Description
Radar Altimeter PH-11 / A

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AIR FORCE

RADAR ALTIMETER PH-11/A

DESCRIPTION

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determined
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CONTENT

PICTURE LIST

INTRODUCTION

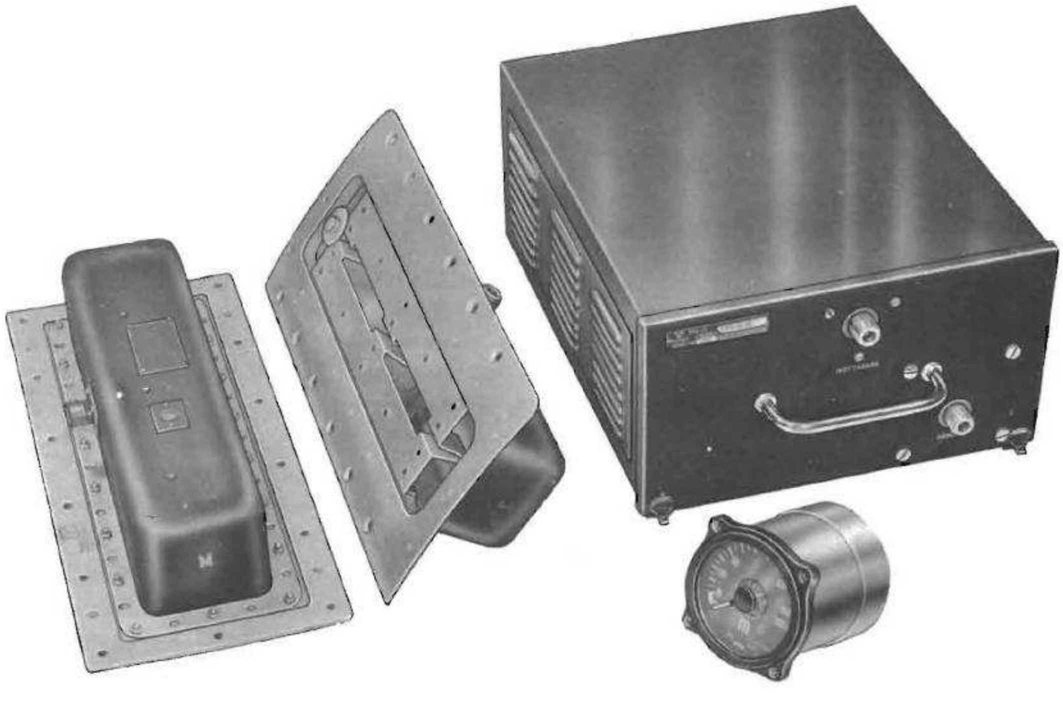
GENERAL

Radar Altimeter PH-111A is an airborne equipment for measuring the altitude of the aircraft over the underlying terrain, preferably above sea level.

The radar altimeter consists of the following units:

device unit	SFR-25877
mounting bed, complete	SFR-25888
receiving antenna	SFR-25884M
transmits antenna	SFR-25884S
indicator	ERMI-VRF 5102

Figure 1. Radar Altimeter PH-11/A



The PH-11/A altimeter is used in miliary aircraft in conjunction with the PN-50A, which provides the stabilized 19V for the tube filaments.
The PH-11/A was derived from the french altimeter AM210, in exactly the same case, and nearly the same circuit. However, the PH-11/A has only the low range (0-200 meter) on the indicator.

TECHNICAL DATA

Indicator range:	10-200 m
Accuracy:	± 5% or ± 2 m within roll angles 50 °, as well rise and dive angles 40 °
Drop-out:	300-800 m over land and 500-1000 m above water.
Locking height (lock on):	600-300 m above ground and 800-300 m above water
Modulation type:	FM
Output:	0.7 W ± 30%
Average frequency:	440 MHz
Frequency swing:	40 MHz + 0 / -2 MHz
Modulation frequency:	135 Hz ± 1 Hz
Frequency difference:	72 Hz / m
Transmitter Amplitude modulation:	< 7%
Modulator motor speed:	4050 rpm
LF amplifier's characteristics:	2 kHz 73 ± 3 dB gain 7 kHz 98 ± 3 dB _ "_ 20 kHz 109 ± 3 dB - "-
Power sources:	28 V / 4 A = max 19 V / 2 A = stabilized

Weights and Measures:

Unit	Weight kg	Length mm	Width mm	Height mm
unit	10	370	270	155
mounting bed complete	1	430	265	105
the antennas	2x 0.65	340	110	75
indicator	0.85	conform standard		

FM RADAR PRINCIPLE

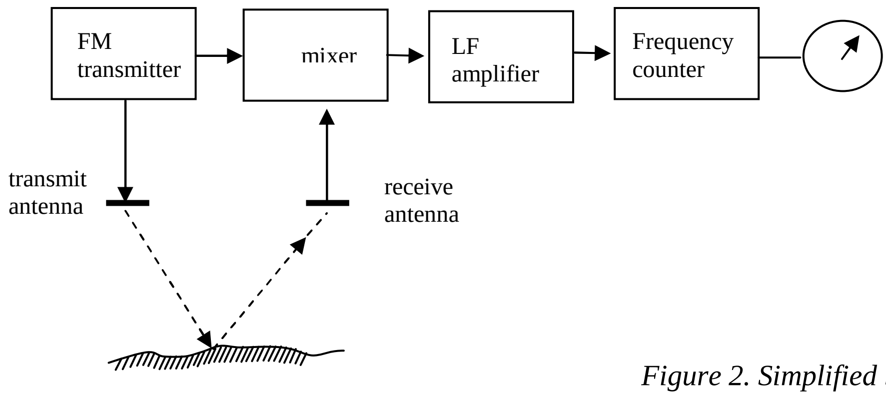


Figure 2. Simplified block diagram of an FM radar altimeter.

Frequency modulated radar is mainly used when determining the absolute height of an aircraft to
the ground. A frequency-modulated radar altimeter contains a transmitter whose frequency varies periodically. The signal of the transmitter is transmitted directly to the receiver and partly to the ground where it is reflected.
The reflected signal arrives at the receiver with a delay equal to the time of its way back and forth.
Since the transmitter constantly changes frequency, the reflected signal frequency differs from the
direct signal frequency. This difference frequency is thus proportional to the height.

Difference frequency is then measured with a frequency counter. This controls a display tool, which is
graded in meters. The transmitter frequency varies between two limits, f1 and f2 according to a periodic function of time. This function is called the modulation frequency, (fm) and can theoretically be assumed to be triangular.

The solid curve in Fig. 3a represents the transmitted signal which is simultaneously fed into the receiver. The transmitted signal travels the distance 2h (h = aircraft height)
from the transmitter to the ground and return to the receiver at the constant velocity c (radio wave propagation velocity).

The signal delay time will then be:

$$\Delta t = 2h / c \; .... (1)$$

The reflected signal is represented in Figure 3a of the dashed curve. Meanwhile, the send frequency has changed with the amount Δf. From the curve it appears that Δf is proportional to t and hence to h.

However, this does not apply when the transmitter frequency is near the limit values f1 or f2, where the transmitted and the reflected signals curves will intersect and the difference frequency becomes 0. This occurs at the beginning and end of each half-period T / 2 (see Figure 3b).

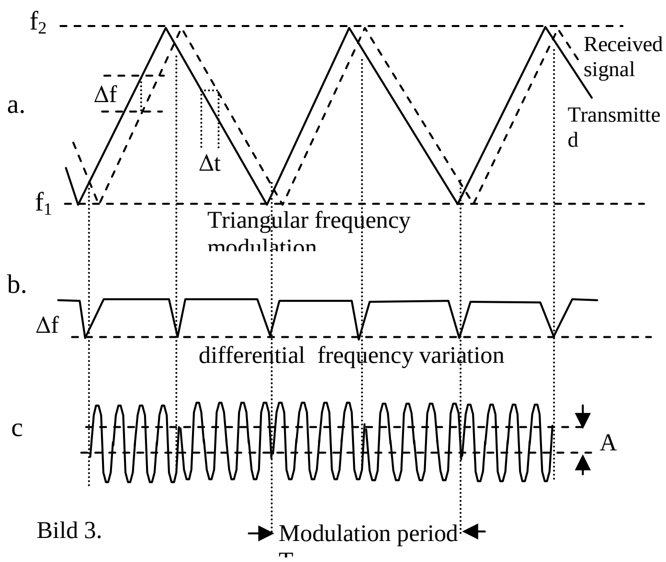


Bild 3.

