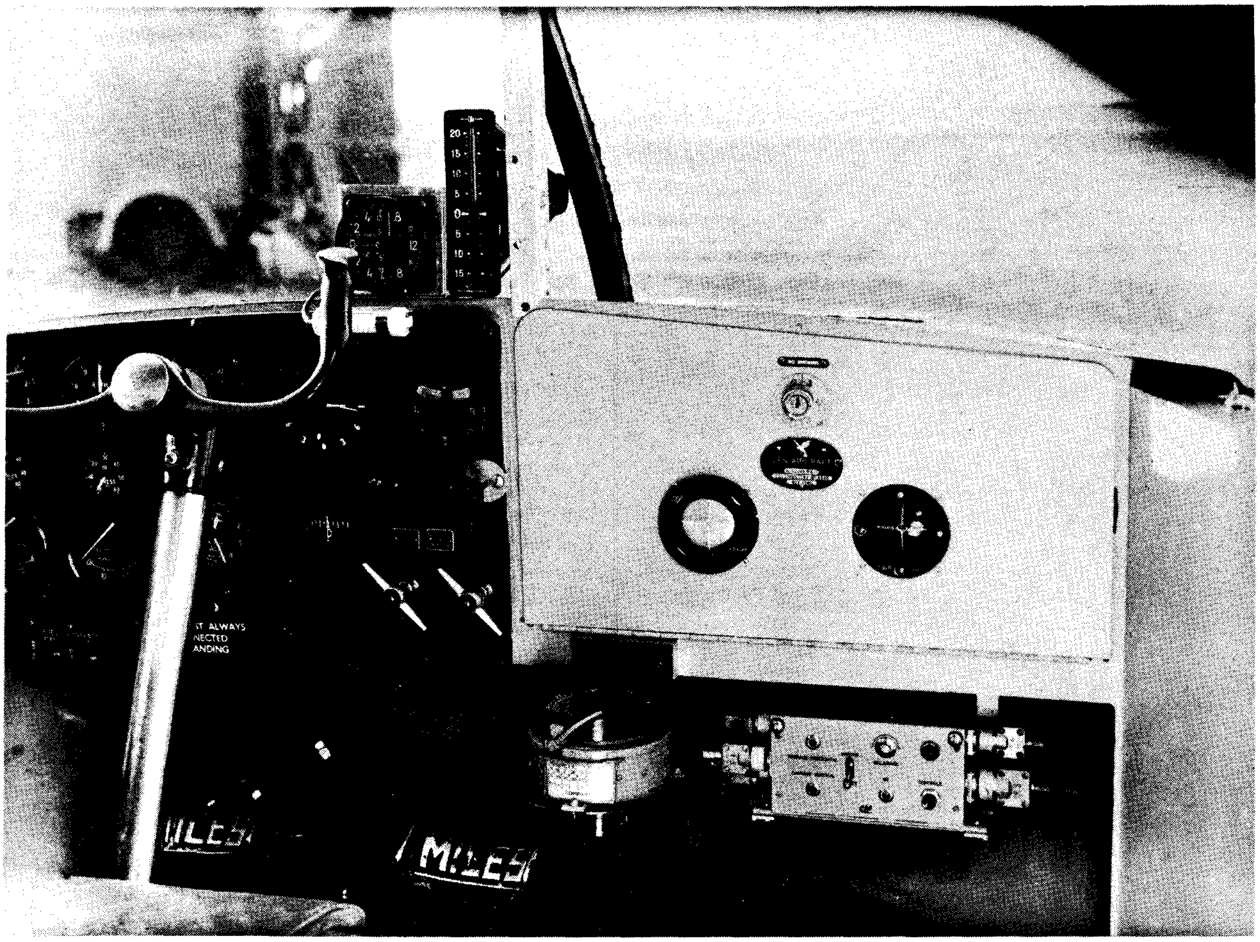

Fig. 11 - AIRBORNE INDICATORS

Fig. 12 - RECEIVER ANTENNA
(Airborne)

