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THE HIGH RESOLUTION RADAR 'TOR', (U)
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THE HIGH RESOLUTION RADAR "TOR"

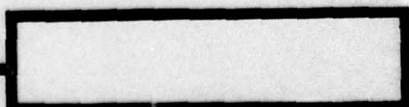
by

T. Gawron, B. Jankowski



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FIRST LINE OF TEXT

THE HIGH RESOLUTION RADAR "TOR"

FIRST LINE OF TITLE

T. Gawron and B. Jankowski

Manuscript supplied to PIT (Polish Technological Institute) on February 15, 1966

Summary

There is discussed the design and properties of the high resolution radar "TOR" which operates in the Q band, with a sensing impulse of breadth 20 ns, antenna beam of breadth 0.25° in azimuth. The radar is designed for control of motion on the surface of an airfield or control of motion of ships in water ports and channels.

1. Design of the System.

The high resolution radar TOR was worked out for control of motion of objects on not too large areas. There can be mentioned here first of all, the control of motion of vessels on the surface of airfields with communications and control of the motion of ships in water ports and canals.

One of the important aspects of control of the operation of an airport is control of the motion on the surface of the airfield. The controller in the control tower must be currently informed about the state of occupation of the take-off roads and approaches, about

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Figure 1. Fragment of the illustration of an airport.

the motion of airplanes or other vehicles on these roads. In small airports the motion of the vehicles on the surface of the airfield can be controlled optically in the control tower. In large ports of substantial airplane motion it is necessary to assure effective control of motion on extended take-off strips and approaches also under difficult atmospheric conditions and at night time.

A valued help for control of motion on the surface of an airfield is the high resolution radar TOR, which makes possible the obtaining, on a panoramic illustration of an actual map of the surface of the airfield with a clear picturing of the take-off strips, of the approach roads, with the making clear of buildings, lanterns along the strips, as well as of objects moving and non-moving located on the take-off strips and approach roads.

In figure 1 there is presented an illustration on the indicator of the model of the TOR system, of the area of an airfield with communications with markedly visible echoes from a landing aircraft

on the strip, as well as a powerful echo from an aircraft waiting near the intersection of the take-off roads.

Control of the motion of ships in water? ports and channels requires the obtaining of the current situation in those water? ports with sufficiently great accuracy and resolution. There satisfies these requirements the illustration obtained from the high resolution system TOR. On Figure 2 there is presented a fragment of an illustration on the paroramic indicator of a seaport with visible floating objects.

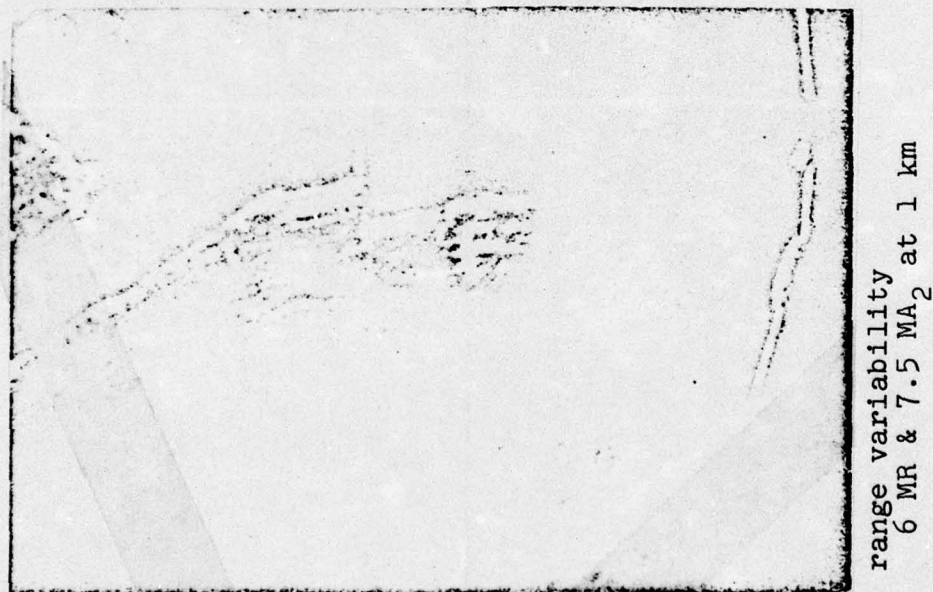


Figure 2. Fragment of the illustration of a seaport.