Then Δt has no relation to T / 2, this has no practical significance.

Introduction

As previously mentioned, the size of Δf is dependent on Δt. During a half-period (T / 2) of the modulating frequency fm, the signal frequency changes from f1 to f2,

$$T / 2 = 1 / 2fm \text{ .... (2)}$$

You can thus write:

$$\frac{\Delta f}{\Delta t} = \frac{f2-f1}{T/2} \text{ .... (3)}$$

By inserting Equation 2 in Equation 3 and solving Δf, you get:

$$\Delta f = (f2-f1).\ 2Fm.\ \Delta t \text{ .... (4)}$$

According to equation 1, $\Delta t = 2h / c$, eq 4 can be rewritten as

$$\Delta f = (f2-f1).\ 4fm.\ h / c \text{ ……...... (5)}$$

From this equation you can get the important connection $\Delta f /h$, the freq. difference per meter.

$$\Delta f / h = (f2-f1) \bullet 4f m / c \text{ .... (6)}$$

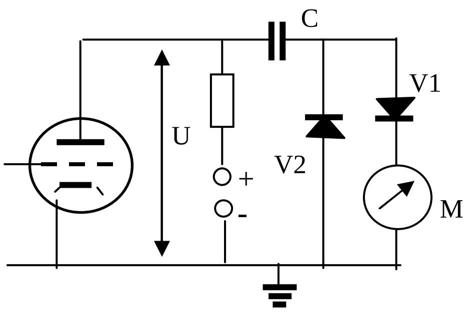
Example:
For PH-11 / A, fm = 135 Hz, f2-f1 is 40 MHz and C = 3.10 ^ 8 m / s

$$\Delta f / h = (40.10\text{^}6 .\ 4.\ 135) / 3.10\text{^}8 = 72 \text{ Hz / m}$$

Thus, for each meter's height change, the difference rate from the mixer is changed with 72 Hz. (This is a theoretical value. Due to system errors, such as discussed later, this does not exactly match.

a. This differential frequency voltage is amplified in an LF amplifier after which it triggers a multivibrator. The multivibrator generates a square voltage with the same frequency as the triggering signal and with: constant amplitude. The square voltage is rectified and differentiated, acting as a frequency counter. The frequency counter feeds an indicator, which is graded directly in meters.

Frequency counter
The frequency counter consists of a triggered



multivibrator, which leaves a square voltage with constant amplitude as well as a device that generates a current corresponding to the frequency.

The square wave from the multivibrator charges during the positive half periods the capacitor C. The diode V1 becomes conductive and a current flows through the indicator M.

During the negative half periods, the diode V2 conducts and discharges the capacitor. If U is the voltage variant over the multivibrator, then capacitor C receives a half-charge every half-hour:

$$Q = C \cdot U \text{ .... (7)}$$

Figure 4. Frequency counter.

The number of charges per time unit is Δf and the indicator is passed by a current:

$$I = \Delta f \bullet C.\ U \text{ . . . . (8)}$$

If now C and U are constant, the current I depends on the amount Δf. By inserting the expression for f (eq 5) you get

$$I = ((f2-f1)\ 4fm \bullet h / c).\ CU. \text{ . . . . (9)}$$

Provided that the frequency swing f2-f1 and the modulation frequency fm are also known and constant, it is seen from the above equation that the current through the indicator depends on the height h. Thus, the indicator can be read directly in meters.

SYSTEMATIC ERRORS

General
In frequency-modulated radar altimeters, there are three main errors, namely the remaining altitude error, the path difference error, and the fixed error.

Remaining altitude error
The remaining altitude error is caused by the reflected signal having a longer path than the direct signal especially at zero height. The reflected signal goes partly through the antenna lines Ls and Lm, (see Figure 5), and partly by air, the hs and hm distances.
The delay in the wiring is longer than the corresponding distance of air, due to the signal propagation rate being lower in line than in air.
The hs and hm distances depend on the altitude of the aircraft above the ground, giving rise to the so-called road difference, The error, is discussed in the next section.

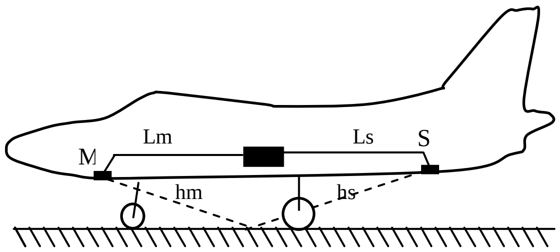


Figure 5. *The remaining altitude error.*

The remaining altitude value hk can be obtained from the equation

$$hk = 0.5\ ((Ls+Lm)\ /\ m + hs + hm)\ \ldots\ldots\ldots\ldots\ (10)$$

where Ls and Lm are the antenna cable lengths, m the relative rate of propagation velocity of the conduit and the hs and hm signal path in air (see Figure 5).
If Ls and Lm are 8 m each, m = 0.66 for polythen insulated coax, and hs and hm 5m each, one gets:

$$hk = 0.5\ ((8 + 8)\ /\ 0.66) + 5 + 5) = \sim 17\ m$$

Thus, when the aircraft is on the ground, a certain current is obtained through the indicator. This current corresponds to the remaining high frequency difference frequency. To get 0 indication, the current corresponding to the remaining altitude window is compensated, with a countercurrent current I through the indicator. (2 mA for full scale = 300 m on the indicator):

$$I = \frac{17}{300} \cdot 2 = 0.11\ mA = 110\ uA$$

Path-difference error

The path difference error occurs because the antennas are mounted at a certain distance from each other. The error is largest when the aircraft is on the ground and decreases with increasing flight height. When the aircraft is on the ground, the signal travels hs + hm in Figure 5 (except for cables).

This path is longer than h's + h'm (Figure 6). Thus you get a difference depending on h:

$$(hs + hm) - (hs + h'm)$$

Since the "height" is equal to half way for the signal, the path difference error becomes half of the above.
The path difference error is compensated in the remaining altitude when the aircraft is on the ground (see figure 5). From Figure 17 shows that 0 meters on the indicator are excellent at the second scale, so some current flows at 0 meter height. This current thus arises from the differential difference.

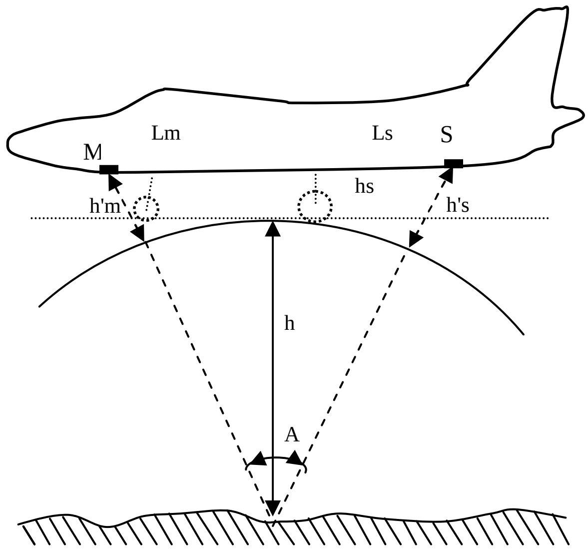


Fig. 6. Path separation error.

As the aircraft climbs, the error decreases with increasing height (h's and h'm, and the angle A in Figure 6 decreases). Consideration of the error at altitudes below 30 meters has been taken by adapting the gradient on the scale. At altitudes above 30 meters the error is so small that it has no practical significance.

Fixed error

The fixed error results from the given countercurrent through the indicator.

Figure 7a shows the resulting difference frequency at height h. In Figure 7b, the height is increased by 1/16 λ which means a phase change of approximately 45 ° (the wave path has increased 2 x 1/16 λ = 1/8 λ phi = 45 °) at the beginning and end of the modulation period.