CHAPTER VI

TECHNICAL SPECIFICATIONS FOR A LANDING SYSTEM UTILIZING DECIMETRIC WAVES, REQUESTED BY THE SECRETARIAT GENERAL A L'AVIATION CIVILE ET COMMERCIALE

COMPRISING: A LOCALIZER EQUIPMENT
A GLIDE PATH EQUIPMENT
A DISTANCE MEASURING EQUIPMENT

PART I.- GROUND EQUIPMENT

I.- GENERAL

1.1.1 The ground equipment of the landing system shall comprise the following basic components:

a) a single transmitter successively feeding, on a common radio frequency carrier, the antennas of the runway localizer equipment, glide path equipment, associated distance measuring equipment and the system identification equipment.

b) two localizer antennas located one on each side of the runway, which shall radiate two radio frequency field patterns. One of the antennas shall be located close to the transmitter and shall be fed by the transmitter by means of a flexible coaxial feeder; the other antenna shall be fed by means of an air-insulated coaxial or a waveguide, crossing the runway substantially perpendicular to the centreline.

c) a glide path antenna which shall radiate two radio frequency field patterns off-set in relation to each other in the vertical plane. This antenna shall be located close to the common transmitter.

d) a receiver and antenna for reception of interrogation signals radiated by an aircraft equipment in connection with the indications to be obtained from the associated Distance Measuring Equipment.

e) a DME transmitter antenna fed by the common transmitter during the time interval reserved for radiation of DME signals as shall be described hereafter.

1.1.2 The common transmitter and the two antennas mentioned in b) shall comprise the runway localizer equipment.

1.1.3 The common transmitter and the antenna mentioned in c) shall comprise the glide path equipment.

1.1.4 The common transmitter, the receiver mentioned in d) and the two antennas mentioned in d) and e) shall comprise the transponder of the associated Distance Measuring Equipment.

II.- RADIO FREQUENCIES

The common transmitter shall operate in the band 1173.5 Mc/s. to 1186 Mc/s. There shall be 6 usable channels in this band. Adjacent channel separation shall be 2.5 Mc/s. As each of the usable frequencies is common to the runway localizer, glide path and transponder of the associated distance measuring equipment, they shall be called "common transmitting frequencies". The following shall be the six usable frequencies:

First common transmitting frequency 1173.5
Second common transmitting frequency 1176
Third common transmitting frequency 1178.5
....
Sixth common transmitting frequency .... 1186 Mc/s.

The frequency tolerance of each common transmitting frequency shall be ± 100 kc/s.

Note.- The transmitter is to be designed so that at a later stage of development it may operate on any of 40 channels with a separation of 1.5 Mc/s. in the band 1126 to 1186 Mc/s.

POLARIZATION.- The radiation from the localizer, glide path and DME transponder antennas shall be vertically polarized.

III.- MODULATION

The localizer and glide path antennas shall be fed sequentially by the common transmitter, whose radio frequency carrier shall be appropriately modulated by means of rectangular pulse trains.

The pulse trains radiated by the localizer equipment shall have repetition frequencies of 20 and 24 kc/s.

The pulse trains radiated by the glide path equipment shall have repetition frequencies of 30 and 34 kc/s.

The duration of a full emission cycle of the common transmitter shall be approximately 1/10 sec., divided as follows:

1) one pulse train at 20 kc/s.- approximate duration, 1/60 sec. (localizer)
2) space of 1/360 sec. approximately.
3) one pulse train at 30 kc/s.- approximate duration 1/60 sec. (glide path)
4) space of approximately 1/360 sec.
5) one pulse train at 24 kc/s.- approximate duration 1/60 sec. (localizer)
6) space of approximately 1/360 sec.
7) one pulse train at 34 kc/s.- approximate duration 1/60 sec. (glide path)
8) space of approximately 1/40 sec.
   This last space of 1/40 sec. shall constitute the time space reserved for radiation of DME and beacon identification signals.

Note.- It is recommended that the pulse front be such that the tenth harmonic does not exceed 5% of the basic.