For the obtaining of an illustration of the situation on the relatively small areas of airfields or seaports extending to a distance of several kilometers, with the preservation of a resolution of the order of several meters, the use of nanosecond sensing impulses is indispensable, and (also) an antenna of azimuthal beam width of the order of $1/4^\circ$, with observation of a span of the antenna that does not exceed the requirements for resolution in azimuth. In the beam along with the above in the

TOR system there are used sensing impulses with a breadth of 20 ns and the system is designed in the 8 mm band which has made possible with an antenna span of approx 2 m to get a beam breadth in azimuth of the order of 0.25° . There were carried out measurements of the resolution of the system from which there results that the distance-resolution amounts to around 6 m and the resolution in the perpendicular direction (azimuthal) to around 7.5 m at a distance of 1 km.

The advantages of such a high resolving power have been confirmed at the time of practical tests of a model of the system at an aircraft occasion and of a prototype at a sea occasion. Beyond the good fulfillment of the function of motion control in both cases, the tests in the sea occasion showed that this system can give navigational help to ships entering or leaving a port at a time of very bad visibility.

2. Description of the Design of the High Resolution Radar Station.

2.1. The Antenna.

The antenna of the TOR system is a reflecting antenna with a parabolic reflector of double curvature illuminated by a horn (see Figure 3). The width of the beam in the azimuth plane amounts to 0.25° between the half power points. In the plane of elevation the beam has a characteristic of the "reverse cosecant squared" type in order to assure uniform illumination of the surface of the earth or water within the range of the station. In the case of small breadth of the in-phase component of the beam in the plane of elevation (around 1°) there is obtained direction of the energy radiated onto the surface of the earth or water while assuring as small as possible illumination of the spaces located above, that give masking reflections from clouds or rain.



Figure 3. Antenna

In order to decrease the intensity of signals reflected from clouds, rain or the mean (intermediate) wave (for sea applications), in the TOR system there is introduced continuous regulation of the ellipticity of the radiated electromagnetic wave from level polarization through circular to vertical. The system is supplied with a waveguide polarizer built onto a square waveguide excited in the H_{10} and H_{01} modes.

Two fins turned with respect to one another at an angle of 45° , dielectric fins placed into the cross section of the square waveguide, make it possible to regulate ratio of the amplitudes of the H_{10} and H_{01} waves, as well as the phase angle between them, in order to obtain the desired polarization of the radiated wave. The fin that regulates the phase difference between the components H_{10} and H_{01} permits compensation of the depolarizing effect caused by the reflector, horn, and by the waveguide that hooks together the horn with the polarizer. The change in the polarization of the radiated wave is obtained by the continuous remote regulation of the ratio of the components H_{10} and H_{01} by changing the position of the 2nd dielectric fan.

FIRST The level of the antenna's side lobes amounts to 20 db below the main lobe.

The antenna's reflector possesses a span of 2317 x 790 mm. The reflector is made as a shelled structure with a laminate of epoxide-glass. This construction assures the possibility of obtaining great precision of the surface of the mirror, a suitable mechanical stiffness, and a sufficiently small thermal distortion. Moreover an advantage of this construction is its relatively small weight. The mean square error of the reflector's surface design is of the order of 0.25 mm.

The antenna is driven ambiently with a speed of 40 rot/min by an asynchronous motor of 1 kW power.

2.2. The Waveguide System.

Rectangular waveguide which conducts energy (in) b. per hour to the antenna and receives signals to the receiver, possesses a cross section of dimensions 7.110 x 3.555 mm.

In the waveguide system there is used a ferrite circulator of the Y type, with a matched load in one branch, which fulfills the role of isolator for the magnetron generator. The use of an isolator is dictated by the great electrical length of the transmission line.