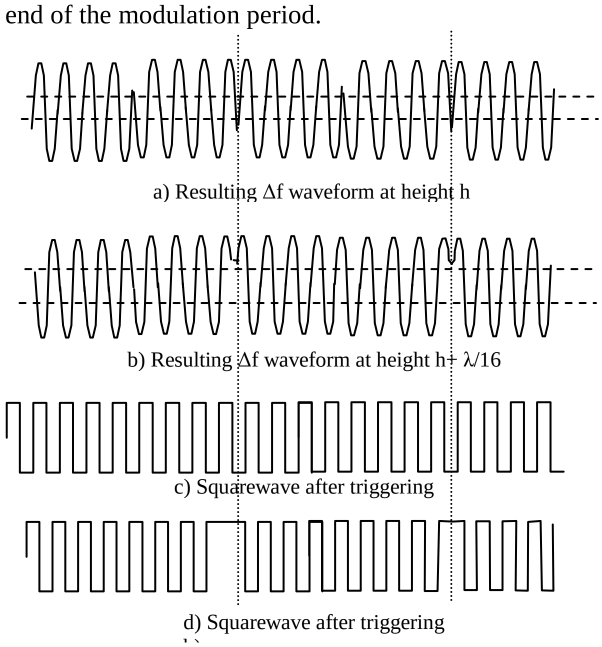


Fig. 7. The fixed error.

The images show that the number of pulses from the multivibrator decreases instead of increasing at elevated height. This results in a smaller current through the indicator, and the result decreases, despite increased height.

The reason for this is that a height change does not always mean a change of a whole number of periods of the difference frequency within the modulation period.
However, since the multivibrator can only produce pulses of entire difference frequency periods, the error occurs within each modulation period (compare Figure 8).

If now the number of Δf periods within the modulation period is assumed to be **n** we obtain:

$$\Delta f = n.\ f\ m \ \ldots\ldots\ldots (11)$$

Reduces or increases the number of periods with the minimum number ie 1, this means a change of

$$\Delta f = fm \ \ldots\ldots\ldots (12)$$

From equation 5, solve h

$$h = \frac{\Delta f.\ c}{4fm\ (f2 - f1)} \quad \ldots\ldots\ldots\ldots (13)$$

If you enter eq 11 eq 12, you get the fixed error Δh

$$\Delta h = \frac{c}{4\ (f2 - f1)} \quad \ldots\ldots\ldots\ldots (14)$$

which for PH-11/A becomes 1,875 m.

If you perform an analysis of a height range, similar to that made in Figure 7, a curve, as shown in Figure 8, is obtained.

From the picture, it appears that the difference frequency, which is proportional to the height indication, changes in steps of fm. The height range within each multiple of fm is called the fixed error.
The height indication is thus not proportional to the height of the flight at any moment, but changes in steps of fm, which is also evident from eq 11. (fm = 135 Hz, thus corresponding to 1,875 m because Δf / h = 72 Hz).

Under normal flight conditions, the fixed error is leveled out of the minor height variations of the underlying terrain and of differences in air pressure and humidity, but under certain circumstances may cause slight variations of the height.

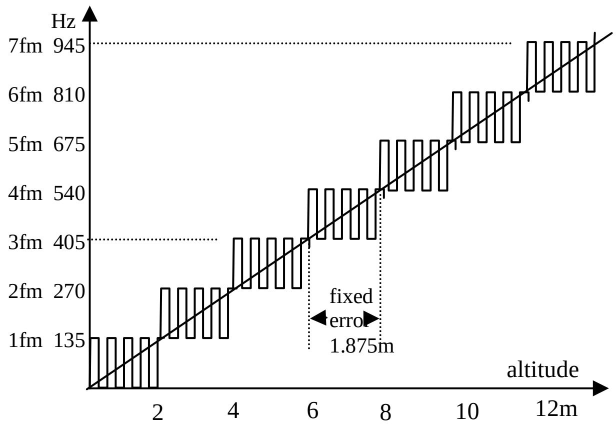


Fig 8. The fixed error as function from altitude

OPERATION

GENERAL

The altimeter measures the absolute height of the aircraft over the underlying terrain in the range of 10-200 meters. In the event of overflying of terrain changes which are small in relation to the aircraft speed, it measures however, the average of the height. When the altimeter is turned off, the indicator pointer must be on the first (thin) scalemark.

TO START

1. Set the RADAR HEIGHT Meter (S32 LUNA switch) to the ON position.
2. Wait about 2 minutes.
3. The altimeter is ready for use.

ORIENTATION FOR FLIGHTS

More important data

Indicator range:	10 -200 m
Accuracy:	± 2 m between 10 and 40 m, over 40 m ± 5%
Max roll angle:	± 50 °
Max pitch and dive angles:	± 40 °

Normal behavior of the device

When switched on, the display instrument gives first negative results, and after about 30 seconds a short turn upwards. If the aircraft is set up near another aircraft, tanks, forests or the like, the instrument can show distance to these instead of under the aircraft, because the reflections from these objects may be more powerful than ground cuttings.

For rolling on the taxiway, for the same reason, the shuttle shifts between the minus position and the indication of distance to objects next to the aircraft.

When rolling on the runway, the pointer must be below 10 m. At startup, the indicator should "hook up" immediately after take-off and follow the rise to 200m the line to then rise further towards its maximum position, where it drops at 300-1000m flight altitude depending on aircraft type and underlying terrain. When the indicator drops, the pointer will go down with a few quick jumps and show between 40 and 10 m to show below the 10 m line at 2000 m altitude or above. Because the reflected signal is much more powerful over water, drop-out occurs at greater altitude over water than over land.

When diving 'from heights above the drop-out height (when the pointer is less than 10m-wide), the pointer usually makes some noise before it rises significantly above 200m, ie lock-in, to show the height above the ground down to less than 10 m.

When flying on the border between drop-out and lock-in height, the pointer commutes regularly throughout the scale, preferably the lower part. This is quite normal, and is because the signal n is reflected differently over water and solid land, where "one moment can be in the lock-in height." You can see a lake or lake for the next moment in the drop- out-height above a field or forest. Similarly, objects on the ground reflect the signal different.

When banking within the lock-in area more than ± 50°, the pointer will first be worried for a moment, then quickly fall out and drop below the 10m line. When the roll angle returns to less than 50 °, the lock-in resets and the instrument shows the current flight height above the ground. The ratio is the same when the maximum dive and pitch angles are exceeded. Note that the PH-11/ A always measures the shortest height above the underlying terrain, regardless of the position of the aircraft in the specified bank, dive and pitch angles. The height indicated, however, refers to the distance from the intended plane located below the body of the folded wheel in the rear landing point and underlying terrain. This means that the lower wing tip may be below the indicated flight height when lowering at low altitude.

When flying over forest, the altimeter shows distance to an imaginary altitude between the ground and the tree tops. The denser the forest is, the closer the tree tops are, is this intended plan.

When flying at low altitude over water, the indication is extremely stable down to 10 m. The only fault indication that is usually seen here is the system error (± 2 m below 40 m and ± 5% above 40 m flight altitude). When flying over ice, the indication is as stable, but the altimeter measures the distance to points between the ice and underlying medium (water or ground). This should be observed when flying over the glaciers and thicker icebergs.

At landing gear, the drop-out-lock-in heights are around 100-200 m lower than with a landing gear set. This is due to the fact that the signal is also reflected by the landing point, which at air altitudes above 100-200 m causes the device to show certain tendencies to choose between ground-reflected signal and signal reflected by the landing point.

This can result in some troubled display results on the instrument.

Radar Altimeter PH-11 / A is therefore **not a suitable landing instrument**, but a low-flying instrument, which is suitable for use in low-altitude flight, even in pale or dark conditions. It is also a very useful low-flying instrument on special occasions such as plan bombardment against ship's pins, etc.

Some possible errors and the way they express themselves on the indicator instrument

Any errors in the device appear on the instrument in the first place so that drop-out is obtained, because the instrument shows less than 10m, in other hand, so that the pointer becomes very worried and commutes back and forth over the scale or a larger part thereof. Any direct error display in addition to system error 2 m or. ± 5% should not be possible. Since the radar altimeter has not yet been in operation on aircraft 32 at the floodplains, only a few possible
wrong and the way in which they practically expressed themselves in simulation are discussed.

• In case of power failure, the instrument does not show a fault or (if the interruption is at 19 volt voltage), a negative impact is when the pointer goes to the lower stop.

• In case of interruption of the transmitter antenna (the rear antenna, located immediately in front of the tails), the instrument shows a fixed position, usually around 0 m, regardless of flight altitude and speed. Due to the location of the transmitter antenna, it is subjected to very strong vibration stresses if the traces run in the runway during aerodynamic braking.