IV.- UHF AMPLITUDE COMPARISON LOCALIZER - and ASSOCIATED MONITOR

1.4.1 General

1.4.1.1 The localizer shall radiate two radio frequency field patterns. These two patterns shall be characterized by a common radio frequency carrier, modulated by the pulse trains at 20 kc/s. and 24 kc/s. respectively for each of the two patterns as specified in III. The two patterns shall be arranged to intersect so as to produce an on-course line.

1.4.1.2 The on-course line in any horizontal plane shall be defined as the locus of points at which the peak amplitudes of the 20 kc/s. and 24 kc/s. pulse repetition frequencies shall be equal.

1.4.1.3 When an observer is placed on the centre line and faces the localizer at the approach end of the runway, the amplitude of pulses at the 20 kc/s. repetition frequency shall predominate at any point on his left hand and the amplitude of pulses at the 24 kc/s. repetition frequency shall predominate at any point on his right hand.

1.4.1.4 Any horizontal section of the overall radio frequency field pattern shall be symmetrical about the on-course line in that section.

1.4.2 Coverage

The localizer shall provide signals sufficient to allow satisfactory operation of a typical aircraft installation.

a) over a first sector defined by:

- two vertical planes perpendicular to the on-course line, located in front of the antennas at a distance of 150 m and 40 Km respectively.
- two vertical planes forming a dihedral at least 20° wide centred on the on-course line.
- two planes perpendicular to the lateral plane containing the on-course line, forming with the ground, angles of elevation of more than 1° and less than 7°, the latter crossing the approach end of the runway at a height of 600 m.

b) over a second sector defined by:

- two vertical planes perpendicular to the on-course line, located in front of the antennas at a distance of 150 m and 15 Km respectively.
- two vertical planes forming a dihedral of at least 90° wide centred on the on-course line.

- two planes perpendicular to the vertical plane containing the on-course line, forming angles of more than 0.75° and less than 7° with reference to the ground.

The localizer shall not radiate any false courses between a lower elevation angle above the horizontal of 0.75° and an upper elevation angle of 7° (max.).

1.4.3 Radio frequency field patterns

1.4.3.1 The patterns determining the on-course line shall intersect so that, on the glide path, at a distance of more than 300 m from the antennas, the ratio, of the field strengths (expressed in microvolts per meter), is 1.8 for an angular deviation of 0.25° from the on-course line of 2.5°.

1.4.3.2 The ratio of the field strengths shall increase in a substantially linear fashion from the on-course line to 4° ± 0.4° from the on-course line, where it shall not be less than 2.6. This ratio shall then remain greater than 1.8 for angular deviations between 4° and 45°.

Note.- The field strength ratio of 1.8 shall be that which causes the pointer of the indicator of a typical aircraft installation to be fully deflected.

1.4.4 Stability and Accuracy of the course produced by the Localizer

1.4.4.1 The course produced by the localizer shall have no bends troublesome to pilots.

Note.- Bends or other irregularities that are not acceptable will be in principle ascertained by flight tests in stable air conditions.

1.4.4.2 The accuracy of the on-course line shall be within 1/4 degree at distances greater than 3 Km over all terrain not providing obstructions to propagation.

The direction of the on-course line shall not deviate by more than 3° from the runway centre line, at 150 m from the antennas.

1.4.4.3 The accuracy of the on-course line at the approach end of the runway shall be such that the on-course line passes within the sector covered by two lines parallel to the runway, located at 20 m on each side of the centre line and extending from the transverse line located 150 m in front of the antennas to the approach end of the runway line.

1.4.5 Monitoring

1.4.5.1 Suitable equipment located in the radiation field of the localizer antennas shall provide signals for the operation of an automatic monitor. The monitor shall transmit a warning to a control point, and shall cause radiation from the common transmitter to cease if any of the following conditions arise:

a) shift of the on-course line more than one-third of one degree from the centre line of the runway;

b) reduction of power output to less than 50% of normal;

c) change of more than 10% in the course width specified in 1.4.3.1 (The condition in c) shall not be required in the case of the development of a prototype).