The selector switch NO has been designed into a conventional series system with tubes NO and ANO. The tube NO is given a polarity initially by a DC and an impulse voltage. A rotary joint has been worked out onto the round waveguide. The parts rotating with respect to one another are connected without touching by means of a radial choke. The transitions from rectangular waveguide to round wave guide are supplied with a halfwave choke

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for suppression of parasitic modes of the round wave guide that operates in the H_{11} mode (TE_{11}). The matching of the joint from the rectangular waveguide side is assured by two inductive diaphragm.

The other side of the waveguide line is made up of elements bringing heterodyn(ing?) power in b per hour. The main elements of this side are: a ferrite circulator fulfilling the role of heterodyne isolator, a "knife" attenuator for the regulation of the level of heterodyn(ing?) power, a divider of the heterodyne signal between mixers of the signal and afc (automatic freq control) designed in the form of an annular hybrid. The mixers of the signal and afc are designed in the form of equalizing mixers on annular hybrids.

All the waveguide elements that bring large power are filled with most air compressed to 1 1/2 atmospheres. The compressed air is supplied from a pressure system, which automatically replenishes the pressure from a balancing tank.

2.3. The Transmitter.

The transmitter of the TOR system is composed of two basic parts: the power generator in b per hour as well as of a pulse generator.

The power generator in b per hour is a magnetron tube operating in the Q band. The magnetron used possesses a waveguide output and constitutes a structural whole with a permanent magnet. Heating is switched in for the initial period of warming up. During operation the heating gets switched out; the cathode warms itself up by reverse bombardment. The impulse power in b per hour generated by the magnetron amounts to $P \approx 20$ kW.

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The pulse generator is composed of three basic parts:

The timer produces releasing impulses for the controlling system of the modulator, for the NO system, and for the indicator P. Suitable delay between the individual releasing pulses are obtained by use of delay lines.

The basic part of the timer is a blocking generator which produces a sequence of pulses of great stability with a frequency of repetition of 12.000 pulses/sec.

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The control system gives at its output a sequence of pulses of amplitude 100 V, $\tau=20$ ns, $f_p=12000$ puls/sec. This system possesses a releasing pulse amplifier, a blocking generator, a separator, and two levels of amplification. The blocking generator produces a pulse of breadth $\tau=40$ ns. An impulse of 20 ns is formed by introducing a negative feedback coupling between the two last levels of amplification through a delay line of well-matched delay. From the divider at the output of the final amplifier there is taken a pulse and after a delay of one half of its breadth, it is added to the input of the forward amplifier causing a cut-off of the current in the tube and a limitation of the breadth of the pulse produced by the blocking generator.

The modulator produces power modulating pulses of amplitude 13-14 kV, which are applied directly to the cathode of the magnetron. The amplifier is built on two parallelly operating GMI83 tubes. The amplifier is supplied with a divider for observation and measurements of the impulse on a synchroscope.

2.4. The Receiver.

At the output of the receiver there is located a balanced mixer designed on an annular branching in the form of a twisted waveguide in the E-plane, from which there are brought forth

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(extended) four arms. The noise figure F-18-20 dB. An identical mixer is used in the afc system. The heterodyne (signal) is built in a reflex klystron that operates in the Q band, and which generates power of around 5 mW. Thanks to a selsyn connection, the electronic tuning of the klystron can happen far from the control station of the indicator P.

In the system there is used an automatic subsystem for frequency regulation, which assures tuning of the klystron to the actual current frequency of the magnetron.

FIRST LINE OF TITLE

The intermediate frequency signal (80 MHz) gets amplified by about 100 db in an intermediate frequency amplifier of band breadth 50 MHz. An intermediate frequency preamplifier is placed beside the signal mixer to obtain a direct connection without the use of cables. The output level operates on the (a) E88CC in a cascode system, the rest on 6Z9 tubes. Resonant circuits of individual levels in "threesomes" are set up at various frequencies in order to obtain a band of width 50 MHz. The amplification of the preamplifier amounts to 40 dB. From the preamplifier the signal is sent through by coax to an intermediate frequency logarithmic amplifier that is located in the receiver block. The intermediate frequency amplifier gives an amplification of 60 dB in a band of 50 MHz. It is composed of four three level resonant (tuned) amplifiers "(threesomes)" operating on 6Z9P tubes. The logarithmic characteristic is obtained by summing of the detected signals taken through separators from each "threesome". These signals are applied to a delay line which equalizes the delays arising in the amplifiers in order to prevent a spreading of the signal.