Should the fault be a leakage in the antenna cable, the pointer commands a lot of concern.

• If the receiver antenna or its connection cable is interrupted, the instrument will display approximately 0 m independently of flight altitude and speed. In case of accidental contact, the pointer commands a lot of concern over the entire area or most of it.

• If the switching points on the modulator motor sparks, the motor speed increases, with the pointer lowering 10 m line.

• In case of failure of other components, the t-shirt drop-out or, exceptionally, very worrying rash.

CONSTRUCTION

MOUNT

The mounting bed (Figure 9) carries the unit. The bed is resilient so that the appliance's tubes and other delicate details are protected from vibration and shock.

Figure 9. Mounting bed.

The bed is made of light metal and black-painted. The resilient elements, which are located between the bed and the two
The transverse rails consist of four spiral springs filled with steel wool. The bed is screwed into the rails with four screws and intermediate steel wool trays.

The bed has two control pins, which fit the device unit. At the front are two fastening screws with lighted nuts. On the front of the appliance, two lightly rounded mounting brackets over which nuts fit.

At the back there is a connector box with three connectors and the circuit for compensating the remaining height.

The connectors consist of a 15-pole casing, with two control pins, for the device unit, a 8-pole pin for connecting the indicators, and a 4-pin power plug.

The compensation circuit consists of four resistors 6R01 … 6R04 and a potentiometer 6P01. The circuit diagram can be found in Annex 7 and the detailed location in Annex 6.

UNITS

General

The main unit contains the following subunits:

1 transmitter unit with modulation motor
2 mixing unit
3 LF unit
4 altitude unit
5 power unit

The details in the different subunits are marked with a group number in front of the designation.
For example, tube 1 of the low frequency unit is labeled 3Z01.
The unit is structured on a rectangular framework on which front panel is attached.
The framework is divided into a front and a rear section.

The sections are separated by a vertical wall of light metal plate. In the rear section is the power unit. Other units are in the front section.

In the rear lower edge of the frame is a 15-pole pin tag fixed.
The front panel has a handle and coaxial connectors for the coax lines to the transmitter and receiver antennas. The main unit is enclosed in an aluminum alloy hood.
On the long side of the hood there are "slots" for ventilation. For the same purpose there are a number of holes in the hood bottom. The slots and holes are covered with fine wire mesh.
The cover is attached to the back with two lightweight, unloossable screws.

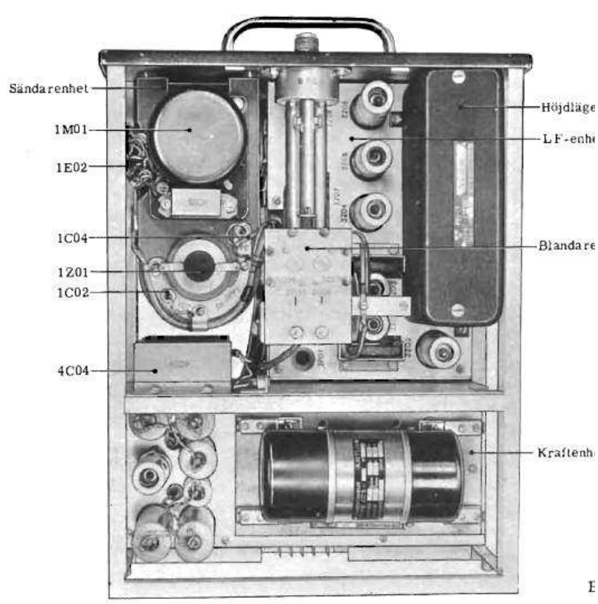


Figure 10. Topview of the main unit.

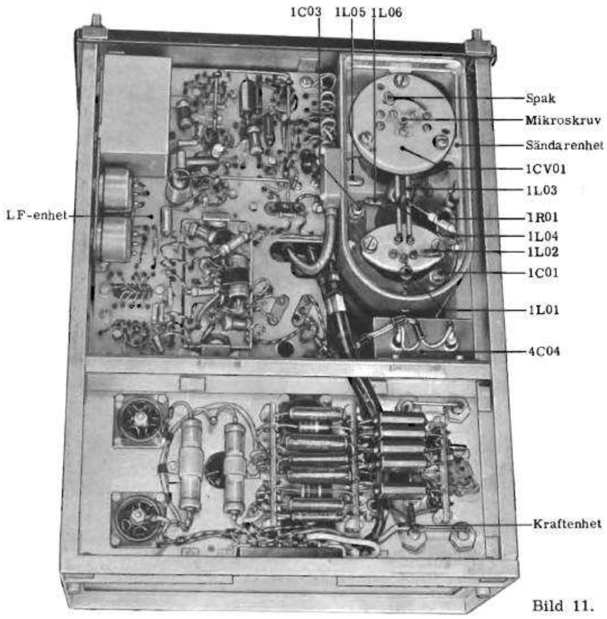


Figure 11. Bottom of the main unit (transmitter unit cover removed)

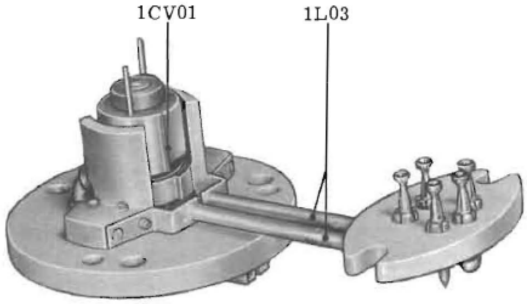


Figure 12. Modulation Condenser and Lecher Line.

The transmitter unit

The transmitter is enclosed in a molded light metal box that has a lid of light metal plate. The box is screwed to the front panel with four screws (see Figures 10 and 11).

On the top of the box and partially recessed, the modulation motor lMO1 is connected with the associated lE02 connector.
The metallic part of the transmission tube 1Z01 is completely recessed. The tube is held in place by two resilient clamps.

Around the transmitter tube there is a horseshoe-shaped brass plate in which the conductors 1C02 and 1C04 are attached.
On the outside of the bottom lid is a bent contact piece, which holds the cover in place and partly stubs the unit cover on which a corresponding ink is riveted.
For the connection to be good on the inside of the lid, a number of resilient pads that make contact with the box are provided inside. The lid can be loosened by grasping your fingers over the rounded edge, pulling upwards and then backwards.

Around the tube holder for the transmitter tube is a rail for the connection of the same type as on the top of the box. On the rail, the feed-thru capacitors 1C01 and 1C03 are fixed.
Between the tube holder's anode and grid connections is a lead lead, 1L03, connected.

The other end of the lecher line is attached to a steatite plate and connected to the two fixed plates on the modulating capacitor 1CV01. Centrally between the plates is a bush in which the rotor shaft is running. The bushing is attached with three screws.

The rotor consists of two opposite, cylindrical parts, electrically connected to each other, but isolated from the shaft with woven laminate. In the woven laminate there are two raised pins that engage the modulation motor carrier wheel (Figure 12).

The rotor shaft is displaceable in axial direction with a microscrew. By changing the rotor position

in relation to the solid plates, the capacitor's maximum capacitance is trimmed.
Between the rotor and the bushing is a metal ring with fringes on the periphery. The ring is isolated from the other parts and can be rotated with a lever. Turning the ring trims the capacitor's mincapacity.
The microscrew and lever are accessible from the outside of the transmitter unit through two holes in the cover.

Above the leak line is the antenna connection loop 1L04. The loop is attached to a rotary plexiglass pen. The rod can be rotated since its fixing screw, accessible under the modulation motor, has been released. From the one end of the coupling loop, a coaxial wire leads to the casing 1E01, from the other end a matching stub goes.
On the inside of the box, in the middle of the lecher line, there is a coupling device 1L05 for the mixer unit. The device consists of a bent tube with 0.2 mm air gap. In the tube is a coupling loop inserted.

Modulation motor

Modulation motor 1M01 is a centrifugal-controlled shunt motor (Figure 13). The motor is attached to the top unit with two screws. The connections are made over a 5-pin connector 1E02.
The pin is located on the motor and the casing of the transmitter unit.