1.4.5.2 Means shall be provided so that any of the conditions a), b) and c) in 1.4.5.1 can persist for a certain period before the warning is transmitted and radiation ceases. The duration of this period shall be adjustable within the limits of 4 and 10 seconds.

Note.- The monitoring equipment may also be used to operate a system for readjusting the on-course line.

1.4.5.3 Failure of the monitor itself shall automatically cause radiation to cease.

V.- UHF AMPLITUDE COMPARISON GLIDE PATH EQUIPMENT AND ASSOCIATED MONITOR

1.5.1 General

1.5.1.1 The glide path equipment shall radiate two radio frequency field patterns. These two patterns shall be characterized by a common radio frequency carrier modulated by the pulse trains at 30 and 34 kc/s., during the periods provided for this purpose as specified in III.

The two patterns shall be arranged to intersect so as to provide a straight descent path in the vertical plane containing the centre line of the runway.

1.5.1.2 The amplitude of pulses at the repetition frequency of 34 kc/s. shall predominate at any point below the descent path.

1.5.1.3 The descent path shall be defined as the locus of points in the vertical plane containing the centre line of the runway at which the amplitudes of the 30 kc/s. and 34 kc/s. pulses are equal.

1.5.1.4 The glide path equipment normally shall be capable of adjustment to produce a descent path at any angle between 2-1/4 and 3 degrees with respect to the horizontal.

Note.- In exceptional cases this angle may be adjusted between 3 and 4 degrees.

1.5.1.5 The descent path shall be such that the optimum touchdown point is located on the runway centre line at a distance of 150 to 300 metres from the approach end of the runway.

Note 1).- The optimum touchdown point specified above is taken for an aircraft with its ASV 23 receiver antenna at about 6 metres above the wheels. It therefore is the same as the "reference point" defined in Annex 10 to the Convention on International Civil Aviation.

Note 2).- Some deviations to 1.5.1.5 may be envisaged as a result of local conditions.

1.5.2 Coverage

The glide path equipment shall provide signals sufficient to allow satisfactory operation of a typical aircraft installation in the following sectors located in front of the antennas:

a) sectors of 8 degrees on each side of the centre line of the descent path up to a distance of 40 Kms and between an angle of 1.5° and 5° above the horizontal respectively.

b) sectors limited in azimuth as in a), up to a distance of at least 20 Kms and between an angle, enclosing the angle in a), of 0.75° and 7° above the horizontal respectively.

c) sectors of 25 degrees on each side of the centre line of the descent path, up to a distance of at least 15 Kms and in elevation as in a).

1.5.3 Radio frequency field patterns

1.5.3.1 The patterns determining the glide path shall intersect so that at a distance of more than 300 metres from the antennas the field ratio, expressed in microvolts per metre, is 1.7 for an angular deviation below the glide path of 0.5° ± 0.05° and above the glide path of 0.6° ± 0.1°.

1.5.3.2 The field ratio shall remain greater than 1.7 for angular deviations exceeding those referred to above, within the vertical coverage limits specified in 1.5.2.

Note 1).- The 1.7 field ratio shall be that for which the glide path pointer of the indicator of a typical aircraft installation is fully deflected.

Note 2).- Taking into account the above conditions and the accuracy and monitoring conditions specified in the following paragraphs, as well as the errors due to reception, (which should not exceed 0.20° (see 2.5.5.)) the lower edge of the glide path sector defined by the full scale upward deflection of the pointer will not project into the obstruction clearing surface (Doc 4809-AGA/558) except in the case of glide path slopes of less than 2.5°.

1.5.4 Accuracy of the glide path

1.5.4.1 The descent path shall be within 0.1° of the published value above all terrain not providing natural obstructions to propagation.

1.5.4.2 The descent path provided by the glide path equipment shall have no bends troublesome to pilots.

Note.- Bends or other irregularities that are not acceptable will in principle be ascertained by flight tests in stable air conditions.