In the control grids of the first two levels of the amplifier there is used manual and time varied gain control. The amplifier is supplied with a differentiating system for the elimination of the DC component of echo signals.

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FIRST The video amplifier possesses an amplification of 24 dB in a 30 MHz band.

2.5. The Indicator P.

The indicator P possess a rotary deflection coil. There is used a picture tube of great resolution (around 1000 lines/diameter) with a screen diameter of 31 cm. In the lower part of the indicator there is located the control console which contains the organs of control, of tuning, and of monitoring of the whole station. In the indicator's housing beyond the picture tube and the deflection coil along with the drive, there are found the systems for the generator of distance signals, the video amplifier, the time base generator, and the high voltage power pack. The low voltage power packs of the indicator system are placed in the receiver block whence the DC voltages are supplied to the indicator by rubber covered cables.

→ The deflection coil is driven by a motor that is supplied from a servomechanical system for transmitting angular data. In the system there are used selsyns in a coarse circuit, and a precise transmission of angular data is coupled by a mechanical transmission 1:7.

In the indicator generator there are generated indicators of distance for every 1 km, of breadth 20 ns.

In the indicator there have been provided two time base ranges 3 and 6 km. The 3 km range has an amplitude stretched over the whole diameter of the screen so that there is used an illustration of 1.5 km per radius (of screen). The 6 km range has a regulated amplitude of the time base from 6 km per radius to 6 km per diameter. Such a design was dictated by use of continual shifting of the center of illustration by one radius in an arbitrary direction.

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FIRST The picture tube is supplied with a 12 kV voltage. In the high voltage power pack there is used a 25 kHz generator.

2.6. Power Supply.

The TOR station is supplied by a single phase voltage of 220 V at a frequency of 427 Hz, with the exception of the motor that drives the antenna, which supplied at a frequency of 50 Hz. The use of elevated frequencies for the voltage supply has made possible an important diminution of the overall dimensions of the DC voltage power packs, as well as a diminution of the undersired scorch effect (flaring of the time base) on the screen of the indicator P. The source of the 220 V, 427 Hz is a converter of output power 3.5 kW, supplied from the 50 Hz network.

The whole input power from the 3x380/220 V 50 Hz network amounts to around 5 kVA.

2.7. Structural Design.

The RSDRTOR is composed of several separate blocks. One Figure 6 there is presented a typical placement of the blocks and subsystems of the TOR system in rooms for monitoring motion on the site of an airfield. The antenna block is composed of the antenna along with the antenna base with its bearing, the drive, the microwave rotary joint, and the selsyns that send a transmission of angular data. The base of the antenna is constructed in the form of a plate mounted in a special hole in the roof of the room.

In the microwave console there is placed the transmitter along with the pulse generator, the microwave subsystem, and the intermediate frequent preamplifier. The microwave console is opened from two sides so as to assure good access to the vertically positioned chassis (Figure 4).

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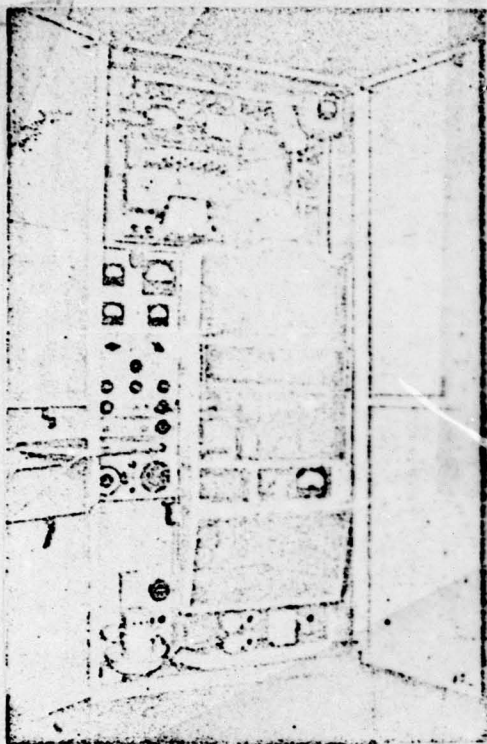


Figure 4. Microwave Console.