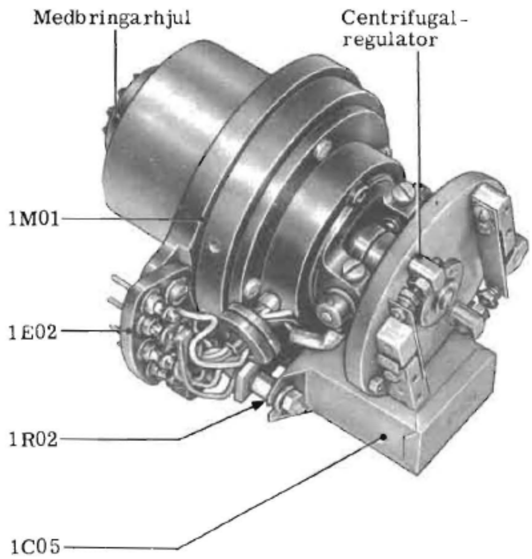


Figure 13. Modulation motor without protective cover.

On the output shaft of the motor is a fitting wheel with a slot hole.
The pins located on the rotor of the modulation capacitor enter the slot holes.

The centrifugal regulator with its three sliprings is located under the protective cover. The controller consists of two contact groups mounted on a round disc, attached to the motor shaft. The controller can be used for regulation at **two alternate speeds, 810 rpm or 4050 rpm**. Here, only 4050 rpm is used, because the contact spring with the greatest pressure being used. The second contact spring with the balance weight holds its group open during operation. The commuter is located under the motor hood. Condenser 1C05 and resistor 1R02 serve as spark extinguisher over the contact spring bridge.

Mixing unit

The mixer unit is attached to the front panel with three screws and nuts. The unit is built around three symmetric coaxial lines 2L03-2L05 (see Figure 14).

In the front of the wires is the casing 2E01. The top of the coaxial lines is slit and has one sliding short-circuit flask. On the rear of the two lower coaxial lines there is a frame with a lid. The cover is attached with six screws.

The body contains two crystal diodes, 2D01 and 2D02, as well as four balancing capacitors 2C03-2C06. The crystal diodes are inserted into the extended inner conductors of the coaxial lines. In the cover there are two insulated springs, which is against the base of the crystals. When changing the crystal, the cover must be screwed off.

On the lid's overhead part is a hood. Under the hood are two stop coils, 2L01 and 2L02, as well as two relaxation capacitors, 2C01 and 2C02.
The balancing capacitors 2C03 and 2C06 are accessible for trimming through a hole in the section wall. Condensers 2C04 and 2C05 can be trimmed from the bottom of the appliance unit through a hole in the LF unit body.

The cable from the coupling loop in the transmitter is inserted through a bushing in the bottom of the base. The lead from the mixer to the LF unit passes through the hood on the lid.

LF unit

The low frequency unit input stage consists of a transistor amplifier. This is a separate device, which is
made up of two plastic laminates with so-called printed circuits on which the components are mounted.
The discs are on each side of a metal base plate, and the entire unit is built into a screen can
of light metal. The cage is screwed to the low-frequency unit with two screws.

The low-frequency unit's other parts are mounted on a frame made of fiberglass laminate. The frame

is fixed on four angles, two on the front panel and two on the section wall.
The surface of the terminal is protected by light metal plate, which has holes for the solder posts. On this protective plate, the height adjustment unit is also fitted with two screws. Detail placement and wiring are found in Annex 1 and 2.

The details are mainly located under the frame while the wires are pulled on the top. LF amplifier Two first tubes, 3Z01 and 3Z03, are mounted on a special terminal, suspended in spiral springs, filled with steel wool. All tubes have shields.

The potentiometers 3P02-3P04 and rotary capacitor 3C24 are located on a plate angle, which is screwed into the frame. The rotary condenser and the potentiometer 3P03 are covered by light metal plate shade. Potentiometers and
The torque capacitor is accessible through holes in the lower frame.
The potentiometer 3P05 is in the transistor amplifier and is accessible through a hole in its underside.
All potentiometers except 3P05 and rotary capacitor have lock nuts. The potentiometer 3P05 is of a trim potentiometer is a multiturn type

Height positioning unit
The height positioning unit is built as a rigid subframe.
The lower part is a fiberglass laminate plinth and between the upper part of the gables a light metal rail. The unit is covered with black-painted aluminum metal plate.
The cover is fastened from the top of the gables with two quick locks (see figure 15).

The device is connected via a 15-pin miniature miniature connector. The subunit is located on the bottom plate of the mainunit and the casing on the body of the LF unit. The device is attached to the LF unit's protective plate with two two-leaf hair screws.

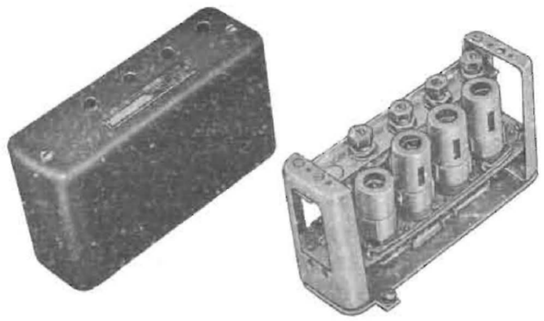


Figure 15. Height positioning unit with removed cover.

On the fiberglass laminate floor are the four tubes 4Z014Z04 and the rotary capacitor 4C02 as well as resistors and capacitors attached. The potentiometers 4P01 - 4P04 are located on the light metal rail. Potentiometers are accessible through four holes in the hood. The height positioning device discharge co-ordinator 4C04 is attached to the section wall behind the transmitter unit. (However, this is not used). The detailed location is shown in Annex 3.

Power Supply
The power unit is located in the rear of the appliance.
It is built on a body of light metal plate, which is screwed into the lower part of the framework.
On the upper side of the frame are converters, electrolytic capacitors and stabilizer tubes attached. Resistance and capacitors are mounted on terminals under the frame. Relaxation Capacitors 5C01, 5C02 and 5C06 holes are fixed with joints. The detailed location is shown in Annex 4.

The rotary converter is attached to a glass fiber laminate plate. The plate is attached with four locks at four shock absorbers, which are screwed into the body of the power unit. The shock absorbers simultaneously constitute voltages to and from the inverter, so the lock is powered during operation. On the bottom of the plate the resistor capacitors 5C03 and 5C04 (Annex 5) are located. The inverter can be removed by maneuvering open the four locks and lift the inverter straight up.

ANTENNAS

The antennas are built-in slit antenna (Boxed-in slot antenna). The transmitter and receiver antennas are exactly the same from a mechanical point of view. Each antenna consists of a rectangular box with flange. The box is auxiliary of light metal plate. Above the box is a plastic window on the inside of which two aluminum flanged flanges are tied. To get good body contact, the flanges also screwed into the box's long sides. Around the plastic window there is a frame that is screwed into the box's flange. A drainage pipe in the plastic window diverts any condensation water. The antenna is screwed into the airplane.

The connection to the appliance is done over a casing on one side of the box.
The transmitter antenna's sheath is marked with red color, the receiver antenna with green.

The coupling to the antenna is made with a transverse tube which constitutes an extension of the coaxial conductor inner conductor.
The pipe is supported on the opposite side of the sleeve. Side aven hf insulator. The coupling is completed with a short-circuited coaxial line, approximately $\lambda / 2$ long.

In the bottom of the box is a hole for a measuring probe. The hole made with respect to is covered with a plate labeled M or S. The marking that the antenna is rated as receiver or transmitter antenna. The classification is the standing wave ratio, using the best of two antennas down for the receiver and is labeled with M.

INDICATOR

The indicator consists of a moving coil instrument enclosed in a metal cover. The external dimensions of the indicator are in line with the major standards.
The scale is graded 10-200 m and has a mechanical zero point, first line, and an electrical, O-line.
Mechanical zeroing is made to the first line. This reset is done with the center screw.

Connection of the indicator takes place over a 3-pin screw type plug.
The internal resistance of the indicator is 1000 ohms and 2 mA is required for full range.

DETAILED DESCRIPTION

GENERAL

The frequency-modulated transmitter transmits a signal whose frequency is determined by a lecher line and a an external capacitor, which is connected to the outer end of the cable. The capacitor is varied by a modulation motor .
The signal is supplied to a slit antenna, which has its maximum radiation perpendicular to the longitudinal axis of the slit and the aircraft.