1.5.5 Monitoring

1.5.5.1 Suitable equipment located in the radiation field of the glide path equipment shall provide signals for the operation of an automatic monitor. The monitor shall transmit a warning to a control point, and shall cause radiation from the glide path equipment to cease if any of the following conditions arise.

a) shift of the descent path of more than 0.1°;

b) reduction of power output to less than 50% of normal;

c) increase of the descent path width of more than 10% over the width specified in 1.5.3.1 (condition c) shall not be required in the case of the development of a prototype).

1.5.5.2 Means shall be provided so that the conditions prescribed in the previous paragraph can persist for a certain period before the warning is transmitted and radiation ceases. The duration of this period shall be adjustable within the limits of 2 and 6 seconds.

Note.- The monitoring equipment may also be used to operate a system for automatically resetting the glide path.

1.5.5.3 Failure of the monitor itself shall automatically cause radiation to cease.

VI.- ASSOCIATED INTERROGATOR-TRANSPONDER DISTANCE MEASURING EQUIPMENT, GROUND EQUIPMENT

1.6.1 General

1.6.1.1 The associated distance measuring equipment is designed to provide the pilot with continuous and accurate indications of the distance of the aircraft from the optimum touchdown point on the runway.

1.6.1.2 The equipment comprises two basic components: an interrogator on the aircraft and the ground transponder using the common transmitter.

Note.- This chapter only refers to the aircraft interrogator where necessary for clarity. The specifications are given in a subsequent chapter.

1.6.1.3 The basic components of the ground transponder are as stated in I, namely, receiver and antenna, common transmitter, transmitting antenna.

1.6.2 Channelling

1.6.2.1 The system shall operate within two frequency bands, namely, 960-986 Mc/s. for the interrogation (see Note to 1.6.2.6) and 1126-1186 Mc/s. for the reply, with 2.5 Mc/s. separation between adjacent radio frequency assignments.

1.6.2.2 The transponder receiver shall operate on the following three interrogation frequencies: 979.75 Mc/s, 982.25 Mc/s. and 984.75 Mc/s.

1.6.2.3 Single pulses with a duration of 2μs ± 10% shall be employed for interrogation and reply.

1.6.2.4 There shall be a suppressed time delay of 3μs ± 0.2μs between interrogation and reply pulses.

1.6.2.5 The pulse repetition frequency shall be between 1400 and 1600 per second.

1.6.2.6 The combination of three interrogation frequencies and six reply frequencies, which are also the six common transmitting frequencies specified in II, shall provide eighteen possible channels.

Note.- This equipment should be regarded as a phase in the development of an equipment operating on 40 common transmitting frequencies spaced at 1.5 Mc/s. and nine interrogator frequencies spaced at 2.5 Mc/s. The interrogator frequencies are to be chosen from the middle of the spacing between the interrogation frequencies laid down by ICAO.

1.6.2.7 The same interrogation and reply frequency combination may not be repeated with less than 200 kilometres separation between ground facilities.

1.6.2.8 Two adjacent reply frequencies may not be repeated except for ground facilities with more than 100 Kms separation.

1.6.2.9 The transponder receiving and transmitting antennas shall operate on vertically polarized energy.

1.6.3 Accuracy of the system

The overall accuracy of the associated distance measuring equipment shall be defined as the mean of 100 measurements of the absolute values of the difference between each reading given by a typical aircraft installation and the corresponding true distance.

The accuracy should be:

a) For distances between 0 and 7.5 Kms, error not to exceed 150 m;

b) For distances between 7.5 Kms and 40 Kms, error not to exceed 2% of true distance.

1.6.4 Coverage

The coverage shall be the same as for the localizer.

1.6.5 Traffic capacity

The equipment should operate normally with 50 aircraft simultaneously interrogating the same ground station.