The receiver block includes the intermediate frequency logarithmic amplifier, the amplifier of the system for transmitting angular data, and power packs of the indicator P. The receiver block is designed in the form of a console.

The indicator P is designed in the form of a free-standing synchroscope, which can be put on the operations table in a position convenient for the operator. It is characterized by easy access to the subsystems. (Figure 5.)

Into the makeup of the TOR system there enters also a network service subsystem constructed for hanging on a wall. A separate subsystem is made up by the converter along with its auxiliary accessories, --constructed in the form of a small stand. The damping used assures quiet operation of the machine.

The pressure system is composed of a small piston compressor with a balancing tank and a moistener of the air which supplies air to the waveguides.

The mentioned set of blocks constitutes a one-channel system.

For increasing the reliability of operation, the TOR system can be designed in a two-channel version, where each of the channels includes a microwave console, a receiving block and an indicator.

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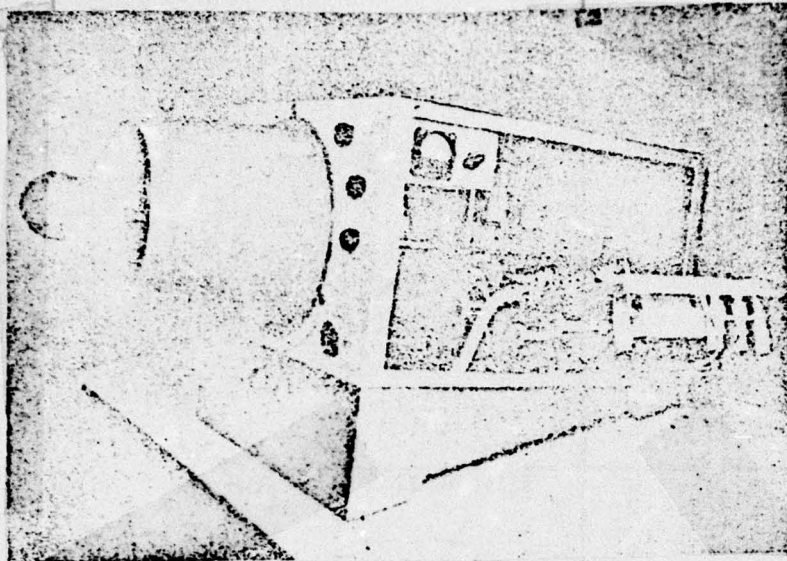


Figure 5. Panoramic Indicator.