The transmitted signal is reflected against the underlying terrain and is received with a certain delay on an antenna identical to the transmitter antenna. The received signal is applied to a balanced crystal mixer, which also receives a direct signal from the transmitter. However, the direct signal from the transmitter has changed its frequency during the time the transmitted signal has passed the transmitter antenna-mark surface-receiver antenna. From the mixer, therefore, a difference frequency is obtained whose amount increases with increasing height.
This differential frequency voltage is applied to a 4-stage low-frequency amplifier whose gain is controlled by an AGC detector with associated DC voltage amplifiers. Gain increases with increasing height to compensate for the decrease in the received power resulting from the increase of path attenuation.

The differential frequency voltage then triggers a multivibrator, which gives a square voltage of the same frequency. This square voltage power amplifier is adapted to a cathode follower and is supplied to the AGC detector and frequency counters.
The frequency counter 3Z08 differentiates and rectifies the square wave, after which the negative peaks pass through the height indicator. The indicator also receives a counter current to compensate for the remaining zero altitude ramp.

The height mode unit is dealt with on page 27.

Power is supplied partly from the airplane's DC power network, and partly from the (19V) stabilization unit, a part of the navigating equipment PN-50 / A. The voltage from the aircraft's network drives a rotary converter, and after filtering, and in some cases stabilization,

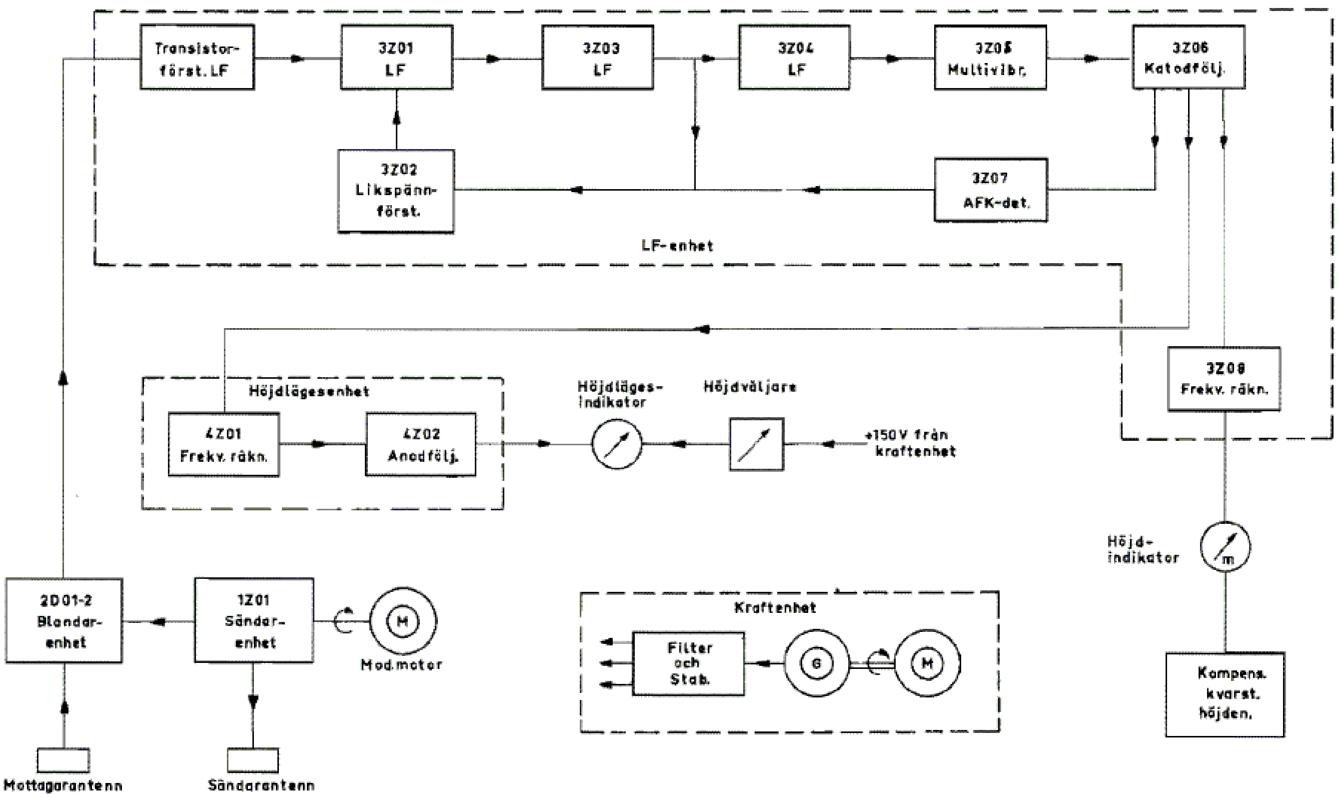


Figure 18. Block diagram of PH-11/A.

is distributed to the different stages.
The Modulation motor is excited directly from the (27V) aircraft's network.

POWER SUPPLY

Power is supplied to the radar altimeter partly from the aircraft's DC power grid, partly from the stabilizer (+19V) included in radar navigation equipment PN-50 / A.

The altimeter is turned on and off with a switch marked RADARHOYDMATARE (or LUNA), which is in the cockpit. The voltages are connected over the four-way connector 6E02 and 15 pole connector 6E01 to Unit 5E01 (See Annex 7). Modulation motor lM01 is connected to the plus line of airplane DC power over connector 2 of sleeve 5E01. The 5M01 inverter is connected over connector 3 in the same sleeve. Condensers 5C01, 5C02 and 5C06 decouple any potential voltages on the 28 V wires.

The 5M01 inverter transforms +27V into 290V ± 5% output voltage. Interference caused by sparking between carbon brushes and collectors is partially shorted by capacitors 5C03 and 5C04. Remaining interference voltages are absorbed in filters.
Resistors 5R01-5R03 and 5R05-5SR088 reduce the output voltage of the inverter to appropriate values for the different circuits. The 32 uF capacitors decouple low voltage interference voltages while the capacitors at 0.01 uF absorb high frequency voltages.

Regulator tube 5Z01 leaves + 150 V constant voltage at 5-30 mA output current. Resistor 5R04 protects the tube from power failure.

The filament wires, with the exception of the transmitter tube, are connected three in series to the stabilized +19 V from the PN-50/A. Condenser 5C11 constitutes a low frequency relaxation between filament wires on tubes 3Z01 and 3Z02. Resistor 5R11 reduces the glow voltage on the tube 3Z04.
The transmitter tube 1Z01 filament is connected to + 19V over the resistor 5R10, thereby obtaining a 12.6V glow voltage.

TRANSMITTER

The transmitter tube 1Z01 is a high frequency stripline. The oscillator circuit of the tube consists of the capacitor 1CV01 and a lecher line 1L03, which is connected between anode and grid. The frequency of the transmitter is determined by the lecher line length-, the connection between the conductors and the connection to the frame as well as the capacitance of the capacitor 1CV01.

Since the rotor in the capacitor 1CV01 rotates, the frequency will vary between two limits (frequency swing). Limits are determined by the capacitor's minimum and maximum capacitance.

The minimum capacitance is changed by turning the lever on the bottom of the transmitter unit. This also affects the maximum capacitance. The maximum capacitance is changed by shifting the rotor up or down, which essentially means a shift of the lower limit of the frequency swing up or down because the mincapacity is affected very little. However, both trimings affect each other, so a frequency change must be done by alternately trimming.
The rotor of the capacitor 1CV01 has two opposite faces, which are electrically connected to each other. When the rotor is rotated, the frequency changes from min to max and back to min in half a turn (Figure 20). Thus, one revolution corresponds to two full periods of modulation frequency.

The modulation motor rotates 4050 rpm which equals 67, 5 r / s. The modulation frequency therefore becomes 2 x 67.5 = 135 Hz. The transmitter tube works in class C and automatically receives negative grid over resistor 1R01. The anode voltage is connected via stop coil IL06 and the output capacitors
1C03 and 1C04 form a HF barrier filter. Same service makes the stop coil 1L02 and the capacitors 1C01 and IC02. The stop coil 1L01 keeps the cathode potential up.

The power to the transmitter antenna is taken with the connection loop 1L04. By changing the position of the loop in relation to the box the output can be optimised.

The lecher line can vary the output power within certain limits. The coupling loop is adapted to the antenna line impedance with a series impedance to the frame. The series impression consists of an open coaxial wire about 1.5 λ long.

The shielded coupling loop 1L05 has a 0.2 mm gap. Through the gap, the loop catches a small part of the transmitter energy. This is connected to the mixer unit where it is mixed with the wave reflected from the ground.