1.6.6 Transponder receiver requirements

1.6.6.1 The transponder receiver local oscillator frequency tolerance shall not exceed ± 100 kc/s.

1.6.6.2 Radiation from the transponder receiver local oscillator shall be adequately suppressed.

1.6.6.3 The receiver sensitivity shall be at least 100 db below one watt.

1.6.6.4 The selectivity of the receiver shall be such that pulses 2.5 Mc/s. removed from the desired centre frequency will not result in operation of the triggering circuits unless the amplitude of the pulses are at least 50 db greater than the minimum required for operation in the desired channel.

1.6.6.5 Means shall be incorporated to protect the receiver against harmful interference by signals outside the DME band.

VII.- SITING OF THE GROUND EQUIPMENT

1.7.1 The transmitters shall be installed in a trailer.

1.7.2 The localizer antennas shall be located on a line at right angles to the runway centre line at a distance of at least 300 metres from the approach end of the runway, and in the direction of the stop and, in order not to constitute an obstruction troublesome to landing. There shall be at least 120 metres distance between the centre of each antenna and the runway centre line. The common transmitter shall be located approximately 10 metres to the right of the righthand localizer antenna, as viewed by an observer facing the runway in the direction of landing.

1.7.3 The glide path antenna shall be located to the common transmitter, namely, approximately on the line joining the localizer antennas, at 10 metres to the right of the righthand antenna, as viewed by an observer facing the runway in the direction of landing.

Note.- Certain deviations to 1.7.1 may be envisaged as a result of local conditions.

PART II.- AIRBORNE EQUIPMENT

I.- GENERAL

2.1.1 The airborne equipment shall comprise the following basic components:

a) common receiver for reception of signals from the runway localizer equipment, the glide path equipment and the associated distance measuring equipment;

b) interrogator box of the associated distance measuring equipment, also containing the video part of the distance measuring equipment;

c) a common antenna for receiver and interrogator;

d) a cross-pointer indicator, operated by the localizer and glide path signals;

Note.- Two cross-pointer indicators may be used with the same receiver.

e) Cathode-ray indicator, operated by the distance signals;

Note 1).- Two distance measuring indicators may be used with the same receiver.

Note 2).- A pointer or a veeder counter indicator will be subsequently developed.

f) airborne equipment remote control panel, comprising:

- an on-off switch;
- a channel switch for selecting the frequency combination corresponding to the ground facility used;
- a sensitivity control knob, as specified in 2.5.3;

g) a dial, giving the letter of the alphabet identifying the ground facility employed;

h) if required, a 24 volt DC/110 volt AC/400 c/s converter for aircraft not equipped with a 400-cycle supply system.

II.- COMMON AIRBORNE RECEIVER

2.2.1 Frequencies

The common receiver of the localizer, glide path and associated distance measuring equipment signals shall operate on the following six frequencies:

1173.5 Mc/s.	1176 Mc/s.	1178.5 Mc/s.
1181 Mc/s.	1183.5 Mc/s.	1186 Mc/s.

2.2.2 The local oscillator frequencies shall be stabilized by means of a common crystal. The instability tolerance shall not be more than ± 70 kc/s.

Note.- The receiver will be designed to receive, at a subsequent stage of development, the 40 frequencies spaced at 1.5 Mc/s. in the 1126 to 1186 Mc/s. band, to which reference has been made in II "Radio Frequencies".

2.2.3 Sensitivity

At maximum sensitivity, the IF amplifier gain measured between the crystal and the second detector shall be at least 80 db.

2.2.4 Selectivity

At maximum sensitivity, the IF pass band shall be 2 Mc/s.± 10% at 3 db down. The band shall be centred on an IF frequency of 22 Mc/s.± 1%.

The IF response for a frequency 2.5 Mc/s. removed from the centre frequency shall be at least 18 db down. The IF response for a frequency 5 Mc/s. from the centre frequency shall be at least 40 db down. The response to the image-frequency shall be at least 20 db down.

2.2.5 Modulation frequency pass band filters

The pass band filter for transmission of signals modulated at 20 and 24 kc/s. should produce, for signals of the same input level, output signals which do not differ in level by more than 1 db from the two modulation frequencies.