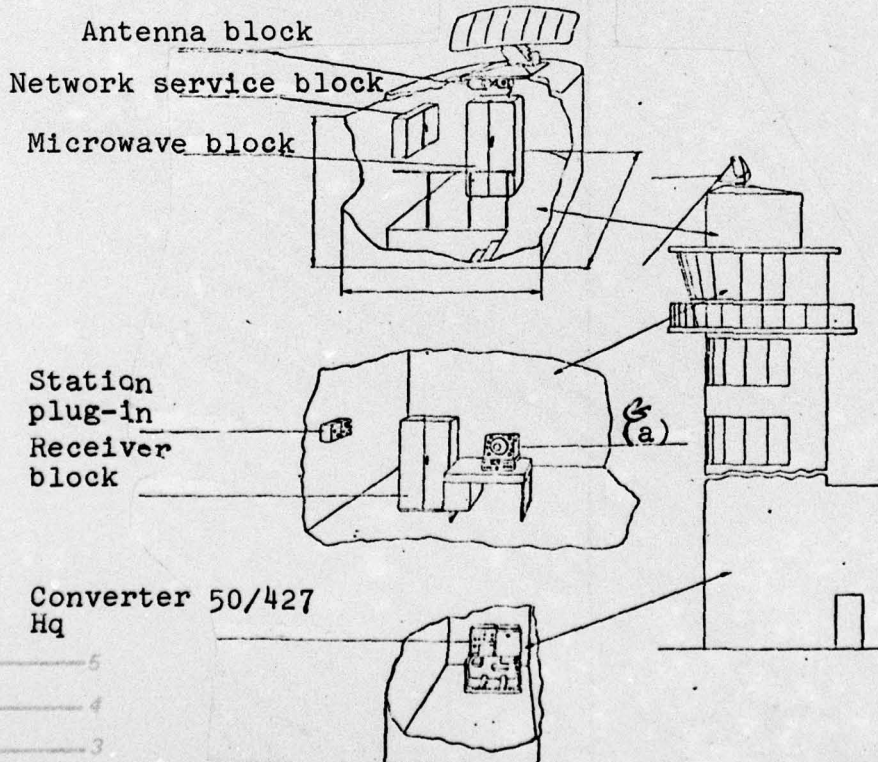


Figure 6. Plan of placement of the apparatus of the TOR radar.

Key: (a) Indicator P.

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3. Tabulation of the Parameters of the High Resolution Radar TOR.

Antenna System

Width of the beam in azimuth - 0.25°
Width of the beam in elevation - 1° (reverse cosecant squared)
Polarization - circular-linear, regulated continuously
Speed of rotation of the antenna - 40 rot/min

Transmitter

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Frequency of operation - Q band
Power in a pulse - 20 kW
Pulse width - 20 ns
Repetition frequency - 12,000 imps/sec

Receiver

Noise figure - 20 dB
Intermediate frequency - 80 MHz
Width of the intermediate freq amplifier's band - 50 MHz
Characteristic of the intermediate freq amplifier - logarithmic
Additional subsystems-afc, ZRW, differentiation

Panoramic Indicator

Diameter of the picture tube - 31 cm
Ranges of the time base - 3 and 6 km

There exists a possibility (capability) of continuous regulation of the shift of the start point of the time base by one (picture tube) radius.

Distance indicators - every 1 km

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Power Supply EXT

From a 3x380/220 V 50 Hz network through a converter 220 V 427 Hz
Power input from the network - around 5 kVA

Summary

The high resolution radar „TOR“ was developed to control surface traffic in great airports as well as to control ship courses and positions in harbours and channels.

A typical display obtainable on the radar „TOR“ is shown in Fig. 1. The airport is shown there with its runways and roads. Lanterns along runways, a taking-off plane on runway and other objects can be seen on the display.

The display showing entrance to the harbour is shown in Fig. 2. Different ships can be observed. Time base is 1,5 km/radius.

The radar „TOR“ operates in Q-band (8 mm wavelength). Pulse width is 20 msec, recurrence frequency 12 000 c per sec and pulse power 30 kW. As aerial a specially shaped parabolic reflector is used which produces the beam of reversed cosoc² type. Azimuth beamwidth is 0,25°, elevation coverage -35°. To make the water surface and airport runways observation suitably effective it is necessary to place the radar on a tower approx 20 metres high. To cancel the disturbing re-

flections from rain the antenna was provided with a polarizer which enables to change polarisation of radiated electromagnetic wave continuously.

A rotary joint ensures connection between rotating antenna and nonrotating transmitter-receiver part. The duplexer includes the TR and ATR tubes. An ferrite isolator is used in the transmitter waveguides which are pressurized under 1,5 Atm. pressure.

The crystallic detector mixer is used as the first stage of the receiver. The logarithmic i. f. amplifier has 80 Mc bandwidth. The i. f. frequency is 50 Mc and video bandwidth -20 Mc.

The P.P.I. display unit uses the tube of 12" diameter and of definition approx 1000 lines per tube diameter. Time base ranges are 1,5, 3,0 and 6,0 km.

The display may be off centred as far as 1 tube radius.

Mains voltage of 400 c/s is applied from 50 c/s/400 c/s converter. Supply power is 5 kVA approx.

Situation of equipment in the control tower is shown in Fig. 6.

The antenna, microwave part and PPI display are shown in Fig. 3-5.



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