At the voltage voltage there is a triangular voltage superposed, which is 6-7 V (top to top).
This voltage frequency corresponds to the modulation frequency, so it can be used for synchronizing the oscillograph. The voltage is applied to the pin 5E01: 1.
Amplitude modulation (AM) occurs by reflection from the transmitter antenna. The antenna and its cable can only be adapted for a frequency, usually the transmitter average frequency. At other frequencies within the turn, reflection on the transmitter occurs. The reflection will increase or decrease the HF amplitude (= amplitude modulation) depending on the phase mode at any moment. In addition to the FM component, the direct signal to the mixer contains an AM component.
This is balanced to less than 7% in the transformer's 3T02 primary winding.

MODULATOR MOTOR

The shunt-connected motor can be connected to 22-29 V with a speed variation of no more than 1% at 4050 rpm. This corresponds to a variation of the modulation frequency by approximately ± 1.5 Hz.

The diagram in Figure 21 shows only the function at 4050 rpm. The motor receives full voltage across the stator when switched on as long as resistor 5R09 is short-circuited by the contact group in the centrifugal regulator. When the speed increases over 4050 rpm, the contacts opens and connects the resistor in series with the rotor, so the current decreases and the speed decreases until the contacts close again, and the progress is repeated. As a result, the speed is kept constant at 4050 rpm.

ANTENNAS

The transmitter and receiver antennas are identical slotted antenna types.
The antenna in Figure 22a consists of two resonant λ/4 legs connected to a transmission line. The distance between the long joints in the legs is many times less than λ and the currents are counterphased, why the fields take apart. In the transverse conductors, however, the currents are in phase, but the length is too small for any effective radiation to take place.

The antenna in Fig. 22b consists of a flat plate with λ/2 long slot with the same width as the antenna in Fig. 22a. In this antenna, the current is not concentrated to the slot edge, but

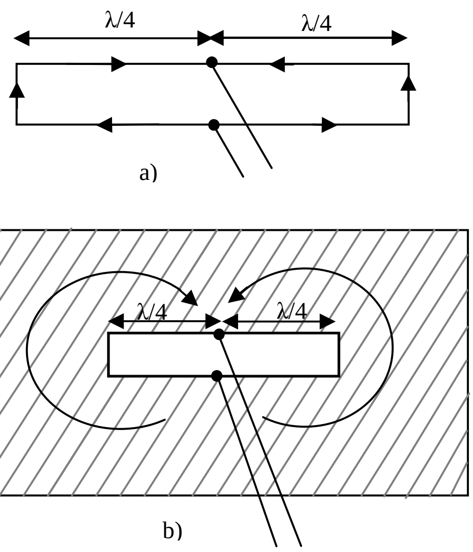


Fig 22 Slot antenna

distributed over the plate surface whereby a good radiation is achieved. The radiation is equal from both sides and vertically polarized if the slot is horizontal as shown in Figure 22b.

The PH-11/A antennas are cavity backed-up slot antennas: a box, λ/8 deep and λ/2 long, placed inside the slot (Fig. 23a), the radiation occurs only from the outside. The radiation is greatest in all directions perpendicular to the length of the slot (Fig. 23b).
The antennas of PH-11 / A (Figure 16) have flanges that form two slots, each approximately λ/8 long, but these are electrically extended with the capacitances formed by the folded parts of the flanges. Thereby the electric length becomes approx λ / 4 for each slot and thus λ / 2 together. The depth of the

box is less than λ / 8, but this is also increased by the flanges capacity.
The feed occurs capacitively with a transverse conductor in the center of the box which is an extension of the coaxial conductor's center conductor. In order for the connection impedance to the antenna to be resistive and equal to the cable (Zo), the power supply conductor is serial coupled with an approx. λ/2 long short-circuited stub. This adjustment, however, corresponds only to the transmitter average frequency, so reflection occurs at other frequencies within the turn.

MIXER

The reflected signal is connected to the mixer over input circuit 2L03-2L05. The circuit is tuned to transmitter average frequency with the displaceable short-circuit wave in coaxial line 2L05 (Fig. 25). phase on the reflected signal are equal in the two coaxial lines 2L03 and 2L04 (Fig. 24c).

The direct signal is coupled across the resistor 2R01 and the balancing capacitors 2C04 and 2C05 to crystal diodes 2D01 and 2D02. The signal is 180 ° phase shifted on both diodes (Figs. 24a and b). The capacitors balance the signals so that the amplitudes become equal on both diodes.

When the two signals with different frequencies are applied to the nonlinear diodes, a mixture is obtained - partly a sum and - partly a differential frequency voltage.
The sum frequency and signal frequency voltages are disconnected to the frame with the filters being formed of the diodes' series coils 2L01 and 2L02 and the capacitors 2C01 and 2C02.
The difference frequency voltage, on the other hand, can pass the filters and is supplied to the transistor preamplifier input transformer •
The primary windings are mutually opposed. By doing so, they take up the amplitude-modulated components that are included in the differential frequency voltage out because the AM components are derived from the transmitter and the signal
From this, the mixer is supplied symmetrically. However, the FM components, which are in counter phase, will co-operate in the windings. The potentiometer 3P05 balances any differences in the crystal currents.

LF AMPLIFIER

The LF amplifier consists of four stages: transistor 3Z09 and tubes 3Z01, 3Z03 and 3Z04 with associated details (Figure 26). The difference frequency voltage from the mixer is coupled over the transformer 3T02 into the transistor and further across the capacitor 3C11 to the grid on the second stage tube 3Z01.
The transistor stage is connected as common base coupling and has such frequency characteristics by means of the input frequency correction elements that the gain increases with increasing frequency.
The second stage is powered by the cathode resistors 3R03 and 3P02 are common for tube 3Z01 and DC voltage amplifier 3Z02.

Condenser 3C02 disconnects any HF voltages to the body. The amplified differential frequency voltage is taken over the anode load resistor 3R04, is passed over the capacitor 3C03 to the next LF stage 3Z03.

This stage is voltage-coupled with resistor 3R06 and capacitor 3C21. The coupling is frequency dependent and the gain is approximately 20 dB from 20 kHz to 100 kHz. A further counterclocking is achieved because the tube lacks screen gauge (compare 3Z04). In this step, an additional gain occurs and the voltage obtained over the anode load resistor 3R09 is connected over the capacitor 3C06 to the next one step, partly to the grid of the DC 3Z02 of the DC voltage amplifier.
The fourth LF stage, with the tube 3Z04 coupled as triode, has conventional RC coupling which corrects the LF amplifier's characteristic at frequencies above 40 kHz.

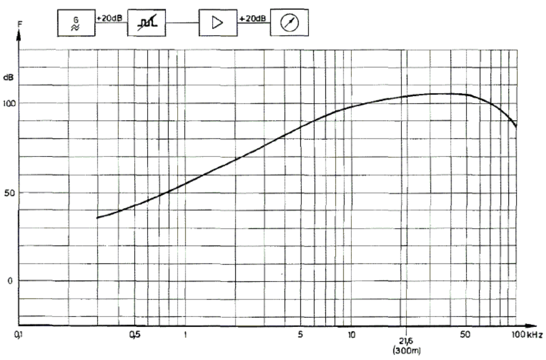


Bild 27. LF-förstärkarens karakteristik.

Figure 28. Curve shapes in the LF unit (Tektronix 531 with separate measuring body, 10 Mohm input resistor).

The signal from the fourth stage is coupled to the multivibrator tube 3Z05 across the parallel connected capacitors 3C12 and 3C13.

In order to achieve even amplification of all frequencies within the altimeter's work area, the characteristic was designed so that low frequency voltages get a small gain, while tensions with high frequencies get a big boost. because the path attenuation at low heights is small, which gives a relatively high differential frequency voltage and vice versa.

The characteristic is achieved by the automatic gain control, as well as the aforementioned frequency dependent couplings.

MULTIVIBRATOR

The multivibrator consists of the 3Z05 double trimmer and associated details (Figure 29).

Resistors 3R19 and 3R17 and potentiometer 3P03 form a voltage divider circuit between +150V and frame. The voltage obtained over 3R17 and 3P03 constitutes a fixed preamble to the first triode, 3Z05a. The potentiometer 3P03 can be set so that the first triode leads or is truncated (lowest resistance).