Likewise, the filter for transmission of signals modulated at 30 and 34 kc/s. should produce, for signals of the same input level, signals which do not differ by more than 1 db. The discrimination between the 24 kc/s. and the 30 kc/s. modulation frequencies shall be more than 18 db.

2.2.6 Single Filters

The pass band of these filters shall be such that a frequency variation of ± 1% produces a maximum variation in level of 0.5 db. The discrimination against the closest unwanted modulation frequency shall be at least 25 db.

2.2.7 IF Automatic Volume Control

The AVC characteristic should be such that at the operating threshold if two 20 kc/s. voltages are impressed, the ratio of which is 20 db, two LF voltages are produced, the ratio of which should not exceed 4 db.

2.2.8 Power supply

The airborne receiver shall be designed to employ normally an input AC voltage of 115 v 400 c/s. The stability of the input voltage, as well as the frequency, shall be ± 2%.

III.- AIRBORNE INTERROGATOR

2.3.1 The airborne interrogator shall transmit on the following three frequencies taken from the frequency band laid down by ICAO for airborne DME interrogators: 979.75 Mc/s, 982.25 Mc/s. and 984.75 Mc/s.

Note.- Subsequently there shall be nine interrogation frequencies (see Note to 1.6.2.6).

2.3.2 The interrogator frequency tolerance shall not be greater than ± 200 kc/s.

2.3.3 Pulse characteristic

2.3.3.1 The interrogator pulse duration shall be 2μs by ± 0.2μs

2.3.3.2 The pulse repetition frequency shall be between 1400 and 1600 c.p.s and the average variation shall be less than ± 1%.

2.3.3.3 The pulse peak power shall be at least 50 watts.

2.3.4 The airborne interrogator power supply shall be 115 volt AC 400 c/s. The required voltage stability and frequency stability shall be ± 2%.

IV.- COMMON INTERROGATOR AND RECEIVER ANTENNA

2.4.1 The common airborne interrogator and receiver antenna shall consist of three vertical half-wave elements in line separated by two folded half-wave elements.

2.4.2 The antenna shall comprise the array in 2.4.1 with a reflector element placed parallel to it at a distance of approximately $\frac{\lambda}{4}$.

The antenna-reflector unit shall be enclosed in a sabre-shape plexiglass housing.

2.4.3 The adapting and filtering elements shall be contained in the base of the antenna.

2.4.4 The antenna shall be connected to the receiver and interrogator units by means of a standard 50 ohm impedance coaxial feeder.

V.- CROSS-POINTER INDICATOR

2.5.1 The cross-pointer indicator shall conform to aeronautical standards.

2.5.2 The current required in the quadrature coils to produce a deflection of one division shall be 30 microamps. The deflection should be proportional to the current over the full scale of ±5 divisions in a substantially linear manner.

2.5.3 The pilot shall have a sensitivity control enabling him to obtain the total deviation in course of 5 divisions: either for an IF voltage ratio of 1.8 or for a ratio of 2.6; the two sensitivities corresponding to angular deviations from the on-course line of 2.5° and 4° respectively.

2.5.4 The indicator shall have two flag alarms conforming to aeronautical standards.

2.5.4.1 Each flag alarm shall be fully visible when the field received only provides a deflection of up to 2-1/2 divisions of the indicator for only one of the two modulation frequencies acting on that flag alarm.

2.5.5 Possible inaccuracies in the receiver (LF sensitivity), and in the indicator (dynamic centering) should not introduce a total error of more than 2 divisions of the indicator.

VI.- CATHODE-RAY DISTANCE MEASURING INDICATOR

2.6.1 The dimensions of the indicator shall conform to aeronautical standards. The depth of the indicator, which is recessed in the instrument panel, shall not exceed 200 mm.

2.6.2 The diameter of the cathode-ray tube employed shall be 72 mm ± 3.

2.6.3 Scales

The indicator shall have two scales: a logarithmic scale measuring distances from 0 to 5 kms and a substantially linear scale for distances from 5 to 40 kms.

2.6.4 A sweep time delay, adjustable between 3 and 5 microseconds, shall permit zero distance to be indicated at the touchdown point on the runway.

Two adjusting screws should be incorporated to permit the sweep zero and the sweep amplitude to be adjusted.

2.6.5 Accuracy

The accuracy should be compatible with the overall accuracy of the system as specified in 1.6.3.

VII.- POWER UNIT

2.7.1 In the case of aircraft not provided with a 400 c/s AC supply, the power required for proper operation of the common receiver and interrogator shall be obtained by means of a converter working on the 24 volt DC aircraft system.

2.7.2 Under normal load the converter should provide 115 volt AC ± 2% at 400 c/s for system voltages between 22 and 30 volt DC. Under similar supply conditions the 400 c/s frequency should not vary by more than ± 2%.

PART III.- GENERAL PROVISIONS

1. The system should be able to operate satisfactorily with an automatic pilot.

2. The ground and aircraft equipment should comply with any general provisions with respect to:

2.1 presentation and dimensions of racks, boxes, etc...;

2.2 climatological conditions;

2.3 endurance tests.

In this latter respect, ground equipment should operate under normal conditions for a period of 1000 hours without replacement of component parts.

The airborne equipment should also be able to operate for 1000 hours, but at 5-hour periods.

During tests, the performance of the equipment shall be verified every 200 hours.

3. Airborne equipment test benches

3.1 Equipment will be developed for use as a "workshop" test bench (emergency repairs, general maintenance and control).

3.2 Equipment will be developed for use as a "runway" test bench, with which the airborne equipment may be left in its normal position in the aeroplane.

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CHAPTER VII

ADVANTAGES OF THE C.S.F. A.S.V 23 SYSTEM OVER THE ILS SYSTEM

The main differences between the two systems are:

1) In the ILS, the glide path is obtained by utilizing the phenomenon of ground reflection of horizontally polarized waves. It follows that a change in the condition of the ground (e.g. humidity), or the fortuitous presence of an obstruction on the terrain may appreciably modify the path angle. Furthermore, parasitic reflections due to normal terrain undulation may produce interference fringes, resulting in the appearance of pronounced ridges on the descent path. The C.S.F. system instead uses antennas which are highly directive and therefore do not rely on ground reflected waves for producing the equisignal path. Consequently, the slope of the path is far more uniform and is unaffected by terrain conditions or surrounding obstructions.

2) The ILS system uses three frequencies to provide azimuth elevation guidance, and an indication of position by means of three marker beacons. In order to utilize the ILS it is thus necessary to have three receivers operating simultaneously. The C.S.F. system, on the contrary, uses a single frequency, and no more, and only one receiver is required to obtain continuous indications of azimuth, elevation and distance from 100 Km out to the point of touchdown. Therefore, notwithstanding the necessity for an airborne interrogator for the last function, the C.S.F. has the advantage over the ILS of a saving in both space and weight.

Moreover, while the ILS system requires two ground transmitters and three beacons, the C.S.F. system uses a single transmitter with three antennas.

3) With the ILS system the distance from the runway during descent is indicated at three specific points only, corresponding to the positions of the three beacons located along the path at 7 Kms, 3 Kms and at the approach end of the runway. Maintenance and supervision of these beacons is difficult owing to their isolated positions. A failure

of any one of the beacons will put the pilot in a difficult position as he will not receive the distance signal he was expecting along his path in order to carry out his landing procedure. With the C.S.F. system, distance is provided continuously even when the aircraft is not entirely on-course, thus making it easy for the pilot to continue his approach and to complete his landing procedure at the right time.

4) Finally, in the ILS, azimuthal guidance is given by a transmitter located on the extended centre line of the runway and at least 2 Km from the stop end of the runway. A course deviation of 0.9° would be sufficient to place an aeroplane off the runway (in the case of 60 m wide runway). With the C.S.F. system, the aeroplane lands exactly between two course antennas located one on each side of the runway at equal distance from the centre line. It follows that a deviation in course of 1°, 2° or 3° does not produce any major difficulty in the operation of the system.

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