The relationship in the second triode, 3Z05b becomes reversed since the grid is connected to the anode of the first triode and both triodes work across the same cathode resistor, 3R21.

Normally, the potentiometer 3P03 is set so that the first triod's operating point is just limiting when no differential frequency voltage is found on the grid. The second triode is then completely open (single brustops are going through).

When a differential frequency voltage (image 28a) from the LF signal is applied to the first grid, the working point of the triode is moved in the negative direction. This occurs because grating current occurs during the part of the positive half-period which reaches over 0V. The current flows through the resistor 3R17 and the potentiometer 3P03 and forms a counter-bias.

Similarly, across resistor 3R18, a counter-voltage occurs which limits and distorts the difference frequency voltage on the grid .

The work of the second triode is moving in a positive direction, taking about the same position as the first triode.
When the signal to the first triode reaches the threshold, the triode conducts. The part that reaches the barrier limit is amplified and reversed.

The voltage across the anode load resistor 3R20 (Fig. 28c) is divided over resistors 3R22 and 3R23 in the ratio 1:6 and controls the second triode.
Condenser 3C15 bypasses the high-frequency components included in the steep edges of the waveform.
The voltage is amplified and reversed in the same way as in the first triode. Over the resistor 3R24 and the potentiometer 3P04 receives a square voltage. A portion of the square voltage is taken out of the potentiometer's center arm and led across the capacitor 3Cl6 to the cathode follower 3Z06.
The cathode follower 3Z06 power amplifies the square wave from the multivibrator. Through the cathode's low impedance is a good adaptation to the following AGC detector and frequency counters is obtained. The square voltage of these is taken over the cathode resistor 3R26.

GAIN CONTROL

The AGC circuit contains a detector with associated filters and a DC voltage amplifier operating over same cathode resistance as the first LF stage. The AGC detector consists of half the double-diode 3Z07,

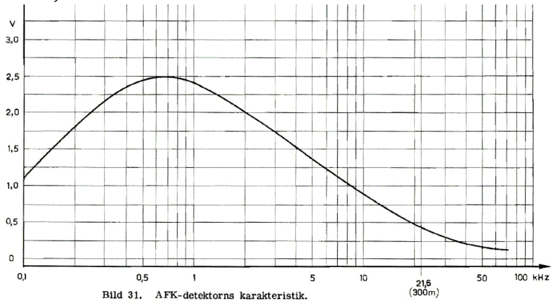


Bild 31. AFK-detektorns karakteristik.

capacitors 3C17 and 3C18 as well as resistors 3R27, and 3R30,
The detector outputs a positive DC voltage across resistors3R28 the 3R28 which decreases the LF gain. The DC voltage is filtered over the resistor 3R31 and the capacitor 3C09 after which it is supplied to the grid of DC voltage amplifier 3Z02 over resistor 3R11.
A change of the DC voltage on the grid causes a change of current through the tube which results in

change of voltage across resistor 3R03 and reostate 3P02.
Because the resistance and the potmeter are also included in the first LF-stage cathode resistance, this means a change of the gain in the stage and thus throughout the LF amplifier.
Disturbances are decoupled by the resistor 3RI0 and the capacitor 3C08 and the DC voltage amplifier.

FREQUENCY COUNTER

The frequency counter differentiates and rectifies the square wave from the multivibrator, as well as measures the result. The counter consists of the three parallel-connected capacitors 3C19, 3C20 and 3C24, double diode 3Z08, height indicator and resistor 6R05 (Figure 32). The positive part of the square wave is differentiated with those parallel coupled capacitors 3C19, 3C20 and 3C24 and internal resistor in the diode half 2-5. The cathode is pre-stressed with +6.3 V, so that a limitation to positive level is obtained simultaneously.

The negative part of the square wave is differentiated with the capacitors and diode halves 1-7, internal resistance in the height indicator and the resistor 6R05.
The negative and differentiated pulses provide a mean current through the height indicator. The mean current is proportional to the pulse rate, which in turn is proportional to the height. A minor change in the differentiation, and thus the average current, can be done for the radar altimeter calibration by changing the capacitance of the variable capacitor 3C24.

The remaining altitude error is compensated as follows. Resistors 6R01 and 6R03 and trimpot 6P01 form a voltage divider between +150 V and the frame. The voltage across the resistor 6R03 produces a counter current through the indicator. This counteracted current compen- sates that portion of the mean current arising from the remaining altitude window. The counter current is set with trimpot 6P01. Due to the bias on diode 5-2, which is connected in series with diode 1-7, a high impedance is made to the positive compensation current.

ALTITUDE INDICATOR

(subframe 4Z)

Generally
The altitude indication is based on a comparison of the altitude dependent voltage from a counter in the radar altimeter and a stabilized adjustable reference voltage.

The altitude indicator comprise the frequency counter, the anode follower, the high position indicator as well as the device for setting the reference voltage.

The frequency counter 4Z01 is of the same type as the LF unit, leaving a voltage output which in each eye glance is proportional to height. The output voltage is amplified in the anode follower 4Z02 and applied to one connection to a moving coil instrument, the second connection of which is fed from a variable voltage divider.

This voltage divider is built of a series of resistors connected to an 11-way switch to eleven selectable voltages, each corresponding to a certain height, that is connected to the indicator.

The voltage divider is fed from the stabilized voltage +150 V in PH-11 (tube 5Z01).
If a certain desired flight height is set on the selector switch (i.e., the voltage divider) and the aircraft is located down at this height, the reference voltage is as great as the 4Z02 output voltage. No current is flowing through the indicator.

Reducing the aircraft's height, decreases the voltage on the anode of 4Z02 and a current, directly proportional to the height change flows through the instrument. The pointer provides indication of the altitude decrease.
Increased flight height has the same course of action, but the pointer is obviously affected in the opposite direction. The instrument itself is a moving coil instrument, attached to the top of the dashboard. The instrument has a scale of + -5m … 0m … +5m.

HEIGHT-SETTING CIRCUITS

The height-setting circuits consist of the frequency counter 4Z01, the anode follower 4Z02, the altitude indicator (does not belong to PH-11/A) and the height selector switch (does not belong to PH-11/A).
Tubes 4Z03 and 4Z04 are used only as an AC resistor and may be replaced by a series resistor.

The frequency counter is of the same type as the LF amplifier, but leaves here a voltage over the resistor 4R04 and the parallel-connected capacitor 4C03. The output voltage increases in a negative direction with increasing height.

Anode follower 4Z02 is a high-voltage DC power amplifier and as a result, idle voltage was low.
The will stream is effected by voltage divider 4R08 and 4R05 which exits a voltage to the control grid 4Z04 over resistor 4R03.

At increasing height, the frequency counter leaves an increasing negative output voltage. This voltage causes a decrease of the current through the tube, and the anode voltage increases.
The height selector unit consists of ten series coupled to stand and at each end of this resistance chain a trim potentiometer. Trim potometers are used for trimming the lowest and highest adjustable indication height.

The switching points between the resistors are connected to each switch on the switch from which the reference voltage corresponding to the set (desired) flight altitude is supplied to the indicator where it is compared to the counter voltage from the anode follower corresponding to the actual flight altitude.

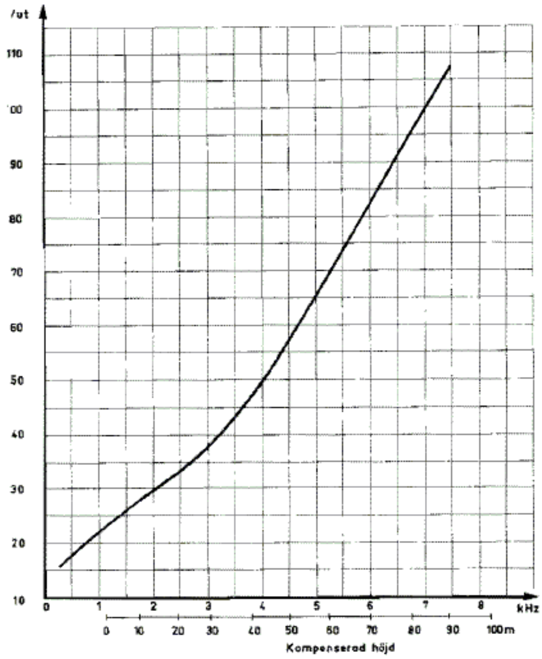


Fig. 35. Altitude unit, output voltage.